DAMS AND WATER TRANSFERS

An Overview

DES BARRAGES ET DES TRANSFERTS D'EAU

Un aperçu

Bulletin 161

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Foreword

In spite of the great difficulty getting information on this subject it was possible to build an overview of water transfers as a tool for development of all countries we have had the opportunity to get and analyze their experience. We had the opportunity of visiting some countries other than those of our members that have some experience on IBWT (Inter Basin Water Transfer), as well.

Not all updated experience is part of this bulletin; however it is our thought that its content is very comprehensive and has room for dynamic improvement, since this subject is improving as water need critically increases.

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1. Introduction

1.1. Integrated Water Resources Development and Management (IWRDM)

Post Rio Summit in 1992, professionals working in water resources sector, have come to a conclusion that 'Integrated Water Resources Development and Management (IWRDM)' is required to generate goods and services essential for the mankind, without affecting sustainability of the natural resources base. Dams have been built on rivers of the world for millennia, for capturing spatially and temporally variable high stage river flows for supply to needy areas and habitats during low flow periods. A dam raises the river water level, stores or diverts the flood flow and enables freshwater abstraction for conveying it over long distances and supply. Needs and demands for freshwater have kept rising in particular during the last few decades, with: growth in *population, urbanization, industrialization, economic regeneration and need for removal of mismatch* between different sections of societies. For supply management, thousands of storage dams ranging from mega to micro scale have been built, many are under construction and many more will be built. Dams have been deployed largely for facilitating supply from upstream watershed with surplus water availability to downstream area with deficit availability against a relatively high demand, which can't be fulfilled from flow, run-of-the-river.

In spite of intense dam building activity during the last century, both per capita availability & storage volume has kept declining because of finite availability and unabated population growth. As such, more and more innovative methods of water management to produce more goods and services with lesser water have been deployed and newer strategies are being devised. A river basin is recognized as a natural unit determining the available quantum of freshwater. Needy areas *more within and less outside* basin boundaries have been provided with water supply, wherever dam & related infrastructure cost was socially acceptable and economically viable. More and more complex structures have been however built in recent times to serve needy areas within and across river basin boundaries hitherto considered expensive. The cost of building safe dams and associated appurtenances including pumping stations, canals, pipelines, tunnels etc. of increasingly: *larger size, at more difficult locations and yet possessing long life*: has been relatively coming down with faster march of material sciences, computational aids in their design, and vastly modernized construction technology and equipment.

1.2. Inter Basin Water Transfer (IBWT), Committee on Dams and Water Transfer (CDWT), Terms of Reference (ToR) & Bulletin

Proposals of schemes for such inter-basin water transfers (IBWT) are now more common, though in past isolated schemes in more than 40 countries barring a few that successfully implemented not one or two but clusters of such schemes for benefiting arid/semiarid areas are well known. Dams large and small constitute the basic structural intervention facilitating IBWT along-with 'within-basin' transfers. Larger dams raise river water levels higher reducing the cost of transfer across ridges between river basin boundaries by means of shorter tunnels or pumping stations needing lesser lift. Larger reservoirs also balance the variability of water availability throughout the year and consequently balance the temporal gap in demand and supply. Depending upon the size and water availability, the gaps spanning over several months to a year or more can be bridged. Many dams now combine water transfer both within and across basin boundaries conjunctively. Many developing countries still have a large mismatch between needs and level of supply that threatens to grow during the next few decades. Some of them have undertaken ambitious proposals for IBWT. Keeping this background in mind, the ICOLD decided in the year 2003 to constitute an International Technical Committee on Dams and Water Transfer (CDWT) to comprehensively study present mode of IBWT, and frame guidelines that will be useful for professionals devising new schemes.

The identified Terms of Reference (ToR) for CDWT are as follows.

1. Collection of information on present status of intra-inter basin, and inter sub-basin transfer of water resources.
2. Guidelines for examination of the need and potential for inter-basin developments.
3. Limits of water transfers from surplus to deficit basins.
4. Benefits and costs analysis.
5. Collaboration with the Committee on the Environment to define the specificities of the environmental impacts of water transfers.
6. Guidelines for study of options for inter-basin transfers.

The CDWT has decided to bring out a bulletin to respond to these ToR in following Chapters.

Chapter 1 Introduction

Chapter 2 Inter-Basin Water Transfer Registry

The CDWT has followed up the work of compilation of salient features of IBWT schemes reported in global literature as could be accessed from a similar effort carried out by its Chairman in his capacity as Secretary General ICID (International Commission on Irrigation and Drainage) way back in 2002-03. The ICID had set up a Task Force on IBWT towards the end of 2003 to carry over the work done by then, to a logical conclusion. The work of the TF.IBWT is expected to end shortly. In the meantime, a draft report was posted on ICID website. It has been extensively utilized in drafting this Chapter.

Chapter 3 Need, Potential and Limit for Inter-Basin Water Transfer: 3.1 Water Balance studies, 3.2 The role of dams in Water Transfers, 3.3 Layout options

It covers in 3 parts the ambit of the ToR. First explains how to decide whether a basin or a sub-basin or a smaller area is water deficit or water surplus depending upon projected needs and likely demands on water availability by transfer from upstream. In the second part, it covers how a dam or a combination of two or more dams can help water transfer. It shows that the transfer can take place either by a conventional canal taking off from a dam and leading the transferred water to another reservoir created above another dam or downstream of the second dam. Or the transfer can take place by pumping water from the first reservoir into a higher level canal leading across the intervening ridge to another basin or sub-basin. The third part of the chapter shows the various possible layouts of combinations of dams / canals / pumping stations for transfer.

Chapter 4 Assessment of Environmental and Social Impacts

It lists all the possible environmental impacts as voiced by social activists and brings out ways to minimize them. Compensatory measures that can be taken are also listed. It is explained that possible impacts are similar to those dealt with in intra-basin WRD. Unfortunately, the literature survey has not indicated assessment of environmental impacts and steps taken to reduce them to a manageable level. The positive impacts of IBWT are well known. The feared negative ones are more imaginary and baseless. Mostly they indicate a red flag, to be taken note of and mitigation planned. Like environmental impacts, social impacts are mostly positive. Negative impacts comprise i) displacement caused by submergence under reservoir waters and that due to water conveyance / conductor system, ii) loss of land acquired for the infrastructure. As appropriate R&R measures are by now in place in countries round the world, these impacts can be minimized. The assessment of environmental impacts is not made in context of population benefitted versus those affected. While making such assessments, the benefits are largely ignored, the impacts are detailed in depth often leading to an unbalanced view of the whole process of assessment and neutrality of the examination is lost.

Chapter 5 Benefit and Cost Analysis

It lists and briefly describes different methods for carrying out benefit cost analysis for a proposed IBWT scheme. As always, direct benefits from such scheme can be quantified fairly accurately. The indirect benefits are difficult to quantify. However keeping in view the experience of the last fifty and odd years, these can be projected. Incidental benefits accruing from such schemes are more difficult and are often subject to conjecture. Cost of an IBWT scheme is many a time higher than a conventional in-basin scheme but as the deficit region of another basin can't be served otherwise, the opportunity costs are weighed against the benefits. Funding agencies both bilateral and multilateral follow specific procedures for carrying out the Benefit-Cost (BC) analysis. Other methods used comprise: discounted cash flow method, the Internal Rate of Return (IRR), the Economic Rate of Return (ERR) methods. The BC analysis helps comparison of various options open for prioritization and adoption of a particular scheme from amongst several technically feasible ones. Finally a scheme has to be financially viable, technically feasible, socially acceptable and environmentally sustainable. It is difficult to achieve all these conditions simultaneously and equally. As such choice of a particular scheme is often a result of trade-offs between these criteria, a society can bear.

Chapter 6 Guidelines for study of options to IBWT

It lists various managerial options of in-basin development to IBWT as articulated by activists opposing IBWT. They are technically examined, and socio-economically assessed before a choice is made. They include: demand management, water saving, and improving water use efficiency of existing schemes. They also include structural measures such as: watershed development and desalination. The chapter 6 addresses advantages, disadvantages of each of these options to enable assessment of their applicability and real value for comparison with the proposed IBWT scheme. The Chapter concludes that effectiveness of the administrative/managerial options that are non-structural in nature are the result of adequacy of Governance that one obtains in a country where IBWT is being planned. Any structural measure can't wish away such status. The CDWT considers the proposed structural options as complementary and not in competition with IBWT. Both of them have to operate within narrow margins and have obvious limitations which are brought out.

2. Inter-Basin Water Transfer Registry

This compilation is part of a work being done by the International Commission on Irrigation and Drainage (ICID) under the label Experiences With Inter Basin Water Transfers For Irrigation, Drainage and Flood Management, by the Task Force on Inter Basin Water Transfers. This work was adapted from the draft updated to 2007, edited by Jancy Vijayan and Bart Schultz.

Some information was brought by CDWT members and incorporated on their work which represents, although incomplete, the projects around the world which deals with this subject.

Country/ state/province	Name of the scheme	Inter basin water transfer		Average transfer (BCM/yr)	Purpose(s)	Year of completion, under constrution/proposed
		From	To			
			Asia			
Pakistan	1. Upper Chenab Canal	Marala at Chenab River	Ravi River	14.57	Irrigation	1912
	2. Haveli Canal	Trimmu at Chenab River	Ravi River	4.60	Irrigation	1939
	3. Marala Ravi Link	Marala at Chenab	Ravi River	1.23	Irrigation	1956
	4. Rasul - Qadirabad Link	Jhelum	Chenab	16.96	Irrigation	1969
	5. Trimmu - Sidhnai Link	Chenab	Ravi	9.80	Irrigation	1969
	6. Sidhnai – Mailsi – Bahawal Link	Ravi	Sutlej with siphon at Mailsi	9.01	Irrigation	1969
	7. Qadirabad – Balloki Link	Chenab	Ravi	16.61	Irrigation	1970
	8. Upper Jhelum Canal	Jhelum River	Chenab River	11.04	Irrigation, hydropower	1915
	9. Montgomery – Pakpattan Link	Ravi River	Sutlej River	0.88	Link	1945
	10. Bombanwala Ravi Badian Depalpur Link	Chenab River	Ravi River	6.18	Link	1956
	11. Balloki – Sulemanki Link – i (bs-i)	Ravi River	Sutlej River	13.25	Link	1955
	12. Balloki - Suleimani Link – II (BS-II)	Ravi	Sutlej	11.98	Link	1970
	13. Taunsa - Panjnad Link	Indus	Chenab	12.58	Link	1970
	14. Chashma – Jhelum Link	Indus	Jhelum	19.39	Link	1971
	15. Pakpattan – Islam Link	Upper Pakpattan Canal	Islam Barrage	0.88	Link	1969
			Sub-total existing IBWT schemes Pakistan	149.0		
	1. Mangla – Marala Link	Mangla at Jhelum River	Chenab River	8.83	Irrigation Flow augmentation	
	2. Kalabagh – Rasul Link	Kalabagh at Indus	Jhelum River	0.88	Irrigation Flow augmentation	
			Sub-total proposed IBWT schemes Pakistan	9.7		
India	1. Ghagra-Sarda	Ghaghara	Sharda	15.16	Irrigation	Completed (?)
	2. Periyar Vegai Link	Periyar	Vaigai	1.29	Irrigation, municipal water supply	1895
	3 Kurnool Cudappa Canal	Krishna	Pennar	2.68	Irrigation, municipal water supply	1863
	4. Telgu Ganga Scheme	Krishna	Chennai metropolitan area	0.34	Irrigation, municipal water supply	Completed (?)
	5. Parambikulam Aliyar Scheme	Parambikulam at Chalakudy River Basin	Aliyar, Bharathapuzha and Cauvery River basins	NA	Irrigation, hydropower	1960s
	6. Madhopur-Beas Link	Ravi	Beas	4.5	Irrigation, municipal water supply	1960
	7. Beas - Sutlej Link	Beas	Sutlej	4.9	Irrigation, municipal water supply	Completed (?)
	8. Indira Gandhi Nahar Scheme	Ravi River	Beas River (Rajasthan)	9.4	Irrigation, water supply	1986
	9. Satluj-Yamuna Link	Bhakra River, Punjab	Yamuna River, Haryana.	4.32 #	Irrigation, municipal and industrial water supply	Haryana portion completed
	10. Sardar Sarovar Scheme	Narmada Basin, Gujarat	Areas in Rajasthan, Maharastra and Madhya Pradesh staes of India	34.22	Irrigation, municipal and industrial water supply hydropower	90% completed in 2006 and full completion by 2008
	11. Tehri Dam Scheme	Bhagirithi, Ganga Basin, Uttarakhand	Uttar Pradesh and Delhi regions	0.44	Irrigation, hydropower, municipal water supply	2006
			Sub-total existing IBWT schemes India	72.9	# not added in the subtotal entry, as are not completed	
	1. Bedti- Varada	Bedti	Krishna	0.24	Irrigation	Under consideration.
	2. Netravati- Hemavati	Netravati	Cauvery	0.19	Irrigation	Under consideration.
	3. Manibhadra-Dowlaiswaram	Mahanadi	Godavari	12.17	Irrigation, municipal and industrial water supply, hydropower	Under consideration.
	4. Polavaram-Vijayawada	Godavari	Krishna	5.33	Irrigation, municipal and industrial water supply	Under consideration.
	5. Inchampalli Low Dam-Pulichintala	Godavari	Krishna	4.37	Irrigation, municipal and industrial water supply, hydropower	Under consideration.
	6. Inchampalli-Nagarjunasagar	Godavari	Krishna	16.43	Irrigation, municipal and industrial water supply, hydropower	Under consideration.
	7. Nagarjunasagar-Pennar Somasila	Krishna	Pennar	12.15	Irrigation, municipal and industrial water supply, flow augmentation, hydropower	Under consideration.
	8. Krishna (almatti)-Pennar	Krishna	Pennar	1.98	Irrigation, municipal and industrial water supply, hydropower	Under consideration.

	9. Somasila-Grand Anicut	Pennar	Cauvery	8.57	Irrigation, municipal water supply, flow augmentation	Under consideration.
	10. Kattalai – Vaigai-Gundar	Cauvery	Vaigai and Gundar	2.25	Irrigation, municipal and industrial water supply	Under consideration.
	11. Parbati –Kalisindh–Chambal	Parbati and Kalisindh	Chambal	1.36	Irrigation, municipal water supply	Under consideration.
	12. Par-Tapi-Narmada	Par-Tapi	Narmada	1.35	Irrigation, hydropower	Under consideration.
	13. Ken-Betwa	Ken	Betwa	1.02	Irrigation, municipal water supply, hydropower	Under consideration.
	14. Pamba-Achankovil-Vaippar	Pamba, Achankovil	Vaippar	0.63	Irrigation, flow augmentation, hydropower	Under consideration.
	15. Krishna (srisailam)-Pennar	Krishna	Pennar	2.31	flow augmentation, hydropower	Under consideration.
	16. Damanganga – Pinjal	Damanganga	Pinjal	0.91	Municipal water supply	Under consideration.
	17.Diversions through 13 Links under Himalayan Components			140.00		
		Sub-total schemes under construction or proposed India		211.0		
China	1. Dujian Weir	Ming River	Minjiang, Fujiang, and Taojiang Rivers	11	Irrigation, flood management	300 BC
	2. Datonghe River - Qinwangchuan water Transfer Scheme	Datonghe River	Qinwangchuan area	0.40	Irrigation	1995
	3. Yangtze to North Jiansu, River	Yangtze River	North Jiansu, River	7	Irrigation, flood management, navigation	1987
	4. Yellow River to Qingdao city water transfer Scheme	Yellow River	Qingdao City	0.24	Irrigation, municipal and industrial water supply, hydropower	1989
	5. Fuer River Water Transfer Scheme	Fuer River	Honhe River	0.10	Irrigation, municipal and industrial water supply	1994
	6. Biliu River - Dialian City Water Transfer Scheme	Biliu River	Dialian city	0.93	Irrigation, municipal water supply, flood management	1983
	7. Wanjiazhai Yellow River Water Transfer Scheme	Wanjiazhai Reservoir	Taiyuan, Dadong and Shuozhou of Shanxi Province	0.32 (first stage)	Flood management, municipal and industrial water supply, hydropower	2002
	8. Dongwan-Shenzhen Water Supply Scheme	Dongjiang River, Dongwan	Shenzhen Reservoir	1.74	Municipal water supply, hydropower	1965
	9. Luan River to Tianjing City Water Transfer Scheme	Luan River	Tianjing City	1.95	Municipal water supply, hydropower	1982-83
			Sub-total existing IBWT schemes China	23.7		
	1. Eastern Route Scheme	lower reaches of Yangtze	Yellow River and then to tiajin	34.3	Irrigation, municipal water supply	Scheme launched on 27 dec. 2002
	2. Middle Route Scheme	middle reaches of Yangtze River	Yellow River	13.0	Irrigation, municipal water supply	under construction and completed by 2010
	3. Western Route Scheme	upper reaches of Yangtze River	Yellow River	17.0	Municipal water supply, flow augmentation	proposed (likely to start in 2010)
		Sub-total Schemes under construction or proposed China		64.3		
Iraq	1. Tharathar Scheme	Tigris (via tharathr lake)	Euphrates	34.68	Irrigation, flood management, hydro power	completed
			Sub-total existing IBWT scheme Iraq	34.68		
Japan	1. Ryoso Irrigation Scheme	Tone River	Ichinomiya River	0.36	Irrigation	1965
	2. Nansatsu Irrigation	Umawatari River and 2 Rivers	Lake Ikeda	0.12	Irrigation	1984
	3. Hatori dam	Tsurunuma River in Agano River	Kumato River, Abukuma River	0.18	Irrigation, hydropower	1956
	4. Dozen-Dogo Plain Scheme	Nakayama River Shigenobu river	Omogo	0.18	Irrigation, hydropower	1967
	5. Asaka Irrigation Canal	Lake Inawashiro (Agano River basin)	Gohyaku River (Abukuma River)	1.58	Irrigation and water supply	1882
	6. Tone Transfer Scheme	Tone River	Ara River	3.94	Irrigation, municipal and industrial water supply	1965
	7. Totsukawa and Kinokawa Scheme	Totsu River, Kino River	Kino River, Yamato River basin	0.32	Irrigation, hydropower	1983
	8. Kagawa Canal Scheme	Yoshino River	Kagawa Prefecture	1.83	Irrigation, municipal and industrial water supply	1981
	9. Toyogawa Canal Scheme	Tenryu River	Toyogawa River	0.50	Irrigation, municipal and industrial water supply	1968
	10. Lake Biwa Canal Scheme	Lake Biwa	Kyoto, Kamo River	0.13	Municipal, hydropower, transportation	1890

