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NVE
NORWEGIAN
WATER RESOURCES AND
ENERGY ADMINISTRATION

# SMALL HYDRO-ELECTRIC POWER DEVELOPMENT IN THE NORTHERN AREA, PAKISTAN

## A MISSION REPORT


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Sverre Husebye
Torodd Jensen

**Sammendrag**/Abstract

The report provides recommendations on the establishment of a mech./el.-workshop for improved maintenance of existing power-plants in the Northern Area, Pakistan. In addition it provides recommendations on upgrading and refurbishing four small hydel plants, the construction of two new, small hydel plants and studies on medium scaled hydel plants.

It is goal to improve existing construction solutions, focus on spin-off effects like training and transfer of technology, improve the standard of living by making electricity available and reduce pressure on the environment.

**Emneord**/Subject Terms

Pakistan, the Northern Area
Small Hydel Plants
Maintenance
Development
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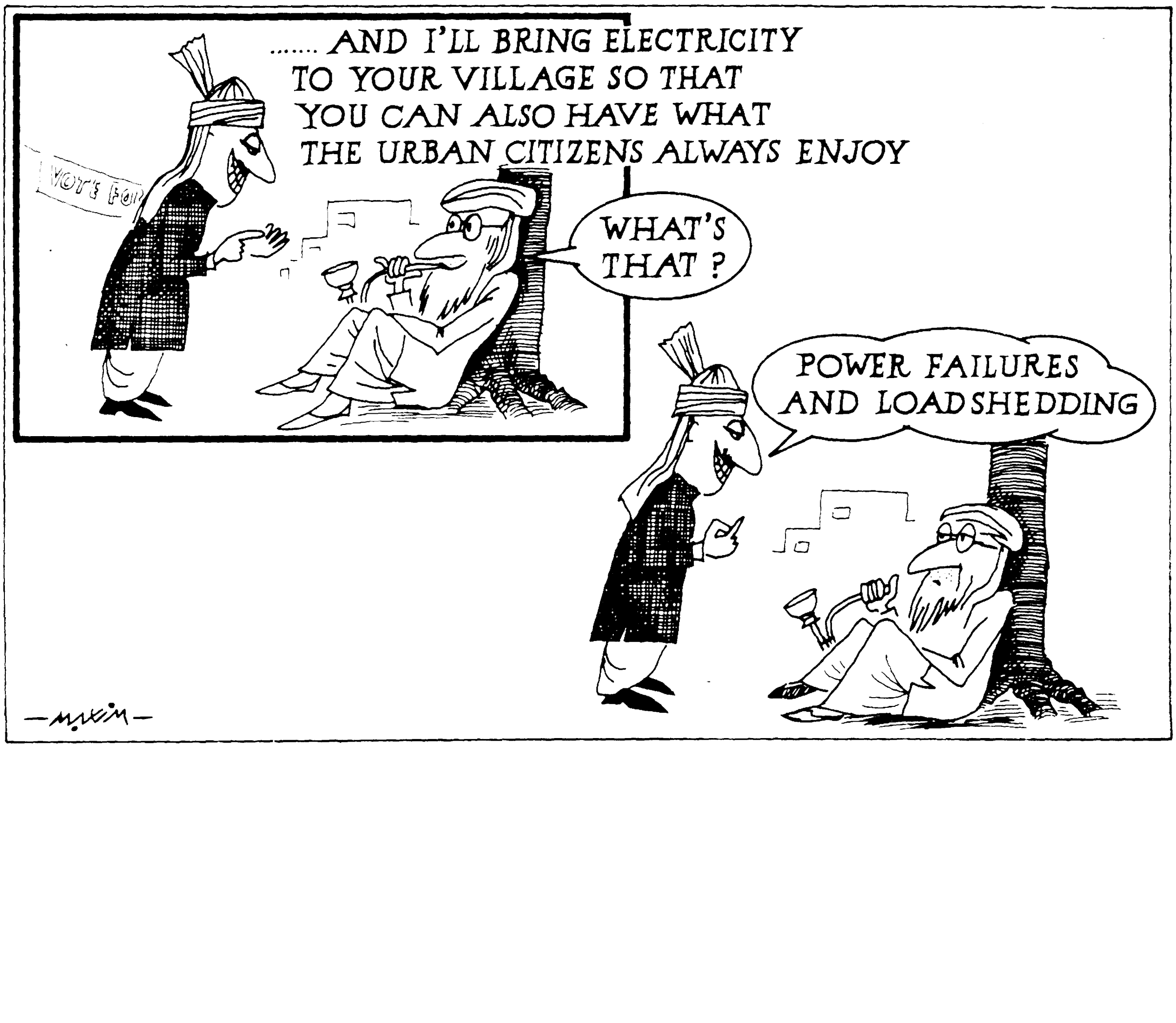
بسم الله الرحمن الرحيم

