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HYDRO-ELECTRIC POWER POTENTIAL IDENTIFIED UNDER PAKISTAN-GERMAN TECHNICAL COOPERATION WITH GTZ ADDITIONAL TO POTENTIAL ON MAIN STEM OF RIVER INDUS

BY

HERBERT KUNTZ

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BY

Herbert Kuntz[1]

Besides the potential on main River Indus, there is also substantial hydropower potential, low-head on barrages and canal-falls and, to much larger extent even, high-head potential on tributaries in northern mountainous areas of Pakistan, including NWFP, N.A. and AJ&K.

GTZ, the German Government Agency for Technical Cooperation, has been active in Pakistan since 1982 to contribute to development of indigenous clean energy resources by training of utility personnel for more efficient operation of power supply systems and to explore possibilities for hydropower development.

In this context, three individual projects of institutional support were arranged for supporting WAPDA Engineering Academy (WEA), Faisalabad; WAPDA Hydro-Electric Planning Organization (HEPO), Lahore; and Sarhad Hydel Development Organization (SHYDO), GoNWFP, Peshawar; operating between 1982 and the beginning of 1998.

Within this cooperation period a complete hydropower inventory on low- and high-head hydro potential was carried out, providing evidence for more than 8000 MW of hydropower potential in these areas.

This technical cooperation was evaluated by a German Government evaluation team in early 1996 and results achieved by then were highly appreciated.

Following this, both governments concluded an agreement on continuation of this technical cooperation within a Programme for National Hydro-Electric Power Development in Pakistan with the aim that by mid 2002 hydropower potential of Pakistan will be developed in an ongoing, largely self-sustaining process.

Under this Programme, Pakistan Federal Ministry of Water and Power and GTZ have jointly taken up the tasks of

- coordination and active support of the development of hydroelectric power through the Ministry of Water and Power;
- preparation of further feasibility studies for the construction of hydroelectric power stations in selected locations;
- completion of Pakistan's hydroelectric power inventories;
- preparation of a comprehensive data base, centrally administrated and accessible;
- further support to the executing organizations necessary for the development of hydroelectric power, at federal and provincial level;
- making available the technical know-how to the country's basic and further-training systems, especially at Technical Universities and Academies for further training of engineers.

Further, it is highly recommended to

- maintain the functioning of WAPDA's Hydro-Electric Planning Organization (HEPO) as the presently only substantial bearer of hydropower know-how in the country;
- include hydropower as special subject into educational programmes at Engineering Universities;

both essential to achieve sustainable development of hydropower in Pakistan.

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[1] Programme Manager of GTZ under Pakistan -German Technical Cooperation for "Programme for National Hydro-Electric Power Development in Pakistan

1. INTRODUCTION

1.1 Basis for Hydropower in Pakistan

All waters and therefore all hydropower in Pakistan, with the exception of somewhat negligible potential of arid areas of Baluchistan, originate from the catchment of the Indus Basin. There are basically **three different sources** of hydropower potential as far as Pakistan is concerned:

- the main rivers such as Indus, Kabul and Jhelum, before entering the wide plains, do provide opportunities for **larger dams for multi-purpose utilization**;
- the barrages on these rivers in the plains, built to feed the irrigation systems and falls within the canals of these systems provide possibilities **for low head hydro-power** development;
- and the smaller tributaries to the main rivers within the northern mountain areas of the country do provide a large variety of **high-head hydropower potential**.

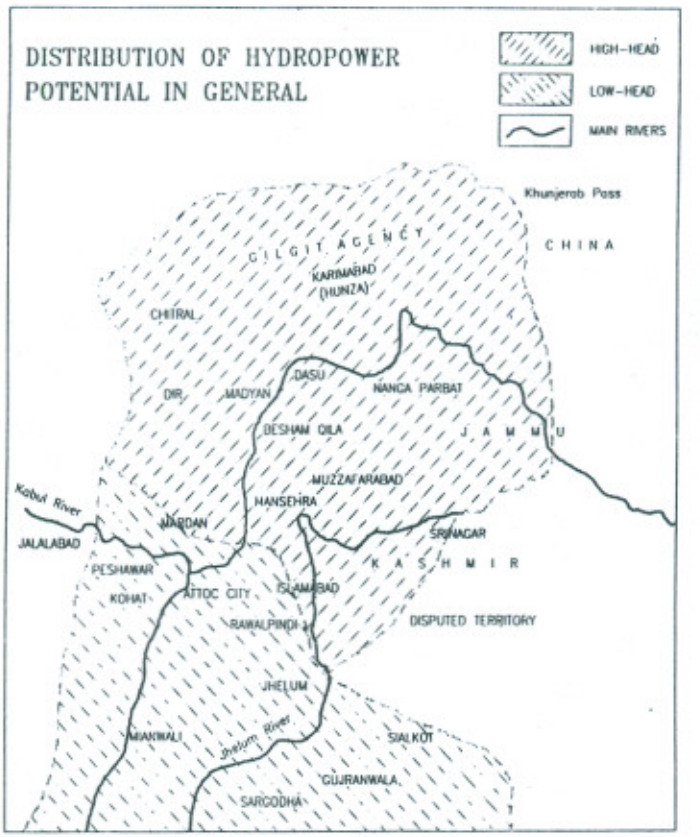


Fig. 1 Distribution of Hydropower in Pakistan in general

Upto mid eighties, systematic studies on hydropower potential have been carried out exclusively on the main rivers, especially on the main stem of River Indus. This is understandable and logical since this has to do with the importance of these rivers being the basis of all life in the Indus River Basin. Consequently, all projects on these main rivers are multipurpose projects and the sequence and timing of their implementation is governed by requirements other than production of electricity, although the major portion of hydro-electric potential of the country lies in these river developments.

Nevertheless, at the time of the first contact between the Pakistan and the German Governments discussing the possibilities for technical cooperation in the field of hydropower development in the year 1981, it was deemed as obvious that there must be additional potential available outside these main river developments, which could be developed in parallel and independently of those. This additional potential would have the advantage that it could be developed as single-purpose electric power projects.

Previously such projects had been developed only sporadically, although, the technology was known to such an extent that it had been done within the country.