	11. Uryu Hydropower Scheme	Ishikari River	Tesio River	1.40	Hydropower	1943
	12. Haji Dam	Gonokawa River	Ota river	0.10	Municipal water supply	1974
			Sub-total existing IBWT schemes Japan	10.6		
	1. Kasumigaura Project	Nakagawa river	Kasumigaura Lake	0.82	Flow augmentation and water quality control	2010
	Sub-total proposed or under construction IBWT schemes Japan			0.8		
Iran	1. Cheshmah Langan	Persian Gulf and Oman Sea	Central Plateau	0.12	Irrigation, municipal and industrial water supply	
	2. First Tunnel from Kouhrang Mountains	Persian Gulf and Oman Sea	Central Plateau	0.30	Irrigation, municipal and industrial water supply	
	3. 2nd Tunnel from Kouhrang Mountains	Persian Gulf and Oman Sea	Central Plateau	0.25	Irrigation, municipal and industrial water supply	
	4. Talghan Dam	Caspian Sea	Central Plateau	0.42	Irrigation and municipal water supply	
	5. Lar Dam	Caspian Sea	Central Plateau	0.18	Potable water supply	
			Sub-total existing IBWT schemes Iran	1.3		
	1. Ghatari Springs	Gharaghum	Central Plateau	0.01	Municipal water supply	Under study
	2. Transfer From Dez to Ghomrud	Persian Gulf and Oman Sea	Central Plateau	0.12	Municipal and industrial water supply	In process
	3. Tang-Sorkh Reservoir Dam	Persian Gulf and Oman Sea	Central Plateau	0.33	Municipal and industrial water supply	Under study
	4. Talvar Dam	Caspian Sea	Central Plateau	0.09	Municipal water supply	In process
	5. Sheshpear Reservoir Dam	Persian Gulf and Oman Sea	Central Plateau	0.06	Municipal water supply	Under study
	6. Ruzbeh Spring	Caspian Sea	Central Plateau	0.01	Municipal water supply	In process
	7. Kamal-Saleh Dam	Persian Gulf and Oman Sea	Central Plateau	0.07	Municipal and Industry	In process
		Sub-total schemes under construction or proposed in Iran		0.7		
Republic of Korea	1. Daechong wide area water supply	Daechong Dam	A-san	0.36	Municipal water supply	1985
	2. Daechong wide area water supply	Daechong Dam	Chunan	0.09	Municipal water supply	1988

	3. Junju systematical wide area water supply	Yongdam Dam	Junju Gunsan	0.26	Municipal water supply	1998
	4. Geum River wide area water supply	Bu-yeo	Gunsan Junju	0.11	Municipal water supply	2000
	5. Chongju-Intake tower	Daechong Dm	Jibuk Filter Plant	-	-	-
			Sub-total existing IBWT schemes Korea	0.8		
	1. SumJin Water Supply Reservoir System	SumJin River	DonJin River	0.11		
		Sub-total schemes under construction or proposed in Korea		0.1		
Malaysia	1. Kelinchi/Terip	Upper Muar Basin	Linggi Basin	0.14	Water supply	1996
			Sub-total existing IBWT scheme Malaysia	0.1		
	1. Kelau-Langat	Kelau River	Langat	0.55	Water supply	Proposed
		Sub-total scheme under construction or proposed Malaysia		0.6		
Central Asian Countries	Karashi Scheme	Amu Darya	Uzbekistan			
	Amu-Bukhara Canal	Amu Darya	Uzbekistan			
	Karakum Canal	Amu Darya	Southern part of Turkmenistan			
		Sub-total existing IBWT schemes Central Asian Countries				
	1.Partial transfer of Siberian Rivers to Urals, West Siberia, Central Asia and Kazakhistan	Ob	Ural, Syr Darya, Amu Darya River system	27	Irrigation, hydropower, Municipal water supply, feeding of Ural Sea and Rivers	Proposed
	Sub-total scheme under construction or proposed Central Asian Countries			27		
Nepal	Melamchi River to Kathmandu City	Melamchi River	Kathmandu City	0.62	Water supply	Under construction.
		Sub-total schemes under construction or proposed Nepal		0.6		
			Sub-total Asia existing schemes Sub-total Asia schemes under construction or proposed	293.1 314.8		
			Americas			
Canada *Alberta*	1. Bow River Irrigation District Little Bow Canal	Bow River, South Sask. Basin Highwood River, Bow River Basin	Bow and Oldman Rivers, South Sask. Basin Little Bow River, Oldman Basin	0.388 0.057	Irrigation Irrigation	(1920) 2000 (1910) 2000

Canada *Alberta*	2. Western Irrigation District	Bow River, South Sask. Basin	Bow and Red Deer Rivers, South Sask. Basin	0.135	Irrigation	1910
Canada *Alberta*	3. Eastern Irrigation District	Bow River, South Sask. Basin	Bow and Red Deer Rivers, South Sask. Basin	0.602	Irrigation	1914
Canada *Alberta*	4. Waterton-Belly-St. MaryTransfers	Waterton, Belly and St. Mary Rivers, Oldman River Basin	Oldman and South Sask., South Sask. Basin	0.467	Irrigation	(1915) 1969
	(a) Belly-St. Mary Canal	Waterton and Belly Rivers, Oldman, South Sask.	St. Mary Reservoir, Oldman, South Sask.	0.173	Irrigation	1959
	(b) Waterton-Belly Canal	Waterton Reservoir, Oldman River Basin	Belly River, Oldman River Basin	0.110	Irrigation	1968
Canada *Alberta*	5. Lethbridge Northern Irrigation District	Oldman River, South Sask. Basin	Little Bow and Oldman Rivers, South Sask. Basin	0.151	Irrigation	1924
Canada *Alberta*	6. Mnt. View-Leavitt-Aetna Irrigation Canal	Belly River, Oldman River Basin	St. Mary River,Oldman River Basin	0.016	Irrigation	(1936) 1945
Canada *Saskatchewan*	7. Cypress Lake Transfers	Belanger and Davis Creeks (Frenchman River) and Battle Creek	Cypress Lake, Frenchman River and Battle Creek	0.019	Irrigation	1939
Canada *Saskatchewan*	8. Swift Current Irrigation Scheme	Swift Current Creek, South Sask. Basin	Rush Lake, Old Wires Lake Basin	0.016	Irrigation	1953
Canada *Ontario*	9. Adam Creek	Mattagami River, Moose River Basin, James Bay	Adam Creek, Mattagami, Moose River Basin	(94.5)#	Flood management	1961
Canada *Manitoba*	10. Seine River Transfer	Seine River, Red River Basin	Red River, Red River Basin	(2.678)#	Flood management	1961
Canada *Manitoba*	11. Red River Floodway	Red River, Nelson Basin	Red River, Nelson Basin	(53.55)#	Flood management	1969
Canada *Manitoba*	12. Portage Transfer	Assiniboine River, Nelson Basin	Lake Manitoba, Nelson Basin	(22.365)#	Flood management	1970
Canada *British Columbia*	13. Vernon Irrigation District	Duteau Creek, Shuswap-Thompson-Fraser River Basin	Vernon Creek, Okanagan Lake, Columbia River Basin	0.190	Irrigation, municipal supply	1907
Canada *Saskatchewan*	14. Qu`Appelle Transfer	Lake Diefenbaker, South Saskatchewan River, Nelson Basin	Qu'Appelle River, Assiniboine River, Nelson Basin	0.082	Irrigation, municipal water supply, recreation	(1959) 1967
Canada *Manitoba*	15. Pasquia Land Resettlement	Pasquia River, Saskatchewan Basin	Carrot River, Saskatchewan Basin	0.154	Drainage, wildlife	1960
Canada *Alberta*	16. Brazeau Hydropower Scheme	Brazeau River, North Sask. Basin	Brazeau River, North Sask. Basin	1.654	Hydropower, flow control	1965
Canada *Saskatchewan*	17. Saskatoon Southeast Water Supply System	Lake Diefenbaker, South Saskatchewan Basin	Little Manitou Lake and other reservoirs en route	0.050	Irrigation, municipal and industrial water supply, wildlife, recreation	1968
Canada *Ontario*	18. Welland Canal	Lake Erie, Great Lakes Basin	Lake Ontario, Great Lakes Basin	7.529	Hydropower, navigation	(1829) 1951
Canada *New Brunswick*	19. St. John Water Supply	Loch Lomond, Mispec River, Bay of Fundy	Little River, Saint John, Bay of Fundy	0.063	Municipal water supply	1900
Canada *British Columbia*	20. Coquitlam-Buntzen	Coquitlam Lake (Coquitlam R.), Fraser River Basin	Buntzen Lake, Burrard Inlet	0.882	Hydropower	1912
Canada *Manitoba*	21. Winnipeg Aqueduct	Shoal Lake, Lake of the Woods Basin	City of Winnipeg, Red River Basin	0.095	Municipal water supply	1919
Canada *Nova Scotia*	22. Sandy Lake	Sandy Lake, Indian River	Northeast River, St. Margaret's Bay	0.170	Hydropower	1927
Canada *British Columbia*	23. Alouette	Alouette Lake, Fraser River Basin	Stave Lake, Fraser River Basin	0.662	Hydropower	1928
Canada *Nova Scotia*	24. Jordan	Jordan Lake via L. Rossignol	Mersey River	0.057	Hydropower	1929
Canada *British Columbia*	25. Bridge River	Carpenter Lake (Bridge River), Fraser River Basin	Seton Lake (Seton R.), Fraser River Basin	2.898	Hydropower	1934
Canada *Ontario*	26. Long Lac	Long Lake, Albany River Basin, James Bay	Aguasabon River, Lake Superior, Great Lakes Basin	1.418	Hydropower, log driving	1939
Canada *Ontario*	27. Onaping	Onaping Lake, Vermilion and Spanish Rivers, Great Lakes Basin	Moncrieff Creek, Spanish River, Great Lakes Basin	0.441	Hydropower (formerly log driving)	1940
Canada *Nova Scotia*	28. Ingram	Ingram River, St. Margarets Bay Lake	St. Croix River	0.019	Hydropower	1940

Canada *Alberta*	29. Ghost-Minnewanka Transfer	Ghost River, Bow River Basin	Lake Minnewanka, Cascade, Bow Basin	0.044	Hydropower	1941
Canada *Ontario*	30. Ogoki	Ogoki River, Albany River Basin, James Bay	Little Jackfish River, Lakes Nipigon, Superior, Great Lakes Basin	3.560	Hydropower	1943
Canada *Nova Scotia*	31. Donahue	Donahue Lake, Larry's River	Dickie Brook, Salmon River, Chedabucto Bay	0.441	Hydropower	1948
Canada *Alberta*	32. Spray Hydro Complex (a) Smith-Dorrien Transfer	Spray and Kananaskis Rivers, Bow Basins Smith-Dorrien Creek, Kananaskis, Bow Basin	Bow River, South Sask. Basin Spray River, Bow River Basin	0.360 0.022	Hydropower Hydropower	(1949) 1959 (1949)1959
Canada *British Columbia*	33. Kemano	Tahtsa Lake (Nechako River), Fraser River Basin	Kemano River, Pacific Ocean	3.623	Hydropower	1952
Canada *Manitoba*	34. Pine Creek Transfer	Pine Creek, Roseau River Basin	Roseau Wildlife Management Pools (US)	0.022	Wildlife	1953
Canada *Quebec*	35. Megiscane transfer	Megiscane River, Bell and Nottaway Rivers, James Bay	Gouin Reservoir, St. Maurice River, St. Lawrence River Basin	0.347	Hydropower	1953
Canada *British Columbia*	36. Doran Lake	Doran Lake, Great Central Lake Stamp and Somass Rivers Alberni Inlet	Taylor River, Sproat Lake, Somass River Alberni Inlet	0.032	Hydropower	1955
Canada *British Columbia*	37. Cheakamus	Cheakamus River, Squamish River Basin, Howe Sound	Squamish River, Howe Sound	1.166	Hydropower	1957
Canada *British Columbia*	38. Ash River	Elsie Lake (Ash R.) Somass River Basin, Vancouver Island	Great Central Lake (Stamp. R.), Somass River Basin, Vancouver Island	0.630	Hydropower	1958
Canada *British Columbia*	39. Campbell River	Heber (Gold), Quinsam and Salmon Rivers, Vancouver Island	Campbell River, Vancouver Island	0.378	Hydropower	1958
Canada *Saskatchewan*	40. Wellington Lake Hydro Scheme	Tazin Lake, Taltson Basin	Charlot River, Lake Athabasca-Slave Basin	0.882	Hydropower	1958

Canada *British Columbia*	41. Victoria Lake	Victoria Lake, Marble River Basin, Vancouver Island	Neroutsos Inlet, Vancouver Island	0.221	Hydropower, industrial water supply	1960
Canada *Quebec*	42. Manouane River	Manouane River, Peribonca River, St. Lawrence River Basin	Bonnard River, Peribonca River, St. Lawrence Basin	3.623	Hydropower	1960
Canada *Ontario*	43. Little Abitibi	Little Abitibi River, Moose River Basin, James Bay	Newpost Creek, Abitibi River, Moose River Basin	1.26	Hydropower	1963
Canada *Newfoundland*	44. Deer Lake	Indian Brook	Birch Lake, Deer Lake	0.158	Hydropower	1963
Canada *Ontario*	45. Opasatika	Oposatika River, Missinaibi River, Moose River Basin, James Bay	Hull and Lost Creeks, Kapuskasing and Mattagami Rivers, Moose River Basin	0.473	Hydropower	1965
Canada *Ontario*	46. London	Lake Huron, Great Lakes Basin	Thames River, Lake St. Clair, Great Lakes Basin	0.095	Municipal water supply	1967
Canada *Newfoundland*	47. Bay d'Espoir	Victoria, White Bear, Grey and Salmon Rivers	NW Brook, Bay d'Espoir	5.828	Hydropower	1969
Canada *Newfoundland*	48. Churchill Falls	Julian-Unknown River	Ossokamanouan-Gabbro Reservoir, Churchill River	6.174	Hydropower	1971
Canada *Newfoundland*	49. Churchill Falls	Naskaupi River	Churchill River	6.300	Hydropower	1971
Canada *Newfoundland*	50. Churchill Falls	Kanairiktok River	Churchill River	4.095	Hydropower	1971
Canada *Quebec*	51. Barriere transfer	Cabonga Reservoir, Gatineau and Ottawa Rivers, St. Lawrence River Basin	Dozois Reservoir, Ottawa River, St. Lawrence River Basin	0.387	Hydropower	1975
Canada *Alberta*	52. Beaver Creek Transfer	Beaver Creek, Athabasca River Basin	Poplar Creek, Athabasca River Basin	0.060	Mining	1976
Canada *Manitoba*	53. Churchill Transfer	Southern Indian Lake, Churchill River Basin	Rat-Burntwood Rivers, Nelson River Basin	24.413	Hydropower	1976
Canada *Quebec*	54. La Grande (Boyk-Sakami Transfer)	Eastmain and Opinaca Rivers, Eastmain River Basin	La Grande River, La Grande River Basin	26.618	Hydropower	1980

Canada *Nova Scotia*	55.Wreck Cove	Cheticamp River, Ingonish River, Indian Brook, McLeod Brook	Gisborne Reservoir, Wreck Cove Brook	0.331	Hydropower	1980
Canada *Nova Scotia*	56. Bloody Creek	Bloody Creek, Annapolis River	Paradise River, Annapolis River	0.113	Hydropower	1981
Canada *Quebec*	57. La Grande (Fregate transfer)	Fregate Lake	La Grande River	0.977	Hydropower	1982
Canada *Quebec*	58. La Grande (Laforge transfer)	Caniapiscau River, Koksoak River Basin	La Grande River, La Grande River Basin	24.885	Hydropower	1983
Canada *Quebec*	59. Portneuf transfer	Portneuf River, St. Lawrence Basin	Pipmuacan Lake, Bersimis River, St. Lawrence Basin	0.315	Hydropower	2004
Canada *Quebec*	60. Sault-aux-Cochons transfer	Sault-aux-Cochons River, St. Lawrence Basin	Pipmuacan Lake, Bersimis River, St. Lawrence Basin	0.205	Hydropower	2004
Canada *Quebec*	61. Manouane (II) transfer	Manouane River, Peribonca River, St. Lawrence Basin	Pipmuacan Lake, Bersimis River, St Lawrence Basin	0.945	Hydropower	2005
			Sub-total existing IBWT schemes Canada	137.5		
	1. Mcgregor transfer	Headwaters of Fraser River	Headwaters of Peace River	6.3	Irrigation, hydropower, municipal water supply	Proposed
	2. Grand Canal Replenishment and Northern Lakes Development	James Bay St. Lawrence River	Great Lake	20.95	Irrigation, municipal and industrial water supply, hydropower, flow augmentation	Proposed
	3. Canadian Water	Several Canadian Rivers like Peace, Atha Basca, and Saskatchowar	Various Western States	184.5	Irrigation, municipal water supply, hydropower	Proposed
	4. Magnum Plan	Peace, Athabasca, Saskatchewar	Missouri	5.75	Irrigation, municipal water supply, hydropower	Proposed
	5. Central, North American Water Scheme	Mackenzie Churchill Nelson	Great Lakes, Western States	184.5	Irrigation, municipal water supply, hydropower	Proposed