# The Nation

WEDNESDAY 12 OCTOBER, 1988



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# APPENDIX

# SMALL HYDRO-ELECTRIC POWER DEVELOPMENT IN THE NORTHERN AREA, PAKISTAN, OCTOBER 1988

## 1 INTRODUCTION

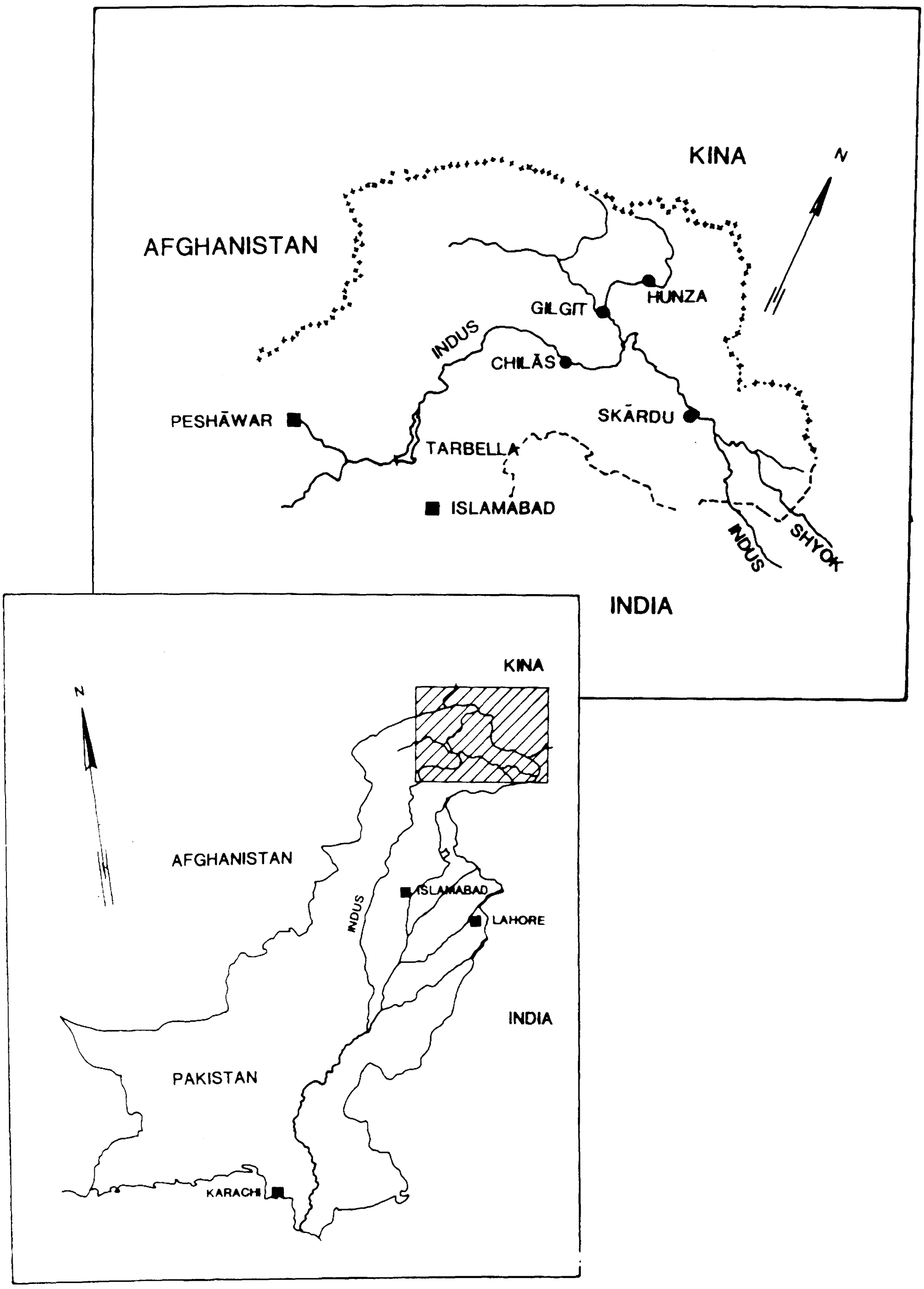
In March 1988 NORAD sent a delegation to Pakistan to evaluate possible Norwegian participation in rural electrification development in Pakistan. One of the conclusions was that Norway should consider to assist Pakistan in the planning and development of small hydro power plants (SHP) in the Northern Area, which consists of Gilgit, Baltistan and Diamar districts.

To improve NORAD's background knowledge and to prepare the terms of reference (TOR) for later consultancy services, another mission was sent to Pakistan, organized and headed by the Norwegian Resident Representative to Pakistan, Mr. Per Skogstad. The other mission members were:

Mr. Fredrik Barth, Professor social anthropology
Mr. Sverre Husebye, M.sc. Physical geography (NVE)
Mr. Torodd Jensen, Hydro power engineer (NVE)

Appendix 1: TOR for the October mission
Appendix 2: List of meetings, persons met and site visits.

The mission stayed in Pakistan from the 10th to the 24th of October. The information given in the meetings is included in our conclusion and in the description of the situation in general, as well as in the description of the different sites.




Location map of the Northern Area, Pakistan

# 2 SUMMARY AND RECOMMENDATIONS

## 2.1 General

Together with the NORAD Representative to Pakistan this October mission consisted of a hydro power engineer, a physical geographer and a social anthropologist. Spesific named projects in the Northern Area should be investigated to improve NORAD's background for decission making on how to be involved in rural electrification. The sites proposed by the Northern Area Public Works Department (NAPWD) were:

**TANGIR SHP project......2MW**
**DARMADAR SHP project.....1-4 MW**
**NOMAL SHP project........2 MW**
**KACHURA SHP project......2 MW**
**GHOWARI SHP project......2-10 MW**
**MAHDIABAD SHP project....1 MW**

SHP: Small Hydro Power

During our stay in the Northern Area, the proposed schemes and some existing hydro power stations were visited. There are no conflicting views or disagreement as regards our conclusions, and our recommendations were positively met both in NAPWD and in WAPDA.

## 2.2 Hydroelectric situation

In the Northern Area, 75 small hydro electric power plants will be in operation in the near future. Some of the present existing 40 power plants lack proper maintenance and the daily operation is difficult. The frequent occurence of power failures and load shedding lead to increased strain for the employees of NAPWD. There are no local facilities for even the smallest maintenance work on el/mech equipment, and they have to wait for weeks to get even the simplest repair work done.

The layout for plants already in operation is based on experience from the construction and operation of irrigation channels. It is clear that intake and waterway solutions can be improved. The el/mech equipment in the power stations consists of several types

of technology, and originating from different manufacturers. There are quality differences, which means that a 20 year old turbine can be better than a one year old one.
The estimate of present demand in the Northern Area is 78 MW which far exeeds what can be produced by constructing small hydro power plants (up to 10 MW). Areas presently without electricity are pressing to be able to join in. There are, however, no existing transmission lines to carry power from future medium scaled power schemes (10-50MW). The mission therefore concludes that small hydro power plants should be built near villages where there is no or little electric power available. The six schemes mentioned in 2.1 will give electricity to such villages.

## 2.3 Socio-cultural aspects.

In the rural areas presently supplied, electric power for domestic use has had a marked welfare effect, benefiting woman and children equally with men in their daily lives. It is also a stimulus to the development of cottage industries and small enterprises. There is no doupt that extension to further areas would be beneficial. It should be stressed, however, that a social scientist should work together with the consultant concerning the implementation of the small hydroelectric schemes and the running of the mech/-el workshop. This may reduce cultural misunderstandings and ease the recruitment of personnel. A social scientist co-operating with locals may improve the chance of reaching the target group (poor people) when local infrastructure is built as power becomes available.

## 2.4 Environmental aspects

The site visits to the proposed projects showed that the development of the schemes will lead to minor negative effect or none at all. The waterresources in the small rivers are limited during the low discharge periode in the early spring (February/ March). In this periode there might be a conflict between irrigation and hydro electric production. There were, however, a clear understanding that irrigation had first priority to water. Where problems occur it could be solved by lift irrigation pumps or by reduced electric production.

In Tangir there seemed to be no such problems at all because the snowmelting in this area starts before the sowing periode. In Nomal, however, the need for irrigation water must be included in the plans. The conclusion is that all the projects evaluated can be implemented.

To meet the power demand in more populated areas like Gilgit town in the future, the development of 10-20 MW schemes (medium scaled) seems to be a necessity. They can be built in the large rivers or be a part of multipurpose schemes in the tributaries. The medium scaled schemes will reduce the need for development of small power plants higher up in the streams, which may sooner or later threaten the wildlife and bird biotops in more fertile zones of the mountains.
Parri and Hanzal schemes are example of medium scaled schemes which should be considered for implementation to meet the power demand in Gilgit town. The environmental effects of these schemes are unknown. There is, however, both a need and wish for transfer of knowledge and training in the environmental field.

There seems to be a lack of reliable hydrological data for the planning of hydroelectric projects in the tributaries. Improved hydrological foundation should be considered to be able to develop small hydro power plants which will have to be runned in close coorperation with irrigation schemes.

The knowledge of both the characteristica and the amount of sediments are important in planning and evaluation of the long term efficiency of turbines, intake and dams. No sediment data were available in connection with the small schemes. In the sedimentological field there might be a need for transfer of technonoly and training.