Hydropower in Pakistan it actually started from such projects, from falls within the irrigation system, first in the foot-hills of the North-West Frontier Province utilizing a 75m fall in Malakand Irrigation System

- in 1938 with Jaban Power Plant (Malakand I) 7 MW
  later augmented to 20 MW
- followed in 1954 with Dargai Hydropower Plant within the same system (Malakand II) 20 MW

and then continued in the plains of the Punjab with typical low-head plants

- 1951 downstream Rasul Barrage on Upper Jhelum Canal 22 MW
- 1959 at Chichoki Malian on Upper Chenab Canal 13 MW
- 1961 at Shadiwal on Upper Jhelum Canal 1[illegible] MW
- 1965 at Nandipur on Upper Chenab Canal 1[illegible] MW

When GTZ came into the picture, it suggested systematic study of areas for inventorization of such potential all over the country.

1.2. GTZ world-wide function as development agency

The Deutsche Gesellschaft für Technische Zusammenarbeit – German Agency for Technical Cooperation with Head Office in Eschborn near Frankfurt/Main – is one of the world's largest organizations for Development Cooperation. It is owned by the German Federal Government, on behalf of which GTZ performs tasks in the field of Technical Cooperation.

On behalf of the Government of the Federal Republic of Germany, GTZ assists partner countries in planning, implementing, managing and monitoring development operations. Through its commissions for the Federal Ministry for Economic Cooperation and Development (BMZ), the Federal Ministry of the Interior, other ministries and also other governments and international institutions, GTZ has, over the years, amassed a wealth of experience and expertise in development cooperation. With over 2,200 ongoing projects and programmes, GTZ has an impressive record which bears witness to its sectoral and regional competence and performance. Some 1,500 GTZ experts and 4,800 locally contracted specialists and staff are currently working in cooperation programmes throughout the world. Supported by a network of GTZ project administration offices in 50 countries, these activities are geared to promoting economic, social, institutional, infrastructural and human-resource development.

Geared to its partners and not commercial interests, GTZ makes full use of the facilities and resources available in both the private and public sectors and cooperates with both governmental and non-governmental organizations. GTZ is owned, controlled and supervised by the Government of the Federal Republic of Germany and is thus obliged to set and maintain high quality standards and to adhere to the principles of the German Development Policy. Its services are tailored to the needs of the partner countries and aimed at sustainable development. Given its unique position as the German Government's executing organization for technical cooperation with partner countries, GTZ enjoys access to the resources of Germany's governments and para-statal agencies, as well as educational institutions, whenever necessary.

GTZ's legal status under private law means it also could be contracted directly by partner countries' governments and international institutions and is thus not only able to cater to such client's needs- and target-group-oriented services, but also to government-owned and supervised executing agencies. GTZ's company profile is distinct from that of consulting companies, a difference which is highly appreciated by GTZ partners world-wide. International recognition of GTZ services is reflected by a steadily growing number of commissions from such organizations as the World Bank, the European Commission, UN agencies and regional development banks.

Within the framework of economic assistance extended by the German Government to developing countries GTZ works under the Federal Ministry for Cooperation and Development (BMZ).

The BMZ defines the general outline of the German Federal Government's development policy. It conducts the political dialogue and determines jointly with partner governments what projects are to be promoted on a government-to-government basis. According to the principles of the German Constitution, the BMZ is accountable to parliament for all its political and budgetary decisions. The Parliamentary Committee on Development Cooperation reviews important decisions of the BMZ. About 600 persons work in the BMZ.

German development policy aims at improving the economic and social conditions in developing countries and at unfolding the talents and abilities of peoples. The Federal Government feels that its policy can be successful only if it finds in the partner countries conditions which are conducive to development.

While the German Government steers and monitors assistance, it relies on a number of executing institutions for the implementation of its policies.

- The German Agency for Technical Cooperation (GTZ) implements projects aiming at strengthening the capabilities of peoples and institutions. It seconds experts from a variety of disciplines to assist the partner countries in a broad range of development tasks.
- The Kreditanstalt für Wiederaufbau (KfW) provides loans and grants primarily to increase, or to better utilize, the agricultural and industrial potential in developing countries (financial cooperation);
- The German Investment and Development Agency (DEG), promotes economic development by effecting investments and establishing joint ventures with the private sector.

Human resource development is supported by providing opportunities for advanced training abroad, e.g. participation in seminars organized by the German Foundation for International Development (DSE).

In addition, several non-governmental institutions active in development cooperation, like the foundations of major German political parties, churches and other NGOs, receive funds from the Federal Government. However, to a large extent, their work is based on the mobilization of private donor funds and they are free to follow their own policy as regards the selection of projects and implementing strategies.

1. GTZ CO-OPERATION IN PAKISTAN'S POWER SECTOR

2.1 Pakistan-German Technical Co-operation in general

German technical and financial assistance to Pakistan after 4 decades of cooperation has reached the level of over 6.0 billion German Marks. This figure places Pakistan among the 5 largest recipient countries.

Traditionally, the major activities in the field of Technical Cooperation executed by GTZ in Pakistan have related to the energy sector and vocational training. In recent years, the social sectors have received increasing importance.

Presently GTZ extends technical cooperation to various federal and provincial institutions in the fields of

- Power Development in particular for Hydropower
- Vocational Training incl. Staff/Instructors' Training
- Basic Education
- Integrated Rural Development
- Environmental Protection
- Livestock
- Health and Family Planning
- Forestry and Watershed Management

2.2. Three initial projects in Power Sector

GTZ Group of Power Development Projects has been carrying out German contribution to power development projects within Pakistan-German Technical Cooperation since 1984

(1) Support to the WAPDA Engineering Academy (WEA) in Faisalabad mainly for Power Wing Engineers, but recently (since August 1995) also started programmes for Water Wing (Civil) Engineers;

(2) Assistance to Hydro-Electric Planning Organization (HEPO);

(3) assistance to Sarhad Hydel Development Organization (SHYDO)/Government of NWFP.

2.3 Results achieved so far to initiate broader hydropower development

2.3.1 In Institutional Development

WAPDA-HEPO as well as SHYDO during the period of cooperation so far have been developed as competent planning organizations for all sorts of hydropower projects, however, still requiring specialized inputs for own inhouse planning work as well as for control of consultants and contractors working on their behalf.