	6. Smith Plan	Liard Mackenzie	Western United States	61.6	Irrigation, municipal water supply, hydropower	Proposed
			Sub-total schemes under construction or proposed Canada	463.6		
USA	1. Chicago Sanitary and Ship Canal Project	Lake Michigan (Chicago river)	Des Plaines river (Mississippi river)	2.9	Pollution control, Municipal, Industrial	1900
	2. Truckee Canal	Truckee river	Pyramid lake	0.15	Irrigation	1906
	3. Los Angeles Aqueduct	Owen valley	Los Angeles	0.36	Municipal	1913
	4. New York Delaware Aqueduct Project	Delaware River	New York City	1.10	Municipal, Industrial & Environmental including Fishery	1930
	5. All American Canal	Colorado river	Imperial and Coachella valleys of South-eastern California.	4.3	Irrigation	1940
	6. Colorado River Aqueduct	Lower Colorado river	California South Coast region	1.5	Municipal, Industrial, Irrigation	1941
	7. Colorado Transmountain Diversion Projects	Upper Colorado and San Juan rivers	South Platte Arkansas Rio Grande	0.70	Irrigation, Municipal	1957
	8. Central Valley Project (Northern California)	Sacramento river	San Joaquin Valley and San Francisco Bay area	4.6	Irrigation, Municipal, Fish and Wild life Environs	1950
	9. Colorado-Big Thompson Project	Lake Granby, Colorado river basin	Big Thompson	0.3 *	Irrigation, Municipal, Industrial	1957
	10. Trinity River Transbasin Diversion Project	Trinity	Sacramento	1.0	Irrigation, Hydropower	1963
	11. San Juan – Rio Chama Project	San Juan river (upper Colorado river basin)	Chama, a tributary of Rio Grande river	0.13 *	Municipal, Industrial, Irrigation	1957
	12. California's State Water Project	Feather river	San Francisco Bay area, San Joaquin Valley and Southern California	5.0	Municipal, Industrial, Irrigation, Hydropower	1973 (1st phase)
	13. Central Arizona Project	Colorado river	Central Arizona Phoenix- Tucson region	1.85	Municipal, Industrial, Irrigation	1985

	14. Central Utah Project	Duchesne river a tributary of Upper Colorado	Bonneville portion of the Great Basin	0.17	Irrigation, Municipal, Industrial	1957
	15. Garrison Diversion Project	Missouri river	Red and Soure rivers	0.1	Municipal, Industrial, Irrigation	Work was stopped for want of detailed EIS
			Sub-total existing IBWT schemes USA	23.73	* The individual amount of diversions is counted under the projects given at sr. no. 7.	
	1. North American Water and Power Alliance (NAWAPA)	North West Canada; Alaska, NW USA	South-West USA; Northern Mexico; South-Central Canada; Great Lakes	200	Irrigation, hydropower, municipal & industrial water supply and navigation	High cost and environmental problems.
	2. Texas Water Plan	Lower Mississippi; Eastern Texas	West Texas; Rio Grande; Texas Gulf Coast; Eastern New Mexico	21.0	Irrigation; municipal and industrial water supply, estuary improvement	Modifications are likely due to cost and environmental problems.
	3. High Plains Water Transfer Alternatives	Middle and Lower Missouri; tributaries of lower Mississippi; Sabine River	Central and Western Nebraska; Eastern Colorado; Western Kansas; Northern Texas; Western New Mexico	13.5	Irrigation	Preliminary study completed in 1982. Recommended for further studies.
			Sub-total schemes under construction or proposed USA	234.5		
Chile	1.Laja Diguillin	Laja River	Diguillin	1.26	Irrigation	1990
	2.Teno-Chimbarongo Canal	Teno River sub-basin, tributary of Mataquito River basin	Chimbarongo sub-basin of Rapel River basin	2.05	Irrigation, hydropower	1975
			Sub-total existing schemes Chile	3.3		

Brazil	Water Transfer Projects			Location in province or region	Water transfer in km³/ year	Purpose	Status/ Year of construction	Salient Features
	Project Name	From	To					
	Rio Sao Francisco Transbasin Diversion	São Francisco River	North East region of Brazil	Pernambuco, Paraíba, Rio Grande do Norte and Ceará, States	2.0 (average)	Multiuse	Proposed	
	Supply System Castanhão – Metropolitan Area of Fortaleza	Jaguaribe River	Metropolitan Area of Fortaleza	Ceará State	0.45 (average)	Urban use	Under construction	
	System Cantareira	Piracicaba River	Metropolitan Area of São Paulo (Tietê River)	São Paulo State	1,0 (max.)	Urban use	Under operation	
	System Henry Borden-Billings	Tietê River Basin	Ocean Basin	São Paulo State	2,2 (max.)	Power Generation	Under operation	Legal subjects reduced its flow, until certain environmental aspects are settled.
	Guandu System	River Guandu	Metropolitan Area of Rio de Janeiro	Rio de Janeiro State	2,0 (max)	Urban use	Under Operation	

			Sub-total schemes Brazil	7,65		
Bolivia	1. Misicuni Multipurpose Scheme	Titiri and Serkheta Rivers	Cochabama	0.2	Irrigation, hydropower, municipal water supply	Under construction
			Sub-total schemes under construction or proposed Bolivia	0.2		
			Sub-total Americas existing schemes	167		
			Sub-total Americas schemes under construction or proposed	707		

			Europe			
Russia	1. Kara-kum	Amu Darya	Caspian Kara Kum, Mary and ultimately to Ashgabat	-	Irrigation, industrial water supply	Completed
	2. Iski-Tyuya Tartar Canal	Zerafshan	Sanzar River	0.38	Flow augmentation	14th century
	3. Volga upstream - Ladozhskoye and Ilmen lakes	Volga upstream	Ladozhskoye and Ilmen lakes	-	Navigation	18th century
	4. Dnepr-Bug Canal	Dnieper River	Western Bug River	-	Navigation	19th century
	5. Moscow-Volga Canal	Moskva River	Volga	60	Navigation, municipal and industrial water supply, recreation	20th century
	6. Karshinsky	-	-	-		Completed
	7. Irdish-Karanganda	Irdish	Karanganda	-		Completed
	8. Nevinnomissky			-		Completed
			Sub-total existing IBWT schemes Russia	60.4		
	1.Northern Rivers to Volga Basin	Onega, Upper Sukhna and Pechora	Volga	20	Irrigation, municipal and industrial water supply	Proposed
			Sub-total schemes under construction or proposed Russia	20		
Romania	1. Ialomita-Mostistea (Dridu-Hagiesti Div.)	Ialomita River basin	Danube River basin	5.0	Irrigation	1985
	2. Danube-Black Sea Canal	Danube	Black Sea	-	Irrigation, navigation, industrial water supply	1994
	3. Ialomita – Baragan Transfer	Ialomita River basin	Arges River basin	1.5	Flow augmentation	1936
	4. Ialomita-Ilfov Transfer	Ialomita River basin	Arges River basin	2.5	Flow augmentation	1976
	5. Cerna-Motru Transfer	Cerna River basin	Jiu River basin	12.0	Flow augmentation	1980
	6. Cocani-Darza Transfer	Arges River basin	Ialomita River basin	5.0	Flow augmentation	1980
	7. Barcau-Varsolt Transfer	Crisuri River basin	Somes River basin	0.4	Municipal and industrial water supply	1994
	8. Topolog-Cumpana Transfer	Olt River basin	Arges River basin	8.0	Flow augmentation	1997
	9. Prut-Barlad Transfer	Prut River basin	Siret River basin	1.6	Flow augmentation	1998
	10. Rhine-Main Danube Canal	Rhine Main	Danube	-	Flow augmentation, navigation	
			Sub-total existing IBWT schemes Romania	36.0		
	1. Siret-Baragan Canal	Siret	Baragan	5.0		Under construction
			Sub-total of proposed IBWT schemes in Romania	5.0		
Slovakia	1. Nitra – Vah	Nitra at a point d/s of Nove Zamky	Vah	11.03	Irrigation, flood management	Completed
	2. Vazsky – Vah	Vazsky Dunaj	Vah	3.46	Irrigation, flood management	Completed
	3. Hnilec – Slana	Dedinky - Hinlee reservoir	Slana	0.28	Hydropower, flow regulation	Completed
	4. Vah – Nitra	Vah	Nitra – Zitava basin	0.31	Irrigation, pollution control	Completed
	5. Turiec – Hron	Turiec (Vah)	Hron	0.38	Hydropower, municipal water supply	Completed
			Sub-total existing IBWT schemes Slovakia	15.5		
	1. Danube southward transfer	Danube	Vah, Nitra, Hron and Ipel	-	Irrigation, flow augmentation	Proposed
	2. Hron – Zitava	Hron (Kozmalovee reservoir and Slatinka reservoir	Zitava	-	Municipal and industrial water supply, pollution control	Proposed
			Sub-total schemes under construction or proposed Slovakia	-		
Turkey	1. Southeast Anatolia Scheme	Euphrates River	Anatolia region	10.00	Irrigation, hydropower, municipal and industrial water supply	1990-1995-2010
			Sub-total existing IBWT scheme Turkey	10.0		
	1. Istanbul Yesilcay and Melen Water Supply Schemes	Goksu River and Canak River	Istanbul	0.15	Municipal water supply	
	2. Greater Melen Scheme	Melen River	Istanbul	0.27	Municipal water supply	
	3. Peace Pipeline Scheme	Tukkey	Syria and Jordan, Palestine, Saudia Arabia, Kuwait, Saudia Arabia, Bahrain, Qatar, United Arab Emirates and Oman,	5.84	Municipal water supply	
	4. Turkish Republic of Northern Cyprus (TRNC) Water Supply Scheme	Soguksu Stream	Lefkosa and Gazi Magosa	0.01	Municipal water supply	

	5. Manavgat River Water Supply Scheme	Manavgat River	Antalya on the Turkish Mediterranean coast- Israel	0.05	Municipal water supply	
Sub-total scheme under construction or proposed Turkey				6.3		
France	1. Lys- Lille region	Lys	Lille region	0.37	Irrigation, municipal water supply	Completed
	2. Neste-Garonne	Neste	Garonne	0.57	Water supply	1963
	3. Durance water supply scheme	Durance	Nearby urban downs	1.26	Municipal water supply	1963
	4. Escant - Lille Roubaix	Escant River	Lille Roubaix c elais and Dunkerque	0.16	Navigation	1976
	5. Cap de - Gave de	Cap de long River	Gave de pau River basin	-	Hydropower	Completed
Sub-total existing IBWT schemes France				2.4		
Spain	1. Upper Ebro-Bilbao	Zodarra	Bilbao	0.2	Irrigation, municipal and industrial water supply	1950
	2. Negratin - Almanzora	Guadalquivir River Basin	Almanzora area	0.05	Irrigation, municipal water supply	2004
	3. Ebro – Tarragonna	Ebro	Tarragonna (Catalonia)	0.12	Irrigation, municipal and industrial water supply	Completed
	4. Tagus – Segura	Tagus	Segura	1.0	Municipal and industrial water supply	Completed in 1979
Sub-total existing IBWT schemes Spain				1.4		
	1. Ebro water transfer scheme	Ebro	Barcelona metropolitan, Júcar basin, Segura basin and Almeria	1.05	Irrigation, municipal and industrial water supply	Proposed
Sub-total schemes under construction or proposed Spain				1.1		
Germany	1. Rhine-Main Region	Danube	Rhine (Kleine Roth Reservoir)	0.47	Water supply and navigation	Completed
Sub-total existing IBWT scheme Germany				0.5		
Finland	1.Helsinki Metropolitan area	Lake Paijanne	Helsinki area	0.10	Municipal water supply	1982
Sub-total existing IBWT scheme Finland				0.1		
Portugal	1.Multipurpose Alqueva Scheme	Guadiana River basin	Sado River basin	0.01	Irrigation, municipal and industrial water supply, hydropower	Under construction
Sub-total scheme under construction or proposed Portugal				0.0		

Czech Republic	1. Danube-Oder-Elbe	Danube	Oder – Elbe	1.89	Irrigation, navigation, municipal water supply	Proposed
Sub-total scheme under construction or proposed Czech Republic				1.9		
Great Britain	1. Bridgewater Canal	Duke of Bridgewater	Manchester	-	Navigation, recreation	1759-61
	2. Forth and Clyde Canal	River Forth.	River Clyde.	-	Recreation	1791
	3. Rochdale Canal	Sowerby Bridge in West Yorkshire, England	Bridgewater Canal in Manchester	-	Closed	1804
	4. Crinan Canal	Loch Fyne and the Firth of Clyde	Sound of Jura	-	Navigation, recreation	1801
	5. Kennet and Avon Canal	Thames at Reading	Avon at Bath	-	Navigation, recreation	1810
	6. Caldonian Canal	Atlantic	North Sea	-	Navigation, recreation	1822
	7. Manchester Ship Canal	Manchester	River Mersey and the sea	-	Navigation, recreation	1894
	8. Grand Union Canal	London, via Northampton and Leicester	Nottingham and the River Trent	-	Navigation, recreation	1900
	9. Stratford-Upon-Avon Canal	Birmingham suburbs	River Avon in Stratford on Avon	-	Navigation, recreation	1964
	10. Lancaster Canal	northern section, Ribble valley	southern section, Ribble valley	-	Navigation, recreation	-
	11. Leeds and Liverpool	North West seaport of Liverpool	Aire and Calder Navigation at Leeds	-	Navigation, recreation	-
	12. Llangollen Canal	Shropshire Union Canal	Shropshire farmlands	-	Navigation, recreation	-
	13. Oxford Canal	River Thames in Oxford	Midlands Canal system.	-	Navigation, recreation	
	14. Shropshire Union Canal	Urban Wolverhampton	River Mersey at Ellesmere Port	-	Navigation, recreation	-
	15. Staffordshire and Worcestershire Canal	Wolverhampton	Farmland of Cannock Chase before joining the Trent and Mersey Canal	-	Navigation, recreation	-
	16. Birmingham Canal	City of Birmingham	Staffordshire and Worcestershire Canal and the start of the Shroshire Union Canal at Aldersley	-	Navigation, recreation	-
Sub-total existing IBWT scheme Great Britain						
Sub-total Europe existing schemes Sub-total Europe schemes under construction or proposed				126 34		

			Africa			
South Africa	1. Orange – Riet	Orange	Riet	0.189	Irrigation	Completed
	2. Orange – Fish	Orange	Fish	0.643	Irrigation, municipal and industrial water supply	Completed
	3. Vaal - Crocodile	Vaal	Crocodile	0.615	Municipal and industrial water supply	Completed
	4. Vaal - Olifants	Vaal	Olifants	0.150	Industrial water supply, hydropower	Completed
	5. Olifants - Sand	Olifants	Sand	0.030	Municipal water supply	Completed
	6. Komati - Oilfants	Komati	Oilfants	0.111	Industrial water supply, hydropower	Completed
	7. Usutu - Oilfants	Usutu	Oilfants	0.081	Industrial water supply, hydropower	Completed
	8. Assegaal - Vaal	Assegaal	Vaal	0.081	Municipal and industrial water supply	Completed
	9. Buffalo - Vaal	Buffalo	Vaal	0.050	Municipal and industrial water supply	Completed
	10. Tugerla - Vaal	Tugerla	Vaal	0.630	Municipal and industrial water supply	Completed
	11. Tugela - Mhlatuze	Tugela	Mhlatuze	0.046	Municipal and industrial water supply	Completed
	12. Mooi - Mgeni	Mooi	Mgeni	0.069	Municipal and industrial water supply	Completed
	13. Fish - Sundays	Fish	Sundays	0.20	Municipal and industrial water supply	Completed
	14. Orange – Lower Vaal	Orange	Lower Vaal	0.052	Municipal and industrial water supply	Completed
	15. Caledon - Modder	Caledon (Orange)	Modder	0.040	Municipal and industrial water supply	Completed
	16. Lesotho – Vaal	Lesotho Highland scheme	Vaal	0.574	Municipal and industrial water supply	Completed
			Sub-total existing IBWT schemes South Africa	3.6		
	1. Zambezi transfer scheme	Zambezi River	South Africa	-	-	Conceptual stage
			Sub-total scheme under construction or proposed South Africa	-		
Morocco	1. Beni Moussa scheme	Oued El Rbia River	Tensift River	1.51	Irrigation	
	2. Al Wahda Scheme	Ouerga River	Moulouya	0.77	Municipal and industrial water supply	
			Sub-total existing IBWT scheme Morocco	2.3		
	1. Guerdane Scheme	Tensift basin	Souss-Massa	0.05		
			Sub-total scheme under construction or proposed Morocco	0.1		
Lybia	1. Great Man Made River scheme (Phase I)	Sarir and Tazerbo	Sirt and Benghazi	0.73	Irrigation, municipal and industrial water supply	1993
	2. Great Man Made River scheme (Phase II)	East and North Jabal Hsona	Tripoli	0.73	Irrigation, municipal and industrial water supply	1996
			Sub-total existing IBWT scheme Lybia	1.5		
	1. Great Man Made River scheme (Phase IV)	Jaghboub and Ghadames	Tobruck and Tripoli	0.69	Irrigation, municipal and industrial water supply	Proposed
			Sub-total proposed IBWTscheme Lybia	0.7		
Lesotho	1.Lesotho Highlands Water Scheme	Senqu River	South Africa	0.95	Hydropower, water supply	1990
			Sub-total existing IBWT scheme Lesotho	1.0		
	1. Lesotho Highlands Water scheme (Phase II)	Senqu River	South Africa	1.23	Irrigation, hydropower, water supply	Proposed
			Sub-total scheme under construction or proposed Lesotho	1.2		
Sudan	1. Jonglei Canal scheme	Sudd region	Sabat	5.00	Irrigation, flood management, navigation, municipal water supply	Proposed
			Sub-total proposed IBWTscheme Sudan	5.0		
Tanzania	1. Zanzibar Urban Water Supply Development Scheme			-	Water supply	Expected to complete in 2009
			Sub-total proposed IBWT scheme Tanzania	-		
Nigeria	1. Gurara water transfer scheme	Gurara River	Abuja	1.50	Water supply, environment protection	Under construction.
	2. Komadugu-Yobe Scheme	Komadugu, Yobe	Lake Chad	-	Environment protection	Under study.
			Sub-total under construction or proposed schemes Nigeria	>1.5		
Republic of Congo	1. Lake Chad Scheme	Congo Basin	Lake Chad	28.4	Irrigation, municipal water supply, navigation, hydropower, environment restoration	Under process.
			Sub-total proposed IBWT scheme Republic of Congo	28.4		

Sub-total Africa existing schemes Sub-total Africa schemes under construction or proposed				8.4 36.9		
Oceania						
Australia	1. Snowy Mountain Scheme	Eucumbene River, Tooma River and Upper Murrumbidgee	Murrumbidgee through its tributary Tumut, Lake Eucumbene and Murray River	2.3	Irrigation, hydropower	1974
Sub-total existing IBWT scheme Australia				2.3		
	1. Kimberley Pipeline	Kimberley	Perth	-		Conceptual stage
Sub-total proposed IBWTscheme Australia				-		

Algeria Constantine	Beni Haroun water transfer system	Beni Haroun Dam	Constantine	0,504	Water supply and irrigation	2007 & under construction
Algeria	Akbou-Bejaia Water Transfer system	Tichy-Haf Dam	Bejaia	0,09	Water supply and irrigation	2010
Algeria Tizi Ouzou / Boumerdes / Algiers	Water transfer Taksebt-Algiers	Taksebt Dam	Algiers	0,22	Water supply	2008
Algeria Bouira / Tizi Ouzou	Koudiat Acerdoune Water Transfer system I	Koudiat Acerdoune Dam	Ouadhias	0,039	Water supply and irrigation	Under construction
Algeria Médéa / Bouira	Koudiat Acerdoune Water Transfer system III	Koudiat Acerdoune Dam	Boughzoul	0,075	Water supply and irrigation	Under construction
Algeria	Mostaganem–Arzew–Oran Water Transfer System	Chéliff and Kerrada Dams	Mostaganem and Oran cities	0,155	Water supply	
Algeria	Setif-Hodna Water Transfer System	Tabellout Dam	Draa Diss Dam	0,313	Water supply and irrigation	
Algeria Tamanrasset	Water supply Tamanrasset	In Salah Water Table	Tamanrasset	0,036	Drinking water	2011
Algeria Tissemsilt	Water supply of Tissemsilt II	Koudiat Rosfa Dam	Tissemsilt	0,023	Water supply	
Algeria Mostaganem	Water supply of Dahra region from Kramis Dam	Kramis Dam	Mostaganem	0,009	Water supply	

3. Need, Potential and Limit for Inter-Basin Water Transfer

The growth in economy and population growth hit a ceiling of sustainability on two primary resource caps namely land and water. However, it is not possible to revert back to original position in terms of per capita availability without causing social or political distress. In such situations, the inter-basin transfer of water provides a solution to generate the space for development and sustenance of the gains made over time.