## 2.5 CONCLUSIONS

**A**

A team with special knowhow on upgrading and refurbishing turbines and electric equipment should, together with a civil engineer with knowhow on intake and waterway problems, be sendt to Pakistan as soon as possible to evaluate spesifically mentioned plants in operation (Kargah phase 5 (200 kW), Hassanabad phase 1 and 2 (160,400 kW), Skardu phase 1(320 kW)). The report from the team should give background knowledge for TOR for upgrading/refurbishing work on the mentioned plants. These plants should have first priority because they can be examples for other plants in similar situation.

**B**

The planning for the immediate construction of an el/mech workshop to allow local repair work should be given same priority like A. This workshop will benefit the whole area, and it should be located in Gilgit. Employees from NAPWD should be trained by Norwegian manufactures, preferably at the same time when the work concerning A is carried out. The same manufacturers should assist in the daily running of the workshop the first one to two years.

**C**

Of the six schemes mentioned, we have chosen two for immediate development. TANGIR SHP will give power to an isolated valley where only a few houses have electricity today. This scheme is also given first priority in NAPWD. NOMAL SHP will also give power to villages presently without electricity. Even more important is that the implementation of this scheme will give the power needed to run the workshop at Gilgit, power which for the moment is un-available. To serve the workshop it is necessary to construct a 30 km long 33 KV line from Nomal to Gilgit. This construction could start first year. Tangir and Nomal costs less each kW and have the highest score both regarding

socio culturel and environment aspects compared to the other schemes. We suggest that detailed studies are carried out, without feasibility studies. TOR will give the scope of work and the necessary co-operation with employees at NAPWD and WAPDA.
A hydrological engineer should participate in the first visit to Pakistan to evaluate present hydrological knowledge concerning the schemes and if necessary install hydrological gauging stations in Tangir and Nomal rivers.

**D**
Small hydel plants have been constructed the last 25 years in the Northern area, and the area is now facing the demand for implementation of medium scaled hydro power plants. We therefore suggest that the Norwegian contribution should also include the following:

A review of the existing feasibility study for the PARRI multi purpose scheme. Output 10-20 MW and irrigation of 20,000 acres of dry land. This scheme requires solutions in which Norwegian technology is at its very best, and the review can give important information to engineers in WAPDA.

A review of the existing feasibility study for the HANZAL (Gilgit) scheme (6-15 MW) to find out if this low head run of the river scheme is feasible or not. This work should also include a pre-feasibility study on alternative sites in the Gilgit river.

**E**
If sufficient budget, the study for implementation of DARMADAR (1-3 MW) and MEHDIABAD (1 MW) SHP should start one year after the studies for TANGIR and NOMAL. The construction budget for TANGIR, NOMAL, mech/el workshop and refurbishing of the mentioned existing plants will then be known. The Kachura scheme will be implemented by NAPWD themselves and the team found that the Ghowari scheme would

be expensive unless constructed as a 10 MW scheme. Priority on medium scaled projects should be given to schemes which would serve the Gilgit area since Gilgit is the capital in the Northern Area.

2.6 Remarks and annual cost estimate.

A special TOR should be written for items **A** and **B** and another for **C** and **D**. For the work under **C** and **D**, one engineer from WAPDA should join the consultant from the very beginning, and work together with him in Pakistan and Norway. This engineer should have attended the one year hydro power course at Norwegian Technical University, NTH. Another engineer from WAPDA should start on the NTH course in September 1989. After having completed this theoretical course, he should join the consultant and work with him until the mentioned schemes are commissioned.
The studies on medium scaled power plants will give the opportunity not only to transfer knowhow on planning underground schemes to WAPDA, but also transfer knowhow on environmental problems to an environmental office at WAPDA, which is planned to be established.

**ANNUAL COST ESTIMATE**

| | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|
| | Million NOK | | | |
| Refurbish/upgrading mission | 0,4 | - | - | - |
| Kargah 5 (uprating) | | | | |
| Hasssanabad 1,2 (upgrading,refurbishing) | 5,0 | 10,6 | | |
| Skardu 1 (refurbishing) | | | | |
| Workshop (equipment, constr., supervision) | 12,5 | 3,6 | 1,0 | 0,5 |
| 33 KV-line Nomal-Gilgit (constr.) | 1,7 | 3,3 | | |
| Training, visits | 1,4 | | | |
| Tangir, Nomal (detailed study) | 4,0 | | | |
| Tangir,Nomal (constr., training, establish office) | - | 20,5 | 35,0 | 20,5 |
| Review medium scaled projects | - | 3,0 | | |
| Budget mill NOK (01.01.1989) | 25 | 41 | 36 | 21 |

# 3 GENERAL INTRODUCTION

## 3.1 Hydro electric power aspects

### 3.1.1 Hydro Electric Generating and Electric Demand

The Northern Area consists of Gilgit, Baltistan and Diamar districts situated between longitude 62-76 degree East and latitude 34-36,5 degree North. Total area is about 69600 square km. The population of the Northern Area was 0.65 million in 1981. The distribution of the population follows the lines of streams and rivers on the alluvial fans where water is available. The total requirement for electric power is about 78 MW, which includes domestic, commercial and industrial demand.

The mountainous terrain with a lot of water resources makes the Northern Area suitable for hydro electric generation on small, medium and large scale production. Since the population is located in the valleys, the development efforts so far have concentrated on building small hydel stations to serve the villages. Except for powerstations situated in the same nullah, very few powerplants are interconnected in a grid. The existing transmission lines are built to deliver the power over short distances, as it normally is 11 KV leading the power to a distribution grid.

The present production from 40 existing small hydro electric powerstations is 8.5 MW. 35 small hydel schemes are under construction. These stations will generate an additional power of 22 MW by 1991. Sites for the construction of additional 19 hydel projects have been identified in the Northern Area. It is expected that another 22 MW electricity can be generated if all the sites are found feasible and developed (see details of data and location map in Appendix 3 and 4).

Six of the 19 sites have been selected as priority projects.

TANGIR HYDEL PROJECT.........2 MW, DIAMAR DISTRICT
DARMADAR HYDEL PROJECT.....1-4 MW, GILGIT DISTRICT
NOMAL HYDEL PROJECT..........2 MW, GILGIT DISTRICT
KACHURA HYDEL PROJECT........2 MW, SKARDU DISTRICT
GHOWARI HYDEL PROJECT.....2-10 MW, SKARDU DISTRICT
MEHDIABAD HYDEL PROJECT......1 MW, SKARDU DISTRICT

From NA PWD top priority is given to Darmadar and Tangir valleys.

The very high mountains with glaciers and the climate of warm summers and cold winters, give large variation of water flow in the rivers. The whole area is dry, but the melting season from May to September gives a very high flow in the big and small rivers, hence there is no lack of water during summertime. Wintertime, however, with little water flow in the small rivers sets the limitation for hydro electric generating. In the nullahs where the small plants are located there are few potential reservoir sites. Therefore, to cover the electricity demand during wintertime, the NA PWD is forced to look for sites in the bigger rivers like the Gilgit river. Hydro power plants in the big rivers will be RUN OF THE RIVER PLANTS with little or no regulation potential. For peak load time during winter season it is therefore necessary to have backup diesel units where the hydel production is limited.