In addition to this, within the training project, WAPDA-WEA/GTZ have built up a complete integrated training system for Power Engineers mainly at the WAPDA Engineering Academy (WEA) Faisalabad but also utilizing other training centres of

WAPDA. This system is gradually being improved and extended to benefit Civil Engineers and also vocational training of staff in all fields of WAPDA's operations and suitable to support formal training for engineers of both WAPDA-HEPO and SHYDO; as well as succeeding companies in future restructured sector.

2.3.2 In Tools And Basic Data For Sustainable Development

A documentation of specific guidelines in the form of modules for all steps and aspects of hydropower development called DIPEO is under continuous development. It comprises:

D for **D**efinition of requirements and objectives
- to prepare the working basis

I for **I**dentification of hydropower potential
- to match the demand on local, regional and national basis

P for **P**lanning of individual projects
- to establish feasibility of individual projects

E for **E**xecution/implementation
- to tender, contract, build, erect and commission hydel plants and related T&D systems

O for **O**peration
- of power plants and related T&D systems.

The original idea of System DIPEO started in 1980 in Peru. It was to develop tools for smaller hydropower projects and systems for regional electrification within remote areas. In Pakistan, it was started within the cooperation with SHYDO and later also transferred to WAPDA-HEPO for application in AJK and NA. In the meantime, modules to cover larger projects with impact on countrywide power supply systems are being developed and implemented.

Further extensive data banks have been built up out of which the hydrologic data collection jointly developed with SHYDO and WAPDA may be considered the most important.

Here in collaboration with SHYDO as well as WAPDA Surface Water Hydrology Project (SWHP) the network of hydrological gauging stations has been extended into the smaller tributaries on higher altitudes to become representative and workable in integrated correlation models. Data processing has been considerably improved with the utilization of modern hardware and software. This has helped to enhance the reliability of the data and especially to expedite the work.

Besides SWHP, cooperation has also been established with other organizations required to support hydropower development, such as:

- Power System Planning WAPDA;
- System Control/Load Dispatch WAPDA;
- Central Material Testing Laboratory (CMTL) WAPDA;
- Irrigation Research Institute (IRI), Government of Punjab, Lahore;
- Pakistan Meteorological Department, Lahore.

- Centre of Excellence in Water Resources Engineering (CEWRE), UET, Lahore;

and to secondary beneficiaries of WAPDA-HEPO-planning work, such as

- Kashmir Electricity Board, Muzaffarabad;
- Northern Areas Public Works Department, Gilgit.

2.3.3 On Projects

During the cooperation with SHYDO and WAPDA-HEPO a complete inventory of the hydropower potential of Pakistan has been established and priorities for development of individual sites have been set.

This includes

- low-head hydel potential on barrages and canal falls
- high-head hydel potential in the northern mountain belt of the country for local requirement as well as for feeding into the country-wide grid-system;

Since this programme was carried out geographically region by region, it became possible very soon to take up individual projects – starting with low-heads in the first instance – via feasibility studies and tender design to implementation

- projects presently under construction from this programme are Chashma Hydropower Project and Reshun Hydropower Station for electricity supply in rather isolated Chitral Valley, the latter commissioned in November 1998.

All work has been carried out under maximum utilization of in-country manpower resources. Inputs of the GTZ-team are being planned and provided in a manner that on-the-job training of counterpart personnel is given high importance.

This has a double effect:

- know-how transfer is taking place from international team whilst working on the job;
- project-studies are carried out the more economic way, with lower forex requirement;

strengthening Pakistan's institutions and securing sustainability of development.

3. HYDROPOWER POTENTIAL IDENTIFIED

3.1 Initial Process

During a Project Identification Mission of the German Federal Ministry for Economic Cooperation and Development (BMZ) to Pakistan in September 1981, the Government of Pakistan and WAPDA requested for technical assistance to develop "Small Hydel" and Technical Training to WAPDA's Engineers.

However, it was found soon that the term "Small Hydro" as understood by WAPDA was understood the American way as Low-Head Hydels (small in head), whereas GTZ from its own practice started thinking of powerstations small in capacity as they may be required for power supply in remote rural areas, mainly in mountain valleys with relatively high

heads and small discharge. Two very different technologies as far as the civil structures as well as the equipment are concerned.

However, the subsequent discussion revealed that both could be of interest for Pakistan Power Market

- low-heads of bigger size (> 5 MW to > 100 MW) in proximity to main consumers in the plains;
- higher-heads of smaller size (< 5 MW – 10 MW) in proximity to consumers in thinly populated mountainous areas of the north and north-west;

and agreements were concluded between the two governments to support both within two separate projects for technical cooperation to assist Pakistan to build up the engineering institutions for identification and development of relevant potential.

3.2 Low-head hydropower potential

Within the project of technical cooperation with WAPDA's Hydro-Electric Planning Organization (HEPO), the following potential was identified at 101 selected sites:

On by-passes to Indus Barrages, estimated

• Chashma	1250 GWh/a	270 MW[1]
• Taunsa	765 GWh/a	144 MW
• Jinnah	815 GWh/a	140 MW
• Guddu	270 GWh/a	50 MW

On main canal falls

• Chashma-Jhelum Link Tail	310 GWh/a	40 MW
• Rohri Canal Combined	110 GWh/a	12 MW[2]
• Balloki Suleimanke Link Canal RD 106	70 GWh/a	9 MW
• Balloki Suleimanke Link Canal Tail	45 GWh/a	6 MW

In the meantime, 6 of these projects have been brought to feasibility level and two are followed up in private sector.

In addition to these projects, a desk-study was carried out by WAPDA-HEPO/GTZ for an inventory of small low-head sites under which 539 sites were listed with their salient features included, resulting in a total capacity of approx. 510 MW.

Within the field of low-head hydel a total potential of approx. 1080 MW good for an annual energy production of 6640 GWh has been identified.

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1 Finally the Chashma project was reduced to an installed capacity of 184 MW (8 instead of 12 units). Presently this is under construction and is expected to be commissioned by mid 2000.

2 On Rohri Canal, two sites were combined and another site was abandoned thus 8 projects were identified.

3.3 From small-hydropower to high-head in general

In parallel to the efforts on low-head hydropower with HEPO of WAPDA on federal level, a second project was started for development of small (high-head) hydropower potential within NWFP, the province where most of such resources and demand had to be expected.