3.1. Water Balance studies

As stated, this Committee, revising some international models, recommends an overall model since water transfers have several peculiarities in their conception, construction and operation, involving from technical-economical issues to social-political ones widely varying from country to country. Among these features, it can be included:

i. Spatial heterogeneity of water demands;
ii. Different water uses, including: human supply and quenching of animals' thirst, irrigation, energy generation, farming and industrial demands, diffuse, urban demands;
iii. Impacts on the source (transferring) basin, particularly in power generation and firm flow for other uses already in operation or proposed;
iv. Impacts on the receiving basins (transferee), transforming intermittent flows in perennial rivers, changing uses, soil occupation modifying the demands.

This study cannot be split apart from other studies considering environmental, socio economic and cost benefit. It starts with the collection of data that gives the present and future situations in terms of water availability, basically surface and underground, and the demands for water use.

The main information resulting from preliminary studies comprises the following main items:

i. Legal constraints;
ii. Study of scenarios;
iii. Prospective analysis of water demand in the basins;
iv. Study of water availability in the basins;
v. Assembling water demand scenarios;
vi. Identification of investment opportunities;
vii. Local policy for investments in the area.

3.1.1.Water availability in source basin

Taking into account the sum of all available flow (rain, groundwater, snow melting[1]) it has to be described its flow distribution by means of flow duration curves derived from extensive hydrology research and modeling. Figure 3.1 illustrates this type of curve.

As a rule the maximum withdrawal is regulated by the Water Authority and is a function of the present and future uses proposed for the water in the source. In the same way the duration curve of a maximum withdrawal is derived as shown in Figure 3.1.

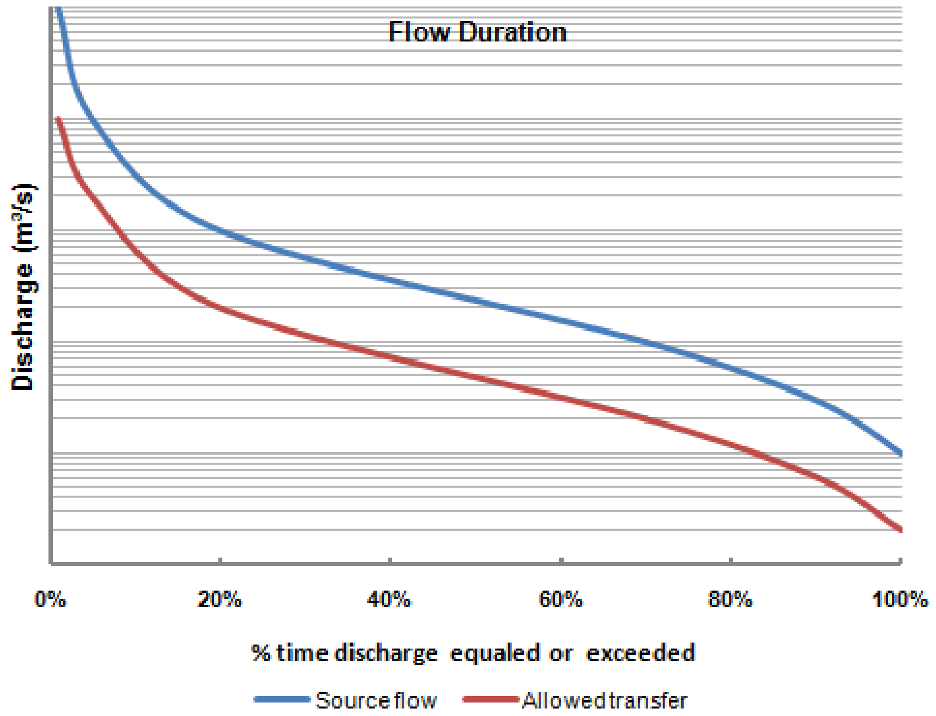

Figure 3.1– Annual flow duration curves. The allowed transfer includes losses due to evaporation, operation and management.

3.1.2.Water availability in receiving basins

In some cases the benefitted basins have water resources which are not enough to fulfill its needs in the proposed scenarios and have to be analyzed and modeled in the same way source basins were studied. For example, in case the demands are expected to be supplied starting from reservoirs, one can use some form of condensing data as shown in the table of Figure 3.2.

State/Basin/Sub-Basin	Surface water resources			Underground water resources		
	Regulated Flows			Aquifer	Renewable resources (based on recharge by average rainfall) (m^3/s)	Resources in dynamic storage of aquifer (m^3/s)
	Reservoir	Gross regulated flows Q (m^3/s)				
		assured 99%	assured 90%			

Figure 3.2 – Table with the resume of available water in target region.

For each region the demand forecast, for the furthest scenario, has to take into account its own hydrology and legal and environmental constraints resulting in the net flow distributed according to its percentage of flow duration.

Reuse (urban, industrial) although saving small amounts of the total demand can be included in the final figures to issue the demand.

[1] Other sources are dealt with in chapter 5.

Whenever possible, the introduction of regulating reservoirs along transfer path improve the average transferred flow leading to also improve hydraulic characteristics of the system, bringing some synergy to the operation, as well.

3.1.3.Water need in receiving basins

Together, all these information and studies will propose a final scenario which establishes the water amount in the transferee basin and its time distribution.

In the more complex case the transfer flow rate is not established as a constant value, and varies depending on the demand variation for water in the target regions. The transfer system will then be conceived to convey the maximum flow determined for the chosen alternative.

The lower curve in Figure 3.1 represents the upper boundary for the flows. A summary of the studies may be consisted in a table as illustrated in Figure 3.3.

Water demand (m^3/s)

Use	Present	Scenario 1	Scenario 2	Scenario 3
Urban				
Industrial				
Diffuse				
Irrigation				
Others				

Figure 3.3 – Consisting scenarios for water use in the receiving basins.

Finally, the water flows as consisted in the previous table, have to be distributed according to every delivery spot which, depending on the size of the benefitted basin, may have climate differences and different periods of peak flows, which makes very difficult to establish the planning of time variation of conveyance.

3.1.4.Planning and Implementation strategies:

Almost as a rule, the IBWT proposals envisage the transfer of resources across diverse administrative and regional boundaries. The donor and receiver basin stake holders have to be brought together for planning and formulation of the schemes. As against an inter regional power grid where power can flow dynamically between surplus and deficit regions with each region capable of assuming the role of a surplus or deficit region; the IBWT proposals fix the roles of export and import basins permanently. In such scenarios multiple demand projections and ultimate usage patterns are propagated by different interest groups. A consensual approach is a must for driving the technological planning of the IBWT schemes. Evaluation of surplus has been found to be a very difficult exercise. There are a multiple set of options available from technology point of view and each one of them may hold special appeal to an individual group of stake holders. The planning agency has to perforce evaluate each one of them threadbare and more often combine them to evolve an acceptable solution. This involves a much more rigorous exercise in hydrological and structural layout planning than a single stand alone intra-basin project.

3.1.5.System modeling

The considerations described in the preceding items give information to prepare the model scheme which represents the system with all necessary hydraulic features, to be simulated in any available software which will model all flows distribution and give orientation for operation procedures.

Establishing all availability, demands (Figure 3.1), losses and priorities it is possible to distribute the flows according to the hydrology in both basins, as well as to the uses in every spot to be supplied. This study will also model the time evolution of demand growth up to the limit of the established scenario.

This model is also the basis for dimensioning the hydraulics of the system as, for example, canal, gates and spillway dimensions.

On the other hand it is also possible to give the first input for operation of the system. Considering the integrated operation of all reservoirs, including the regulating ones it is possible to reduce to a minimum the losses due to management. In other words, to reduce spilling of transferred water.

One of the results can be consolidated in terms of duration curve showing the time distribution of flows considering the limitations imposed by the source trying to operate the system as close as possible of the available flows. Figure 3.4 illustrates the idea.

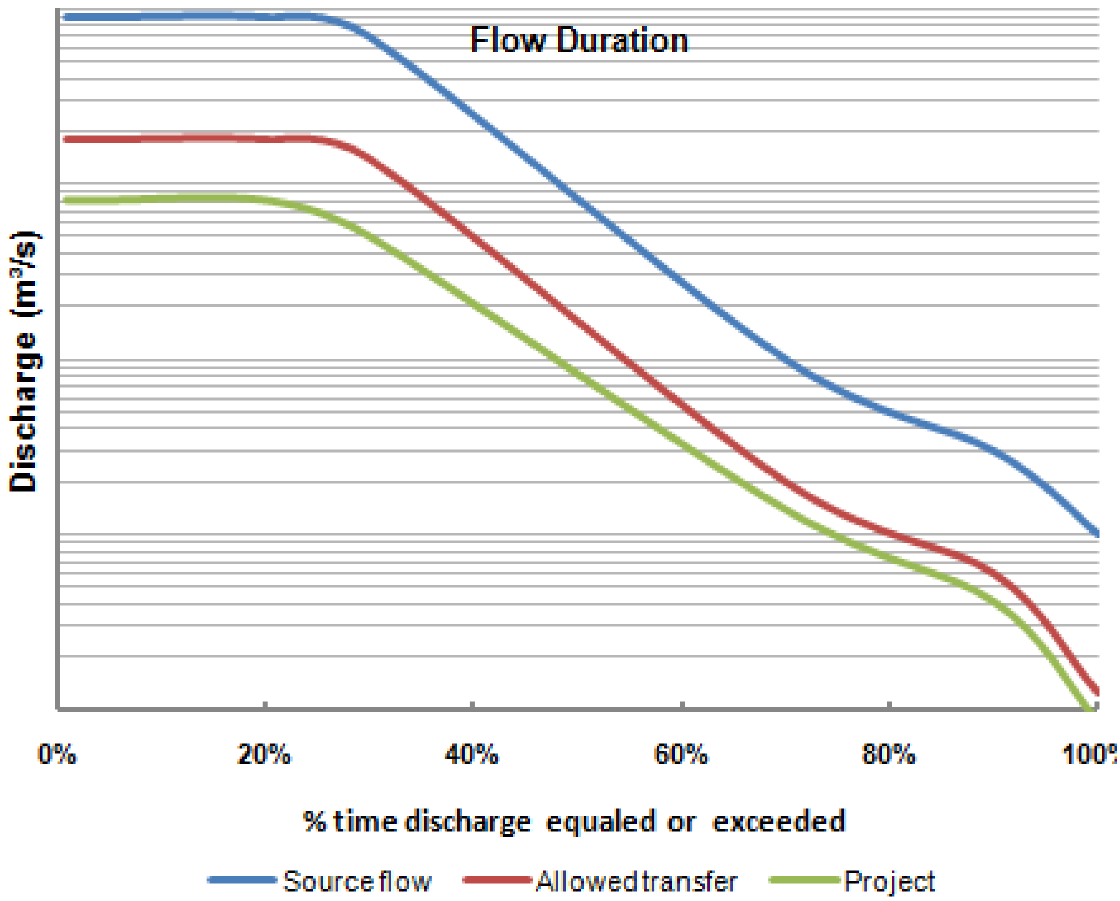

Figure 3.4 – Percent of time duration for transferred flows. In this case the source is a regulating reservoir that maintains the maximum flow for 25 to 30% of the time.

3.1.6. Management

The key to management of an IBWT scheme is to finalize an operational policy in tune with the stakeholders in donor as well as receiver basins. The operational policies and assurances are demanded by the groups' right at the time of planning and designing of the individual components of the schemes. Such operational plans have to take into account the historical practices of the riparian areas in the donor basins. Administrative mechanisms in form of reservoir regulation groups comprising of key personnel from both the basin areas have to be set up and mandated for operation in various phases of the hydrological cycle. The group will also need an independent neutral arbiter who can resolve the differences in real time in a dispassionate manner and can be relied upon by both the parties (viz. donor and receiver) to play the role.

The operational and management model has to have the components of flood management in monsoon and consumption management in the lean season. Explicit mechanisms of surplus as well as deficit sharing have to be put into the model. The model does not remain merely hydrological but also has components of assessing and distributing resources generated out of power production, etc. This needs financial modules as well which can be stand alone or can be integrated with hydrological operational models.

This Committee understands that the Transfer System has to be approached as a single entity and operated by a single entity as well. This concept, now possible due to the impressive development of hardware and SCADA systems (Supervisory Control and Data Acquisition), leads to a more and better integrated management increasing the efficiency of operators and managers.

The hierarchical structure of the Digital Supervision and Control System DSCS considering all system units as pumping stations, power plants, control structures, derivation, valves, flow and levels monitoring, etc., can be conceived in four functional levels.

Level 0

Corresponds to the lowest level of operation, and is only used in the commissioning, during equipment maintenance or in emergencies. In normal situation the system is always operated from the level 1 or higher.

This is a risky operation, since the functions of control and supervision of the SDSC are not acting.

Level 1

The lower part of DSCS, identified as Level 1, meets the local subsystems data acquisition and control for the elements of the pumping stations, hydroelectric dams, control structures, valves, monitoring units, etc.

The equipment in this level of DSCS, which are the units of acquisition and control (UAC) form subsystems functionally autonomous and independent of each other and the upper levels, as regards the implementation of the basic functions of control, interlocks, automation, measurement and factoring necessary for the correct and safe operation of equipment.

In case of loss of UAC, only that equipment will lose their functions, thus maintaining the integrity of the system as a whole. Therefore, the UAC, and the PLC (programmable logical controller) - which is the intelligent part of the panel, allows the equipment to operate safely.

Level 2

Level 2 of the DSCS is responsible for the supervision and control of their corresponding pumping station or power plant and control structures Bunger valves, etc. Thus, through the equipment of level 2, is possible to control the main and auxiliary equipment at a pumping station and power plant, monitoring devices of reservoirs levels, control of gates or valves and monitoring remote outlets devices.

Level 2 consists of computing platforms for the transmission or reception of data from the Operation Control Centre (OCC).

Level 2, in addition to the functions of supervision and control, also possess native database software in SCADA. In this database will be stored all information concerning the area of performance of this level.

Level 3

Level 3 is responsible for supervision and control of equipment and systems throughout the entire Water Transfer System, including pumping stations, hydroelectric plants, transmission systems, control structures and diversion units.

Level 3 consists of computing platforms of operation system running on hot standby, making the operation of any equipment interchangeable. Level 3 is located in the OCC, with the main data base and processing units. Its architecture can be illustrated as shown in Figure 3.5. The summary of the hierarchy architecture is sketched in Figure 3.6.