According to the available information, WAPDA will be responsible for the planning and implementation of hydro electric power plants with output more than 5MW. NA PWD will be responsible for the development of hydel plants with output less than 5 MW. WAPDA will, however, be given the opportunity to comment on all projects.

### 3.1.2 Existing Small Hydro Electric Power Plants

All of the SHP visited was run of the river plants with a simple intake construction, feeder channel, pipeline and a power house on the surface. The intake construction normally caused problems both during the high flow season (stones and siltation in the waterway) and during the low flow season (leakages to the river). Appendix 7,fig 2. The head race channels were constructed to give high water velocity. The reason for this was that it reduced the cross section of the channel (which was less expensive), and the fear of freezing during cold winter weeks. However, the high velocity also caused icing problems within the channels as well as in the forebay and trashrack in front of the pipeline. App 7, fig 1. The pipelines and equipments in the power stations always consisted of two or more units. One of the reasons for this was bad access roads which prevented heavy and voluminous constructions (App 7, fig 3,4). The silty water caused problems to the turbines and gaide vanes and some runners (especially the cross flow runners) had to be regularly repared. According to our informers, some of the turbines in operation had very low efficiency.

The generators normally had 1500 rpm. The rotation of the turbine runners was raised by gear. The transmission voltage is 11 KV from the power stations to the local 400 V grid. Some places upgrading of the transmission line to 33KV could be feasible. In general only powerplants in the same watercourse were connected to the same grid.

To get information on local knowhow of construction and operation of SHP plants, the following existing stations were visited (stations in other nullahs than the proposed 6 schemes):

KARGAH PHASE 1,2,3,4,5,6 AND 7 (power for Gilgit town)
HASSANABAD PHASE 1 AND 2 (power for Hunza village)
SKARDU PHASE 1 AND 2 (power for Skardu village)

### 3.1.3 Maintenance and Operation

No local workshop is available to repair even uncomplicated damage of parts of turbines, generators or panels. The parts are brought to Lahore for fabrication and repair. This consumes time and money, in addition to the inconvenience to the consumers facing the blackouts for days and days, before the parts arrive from Lahore.

No training facilities are available for engineers and technicians on the machinery. The engineers and technicians who are responsible for installation of the turbo generating stations and their future maintenance, need proper training on similar machinery in the manufacturers' workshops. In this way they will be able to rectify machinery faults during operation.

## 3.2 Socio-cultural aspects

### 3.2.1 Population and cultural position

The Northern Area comprises a territory of some 27 000 sq miles with low population density and scattered settlements. The local economy is based on irrigation agriculture, and stockbreeding/dairy production. Staple crops are wheat and maize, with a number of subsidiary crops inluding millet and buckwheat, apricots and other fruits, walnuts, potatoes. Main domestic animals are cattle, goats and sheep, with yak and yak-cow crossbreds in the north and east. Donkeys are still extensively used for transport. In the southwestern zone, there is also a considerable extraction of timber.

The area is socially and culturally diverse. Most areas have for many centuries been organized in small, centralized kingdoms with a varying degree of independence or linkage to Kashimir; the remaining areas have been stateless (anarchic) tribal groups, each locality governing itself through council meetings of free equals. Religion is universally Muslim, with Sunnis, Shiahs and Ismailis represented. Of these, Sunnis are more or less cosely linked with the down-country Pakistani mainstream; Shiahs have a long tradition of initimate scholarly contact with centres in Najaf (Iraq) and more recently Qom (Iran); while Ismailis have their unitary, cosmoplitan organization led by the Aga Khan.

Ethnologically, there are several distinct components:

Gilgit area is Shina-speaking, traditionally organized in several small kingdoms, and mainly of the Shiah and also Ismaili persuasion. Gilgit town has long been a centre for the area, and has a mixed population of all the different people of the region, and presently a total population of ca 50 000.

Hunza valley is composed of the traditional kingdoms of Hunza and Nagar, both Burushaski-speaking (a language of no known affinity). Hunza is Ismaili in religion, Nagar is Shiah.

Baltistan was a traditional kingdom based on Skardu. The language is a Tibetan dialect, and religion is overwhelmingly Shiah.

Kohistan is composed of various tribal and traditionally statless societies speaking Shina and several other languages of the Dardic branch of the Indian stock. All these groups are of Sunni persuasion.

Gujars form an additional group, scattered through most of the highlands areas as a transhumant or nomadic population of small stock breeders. They occupy the high mountain pastures and the highest agricultural settlements, and speak Gujri, a language of lowlands affinity. They embrace the Sunni faith.

### 3.2.2 Socio-cultural effects of electrification and estimates of demand

The Northern Area is an extremely poor area due to the marginal environment and limited natural resources. The different local cultures have, however, developed a set of remarkably successful ecologic adaptations, through extensive terracing, irrigation, crop and stock combinations, and carefully balanced development and utilization of resources. Over the last twenty years the government has also invested considerable funds in development, and rapid change is under way through the construction of roads, educational and health facilities, security, and civil administration. Electrification is an important and valuable component of this development.

Present supplies of electricity go overwhelmingly to domestic illuminiation and illumination of public offices and schools. Large areas are still without electricity and depend entirely on kerosene lamps (kerosene is available at 3 Rps/liter) or even chil, small torches of harpic-saturated wood. Heating and cooking are by open wood fire. These practices cause great problems of smoke and soot in dwellings, restrictions on all non-daylight activities, and rising pressure of over-exploitation on natural vegetation. Provision of electric light is strongly esired by the whole population, and is particularly attractive as it is made available at the price of 0.26 Rps/kWh (the equilvalent of 0.08 NOK) and an installation fee of Rps. 100, expenses apparently within the means of nearly all households.

The main benefits of electricity are seen by the people as the availability of early morning and especially evening light for housework and other in-doors activities, reduced soot and smoke in the houses, reduced time spent collecting wood, enhanced facilities for the children who attend school to do their studies and homework (they are generally needed to assist in productive tasks during after-school daylight hours), as well as generally enhanced comforts. It should be noted that these are benefits which reach women and children to even greater extent than men; and the facilities are so eagerly sought that where available they are limited to a maximum of 0.2-0.5 kW/consumer/household, so as to reach a maximum number of households. There is, moreover, an expressed demand for increased domestic supplies, to be used for supplementary heating, hot water, and power for minor household appliances. Demand is currently estimated to be ca 1 kW/household during peak hours. This is probably only a preliminary level, which will be raised within few years.

Public demand will also expand, as more and better facilities of schools, hospitals and dispensaries, and administrative offices are developed. In the town of Gilgit, and other local centres, there may also be a need for public street lighting.