For the purpose of this development, Small Hydropower Development Organization (SHYDO) was established by the Government of NWFP in Peshawar in 1986.

From 1987 onwards, investigation- and planning-works started under this cooperation project and, in the first instance, a masterplan for electrification of these areas from proximity hydropower was established and relevant sites in the range of 0.5 – 5.0 MW were identified.

However, the SHYDO-GTZ expert teams, whilst working in the field very soon found out that there must be much more potential available in these areas than required to satisfy the local demand even for centuries.

At the same time, it was realized that inventory within the area of NWFP alone would be half of the work only and therefore it should be endeavoured to investigate the potential on even terms for all of the northern mountain belt of Pakistan. Therefore, two actions were taken

- the activities with SHYDO/GONWFP were extended beyond "small hydel" and SHYDO was established in 1993 under the provincial legislation as Sarhad Hydel Development Organization;
- the cooperation with WAPDA-HEPO was extended to cover high-head potential in the remaining areas, mainly in the territories of the Azad State of Jammu & Kashmir and the federally administrated Northern Areas.

3.4 Hydropower in Mountain Areas in general

The definition of high-head hydropower in this context needs some further general explanation

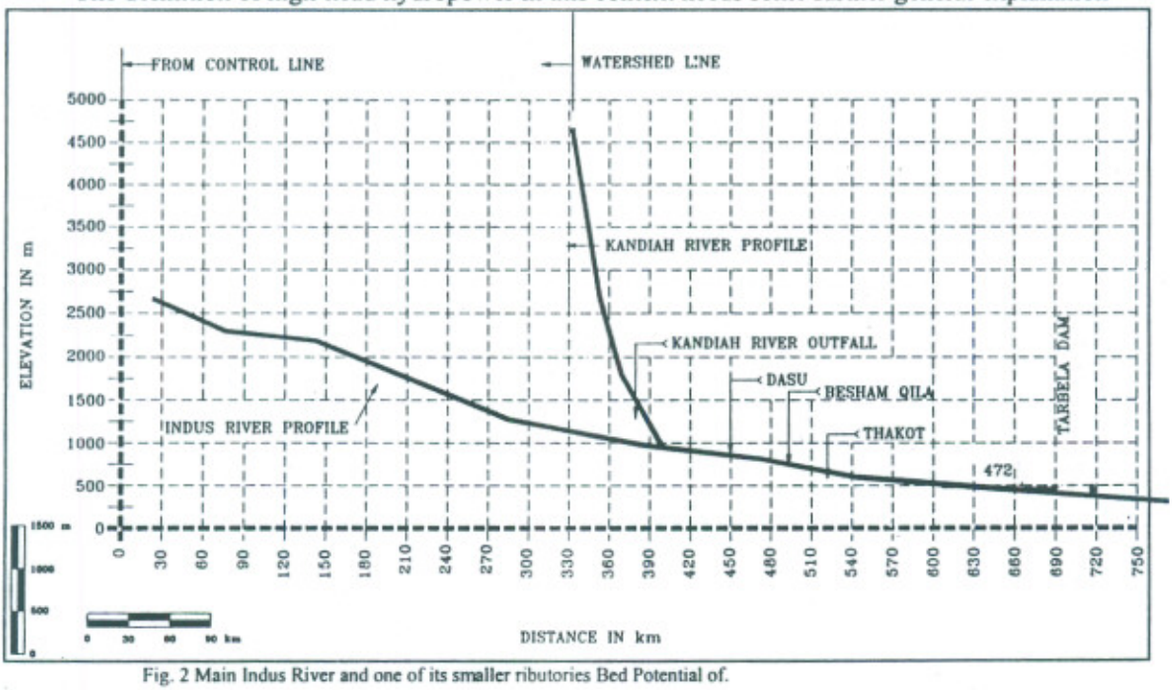


Fig. 2 Main Indus River and one of its smaller ributories Bed Potential of.

High head hydropower as defined here mainly results from the high gradients of the smaller rivers in these territories. Whereas Indus River within the mountain Region of Northern Pakistan down to Tarbela has an average gradient of about 3.25‰, the tributaries are much steeper. The Kandia River e.g. over a distance of 50 km, falls about 3500 m, about 70‰ -about 20 times more, as may be seen from Fig. 2 above.

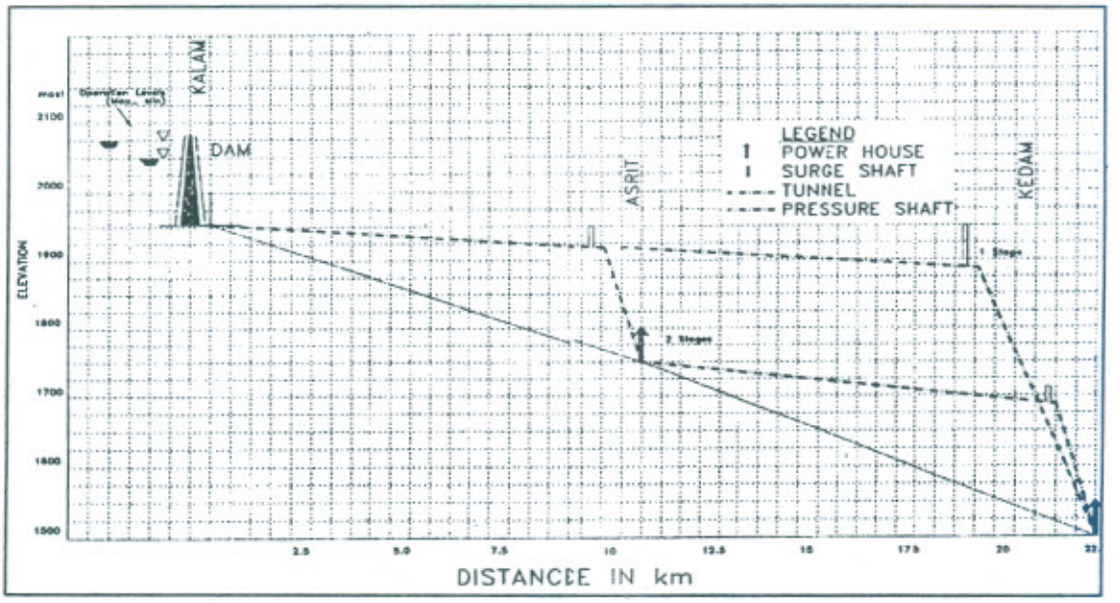


Fig.3. Development alternatives on a mountain river (Swat River).