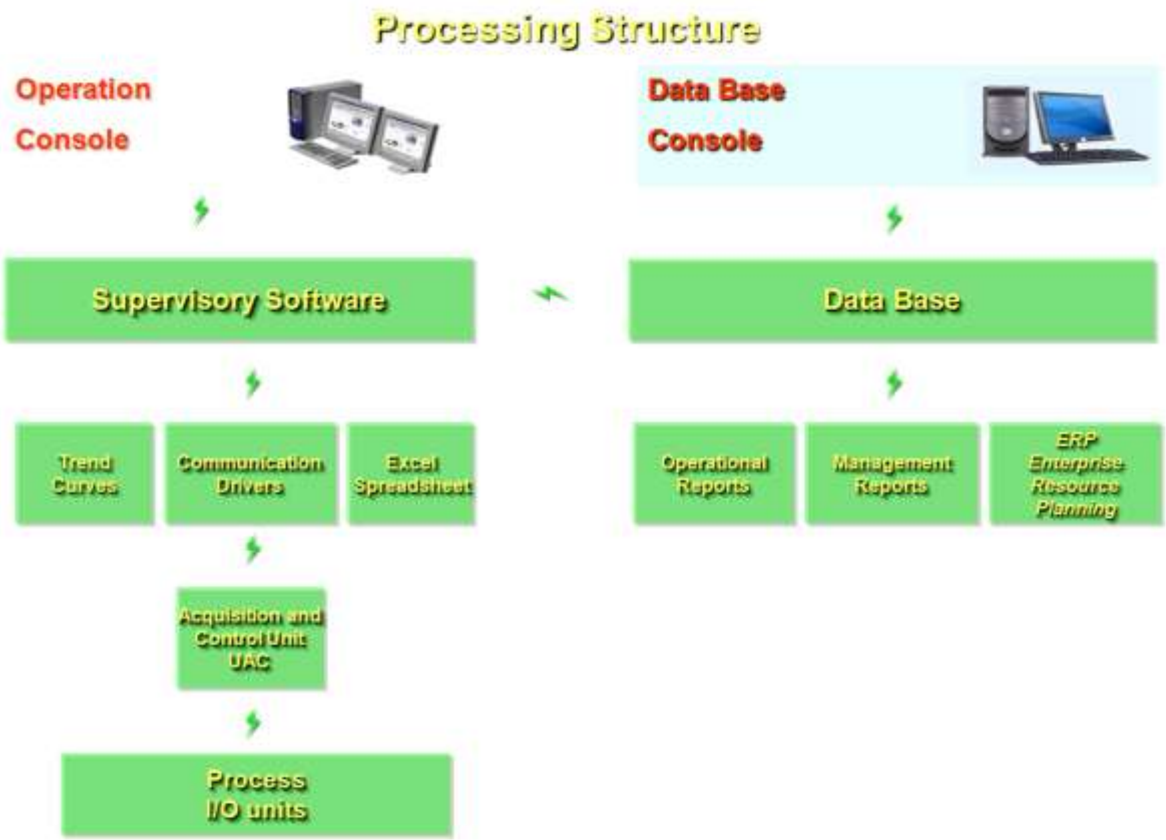

Figure 3.5 – Process architecture in Level 3.

Figure 3.6 - Summary of the hierarchy architecture.

One of the important objectives of the SCADA system, during operation, is the possibility of learning based on data acquisition whose trends are always improved since all input data are very dynamic. For example, climate, demands and legal improvements modify with time and are the backbone of the operation model improved from that described in item 3.1.4.

As a final remark, the greater the Transfer System higher is the inertia of system response. The management of water intake for the system has to be planned from days to months before the action of modifying demands supply, since it takes long time to modify the water volume of the system to adapt the corresponding flow. For this case the management has to deal with volume transfer instead of flow. This procedure reduces the loss of unused transferred water spilling.

3.2. The role of dams in Water Transfers

3.2.1.General

Dams play important roles in inter-basin water transfer (IBWT) schemes from hydrological and hydraulic points of view. The principal roles of dams, taking into account that many dams serve for more than one role, are:

- Water diversion,
- Flow regulating reservoir,
- Link between water conveyance systems, and
- Rise of a water level.

3.2.2.Water Diversion

The basic concept of IBWTs is to transfer water from a source river basin to a recipient river basin by utilizing a water conveyance system that in general consists of aqueducts, canals, tunnels, pipelines, or their combination, including or excluding pumping stations, pondages or hydropower stations.

Dams constructed in the source river ensure hydraulically required water depth at the intake of the water conveyance system and divert the river water to the system as illustrated in Figure 3.2.1.

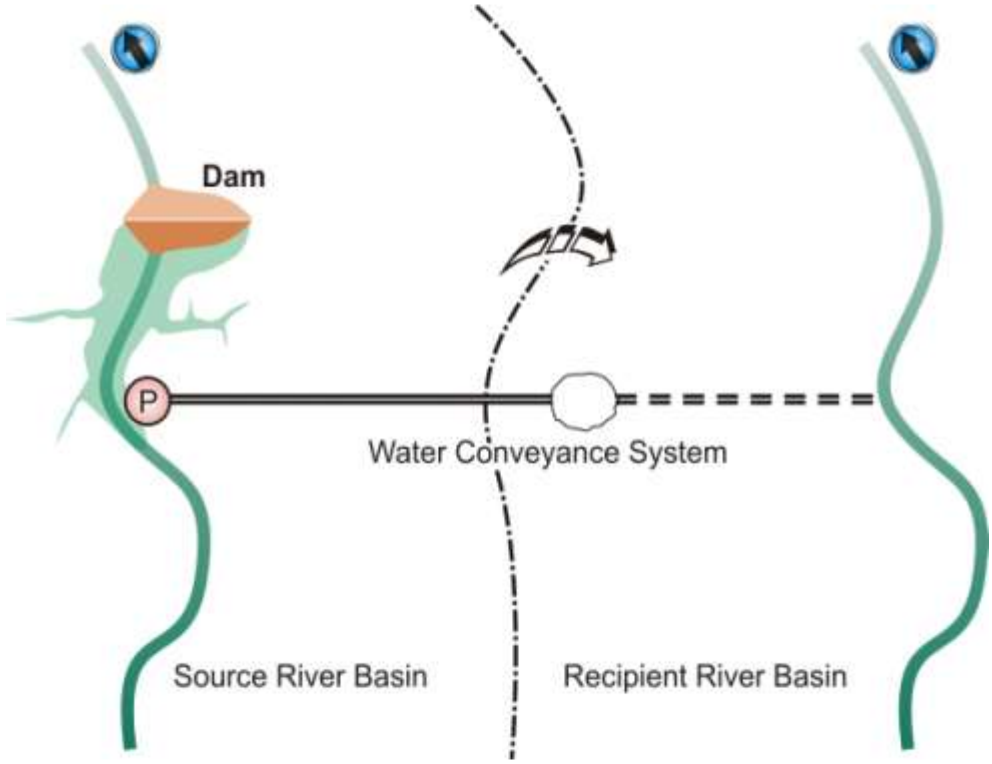

Figure 3.2.1 Dam for Water Diversion in IBWTs

When the water conveyance systems cross multi-river basins including relay rivers, more than one dam may be provided for the water diversion purpose (see Figure 3.2.2).

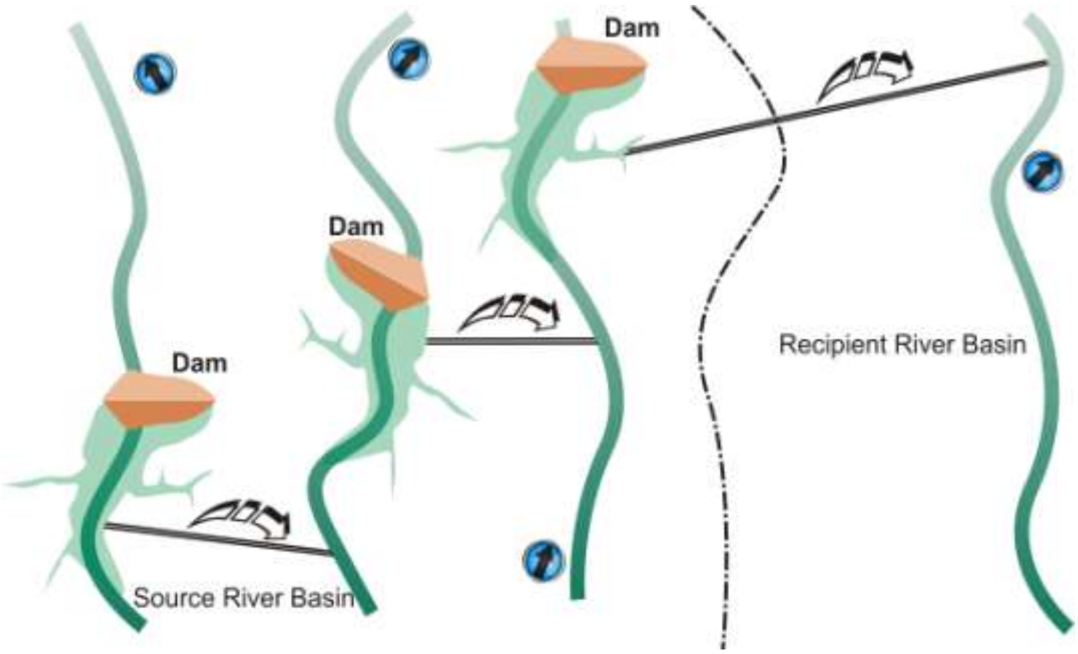

Figure 3.2.2 Multiple Dams for Water Diversion

3.2.3.Water Reservoir

Dams in IBWTs play a role to build a water reservoir that aims at storing and regulating the stream flows in the source river for efficient water resources utilization. These dams with reservoirs are provided in the source river, relay river or recipient river according to the availability of the suitable dam sites. Such dams usually have the water diversion function as well, while in some cases two separate dams for reservoir and diversion are proposed. Refer to Figure 3.2.3.

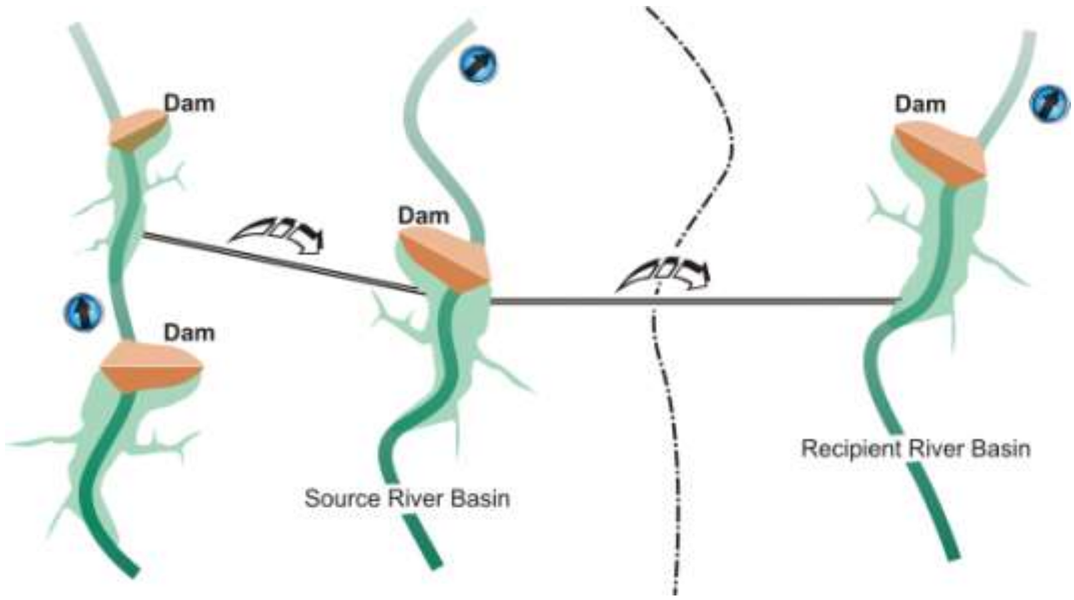

Figure 3.2.3 Dams for Water Reservoir in IBWTs

3.2.4.Link between Water Conveyance Systems

Dams have a function as a link between multiple water conveyance systems, in the case that the IBWT diverts more than one river courses or includes relay rivers as indicated in Figure 3.2.4.

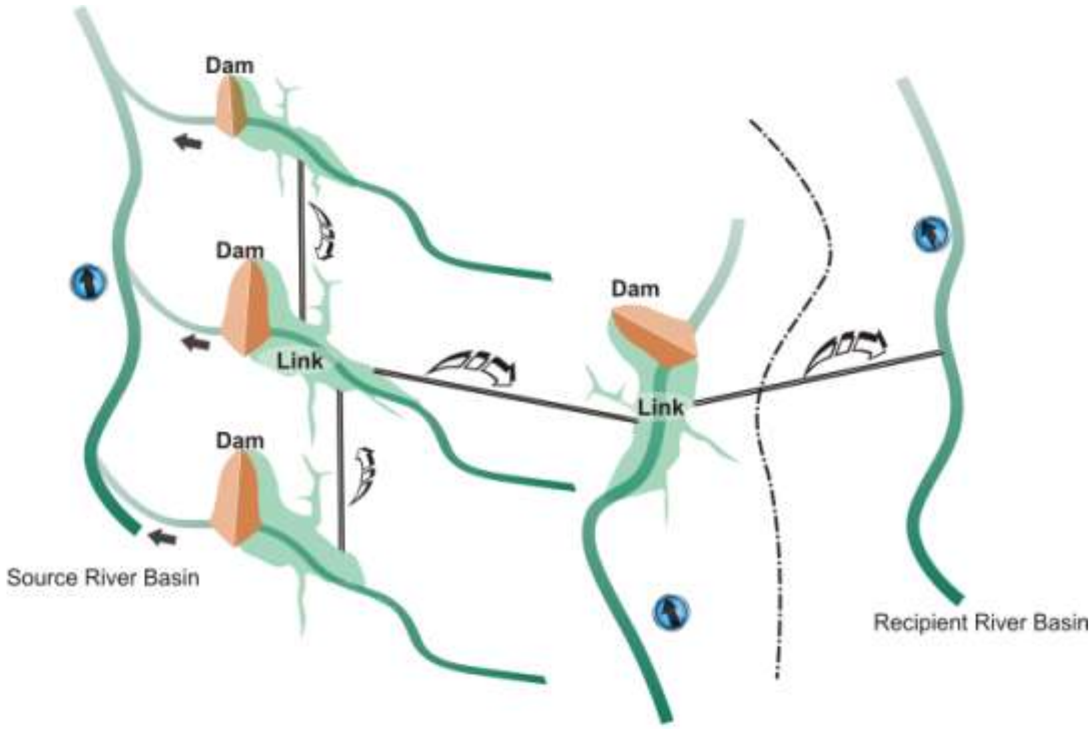

Figure 3.2.4 Dams for Link between Water Conveyance Systems in IBWTs.

3.2.5. Rise of Water Level

Dams built in the source river contribute to the rise of the river water level, so that the water conveyance system can be a gravity flow or have less pumping head as illustrated in Figure 3.2.5. It is noted that this is normally a subsidiary benefit that occurs when dams are required for the water diversion or reservoir purposes, and planning a dam mainly for the rise of water level is considered to be a rare case.

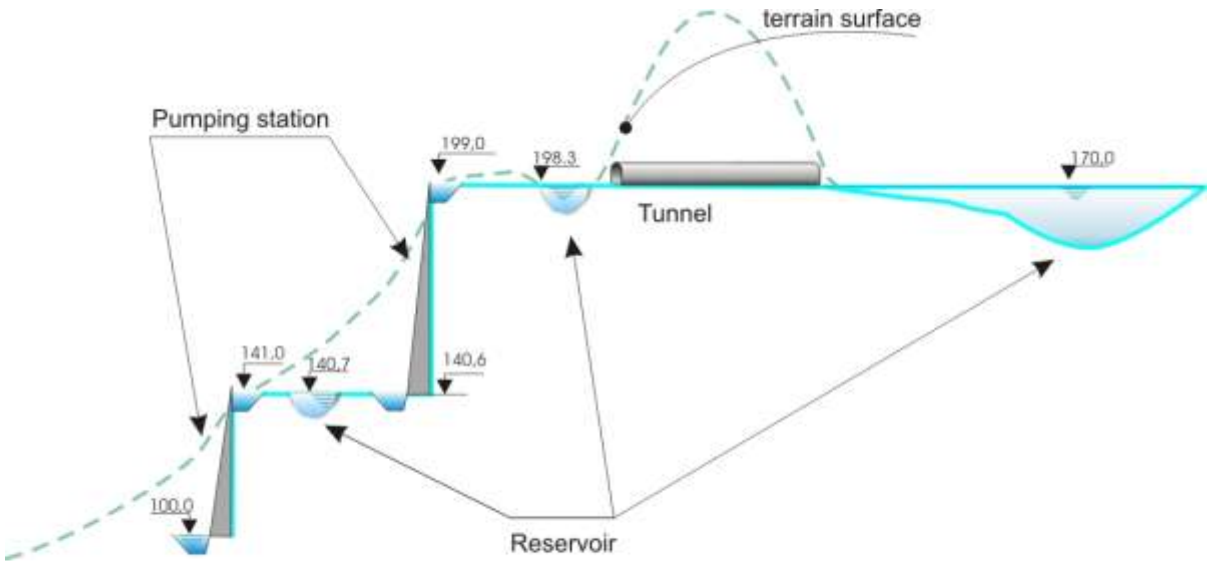

Figure 3.2.5 Dams and pumping stations for Rising the Water Level in IBWTs.

3.3. Approaches to transfer planning:

In general, there are two approaches to planning a transfer through IBWT.

a. Point to point transfer
b. Command area substitution

3.3.1.Point to point transfer:

Such transfer involves a head diversion point from where a canal or a tunnel or a combination emerges and transfers the waters to the adjoining basins. In such schemes often there are hydropower generation facilities utilizing the drops, if any or there can be pumping stations if the topography of the area so demands. Such transfers serve the purpose of augmenting the utilization from a reservoir or diversion structure further downstream of the outfall point in the recipient basin. However, utilization of the waters being transferred en-route may or may not be present.

Such transfers involving canals have the possibility of developing en-route irrigation benefits thereby improving the benefits of the project proposal.

Point to point transfers can also be useful in flood management and the reduction of damages in the donor basin due to limited carrying capacity of the river channel. In hilly terrains, such transfers are associated with hydropower production.

3.3.2. Command area substitution:

Long distance water transfers across a set of adjoining basins need to be planned through this approach to minimize the conveyance costs and size of conveyance structures. Such transfers are also able to take the benefit of pre-existing reservoirs at higher levels that are otherwise fully committed to their own command areas but can serve as sources provided some of their command is taken over by waters supplied from an adjoining basin.

Such transfers also carry the advantage of reduction in pumping effort in specific cases as the relative difference between the head works in the adjoining basin and the potential command may be lesser than that between a low level reservoir within the same command.

Substitution approaches are often associated with better reliability of supplies to some of the served areas as the relative distance and intervening use in u/s reaches of canal can decrease due to such arrangement.