Finally increasing electrification of productive and commercial activities is eagerly anticipated. In areas where electricity is available, electric flour mills, saws for producing building materials, and auto repair workshops have appeared, and more will be established as soon as further electrical power becomes available. Commercial and entrepreneurial interests are also impatient to be able to establish sewing/tailoring businesses, refrigeration facilities, fruit processing and canning, and expanding facilities for tourism. Areas presently without electricity are pressing to be able to join in all the development here listed. With regard to irrigation, on the other hand, local development continues to be based on gravity flow in long channels, rather than pumps. A preliminary evaluation would seem to support this policy both for ecologic and cultural reasons and because of the scarcity of energy in the foreseeable future; and the team will consequently not give priority to exploring the possibilities for lift irrigation and sprinkler schemes except under very special conditions.

## 3.3. Environmental aspects

### 3.3.1 General

Geographically, Pakistan comprises three main regions: 1) The mountainous north where three of the world's great mountain ranges meet: The Hindu Kush, the Karakorams and the Himalayas. 2) The Baluchistan in the south-west which is an enormous but sparsely populated plateau (covers 44 percent of Pakistan's total area). 3) Punjab and Sind which covers the plains of the Indus River and its five main tributaries. Apart from these irrigated plains, Pakistan is largely barren mountains and arid plateau. Except for Baluchistan, the Indus river drains the whole country.

### 3.3.2 Geology

The Northern Area is dominated by the Karakorams and partly the Himalayas which are among the highest and youngest mountains in the world. In Pakistan there are 82 peaks that rise more than 7000 m above sea level. Nearly all of them are to be found within the Northern Area. The world's second highest mountain, the K-2 (8611 m.a.sl), Rakaposhi (7788 m.a.sl) and the Nanga-Parbat (8125 m.a.sl) are some well known peaks within the region.

Throughout the Karakorams length the outstanding orographic features are:

- The arcuate and parallel mountain ranges with northward convexity. Their trend: E-W or NW-SE.
- The swinging of the strike of rocks consequent on that of the ranges.

A wide varity of sedimentary, igneous and metamorphic rocks are exposed in the area (tab 1). Since these rocks are the source of the soil materials, the latter exhibit large variations in mineralogic make-up etc. from place to place.

Tab. 1 Geology at Hanzal, Gilgit river (from WAPDA).

| STRATIGRAPHY | | | |
|---|---|---|---|
| SYSTEM | GROUP | THICKNESS | CHARACTER |
| Quarternary | - | 0-100 ft | Lake deposits, moraines stream gravels, alluvium |
| Tertiary | Granodiorite Hornblends Granite | Unknown | Biorite, Granodiorite, Biotite, Granite, Pegmatite, Hornblende, Gneiss, Hornblendtite |
| Cretaceus | Yasin Group | 2000 ft | Limestone, Tuff, Quartzitic, Limestone |
| Mesozoic | Greenstone Group | Several thousand feet | Epidorite, Dolerite, Basalt, Andesite, Hornblend gneiss |
| Permian Carboniferous | Darkot Group | 14,100 ft | Slates, Quartzite, limestone, gneiss |

### 3.3.3 Geological history

The geological history and formation of the Karakorams and Himalayas can be explained as follows. In pre-Himalayan days, the area was occupied by the Sea of Tethys lying between two continents of ancient hard rocks, Angaraland to the north and Gondwanaland to the south. Sedimentary materials in enormous quantities were accumulated layer upon layer. The sandy materials forming the sandstone while organic remains such as shells and the bones of sea animals became limestone. About 55 million years ago the northward-drifting Indian geological plate collided with the Asian plate and the sea of Tethys was compressed and contorted into fold mountains. The uplift of the mountains continued in several intermittent phases, separated by long periods of time. The Indian plate is still drifting northwards at about 5 cm a year, causing the mountains to rise about 7 mm in the same period. Because of this the area is geological unstable and earthquakes are a common feature. The Indus River with its tremendous gorge between Besham and Chilas flows in this unstable collision belt where there is an earth tremor, on average, every three minutes. Earthquakes in the Northern Area may result in minor damage on the small scaled schemes. Since the constructions are small, this will not lead to any serious negative, additional effects on the environment.

### 3.3.4 Geomorphology

The Northern Area was glaciated during Quarternary. The landforms reflect the erosional, depositonal and landforming processes of glaciers, such as: U-shaped- and hanging valleys, step-like gradient, circues, different types of moraines, erratics, glaciofluvial- and glaciolacustrine sediments. Because of the recent subaeril erosional processes the young and active landforms often dominate the old ice-sculptured landscape. Sedimentary and unconsolidated rocks, steep hillsides and lack of vegetation cover favorize the denudation and erosional processes. Most common are frost and chemical weathering, mass movement as land and rockslides and different kinds of fluvial erosion.

Features such as gullies, ravines, canyons in both rock and loose material, fans, terraces, flood plains, and braided streams are most frequent. The origin of the fans are both slides and fluvial deposition. In several places different generations of fans, fluvial- and quarternary deposits are to be seen.

The active sediment producing processes combined with large accumulations of sediments along the hillsides and valley floors together with the high mountain glaciers create rich sediment sources of all kinds of particles to the rivers.

The rich flow of sediment to the streams and rivers results in heavy sediment load. Both suspended and bedload transport are important processes. The amount of sediments changes throughout the year due to the variations in discharge. The highest values occur in the spring and summer months when there is snow and glacial melting in the mountain areas.

### 3.3.5 Hydrology

The hydrology in the Northern Area is dominated by three months of low water flow during the winter (Dec.-Feb.) and high flow in spring/ summer due to snow and glacial melting in the high mountain areas. Because of the low precipitation (100-200mm/year) and high evaporation many streams are ephemeral or intermittent. The perennial streams which are of interest for irrigation, water supply and hydro-electric power drain high mountain areas with sufficient precipitation within their water-sheds. Further south in the Chilas region there is more precipitation because of the monsoon effect.

The glacier and snow-fed Indus river above Basha does not show extreme variations in annual average flows (tab 2).

Tab 2

Annual average flow at Basha (152,100 $km^2$) located between Partab Bridge (1962-79) and Barzin (1974-79). The flow is estimated on the basis of a uniform runoff ($m^3/km^2$) between the two stations (from WAPDA):

| TYPE OF FLOW | DISCHARGE $m^3/s$ |
|---|---|
| Long term average | 1970 |
| Maximum annual average | 2660 |
| Minimum annual average | 1600 |
| Maximum monthly average (July 73) | 8370 |
| Minimum monthly average (Feb. 63) | 287 |

The river regime is quite regular. Flows start to rise in early spring reaching the peak in July or August. The melting season ends in September. Flow recession proceeds regularly during winter until the next spring.

Based on hydrological data the 100 year flow is 11 700 $m^3/s$. One important feature of studies in the Indus and other rivers such as the Gilgit river are the natural dam outburst floods. More frequently, glacial formed dams which impound in tributary valleys, are overtopped or collapse suddenly forming flood waves. Natural dams due to large landslides are known to occur in river basins. The failure of such dams have created large flood waves in both the Indus and Gilgit rivers. Floods caused by such events are estimated to have equaled or exceeded 40 000 $m^3/s$ (Indus) as much as four times since 1833. The 20 000 $m^3/s$ flow was equaled or exceeded at least nine times during the 1833-1933 period, corresponding to a recurrence interval of 11 years. Floods caused by outburst of glacial formed dams seems to have exceeded 11 000 $m^3/s$ at least seventeen times in 100 years, with a frequency of one in six years.