High-head hydropower as defined in this paper as a matter of principle refers to utilization of the natural head and not to heads created artificially by means of dams. An example is shown in figure 3, where a dam of 160 m had been planned with a powerhouse at its foot and for this 160 m of head it was called a "high-head" plant. The downstream natural gradient of 11‰ providing another 420 m of head was not considered. Environmental considerations in the meantime outlaw the dam. On the other hand, an intake structure of a height of only about 10 m is required to utilize the natural head of 420 m.

Besides this favourable morphology in case of northern Pakistan, there also is the fact that there is higher precipitation on higher altitudes.

3.5 Inventory of High-Head Hydropower Potential - The results

The efforts of both the "extended" project's work-programmes combined have resulted in an area-covering hydropower inventory which on its completion[3] will result in a complete overview of the exploitable potential of Pakistan.

The main areas where high-head hydropower potential has been identified are located as shown in the map in fig. 4.

3 In the meantime, only identification of full potential in Chitral District is left. This will be completed by December 2000 approx. and may be roughly estimated in the range of 1500 – 1800 MW.

Western Areas
catchments of Kabul River

Central Areas
catchments of Indus in Kohistan

Eastern Areas
Catchments of Jhelum River

Northern Areas
Catchments of Upper Indus

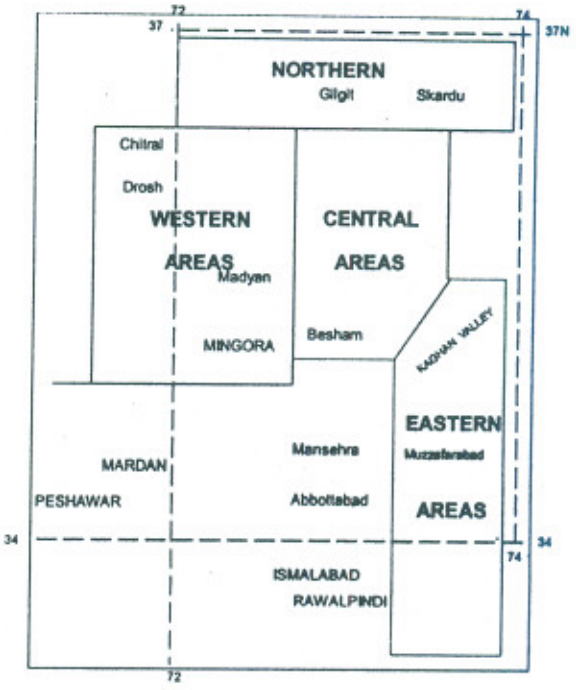


Fig. 4

As may be seen in more detail from the following pages, the potential identified as promising to be technically and economically feasible at present border conditions there will totally be approximately 7500 MW.

The major high-head sites on the following pages are tabulated showing design discharge in m^3/s, length of head race required, (in the horizontal), head in metres, annual energy production in GWh and installed capacity (in MW).

3.5.1 Western Areas - catchments of Chitral, Swat, Panjkoora.

Since Chitral District is totally isolated from remaining areas of Pakistan, for the time being it has not been considered to develop potential for supply electricity to the national grid for the period upto 2025, only potential has been identified to supply local demand of the district, estimated to approx. 20 MW in the year 2011 and to be supplied within an isolated system.

However, in case it could be interconnected to the main system, the potential identified so far would be 1000 MW at 25 sites.

In Panjkoora catchment of the Dir District, these have been identified as main sites

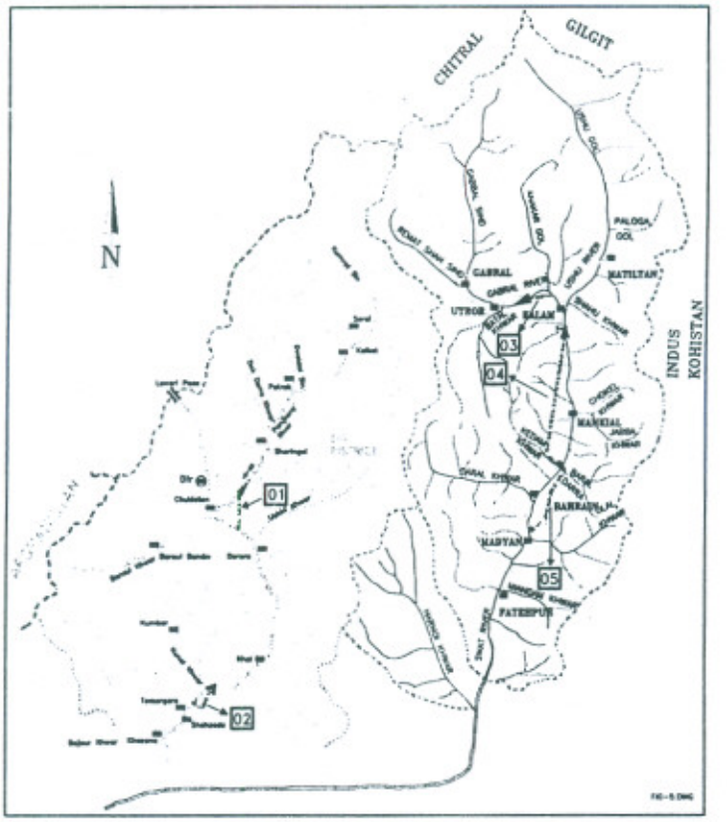
	Name of Site	m^3/s	M/m*	GWh/a	MW
(01)	Sharmai Damor	70	7000/220	575	115
(02)	Koto	114	2200/60	265	53
And 14 smaller sites				790	180

* meters of headrace achieving meters of head

In Upper Swat Valley, these have been identified as possible development of main river system Gabral Swat

(03)	Kalam	75	3800/170	390	100
(04)	Kedam	120	22300/435	1815	410
(05)	Madyan	120	12300/160	655	145
And 7 smaller schemes				525	107