However, such schemes have to be planned with a very vigorous consensus building approach when the commands are lying in separate administrative or political units. Very often the existing beneficiaries of an existing scheme who have to move from their source within their own administrative jurisdiction to another new source which may not be within their jurisdiction, resist such change. Apprehensions have to be addressed with the help of sound operational plans and rigorous studies to demonstrate through various simulations the reliability of the proposed scheme.

3.4. Layout options

The hydraulic layouts of IBWTs vary quite widely. However, discussions here are limited to the layout options relating to the arrangement of dams. The variety of water conveyance systems, for example waterway structural types, flow conditions (gravity or pumping), or pumping station position, is not subject to consideration.

The layouts are primarily categorized into the following four options in terms of the number and position of source, relay and recipient rivers and the water transfer directions:

I. Water transfer from a single source river to a single recipient river through a single water conveyance system (Figure 3.3.1);

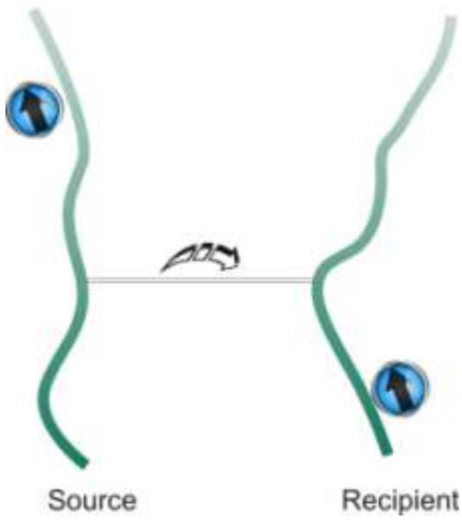

Figure 3.3.1 Schematic Layout of Option 1

II. Water transfer from multiple source rivers to a single recipient river through multiple water conveyance systems (see Figure 3.3.2);

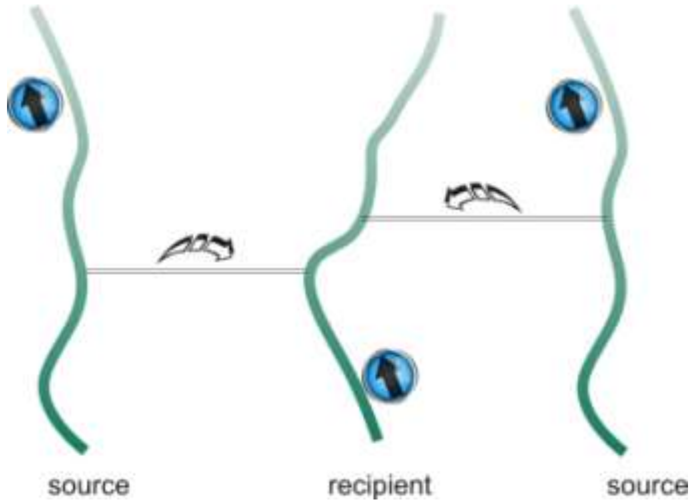

Figure 3.3.2 Schematic Layout of Option 2

III. Water transfer from a single source river to multiple recipient rivers through multiple water conveyance systems (Figure 3.3.3);

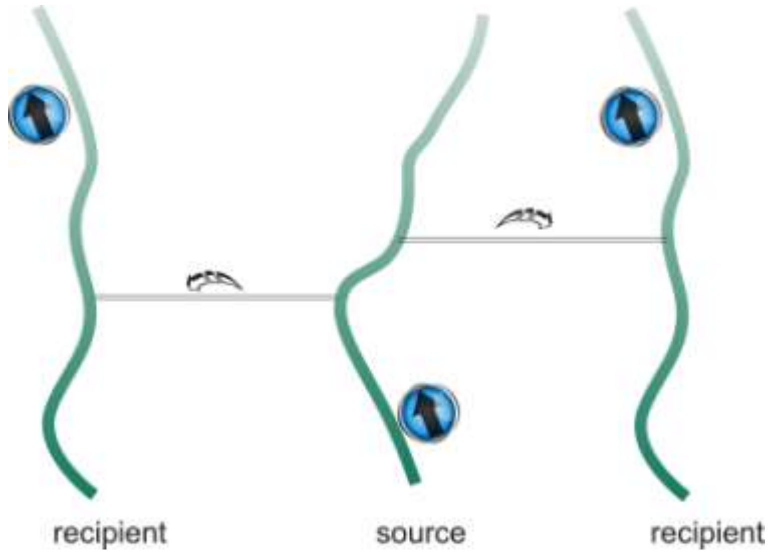

Figure 3.3.3 Schematic Layout of Option 3

IV. Water transfer from a single source river to a single recipient river via relay rivers (single or multiple) through multiple water conveyance systems (see Figure 3.3.4).

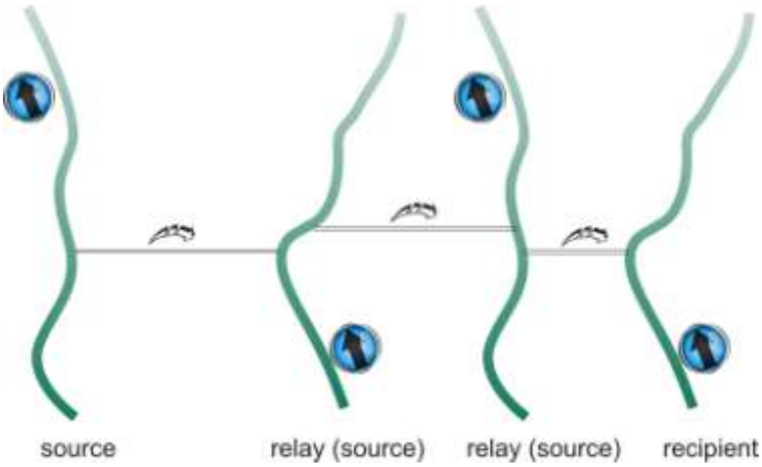

Figure 3.3.4 Schematic Layout of Option 4

Each option is further classified into the following three sub-options from the viewpoint of the arrangement and role of dams in particular the position of a dam that has a reservoir function:

- Sub-option A: Each source river has a single dam with a reservoir. Recipient rivers have no dam.
- Sub-option B: Each source river has multiple dams, where the upstream dam has a reservoir. This would be adopted when the suitable reservoir site is far from the water diversion site. Recipient rivers have no dam.
- Sub-option C: Each recipient river has a single dam with a reservoir. Each source river has a single dam for water diversion. This would be adopted when no suitable dam sites are available in source rivers or a reservoir in the recipient river is more advantageous than that in the source river.

Combining the above four options and three sub-options, a total of 12 layout options are composed as below.

- Option 1A: One dam with a reservoir in a single source river; and a single water conveyance system to a single recipient river;
- Option 1B: More than one dam in a single source river, of which the upstream dam has a reservoir; and a single water conveyance system to a single recipient river;
- Option 1C: One dam in a single source river; a single water conveyance system to a single recipient river; and one dam with a reservoir in the recipient river;
- Option 2A: Multiple independent source rivers, where one dam in each source river; and multiple water conveyance systems to a single recipient river;
- Option 2B: Multiple independent source rivers, where more than one dam in each source river, of which the upstream dam has a reservoir; and multiple water conveyance systems to a single recipient river;;
- Option 2C: Multiple independent source rivers, where one dam in each source river; multiple water conveyance systems to a single recipient river; and one dam with a reservoir in the recipient river;
- Option 3A: One dam in a single source river; and multiple water conveyance systems to multiple recipient rivers;
- Option 3B: More than one dam in a single source river, of which the upstream dam has a reservoir; and multiple water conveyance systems to multiple recipient rivers;
- Option 3C: One dam in a single source river; multiple water conveyance systems to multiple recipient rivers; and one dam with a reservoir in each recipient river
- Option 4A: Multiple source and relay rivers, where one dam in each source/relay river; and multiple water conveyance systems from the source river to a single recipient river via relay rivers;
- Option 4B: Multiple source and relay rivers, where more than one dam in the source river, of which the upstream dam has a reservoir; and multiple water conveyance systems from the source river to a single recipient river via relay rivers;
- Option 4C: Multiple source and relay rivers, where one dam in each source/relay river; multiple water conveyance systems from the source river to a single recipient river via relay rivers; and one dam with a reservoir in the recipient river.

4. Assessment of Environmental and Social Impacts

4.1. River Ecosystems

4.1.1.General

Inter-basin water transfer (IBWT) schemes divert river water from source basins to recipient basins through water conveyance facilities. The IBWTs associated with dams in general utilize relatively uniform river flows that are regulated by water reservoirs, built at source river basins. Water transfer methods can be classified into three types: free water flows by gravity, pressurized flows by pumping, and combination of free and pressurized flows, in which facilities such as open channels, tunnels, pipelines, pumping stations, regulating ponds would be employed.

Changes in flow regimes and water quality due to water transfers may affect ecosystems in both source and recipient rivers. The following mainly focuses on possible adverse impacts of IBWT schemes to be utilized as references during project planning and implementation to mitigate the impacts.

4.1.2. Impacts on Source Basins

Dams and water transfers alter the natural flow regime of source river basins. Stream flows controlled and averaged by dams, and reduced through water diversion may have impacts on aquatic ecosystems that are maintained under the natural runoff of rivers.

Decreased natural floods result in variation of natural productivity in riparian areas, floodplains and deltas, since numerous species of riparian plants depend on shallow floodplains recharged by regular flood events.

Timing, duration and frequency of floods are critical for inhabitants along the downstream reaches. Small floods may trigger migration of fish and invertebrates, while large flood events contribute to scouring of sediments, which result in creation and maintenance of their habitats. Floodplains and backwater habitats are essential to sustain suitable spawning areas. Reduced floods cause negative effect on biodiversity and productivity of fish, which may lead to extinction of some species and considerable reduction of fish catch.

In many regions of Africa, livelihood of people essentially depends on floodplain agriculture that utilizes fertile soil after flood events. Decreased floods may gradually degrade soil in floodplains and adversely affect agricultural productivity.

Biological linkages extend along lateral belts in parallel with the river, where wildlife use water for drinking, evacuating and feeding. Such wildlife species in these strips of land on either sides of the river may be affected when stream flows are reduced due to water transfers to other river basins.

Reduced flows and floods may also alter the natural environment at the river mouth such as decrease in freshwater and nutrients, seawater intrusion upstream, and increase in salinity. Since many marine fish spawn in estuaries and deltas, breeding of the fish may be hindered. Reduced nutrients may cause degradation of biological productivity and the decline of fish catch around the coastal area.

Creation of reservoirs may cause alterations of water temperature and quality such as oxygen concentration, turbidity and nutrients. The river water temperature may dramatically decrease due to cold water released from the bottom of the reservoir, which impacts on fish and agricultural production. Increased nutrients may accelerate algal growth in the reservoir and its downstream reaches. When algae spread over the reservoir associated with inflow of excessive nitrogen and phosphorus, eutrophication may occur due to increase in organic matters and COD in the reservoir water. The reservoir eutrophication causes the degradation of the downstream water quality, which may affect fish life and fishery along the river. The degraded downstream water used for irrigation may also impact on agricultural produce.

Reduced stream flows may alter groundwater conditions in the downstream basin, in which deficiencies such as water level lowering or drying-up of wells occur.

4.1.3. Impacts on Recipient Basins

Ecosystems in river basins that receive water from source basins are altered due to changes in flow regimes, water temperature and water quality. If the diverted water is polluted with industrial and municipal waste water, or is degraded due to reservoir eutrophication and dissolved heavy metals, the recipient basins may sustain fatal environmental damages.

New biota from water source basins may invade recipient basins, endangering survival of native biota. These non-native species often exclude the natives, causing drastic variation in natural environments that are no longer able to support the previous biosystems. Aquatic lives may be damaged when they are infected with non-native parasites, bacteria and viruses that are transferred from the source basins.

If transferred water volume is considerably larger than the stream flows in recipient basins, rare species or genetically different organisms may be seriously affected. This may bring about extinction of such rare species and reduction of useful organisms for humans. The reformation of ecosystems may induce the spread of organism harmful to human health, agriculture and fishery, and the increase in vermin through the extinction of their natural enemies.

Groundwater tables may rise due to incremental groundwater flows associated with increased stream flows. When groundwater tables reach the ground surfaces, soil salinization may occur due to the concentration of dissolved salt after water evaporation near the surface. Salt can move laterally through surface water, causing spread of salinization in the surrounding regions. This may substantially hinders agricultural productivity and ecosystems. Salinization may also take place in irrigated farmlands that use transferred water due to poor drainage systems.

4.1.4.Impacts along Water Transfer Facilities

When water transfer facilities include tunnels in mountainous areas, groundwater inflows toward the tunnel can lower groundwater tables in the vicinity along the tunnel. The resulting drying-up of wells may adversely affect water utilization in these regions. If canals are used in flat lands, the rise of groundwater levels caused by water leakage from the canals may induce soil salinization.

Continuous canals often disrupt migration of terrestrial animals and affect natural environments. In the case where part of a river is used as a water transfer channel, lands along this river section are subjected to higher risks of flooding. This is due to the reduction of flow capacity of the river section caused by the transferred supplemental flows.

4.1.5. Prediction of Impacts and Mitigation Measures

Predicting impacts on aquatic ecosystems, floodplain ecosystems and biodiversity caused by dam and water transfer schemes with satisfactory accuracy is difficult at present. This is because reliable baseline data and information are often not available, scientific knowledge and researches on the interactions of ecosystems are insufficient, and constructing mathematical simulation models for such complicated natural systems is often unsuccessful. Therefore, past impact predictions were often limited to judgments based on experience and analogical inference.

Measures to mitigate the impacts have achieved limited success. No definite and efficient mitigation measures are available against the most essential impacts, such as altered flow regimes in both source and recipient river basins, and invading non-native species in the recipient basin, where reducing the transferred water to recipient basins and increasing environmental flows for source basins can be one of effective measures. This, thus, affects project benefits and economic viability. Possible mitigation measures against temperature and the quality of transferred water include discharging from the surface layer of water in the reservoir, avoiding cold water in its lower layers, and the treatment of waste waters from pollution sources and emission sources of nitrogen and phosphorus, within the reservoir catchment. For mitigating impacts on groundwater, conceivable measures are the prevention of water leakage from canals by surface lining and provision of alternative water supply for the drying-up wells. Moreover, compensation for lost resources can be considered, for example, construction of fish hatcheries for lost fish spawning areas.

In order to evaluate the predicted impacts and the validity of mitigation measures, periodic environmental monitoring should be continuous. Typical monitoring items are river flows, water quality and temperature, aquatic species, parasites, bacteria, viruses, groundwater levels, soil salinities, etc.

4.2. Erosion and Sedimentation

4.2.1. General

The IBWTs associated with dams may affect the stability of riverbeds and banks. Varied flow regimes due to water diversions may cause erosion and sedimentation and alter the river channel morphology of both the source basins and recipient basins. The following mainly describes adverse impacts of IBWT schemes to be utilized as references for better planning.

4.2.2. Impacts on Source Basins

The impacts on source basins are also applicable for individual dam projects, which do not involve water transfer. Dams disrupt the continuity of sediment and nutrient transport in rivers. All bed loads and part of suspended loads deposit and form deltas at the upstream end of reservoirs. Since water from the dam contains little sediments and is released through large hydraulic energy, its river downstream is subjected to erosion or scouring. This causes degradation of the riverbed until new equilibrium is achieved.

The degraded river channel may lead to the disappearance or reduction of shores/backwaters and riparian vegetation that provide habitats and foods for native aquatic species and waterfowls. Scouring changes the particle size of the riverbed sediments. Boulders, cobbles and coarse gravels remain along the riverbed through the transported sand

and fine gravels, which reduces suitable spawning and incubating areas for fish. Changes in river water turbidity may have impacts on biota. When turbidity is reduced due to reservoir impoundment, plankton may increase in the reservoir and the downstream river sections.

Sediment trapping at reservoirs, and reduced sediment transport due to decreases in floods and stream flows in the rivers may diminish sediment supply to the river mouth causing extinction of beaches, backward movement of coastlines, and expansion of coastal erosion through waves. The degradation of valuable and rich coastal deltas may be accelerated, which affect ecosystems and fishery around the estuaries.

The riverbed degradation and local scouring may endanger bridge foundations and buried river crossing structures. The lowered water surfaces along the river may disable diverting its water into irrigation intakes.

Sediment bars can develop near tributary confluences owing to the decreased tractive forces according to reduced river flows. The reduced capacity of the river channel due to sediment bars may induce flooding over the surrounding areas.

4.2.3. Impacts on Recipient Basins

River flows in recipient basins are increased due to the transfers of comparatively clean water including little sediments from source basins. This may cause erosion and degradation of riverbeds of the recipient river channels. The riverbed degradation may impact on the stability of structures in the river and vegetation and aquatic ecosystems, similar to those in the source basins.

4.2.4. Impacts along Water Transfer Facilities

Water transferred from reservoirs in source basins that contain little sediments may cause bottom erosion and bank instability along its channels. When the transferred water contains much suspended loads, the channel floor may rise due to sediment deposition, which leads to the reduction of the channel's flow capacity.

4.2.5. Prediction of Impacts and Mitigation Measures

The prediction and evaluation of impacts on source and recipient basins due to sedimentation and erosion should be carried out prior to implementation of IBWTs. Some computer models for the numerical analyses of river hydraulics and sediment transport can be used to simulate river morphology and riverbed variations.

Measures for mitigating the impacts of sediment trapping in reservoirs include the methods listed below;

Trapping sediments making use of check dams and natural screens with afforestation in the watershed of the reservoir;

Diverting incoming sediments downstream with flood flows through channels/tunnels that bypass the reservoir;

Passing of incoming sediments through reservoirs, by releasing flood water from outlets;

Flushing accumulated sediments from the reservoir with stored water and flood water from bottom outlets; and

Dredging of accumulated sediments in the reservoir by mechanical means.

Releasing sediments downstream may cause long term high turbidity in the river water that may have adverse impacts on water utilizations, river ecosystems and recreations. Disposal of the dredged materials would be a serious concern to be addressed.