### 3.3.6 Climate

Climatically the region has considerable diversity. The precipitation varys from north to south and with altitude. The valley floors in the north get the least precipitation. Turning south the precipitation increases from about 150 mm/year in Gilgit to about 500 mm/year in Tangir. Because of lower temperatures the evaporation decreases and the condensation increases with altitude in the mountains. In the higher mountains there is perennial snow, while the temperature in the valleys exceeds 30$^0$C in summer. The winters are cold, frequently below -10$^0$C (Dec.-Feb.). The variation between night and day temperature may also be considerable. The reason is the radiation during the night and the sun heating during the day.

The snow cover in winter varies from approx. 10-20 cm in the valleys to several metres in the mountains.

The climate is continental. In the lower parts it is arid/semi arid while the climate in the mountains may be characterized as cold to polar continental with winter precipitation.

### 3.3.7 Vegetation

The natural vegetation is sparse and reflects the climatic conditions.

In the higher mountains above 4600 m.a.sl. ice caps, glaciers and permanent snow-fields may rise to thousands of metres above the snow line. The edges of these vast ice masses constitute a special habitat, cold and arid, called snow desert. During summer which is of short duration, these deserts are covered, although sparsely, with herbaceous vegetation. This region constitutes the most important water resource of Pakistan in summer.

Between 3400-4000 m.a.sl. there are two ecological zones, based on differences in vegetation:

- Alpine scrub
- Sub alpine forest (3400-3800 m.a.sl)

The sub alpine forest consists mainly of coniferous trees as pine and juniperus. The alpine scrub zone is dominated by scrub formation mostly decidous, and constitutes the most important summer grazing lands in the high mountain area. Below this the hillsides and valleys are dry without any vegetation at all, except some places with scattered grass and scrubs.

Further south as in Tangir or places where there is more precipitation, forests and scrub vegetation exsist down to about 1800 m.a.sl.

Irrigation is an absolute necessity for people living in these areas. The irrigated fields with green trees and crops make a striking contrast to the dry surroundings without any vegetation at all. Among the planted trees are poplar and willow most common. These areas are in addition utilized for growing fruit including apples, apricots, plums, pears, grapes, peaches and cherries. Beside this potatoes and maize are cultivated.

### 3.3.8 Animal life

The wildlife associated with the high mountain zones includes: Snow pigeon, Himalayan snowcock, Alpine cough, Royles high mountain vole, longtailed marmot, Himalayan ibex, snow lepoard. In the alpine zones and further down to approx. 1800 m.a.sl the wildlife includes: Hodgson's mountain finch, common corefinch, redmantled rosefinch, white capped bunting, black throated jay, magpie, white winged grosbeak, chukor, snow pigeon, western tragopan, monal pheasant, stone marten, large eared pika, Royles pika, Chinese birch mouse, musk dear, Himalayan brown bear, black bear, leopard, lynx, woolf, markhor, Persian wild goat and ibex.

The most common domestic animals are: Goats, sheep, cows, a cross between cow and yak, horses, donkeys, ducks and fowl.

In the rivers the carp are natural. However, in some rivers and streams there are trout introduced by man.

### 3.3.9 National parks and reserves

During the sixties and seventies 7 national parks, 72 wildlife sanctuaries and 76 game reserves were designated in Pakistan. In the Northern Area there are a few large sanctuaries to protect and preserve rare mammals such as: Black bear, brown bear, lynx, snow leopard, wolf and different biotopes of birds (Table 3).

Table 3: Wildlife sanctuaries in the Northern Area: Mammals (M) and birds (B) (from WAPDA):

| NAME AND TYPE | AREA $km^2$ | DISTRICT |
|---|---|---|
| Astore (M) | 414,4 | Diamar |
| Baltistan (M) | 414,4 | Baltistan |
| Kargah (M) | 442,9 | Gilgit |
| Nalter (M) | 272,0 | Gilgit |
| Daynor-Nollah (B) | 442,9 | Gilgit |
| Kilik-Minteka (B) | 650,1 | Gilgit |
| Nor-Nollah (B) | 72,5 | Baltistan |
| Nazbar-Nollah (B) | 334,1 | Ghizar |
| Pahora (B) | 75,1 | Ghizar |
| Satpara (B) | 310,9 | Baltistan |
| Sherkillah (B) | 168,4 | Ghizar |
| Tangier (B) | 142,5 | Diamar |
| Ghassi-Bowasdar (B) | 370,4 | Ghizar |

In addition to the wildlife sanctuaries shown in table 3, there are several game reserves and one national park named Kunjerab.

The wood resources have to bear the pressure of the people's need for heating and to some extent building materials. The forests are a limited reserve which in several places have been totally destroyed or decimated to a critical level. In some places the forests are to some extent protected.

## 4. HYDROLOGICAL BACKGROUND

In the Northern Area there are 5 hydro-meteorological stations, situated as follows: Kanin Abad (Hunza river), Dainyor (Gilgit river), Yugo (Shyok river, Skardu), Kachura (Indus river, west of Skardu) and Doylan (Indus river, south of Astore river). In addition there is one station in Naltar-Nallah and one at Nomal. Except for the station in Naltar-Nullah all regular registrations are done in the major rivers.

It is important to point out that the estimates of low flow, maximum flow, average flow etc. in the minor streams, seem to be uncertain. One method in use is to measure the cross section and the gradient of the stream and by hydraulic formulas calculate the different flows. On the locations no scales showing the water level were to be seen. No curves or figures concerning the projects were available to the mission. In some cases the information about flow conditions differed from person to person. The mission's general impression was that especially some figures of low flow seemed to be too high.

The hydrological data on low flow conditions are extremely important in this area. In spring when the minimum flow occurs the need for enough irrigation water is critical because the planting season starts. In addition, there is always a need for water for domestic use. On the technical side, the choice of optimal size and type of turbines depends upon the minimum flow and variations in discharge.

There seems to be a lack of reliable hydrological data in connection with the small scale hydro power projects in the region. It might be possible to collect some hydrological information about small streams from existing small hydro-power stations. However, it is the mission's conclusion that in order to avoid future conflicts between irrigation, domestic use and hydro-power production, the hydrological foundation must be improved.

## 5. SEDIMENTOLOGICAL BACKGROUND

### 5.1 General

High sediment yield of the rivers and streams in the Northern Area are due to the lack of vegetation cover, steep gradient, easily erodible soils and rocks and active sediment producing processes. There are considerable amounts of sediments transported each year (fig 2). In connection with hydro-electric power plants the knowledge of the amount, particle size and mineralogy of sediments are vital. Generally, the bedload affects the reservoir capacity and the suspended load the turbines.

## 5.2 Quantities and effects of the sediment yield

The Tarbella dam in Indus, finished in 1974, is a good example of the amount and consequences of sediment transport in a reservoir. Building of the world's largest earthfilling dam created the artificial Tarbella lake. In 1975 the lake was 60 miles (110 km) long. Today (1988) the delta front is about 10 miles (17 km) from the dam (fig 3). There is a considerable amount of sediment accumulated in the lake every year (table 4). The reduction in storage capacity is considerable (fig 4) and the reservoir will not last for too many decades to come.