Total for Western Areas **5015 GWh/a** **1110 MW**



3.5.2 Central Areas - catchment of smaller tributaries to Indus in Kohistan Area.

Right bank tributaries

	Name of Site	m^3/s	m/m*	GWh/a	MW
(06)	Karrang/Kandia	70	15000/830	1590	460
(07)	Kaigah/Kandia	135	21500/525	1980	565
(08)	Duber & Keyal/Pattan	32	10500/480	490	120
(11)	Khan Khwar	32	4800/250	300	65

* meters of headrace achieving meters of head

Left bank tributaries

(09)	Spat Gah	155	31000/610	2500	700
(10)	Allai Khwar IV	35	2200/750	790	210
	Allai upstream schemes			580	100
23 smaller sites				1800	400

Total for Central Areas **10030 GWh/a 2620 MW**

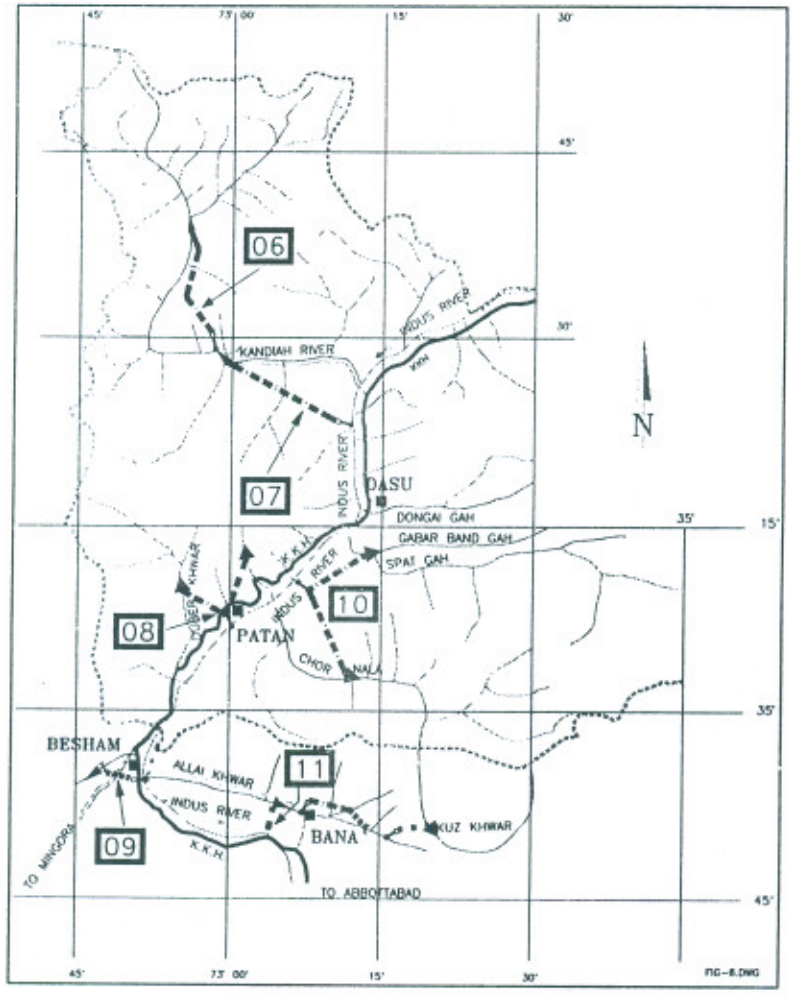


Fig. 9

Kunhar River right side tributary to Jhelum

	Name of Site	m^3/s	m/m*	GWh/a	MW
(12)	Naran	80	11000/340	1000	210
(13)	Suki Kinari	90	17000/930	2750	655

* meters of head race achieving meters of head

since Neelum River, right side tributary to the Jhelum River touches over a long stretch the line of control against Indian occupied territory on mainstream, over and above the Neelum-Jhelum Scheme mentioned in chapter 1 no further sites could be identified. However, on tributaries 4 sites

were identified by French consultants

320	66

Poonch River

	Name of Site	m^3/s	m/m	GWh/a	MW
(14)	Kotli	130	2200/95	600	100
(15)	Sehra	130	4700/65	400	65

smaller tributaries to Jhelum River

(16)	Hari Gehl	20	10000/360	320	55
(17)	Chakoti	120	11000/154	1300	155

Total for Easter Areas	6690 GWh/a	1306 MW
Neelum-Jhelum	5250 GWh/a	996 MW
Kohala	5800 GWh/a	1100 MW
	17740 GWh/a	34020 MW