Mitigation measures against the impacts of riverbed degradation are generally limited to places where significant problems are expected to occur. The typical measures include strengthening of riverbeds (ground sills and riverbed protections) and revetments (vegetation, gabions, ripraps and groins).

Measures for mitigating the impacts of erosion of estuaries and coasts are wave dissipation blocks and revetments, breakwaters, groins and beach nourishment.

Since the environmental impacts due to erosion and sediments develop gradually, arrangement of long term monitoring systems is required. Necessary items to observe are reservoir sediments, sediment transports along the river, riverbed variations, particle size of riverbed materials, estuary and coastal topography, etc.

4.3. Resettlement of Local Population and Loss of Livelihoods

4.3.1. General

Construction of dams and water transfer facilities may cause displacements of inhabitants within the proposed areas. This may result in loss of livelihoods as well as physical stress of people affected by resettlement. The following adverse impacts are common not only for IBWT schemes, but also for any large scale development. However, they are described as references for planning and implementation.

Alteration of river morphology, water quality and riverine ecosystems in the downstream reaches of dams and water recipient basins affects the usable resources of the river basins and the productive activities of riparian people. This may cause loss of the traditional means of livelihoods that include agriculture, fishery, livestock grazing, fuel wood gathering and collecting forest products.

The timing of the social impacts depends on their cause. The impacts are direct and immediate for the people who lose homes and livelihoods due to displacement, while the impacts on livelihoods in the downstream and recipient basins may occur gradually after the completion of construction and future expansion.

4.3.2. Resettlement

Resettlement programs often focus predominantly on the physical relocation of people subject to displacement rather than their economic and social development. An essential economical risk with which the affected people are faced is loss of common resources that closely relate to livelihoods and incomes. The resources include cultivated lands, forests, pastures, groundwater, surface water, fisheries, etc. The breakdown of such complex livelihood systems can induce declined living standards, lack of food security, and malnutrition. Increase in diseases associated with poor drinking water quality may worsen morbidity and mortality rates. Forced displacement may deteriorate traditional social and cultural structures leading to disruption of communities. Such exclusion of the relocated residents from the existing economic and social networks may result in widespread poverty.

The numbers of affected people have sometimes been under-estimated during project planning stage, due to insufficient reliable social impact surveys, and limited and inadequate definition of affected people. The groups who usually suffer due to displacement include those without land or legal title, and the indigenous people. This is because only people who have legal title are entitled for compensation, leaving no considerations to the indigenous or poor people.

Compensation of affected people subjected to resettlement is often made as a one-time payment in the form of cash, land, housing or other properties. Delays in payments, land and housing titles and provision of lifelines and services have sometimes occurred. Selected resettlement sites have often been located in areas that have poor natural resources and degraded environments, and which are not equivalent or better than their original lands. The provision of cultivable lands, basic public services and infrastructure facilities is frequently insufficient. Occurrences of these problems may lead to a serious situation such as abandonment of the resettlement sites.

Little participation of affected people in the planning and implementation stages of the projects is also an essential issue.

4.3.3. Impacts on Livelihoods for People other than Resettled People

Social impacts resulting from the implementation of IBWTs spread over downstream basins of dams and water recipient basins. Many impacts occur gradually in time.

Altered flow regimes and reduced natural floods have impacts on floodplain agriculture, livestock grazing and gathering forest products, which may cause the disruption of economy in the river basins and the instability of livelihoods. This sometimes leads to migration of the affected people to urban areas and dependence on informal wage which may push these people into poverty.

Fishery productions may be affected as the alteration in flow regimes and water quality causes varied ichthyofauna, reduced spawning and incubating areas, and difficulty in migration. Fishery and agriculture are popular livelihood activities and sources of income in the rural areas. Fish are rich sources of low cost protein.

Affected people in the downstream and recipient basins usually have little social, economic and political powers to claim mitigation measures and compensations.

4.3.4. Indigenous Peoples and Gender

Displacement and loss of livelihoods associated with dams and water transfers may have impacts on the lives, cultures and identities of indigenous and tribal people. Rights of indigenous people are often insufficiently defined in national legal frameworks, and have not been effectively protected. Moreover, structural inequality and racial discrimination still exist in the society. The project planning and implementation have poorly addressed fair treatments to ensure consideration of special needs and vulnerabilities of indigenous peoples. Recently, however, international and national laws have substantially been improved in terms of empowering recognition of indigenous people as social minorities, and protection to their cultures and rights.

Meanwhile, gender inequalities and social power structures are eminent forms of prejudice towards women. Women often not allowed owning or inheriting lands and forests, which subject them to unfair compensations when they are displaced during project implementation. Men who face powerlessness due to poverty resort to alcoholism and domestic violence affecting women. Increased immigrants during construction and resulting urbanization may cause spread of venereal diseases and HIV/AIDS among local women. In conclusion, women have disproportionately shared adverse effects due to displacement and loss of livelihoods. This is caused by lack of consideration on gender inequalities in implementing the projects.

4.3.5. Mitigation Measures

Mitigating impacts due to displacement and loss of livelihoods necessitates establishing frameworks that support affected people as project beneficiaries. Efforts to reach a consensus on compensations and mitigation measures are required through dialogues that involve the affected people during the initial stage of projects. Monitoring the lives of affected people after projects completion should be continued so that necessary supplemental measures and supports can be provided.

Successful resettlement process is achieved by minimizing displacement, rendering legislative supports, providing sustainable livelihoods, involving local communities, initiating accountability and commitment from government and project developers, and other preconditions. Typical measures are detailed below:

Constructing frameworks that legally define displacement processes, which stipulate the rights of affected people, the responsibilities of national and local governments, and the procedures of settling claims and conflicts;

Displacing people as a whole local community based on in-depth demographic and socio-cultural studies, to avoid social and cultural disruption;

Minimizing displacement by identifying most suitable locations and routes of project facilities, through workshops with developers, governments and local communities during project planning stage;

Compensating livelihoods by combining land and non-land based activities, promoting industries, and building skills that are in demand in the regional economy;

Providing infrastructures in resettlement sites including power, water supply, schools, food factories, medical services, telecommunication and transportation; and

Determining resettlement and compensation programs within the framework of comprehensive negotiations and dialogues with affected people, project developers, governments, communities near resettlement sites, and other stakeholders.

Affected people in downstream and recipient basins due to loss of livelihoods have not been well assessed and addressed. Thus, mitigation measures have rarely been considered for them. Since impacts occur gradually after project completion, affected people who cannot resist the project implementation will eventually demand mitigation measures. The distribution of impacts over widespread areas consisting of a number of communities entails weakness in unity and difficulty in achieving political will among affected people. However, effective mitigation measures to such complex and dispersive problems remain limited. Apart from those mentioned in Section 4.1, other measures may include cash compensation, provision of alternative farmlands, fishery development in reservoirs, promotion of industries to ensure new livelihoods, and training and guidance for different job opportunities.

Recently, rights of indigenous peoples have been protected and their self-determination has been widely recognized. Prior consent on development projects affecting these people apparently becomes a standard factor in project planning and implementation.

Providing benefits generated by projects to affected women can contribute toward mitigating gender inequality issues. When infrastructures and public services are improved, availability of water and power for household uses including easy access, reduce time consumption on women's chores. Thus, success in raising the living standards of affected people has positive impacts on gender issues.

4.4 Cultural Heritage

The construction of dams and water transfer facilities, which requires removal and modification of extensive land areas, may affect cultural heritage. River valleys often conceal ancient civilizations. Inundation by reservoirs, construction works for project structures and temporary facilities, and river bank erosion due to changes in flow regimes and sediment transport can have impacts. Cultural heritage may include temples, shrines, sacred landscapes, remains, architectures, burial sites, etc. These may be archaeologically precious resources, part of significant cultural life in regional communities, and the remains of aborigines.

Impacts on architectures, burial sites and religious facilities that closely relate to the local people have to be investigated during the planning stage of IBWTs. On the other hand, difficulties in investigating cultural heritage or archaeological resources buried deep in the ground entail lack of sufficient findings during project implementation. Efforts to minimize irreparable losses or damages to cultural properties need to be considered.

When investigations reveal the existence of cultural heritage, mitigation measures such as conservation, relocation and reconstruction of the properties should be initiated.

4.5 Health of People

Environmental alterations resulting from dam and water transfer developments can adversely affect the health of local people residing near source basins, recipient basins and the vicinity of water transfer facilities.

The creation of reservoirs in tropical regions may cause occurrence of various vector-related diseases like malaria, yellow fever, filariasis and schistosomiasis. In tropical, subtropical and arid zones, reservoir eutrophication resulting from nutrient influx enhanced by urbanization and agricultural/industrial developments in the catchment area can bring about multiplication of toxic cyano bacteria that affects human health through contamination of drinking water. Accumulation of mercury in fishes is also a problem associated with reservoirs. Mercury in soil in a harmless form is transformed by bacteria feeding on rotting biomass into toxic methyl-mercury. This causes damage to the central nervous system of humans. Concentrated methyl-mercury through food-chains can adversely affect human health for a long time, beyond generations. These vectors and toxic substances occurring in reservoirs may be released to the downstream areas of dams, and conveyed to other river basins along with transferred water, which may result in expanding affected areas.

The health conditions of displaced people due to project construction often become worse. Inappropriate resettlement programs and insufficient livelihoods can lead to emotional wounds due to community disruption. Starvation and malnutrition usually follows due to lack of food. Unsafe and inconvenient infrastructures in resettlement sites also have impacts on human health. Another concern is the spread of HIV/AIDS transmitted from outside, throughout the construction vicinity.

Examining actual cases that occurred in surrounding areas, neighboring countries or similar climate zones may be useful for predicting the impacts to human health. Mitigation measures have to be studied based on the predicted impacts. Measures may include spraying disinfectants, deforestation and clearing of reservoir areas before impounding, treatment of waste water, clean drinking water supplies to resettlement areas, monitoring water quality and vectors, provision of regional medical facilities, periodic medical check-ups for affected people, and educating people on hygiene and health.

5. Benefit and Cost Analysis

Water transfers around the world have been developed following many different models from geopolitical to financial where the investments can be considered federal, private or composite.

Those cases go from infra structure development without profit but sustainable, to remuneration of private investment.

In this bulletin it is considered both cases for a very complete assemblage of a water transfer system which includes, pump stations, canals, tunnels, galleries, spillways, siphons, dams, hydro mechanical devices, power plants, pumped storage plants and supervision and control digital systems.

It is also considered that the water transfer system is conceived to guarantee a sustainable development of the region where it will be inserted.

All those analyses are based on the establishment of demand growth compared to water availability according to scenarios previously agreed known as Regional Insertion Studies. All analysis will consider the region under study with and without the proposed project so as to define economic indexes that will support the decision of implementing the water transfer system.

5.1. Benefits

Benefits mainly related to Economic Evaluation deal with the project feasibility on the society point of view including integrated sub projects as water supply, irrigation and industrial usage. The main benefits to be evaluated are the following:

i. Improvement of urban supply user welfare as a result to better access to additional water. These benefits are measured by the exceeding consumption, obtained by the difference between willingness to pay and the effectively paid price;
ii. Urban producer's surplus (industry, tourism) and rural (irrigation and intensive diffuse). The producer surplus is related to the net income obtained as a function of the use of raw water;

iii. Reduction in public spending during the drought emergency in the area of Project, distribution of basic food, spending on work fronts and supply of water in tank trucks;
iv. Improvements in public health conditions for the population of the Project area due to the reduction of risk of diseases caused by lack of treated water and the consequent reduction in spending on health care, hospital and medicines;
v. Increased productivity in the work of population due to better health condition;
vi. Increased employment and income of the population in the area of the Project;
vii. Waste reduction of water usage;
viii. Reduction of rural → urban and interior → capitals migration and its consequences on urban economy and infra structure;
ix. Improving the quality of raw water, reducing costs for utilities, industries and, in the long term, for agriculture;
x. Indirect benefits such as the increase on government taxes income reverted to social benefit, water synergy[2], etc. These benefits have to be converted to economic values to be used in economic analysis.

The economic analysis uses the economic value of total benefits, the environmental costs, investment in construction and operating costs. The economic values are obtained by applying shadow prices or economic prices (that take into account the values of goods and social services). The required economic indicators are obtained from the comparison of benefits and economic costs of the analysis scenario. Subsequently, the economic analysis undergoes a sensitivity analysis.

There are few softwares that are able to calculate benefits as described here. As the basis of this description it is mentioned the SMPW (Simulation Model of Public Works) developed for the Inter American Bank of Development.

New trends lead to pricing the raw water as a way to better control its usage as a finite good. Pricing the water will introduce an income that can be considered an economic benefit if considered with its converted value or financial benefit otherwise.

5.2. Cost Estimate

This item is already very well known and no further discussion is needed, except these few remarks:

The first part of the cost evaluation is the sum of the construction and acquisition costs of every unit which defines the water transfer system. Every one of them is very well known and no further discuss is needed. Table 5.1 shows an example of the construction units that should be considered in cost assessment.

However time horizon for construction is of major importance on cost benefit analysis depending on its distribution, since no revenues are due during this period. Interests during this period are applied to both government investment and private equity, if some, as an additional cost for the analysis.

Within this subject it has to be noted that these types of systems may be designed according to the growth scenario established and partially built in phases creating dilution of costs in terms of present value.

The second part of the costs is that concerning operation of the system, which includes the maintenance as well.

The operational costs of the project can be divided into 4 major items:

- Maintenance of Civil Works and Electromechanical Equipment (scheduled for gradual growth according to the expected use growth);
- Manpower and related operational cost;
- Electric power supply[3], and
- Management

[2] In dry regions where rain is poorly distributed, reservoirs are operated keeping all water they can retain, spilling it whenever its full capacity is reached. With the presence of the water transfer water supply is assured and the reservoir can be operated in lower levels. Storing the rain once spilled, more water appears in the system and can be added to the availability of the system. This is the system synergy.

[3] This cost is an important one if the system is non gravitational and consequently, pumps and boosters are employed. In case there is some power recovery by means of hydro power plant or power pump station the related benefit can be considered as avoided cost or as income by selling the energy.

	Item	Cost (%)
1	Land Acquisition and Improvement	1,37
2	People relocation	2,78
3	Transmission lines	1,91
4	Substation	3,81
5	Artificial canals construction	43,34
6	System drainage	4,38
7	Tunnels	4,38
8	Acqueducts	1,54
9	Intakes and pump stations	
9.1	Civil works	1,93
9.2	Eletromechanical equipment	9,08
10	Dams and hydro power plants	
10.1	Civil works	8,05
10.2	Eletromechanical equipment	1,08
11	Control and diversion structures	
11.1	Civil works	0,65
11.2	Eletromechanical equipment	1,07
12	Infrastructure works	3,86
13	Indirect costs	10,77
	Total investment	100,00

Table 5.1 – Example of cost distribution for a Brazilian Water Transfer System with approximately 700 km of canals, 35 dams and reservoirs, 7 hydro power plants, 30 km of tunnels designed for a maximum flow of ~100 m³/s. Environmental costs in this case were estimated as 1,6% additional to the total cost during feasibility studies and may rise to 5 or 6% during construction. These figures are referred to feasibility studies (1999).

During feasibility studies the operational cost, except energy, may be estimated as 1,5 to 2,0% of the total investment per year.

The third part of the costs are those related to taxes, which are a specific function of every country and will be mentioned here as taxes. In this part it is grouped the cost of the money, basically the interest and related taxes of the loans, if some.

Finally, the costs of the entire system may be rated among the various regions (cities, states, countries) crossed by or as consumer, in case they participate in the investment. As a consequence the water price, if some, should also be rated balanced by the volume of water distributed among all regions.

5.3. Benefit and Cost Analysis

The analysis is developed within a conceptual framework applied to a public or private water transfer system to determine whether, or to what extent, that project is worthwhile from a public or social perspective. Cost-benefit analysis differs from a straightforward financial appraisal in that it considers all gains (benefits) and losses (costs) regardless of to whom they accrue. It usually implies the use of accounting prices. Results may be expressed in many ways, including internal rate of return, net present value and benefit cost ratio.

This ratio is the present value of the benefit stream divided by the present value of the cost stream. When the benefit-cost ratio is used, the selection criterion is to accept all independent projects with a benefit-cost ratio of one or greater when discounted at a suitable discount rate, most often the opportunity cost of capital. The benefit-cost ratio may give incorrect ranking among independent projects, and cannot be used for choosing among mutually exclusive alternatives.

Economic and financial analyses of projects are similar since both appraise the profit of an investment. The financial analysis of a project estimates the profit coming back to the investors or to the project-operating entity, whereas economic analysis measures the effect of the project on the national economy. Economical feasibility of a project has to be financially sustainable, as well as economically efficient. If a project is not financially sustainable, economic benefits will not be realized.

Both types of analysis are conducted in monetary terms, the major difference lying in the definition of costs and benefits. In financial analysis all expenditures incurred under the project and revenues resulting from it are taken into account.

Economic analysis attempts to assess the overall impact of a project on improving the economic welfare of the citizens of the region concerned. It assesses a project in the context of the national economy, rather than for the project participants or the project entity that implements the project.

Costs reflect the degree to which consumption elsewhere in society is sacrificed by diverting the resources required by the project from other uses.

The purpose of the financial analysis is to use the project's cash flow forecasts in order to calculate suitable return rates, specifically the financial internal rate of return (FRR) on investment (FRR/C) and own capital (FRR/K) and the corresponding financial net present value (FNPV).

This analysis provides the examiner with essential information on inputs and outputs, their prices and the overall timing structure of revenues and expenditures.

The conventional financial analysis is made up of a series of tables that collect the financial flows of the investment, broken down by total investment operating costs and revenue, sources of financing and cash flow analysis for financial sustainability. This procedure is also very well known, however, some remarks have to be stated.

One example of financial analysis shows quite interesting thoughts. Taking for example a feasibility analysis shown in tables 5.2 and 5.3, referring to a Brazilian example, which represents a part of a major water transfer, in which a maximum o 8 m^3 would be pumped, approximately 400 m of height, 68 km long, with 5 pump stations. In this case energy recovery is not available.