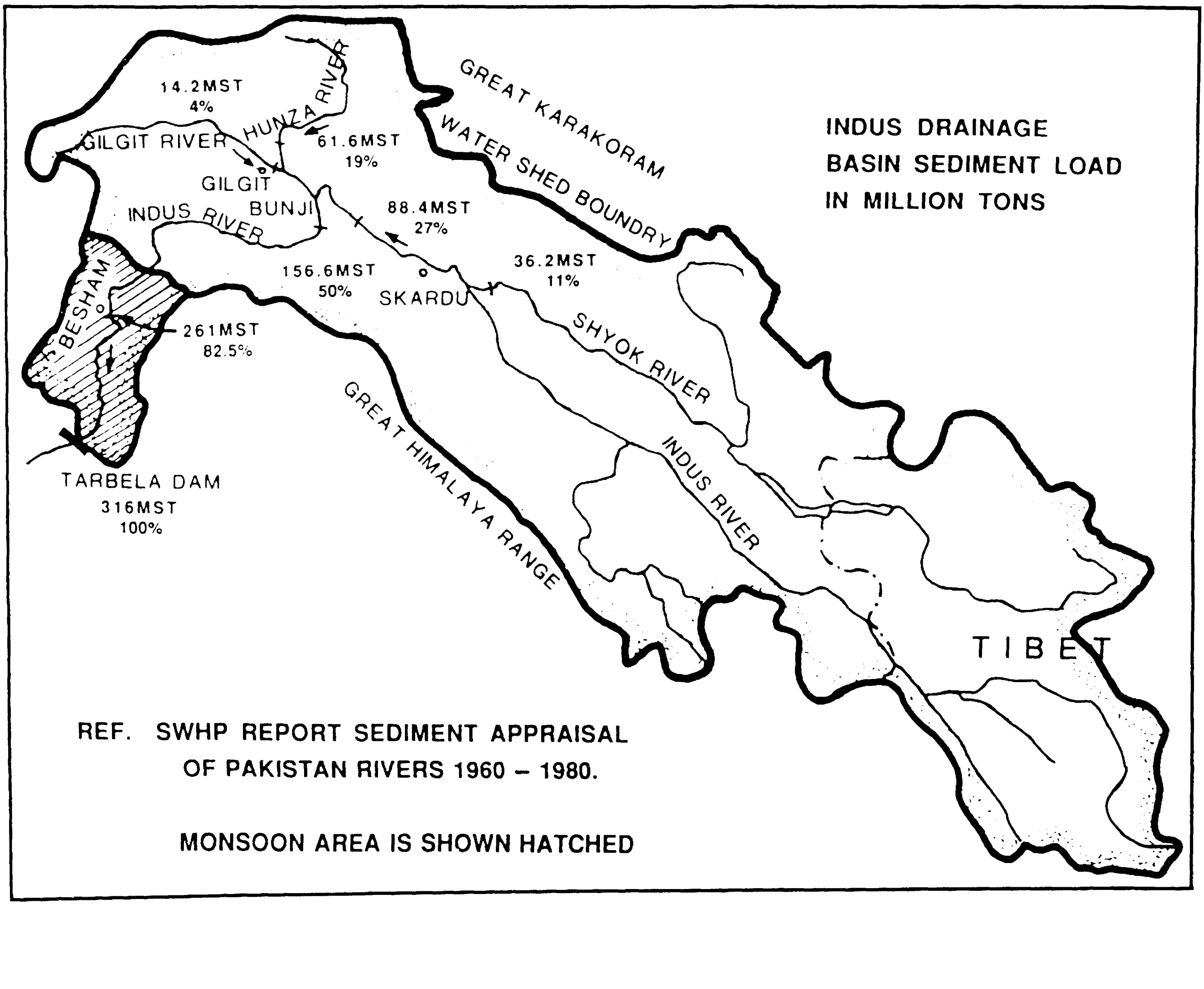



Fig 2: Sediment budget of the Northern Area and the effect on the sediment supply to the Tarbella Dam (from WAPDA, 1987)

Table 4: Annual discharge and accumulated sediments in Tarbella Dam 1975-86.

| YEAR | ANNUAL DISCHARGE $10^6$ acre feet | ANNUAL ACCUMULATION $10^6$ short tons |
|---|---|---|
| 1975 | 57.34 | 177 |
| 1976 | 55.02 | 167 |
| 1977 | 57.80 | 207 |
| 1978 | 69.10 | 324 |
| 1979 | 55.40 | 208 |
| 1980 | 56.20 | 178 |
| 1981 | 56.80 | 203 |
| 1982 | 48.50 | 146 |
| 1983 | 60.30 | 202 |
| 1984 | 62.20 | 305 |
| 1985 | 52.47 | 242 |
| 1986 | 59.55 | 239 |
| Yearly average 1975-86 | 56.73 | 216 |

(From WAPDA, 1987)

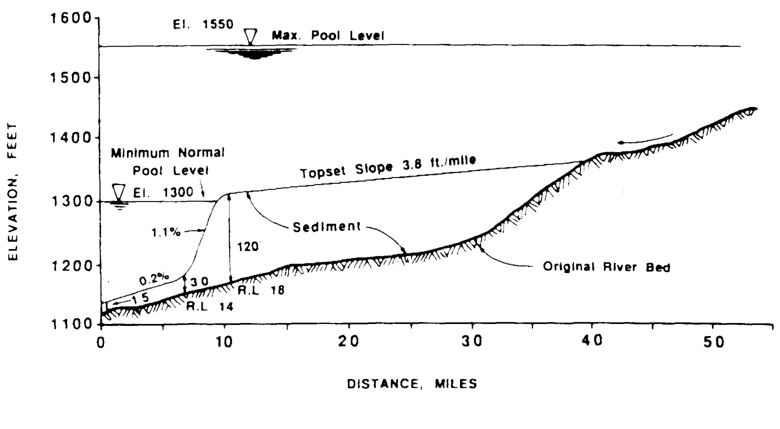



Fig 3 Sketch of the delta accumulation (1975-87) in Tarbella Dam. (From WAPDA, 1987).