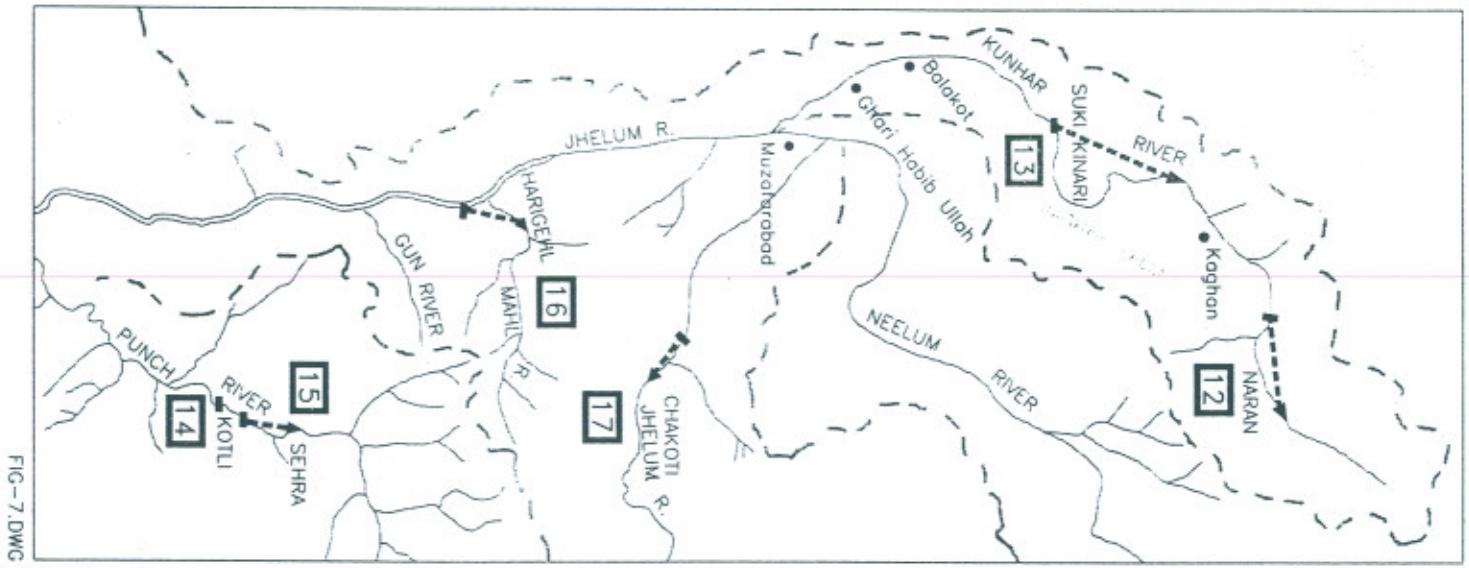


FIG-7.DWG

3.5.4 Northern Areas

As far as the Northern Areas are concerned, totally 120 sites have been identified, out of which 17 with a total capacity of 1020 MW for an annual energy production of 5100 GWh have been found favourable.

Summing up, this leads to the following picture as far as high-head hydropower potential is concerned:

Areas	Capacity (MW)	Annual Energy Production (GWh/a)
Western	1110	5015
Central	2620	10030
Eastern	3400	17740
Northern	1080	5200
Total:	8210	37985

3.6 Possible impact of this potential on Pakistan Power System Development

For development of this potential, if it is to be compared with the development of similar types of potential in the Alpine areas one has to refer back to the status of about one hundred years ago, when development was started there. There is one significant difference however. Unlike in our present situation for northern parts of Pakistan and similar areas, in Europe at that time, there was no experience available which could have been referred to. Now having experience available, the development of the potential could be better planned and more systematic.

Certainly one aspect will be similar, that is that in the first instance one will try to develop the most and more attractive potential and later the less and lesser attractive in economic terms. At present we in Pakistan are at a stage Europe was 100 years ago in the matter of utilization of hydropower. Today we have the option of utilizing in economic terms the better and best hydro potential. This in Europe is no longer possible as they having utilized the economic potential are now concentrating upon the marginal hydel potential left.

The high-head hydropower potential identified so far in Pakistan falls under the first category – the more and most attractive ones.

In a high-head hydropower plant, where usually dams are small, the headrace is likely to be the most expensive component. Since the cost of the headrace is more or less proportional to its length, the requirement of headrace length in the horizontal to gain one meter of head is an important indicator for the competitiveness of the individual site.

A comparison of sites recently identified in NWFP of Pakistan against sites presently under development in Austria, shows for the sites in Pakistan an average of about 10m to achieve 1m head against an average of 40m in case of the sites in Austria. This is due to the fact that in the Alps, the more attractive sites have already been developed, starting about 100 years ago whereas in Asia we have them still available for development.

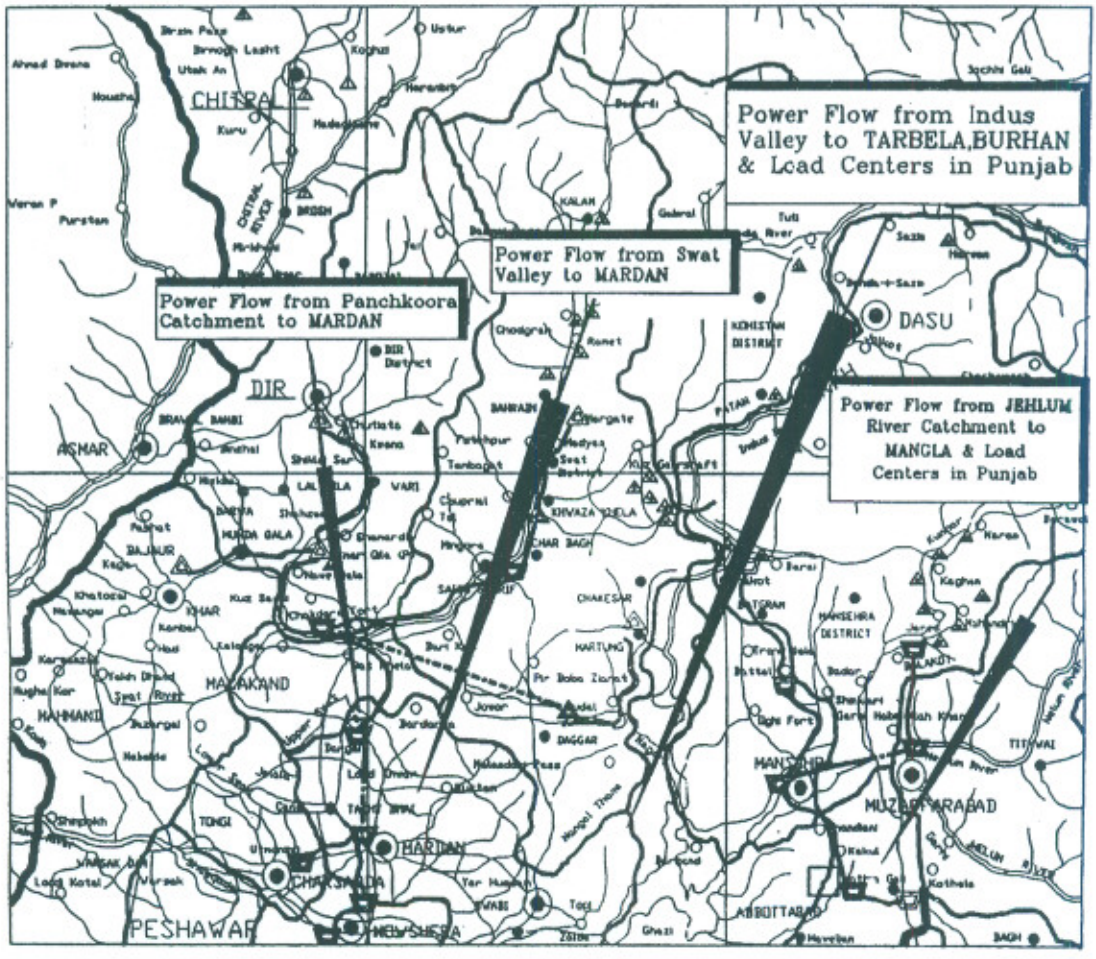
Salient features of the hydropower inventory carried out by WAPDA, SHYDO and GTZ are, that all river catchments and streams have been physically investigated by engineers and geologists. In addition to this, the supporting hydro-meteorological network expansions and area covering data banks on socio-economic and physical features have also been established.