One can realize that if the analysis is made considering the investment, in this case a government one, the general price for the water, automatically leading the NPV (Net Present Value) to 0, i.e., no return considered but investment being refunded, was approximately US$1,0 /$m^3$.

On the other hand, if the investment is considered a national cost for development, and do not need to be refunded, the water price went down to US$ 0,17/m^3.

This is just one of parameters of the equation that finally leads to the decision of implementing or not the project. In this case the alternative was not accepted in favour of other lay out for the same purpose.

A final remark is due; concerning water pricing which deals with crossed subsides in which the water of human or industrial consumption has to have a higher price in favour of the irrigation price, to make it feasible. Water transfers which use pumping are not adequate for irrigation purposes, since the water price tend to be higher, unless other purposes are involved (for example occupation for geopolitical reasons).

EXAMPLE PROJECT

FINANCIAL ANALYSIS WITH INVESTMENT

BASE NOVEMBER 2000

GENERAL	
TOTAL COST	1.288.478,45
LOAN 1	0,00
LOAN 2	900.412,69
INTEREST BANK 1	-
INTEREST BANK 2	10,25%
SPREAD	5,00%
DISCOUNT RATE	10,71%
WATER TARIFF R$/m³	1,962 (US$1,01)

INDEXES	
IRR	10,71%
NPV	0,00
NPV INCOME	1.700.187,17
NPV / NPV inc	0,0%
NPV Consumed energy	83.467,37
NPV OMG	236.039,9

*EXCEPT WHERE INDICATED R$ x 1.000

YEAR	PUMPING	INCOME	FINANCING		DISBURSEMENT											
	m³		BANK 1	BANK 2	CONSTRUCTION	INTERESTS	AMORTIZATION	INCOME TAX 1	INCOME TAX 2	INCOME TAX 3	ENERGY	O&M	INSURANCE	OTHER TAXES	RAW FLOW	NET FLOW
		R$						0,65%	3,00%	0,00%		2,06%		0,30%		
1	0	0	0	230.092	329.325	0	0	0	0	0	0	0		0	99.233	-99.233
2	0	0	0	230.092	329.325	25.310	0	0	0	0	0	0		0	124.544	-124.544
3	0	0	0	230.092	329.325	51.635	0	0	0	0	0	0		0	150.868	-150.868
4	65.198.449	127.920	0	0	0	79.015	102.617	831	3.838	0	5.549	26.543		655	219.049	-91.129
5	72.358.600	141.968	0	0	0	70.895	107.417	923	4.259	0	5.902	26.543		648	216.587	-74.620
6	79.518.751	156.016	0	0	0	61.922	112.586	1.014	4.680	0	6.255	26.543		639	213.639	-57.623
7	86.678.902	170.064	0	0	0	52.020	118.228	1.105	5.102	0	6.608	26.543		629	210.235	-40.171
8	91.073.997	178.688	0	0	0	41.101	124.549	1.161	5.361	0	6.824	26.543		617	206.155	-27.468
9	100.999.204	198.161	0	0	0	29.049	132.039	1.288	5.945	0	7.313	26.543		607	202.783	-4.622
10	108.159.355	212.209	0	0	0	15.689	142.627	1.379	6.366	0	7.666	26.543		601	200.871	11.338
11	115.319.506	226.257	0	70.046	100.168	0	0	1.471	6.788	0	8.019	26.543		429	73.370	152.887
12	122.479.657	240.306	0	70.046	100.168	7.705	0	1.562	7.209	0	8.371	26.543		455	81.967	158.339
13	129.639.808	254.354	0	70.046	100.168	15.719	0	1.653	7.631	0	8.724	26.543		481	90.873	163.481
14	136.799.959	268.402	0	0	0	24.054	31.239	1.745	8.052	0	12.119	26.543		311	104.063	164.339
15	143.960.109	282.450	0	0	0	21.582	32.701	1.836	8.474	0	12.559	26.543		311	104.005	178.445
16	151.120.260	296.499	0	0	0	18.851	34.274	1.927	8.895	0	12.999	26.543		310	103.799	192.699
17	158.280.411	310.547	0	0	0	15.836	35.992	2.019	9.316	0	13.439	26.543		309	103.455	207.092
18	165.440.562	324.595	0	0	0	12.512	37.916	2.110	9.738	0	13.880	26.543		308	103.006	221.589
19	172.600.713	338.643	0	0	0	8.843	40.196	2.201	10.159	0	14.320	26.543		307	102.569	236.074
20	179.760.864	352.692	0	0	0	4.776	43.419	2.292	10.581	0	14.760	26.543		307	102.678	250.013

Figure 5.2 – Financial analysis for one alternative of water transfer layout, considering 30 years of operation added to 3 of construction. Investment was considered as part of the cash flow. This is part of the real spreadsheet, lacking lines down to year 30 and remaining columns on the right side.

EXAMPLE PROJECT

FINANCIAL ANALYSIS WITHOUT INVESTMENT

BASE NOVEMBER 2000

GENERAL

TOTAL COST	1.288.478,45
LOAN 1	0,00
LOAN 2	0,00
INTEREST BANK 1	-
INTEREST BANK 2	10,25%
SPREAD	5,00%
DISCOUNT RATE	10,71%
WATER TARIFF R$/m³	0,329 / US$0,17

INDEXES

IRR	10,71%
NPV	0,00
NPV INCOME	285.278,62
NPV / NPV inc	0,0%
NPV Consumed energy	83.467,37
NPV OMG	236.039,9

*EXCEPT WHERE INDICATED R$ x 1.000

YEAR	PUMPING	INCOME	FINANCING		DISBURSEMENT											
	m³		BANK 1	BANK 2	CONSTRUCTION	INTERESTS	AMORTIZATION	INCOME TAX 1	INCOME TAX 2	INCOME TAX 3	ENERGY	O&M	INSURANCE	OTHER TAXES	RAW FLOW	NET FLOW
		R$						0,65%	3,00%	0,00%		2,06%		0,38%		
1	0	0						0	0	0	0	0		0	0	0
2	0	0						0	0	0	0	0		0	0	0
3	0	0						0	0	0	0	0		0	0	0
4	65.198.449	21.464						140	644	0	5.549	26.543		125	33.000	-11.537
5	72.358.600	23.821						155	715	0	5.902	26.543		127	33.441	-9.620
6	79.518.751	26.178						170	785	0	6.255	26.543		128	33.881	-7.703
7	86.678.902	28.536						185	856	0	6.608	26.543		130	34.322	-5.786
8	91.073.997	29.982						195	899	0	6.824	26.543		131	34.592	-4.610
9	100.999.204	33.250						216	997	0	7.313	26.543		133	35.203	-1.953
10	108.159.355	35.607						231	1.068	0	7.666	26.543		135	35.643	-36
11	115.319.506	37.964						247	1.139	0	8.019	26.543		137	36.084	1.881
12	122.479.657	40.321						262	1.210	0	8.371	26.543		138	36.524	3.797
13	129.639.808	42.679						277	1.280	0	8.724	26.543		140	36.964	5.714
14	136.799.959	45.036						293	1.351	0	12.119	26.543		153	40.459	4.577
15	143.960.109	47.393						308	1.422	0	12.559	26.543		155	40.987	6.406
16	151.120.260	49.750						323	1.493	0	12.999	26.543		157	41.515	8.235
17	158.280.411	52.107						339	1.563	0	13.439	26.543		159	42.043	10.064
18	165.440.562	54.465						354	1.634	0	13.880	26.543		161	42.571	11.893
19	172.600.713	56.822						369	1.705	0	14.320	26.543		163	43.099	13.722
20	179.760.864	59.179						385	1.775	0	14.760	26.543		165	43.628	15.551

Figure 5.3 – Same case keeping the same time basis. Investment was not considered as part of the cash flow. This is part of the real spreadsheet, lacking lines down to year 30 and remaining columns on the right side.

5.4. Value analysis

For transferring water between basins, considering the uncertainties, risk analysis studies should be performed. In these studies the opportunities and threats are analyzed and a Risk Action plan is developed for managing them. Value engineering study should also be done. The Value index in the Value Engineering study is considered based on the consumption cases in the source and destination basins, and the option with the highest Value index from the following equation is selected:

$$\text{VI (Value Index)} = \frac{\text{Worth (benefits, needs, and desires)}}{\text{Cost (disadvantage, money, risk)}}$$

(ref. BS EN 12973:2000 - Value Management – BSI British Standards);

In this equation, worth is the value of the water for the consumer which contains the benefits of consuming the water and the estimated worthiness of social and ecological needs and desires. The cost in the equation contains life Cycle Cost of project, ecological deficiencies, undesired social and cultural disadvantages, and negative risks (threats).

As a result, water transfer between basins is acceptable when Value index of water transfer to the destination is greater than the Value index in source.

6. Guidelines for study of options to IBWT

The Bulletin so far has dealt with following subjects related with CDWT for IBWT schemes: i) need, potential, and limits to such transfers; ii) assessment of environmental and social impacts; iii) ways to conduct benefit cost analysis. The last of the terms of reference (ToR) for CDWT requires a study and identification of logic for possible options to IBWT, by deploying available water resources (WR) within the basin. Such deployment requires study of entire range of Water Resources Development (WRD) in the concerned river basin, micro to macro scale, surface to ground WR, in a discrete & judicious combination to enable it at minimum cost, maximum benefits and minimum wastage of the WR of the basin. It is clear that one adopts IBWT, only when within basin availability is deficient and an economical alternative of IBWT is possible, because it is available in surplus against needs within the source basin. Yet, a study of options as proposed by some students of IBWT is outlined in this chapter, before a decision for IBWT is made. The underlying objective behind this last ToR is to explain & understand the logic, and assess feasibility of various alternative options to avail the water supply for different uses within the river basin and if possible avoid the proposed IBWT scheme to serve those purposes. It underlines the assumption that within basin, the proposed option is able to provide required quantum and quality of water supply within the estimated – financial, social, ecological – costs or uncertainties / risks involved. In other words, the within basin option ought to provide a higher benefit/cost proportion or provides more advantages and less disadvantages. The Chapter 6 in following sections, elaborates these options. It will be seen that some of the suggested options to IBWT really propose local solutions at micro scale, rather than those at regional scale. They are also usually posed as options to the conventionally adopted larger scale within basin solutions and hence are not unique. Nevertheless, some aim at bringing equity to the centre-stage of consideration of IBWT and hence merit serious consideration.

6.1. Micro Watershed Development and Rainwater Harvesting

Micro and macro scale of WRD respectively caters to needs from i) dispersed local to ii) large physically contiguous regional areas; through water transfers over distances small to large as per scale of operation serving relatively larger numbers of beneficiaries. The former operates within a narrow band of hydro-meteorological parameters of intensity, duration, antecedent rainfall, potential evaporation, infiltration capacity etc. and has strong limitations and less flexibility. Being scattered, it calls for dedicated local 'cadre' that facilitates community participation for implementation as compared to the organized WR projects on mega scale, requiring and availing industrial methods for implementation deploying specially skilled trained man-power. It has an eminently crucial role in conserving land and soils in the catchment and irrigation command areas. For the rain-fed areas and non-commanded areas of conventional irrigation schemes, it provides supplementary and protective watering for crops. It recharges ground water and admirably satisfies small needs like rural drinking water needs. Micro scale schemes are basically complementary to macro scale ones. Their dependability is much lower than the latter and cost per unit water made available is often high in relation to larger schemes. Thus hydrologically as well as financially, the former are less viable and yet serve the purpose of meeting with local pockets, which otherwise are missed by the latter. It is seen that in a typical basin spread, about 10% of available water could be harnessed through micro scale, whereas due to larger scale WRD 90% can be availed. Thus they don't pose as option to larger scale of WRD whether it is intra or inter-basin. They are viable options for supplementation.

6.2. Small or Big Dams

A large or a small dam is built depending upon location at which one could avail requisite quantum of water supply for needy users and when proven by study of economical-hydro-geo-technical considerations. In a basin, a discrete judicious combination of large to small facilities is required to satisfy needs of target user community by availing WR at a minimum cost per unit of water made available. Undertaking set up of infrastructure of only small dams in a basin, is as much inefficient hydrologically as well as financially, as undertaking only large dams. The choice of a large or small dam at a given location in a basin is largely a techno-economic decision. Larger dams can raise reservoir elevations higher, facilitating inter-basin or inter-sub-basin transfer at lower cost, because of reduction of cost of tunnel across the ridge and or reduction in length of water transfer facility like a canal or a pipeline. Yet nobody claims that IBWT requires only large dams in preference to small ones. The size of a dam to be built depends upon need for volume of water for serving different purposes – intra or inter-basin. Claims about small dams meeting all demands are not factually correct. Relatively larger proportion of captured water is lost to evaporation in case of small structures. A recent study to revive old tanks in TamilNadu (India) indicated that it is more expensive than building new large systems. For new facilities, capital cost in US$ per 1000 cub m storage, as reported by Keller and Seckler (1999) varied from: for large storages at 8 to 100 US$, to micro: at 160 to 600. O&M costs increase with decreasing size. When large quanta are to be harnessed and or transferred, large organized facilities prove cost-effective and are unavoidable. Ultimately the choice of size of dams for enabling water transfer within or outside the river basin depends upon whether IBWT can be avoided by making a choice of small instead of large dams within the river basin. The foregoing indicates that IBWT can't be avoided simply by building small instead of large dams within that surplus basin. In fact a chance is that in that case even within basin needs can't be supported fully by adoption of the option of small dams.

6.3. Run-of-the-River (RoR) Hydropower Stations

The option indicates a possibility that one can build several RoR stations in place of one or more storages followed by a cascade of RoR stations in d/s, to allow use / reuse of the same WR over and again thus maximizing HP generation from it. This assumption is very likely correct, if the river flow is more or less perennial with little variation month by month as in case of temperate climate river systems often fed by snow / ice melt from the hills on a fairly uniform basis throughout the year. In tropical conditions, such stand-alone installations without upstream storages are not found viable as the river flow variation is so large that installed capacity is far too high for the dependable river flow. Their reliability in post rainy season is questionable. Thus, the option to build RoR HP stations exists for climate centric WR development, and not for an option or a choice of intra or inter basin transfer proposals. Still, the option can be studied to ascertain if RoR HP Stations can help avoid IBWT.

6.4. Solar and Non-conventional Energy as an Alternative to Hydropower

Although these undoubtedly constitute the ultimate inexhaustible sources and options for the future, in place of conventional sources like hydropower or thermal installation, they are at present still in development stage. Present costs remain high and unaffordable for large scale adoption. Secondly, these systems e.g. like bio-mass based gasifiers, require large tracts of land for installation and or growing bio-mass, which might not be available or which would in turn require water supply from conventional WRD schemes. They are therefore presently not viable. Proponents of this option also don't account for the non-point, dispersed nature of the source of energy and difficulties faced in their commercialization by way of absorption in the power grid and in transmission of large blocks of power. It is likely to take a long time to make a breakthrough happen to make this option workable. Till then, the option will continue to serve local needs of energy, presently deprived in the present mode of generation at one source and needing expensive transmission from long distances. Also, it is not likely to generate large blocks of energy as the present conventional system facilitates.

6.5. Account for ill-effects of diversion on both source / recipient basins

The IBWT schemes once implemented, commit certain quantum of w/s to the recipient basin, which does not remain available for any unforeseen demands that might arise in the source basin. Such schemes therefore have potential to jeopardize future water development there. Realistic assessment of such possibility has to be conducted and appropriate provisions made in legal documents, if any.

Secondly, transfer of bulk supplies of WR has potential to pass pollutants and pollution from source basin to recipient basin. It can also transmit invasive species. The option therefore calls for a careful appraisal. No such evidence however has surfaced in the existing IBWT schemes. It can be taken care of by monitoring, treating pollutants / invasive species at the point of abstraction of water from the source basin thus ensuring maintenance of requisite quality of water transferred. Detailed planning for each link during the DPR process however is required to address these issues.

Thirdly, IBWT scheme will reduce in particular the fair weather flow in the source river system, causing reduction of dilution doses and aggravating water quality in the d/s. Such possibility has to be ascertained in advance and appropriate measures are built in the operation systems.

6.6. Give priority to within basin needs

The option aims at providing priority to satisfying present and future needs of human / eco systems within the source basin before computing surplus WR at proposed points of abstraction / transfer to the recipient basin. While computing future needs, liberal provisions have to be made for justified aspirations of people in light of : per capita annual availability of WR, level of deprivation – poverty – lack of education – health & hygiene – livelihood – development and economic growth – and ecological health. Although an IBWT proposal takes into account such issues needing water transfer to the recipient basin, more often than not, needs of the source basin are not worked out and compared. The option thus aims at perhaps a little tilt more than equity between the two: source and the recipient basins permit. Given other parameters being equal, one would go by socio-economic – technological viability of the option.

6.7. Improve WUE in existing within basin schemes

This option aims at comparing the Water Use Efficiency (WUE) for different uses between the two basins, and then considers implementation of IBWT. It may be that the WUE in the source basin is of a higher level than the recipient basin, thus indicating surplus availability of WR in the former for transfer to the latter, which may be squandering its WR and yet facing deficit in availability. Thus IBWT option need not have to encourage low WUE but should be deployed for better performing and a competitive basin. At the same time, the option of IBWT can be discretely used to encourage improvement of WUE in the source basin, otherwise confronting it with the IBWT option.

Indeed, accurate computations for WUE are not easy, what with: i) a mix of consumptive and non-consumptive uses within a multipurpose WRD scheme, ii) varying WUE from upstream to downstream, iii) SW / GW interactions being at different levels in hilly, midland, plains –unoccupied by different mixes of sections of society at various level of socio-economic- industrialization ladder.

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8. Guide to Abbreviations

IWRDM: Integrated Water Resources Development and Management

CDWT: Committee on Dams and Water Transfer

TOR: Term of References

SCADA: Supervisory Control and Data Acquisition

IBWT: Inter Basin Water Transfer

WRD: Water Resources Development

WR: Water Resources

ROR: Run-of-the-River

WUE: Water Use Efficiency

SW: Surface Water

GW: Ground Water

ERR: Economic Rate of Return

ICID: International Commission on Irrigation and Drainage