Identification upto now has concentrated on potentials promising to be economically feasible by yielding IERR of more than 10% and even upto 25% which can be developed in the course of the next 30 – 40 years for about 8150 MW which may rise to 10000 or 12000 MW after conclusion of final feasibility studies. European experience has shown that during the following decades economic parameters will change so that finally towards the end of the next century capacities might be developed about 2 – 3 times of this size now planned for the first three decades.

Over and above, the hydropower potential sites identified for satisfaction of local demand and supply of "excess power" as "export" to National Grid, there is considerable potential to contribute to the National Power Development which will have a major impact on future power development expansion plans.

Most of these power potentials are available in proximity to the existing grid system on 132, 220, 500 kV – level between approx. 30 and 150 km not far from main population and industrial centres, which are the main centres of power demand of Punjab and NWFP.

Following the valleys from more or less North to South, this power can be transmitted



along the "influx lines" to the main grid system. **Fig. 8.**

With regard to the sequence of development, one has to develop the local capacities and experience in parallel. Therefore, it has been proposed to start first with the less complex and smaller sites, where also the absolute amount of investment is less for each individual case and therefore easier to develop. There are basically two categories:

- medium size projects of from approx. 5 to 200 MW each;
- larger river development schemes upto 1000 MW each.

For the next step towards utilization of the potential identified feasibility studies are being prepared starting with medium size potentials upto approx. 200 MW, out of which 10 feasibility studies have been completed, 8 more are under preparation as far as the potential identified so far is concerned.

4. CONTINUATION OF PAKISTAN-GERMAN TECHNICAL COOPERATION

4.1 Evaluation by German Government 1996

During the month of March 1996 a three-members Evaluation Mission was assigned by the German Ministry for Economic Cooperation and Development, who carried out a detailed evaluation in collaboration with one Pakistani expert associated to this Mission by the Government of Pakistan.

The Mission within their final report highly appreciated the results of the projects achieved by then and recommended the continuation of the cooperation for a longer period within a Programme for Hydropower Development on National level, mainly supporting the same agencies as within the preceding projects. However, to enhance the then already existing synergic effects to a higher level to coordinate the Programme with the Ministry of Water and Power.

4.2 Ongoing Cooperation

Following these recommendations, the three individual projects ended by May 1998 and under the bilateral agreement between the Governments of the Islamic Republic of Pakistan and the Federal Republic of Germany were combined to the now ongoing

PROGRAMME FOR NATIONAL HYDRO-ELECTRIC POWER DEVELOPMENT

with the aim to achieve that by mid of the year 2002 Pakistan's hydro-electric power potential will continue to develop in an ongoing largely self-sustaining process.

Under the relevant agreement dated May 28, 1998, the Government of the Federal Republic of Germany and the Government of the Islamic Republic of Pakistan agreed to jointly promote a Programme to develop and utilize Pakistan's hydroelectric power potential with the Ministry of Water and Power to support the institutions of Pakistan which are active in this sector, including the Pakistan Water and Power Development Authority (WAPDA) and the Government of the North-West Frontier Province on the basis of the previous Technical Cooperation with WAPA and the Sarhad Hydel Development Organization (SHYDO). The implementation of this Programme is subject to the over-all frame-work of the new power policy of July 1998.

Under this Programme, the seconded (German) experts advise and support in the following fields:

1) coordination and active support of the development of hydroelectric power through the Ministry of Water and Power;
2) preparation of further feasibility studies for the construction of hydroelectric power stations in selected locations;
3) completion of Pakistan's hydroelectric power inventories, especially by collecting information in the Chitral Valley in the North-West Frontier Province, on the Indus and its tributaries above Tarbela;
4) preparation of a comprehensive data base for the development of hydroelectric power which is centrally administrated and accessible;
5) further development of the executing organizations necessary for the development of hydroelectric power at federal and provincial level, especially with the Pakistan Water and Power Development Authority (WAPDA) and the Sarhad Hydel Development Organization (SHYDO);
6) making available the technical know-how necessary for the development of the hydro-electric power in the Islamic Republic of Pakistan in the country's basic and further-training systems, especially at Technical Universities and Academies for further training of the engineers.

5. CONCLUSIONS AND RECOMMENDATIONS

From the above, it must be concluded that considerable hydropower potential has been identified on the tributaries in addition to the development potential on the main stem of River Indus. Although in its total sum it is only one fourth of what is possible on main Indus, it has a number of advantages of its own.

This potential can be developed separately as single purpose projects, independently from developments on the main stream and powerstations can be operated independent of the irrigation requirements which are dominating the large dam projects. This potential cannot replace development on main Indus which for the national economy is far more important than power development alone. But in parallel to the multi-purpose development on the main river but independent from the same, it significantly can contribute to power development, providing a clean renewable source of energy. Since the sizes of the individual plants vary in a large range on many different sites, it can be developed in many smaller and bigger steps and thus is much more open also for private investment on different scales.

First steps have already been taken to implement the individual projects by including them in the National power system expansion plan and Governments' Five-Years Plan No.9 and subsequent plans. Feasibility-studies have been developed for a number of projects and steps have been taken by the federal and provincial authorities to attract private investment for such projects.

It is recommended to further strengthen the institutions involved in this development, especially to preserve WAPDA's Hydro-Electric Planning Organization to function as a Centre of Excellence of know-how in this field, to support the federal and provincial

governments, PPIB and NEPRA with technical inputs to enable them to take right decisions in the National interest of the country.

Since the development of this potential requires multi-facetted know-how and will stretch over decades and generations, it cannot lead to the desired results if development of individual projects remain dependent on foreign expertise all the time. For long-term sustainable development, it is essential that broad based indigenous know-how is established. Therefore, it is highly recommended that technical universities of the country introduce special study lines on hydropower. A start can be made by early introduction of a post-graduate (M.Sc.) course at CEWRE/UET Lahore.