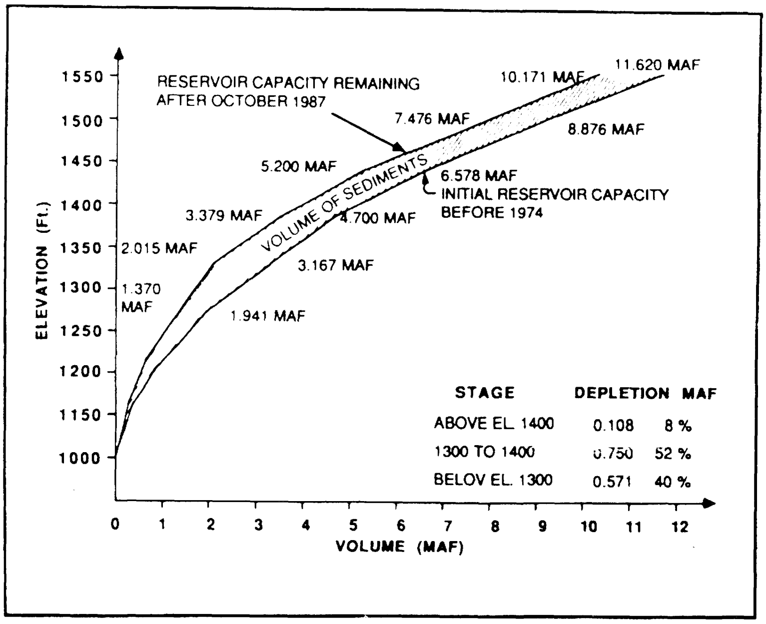



Fig 4 Reservoir sedimentation and loss of storage capacity in Tarbella Dam (1975-87). Figures for remaining capacity up to October 1987 have been taken from hydrographic surveys (from WAPDA, 1987).

Beside the reservoir problems the bedload affects the stability of river beds and thereby the thalweg. Accumulation of coarse sand, gravel and stones in intake channels is another problem concerning the utilization of water from such rivers or streams. This can be solved or minimized by constructing optimal intakes and sediment chambers.

## 5.3 Effects of suspended load

The finer particles such as sand, silt and clay are easily carried in the flow and constitute the suspended sediments. Even if the particles are small, the suspended load usually dominates the bedload. Because of the low settling velocity the particles are easily transported and difficult to remove. These particles reduce the water quality and might have considerable abration effect on rocks and turbines. It is known that coarser particles such as sand abrate more than the fine ones and hard minerals such as quartz more than softer minerals such as mica. In Hasanabad the turbines were worn out in a few months due to abration. There have been problems with worn out turbines in Tangir too.

Considering the erosional potential and the heavy sediment load in the area, the knowledge of the sediment characteristics must not be neglected.

Investigations in Norwegian power plants have shown that turbine wear is dependent on the characteristics of the particles and the velocity of water as it hits the turbine blades. The turbine abration factor (S) is given by the relation between the speed of water as it hits the turbines blades (v), amount of sediments (Gs), the shape of the particles (r), content of quartz (q) and sandparticles (d):

$S = v^3 10^{-4} G_s rqd$ (Bogen 1987).

The equipment used for monitoring the suspended load are either depth integrating or point integrating. A type of sampler in use is a P-63 sampler. The measurements are located in the same spots as the discharge registration. Commonly, measurements are taken once or twice a month. Due to local conditions such as broad rivers and often 10-15 m rise and fall in waterlevel during the year, there might be some practical problems connected with the implementation of an every day monitoring program. However, experiences from studies of the dynamics of the sediment transport processes in Norway have shown the importance of frequent measurements.

In the minor streams there were no monitoring programs. Even if most of the hydropower plants are low head projects, the influence of sediments on the equipment must be taken into consideration. The mission has made some analyses of flow-sediment samples collected in connection with the site visits. The results are given in App. 1.

Of special interest are the results concerning Hassanabad where there are problems with worn out turbin blades. In this sample there was more than 60% quartz and the minerals had extremely sharp edges. The characteristics of the sediments indicate a high abration factor, and therefore a risk to the turbines. The separation of sediments from operation water has to be considered in connection with further improvement of this plant.

## 5.4 Conclusions

There seems to be a lack of data concerning characteristica and amount of sediments in connection with hydropower plants in the Northern Area. The importance of such data in planning and evaluation of the long-term efficiency of the turbines must not be underestimated.

In connection with a monitoring program, instrumentation, analysis, calculations and evaluation of the data, there seems to be a need of transfer of both technology and knowledge.

Concerning projects including construction of weir and dams, the measurement and calculation of bedload transport are essential. The mission was told that the bedload was estimated to be approx. 8-10% of the suspended load. Compared with results from Norway, this amount seems too small. Examinations based on measurements in different Norwegian rivers, show that the bedload varies from 20-50% of the suspended load. The highest amount is measured in glacier-fed streams. An evaluation of the bedload seems therefore essential, especially in connection with the planning of middle sized hydropower plants in the main rivers.

# 6 DESCRIPTION OF SOME EXISTING HYDEL STATIONS

## 6.1 Kargah watercourse

The existing SHP at Kargah is the only hydro electric power plant which serves the capital of the area, Gilgit.

Data on existing power plants:

| Name of station | head m | discharge M/s | installed units number | output(KW) | commissioned year |
|---|---|---|---|---|---|
| Kargah phase 1 | 37 | 1,47 | 2 Francis | 320 | 1965 |
| Kargah phase 2A | 61 | 0,57 | 2 Cross Flow | 180 | |
| Kargah phase 2B | 61 | 0,76 | 2 Cross Flow | 324 | 1978 |
| Kargah phase 3 | 43 | 1,20 | 3 Francis | 300 | 1980 |
| Kargah phase 4 | 43 | 1,20 | 3 Francis | 300 | 1980 |
| Kargah phase 5 | 43 | 0,79 | 2 Francis | 200 | 1984 |

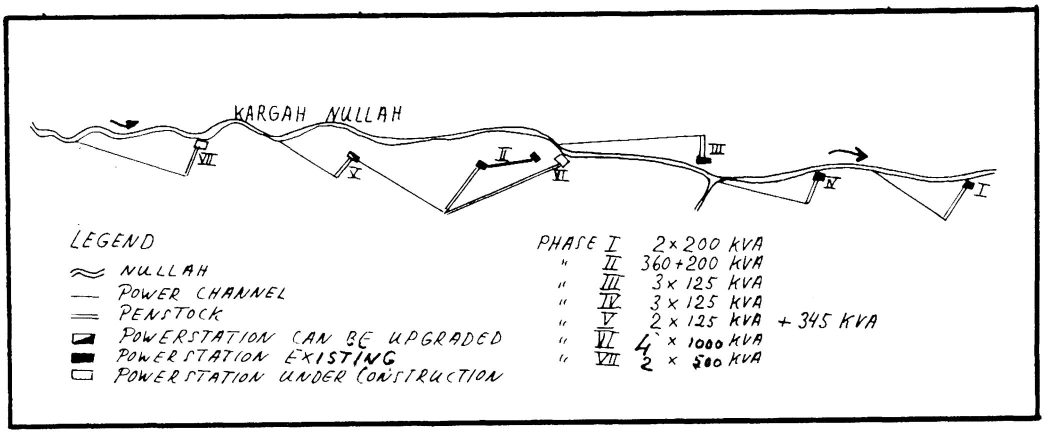
Firm power from these power plants varies from 50% to 70% depending on the efficiency and available water during low flow season. Hence the available power production during winter time from Kargah watercourse today is 1,12 MW.

Information on new schemes in Kargah:

The turbines in phase 1 and 2 (AB) will be replaced by Chinese turbines. Phase 3 and 4 will be replaced by a new scheme presently under construction, with the installation of four units of 1 MW each. Bywater (GB) will deliver the turbines. The discharge will be approximately 1,6 M/s. The old power plants will be runned during the high flow season.

This new powerplant (named phase 6) will use the same intake as Kargah phase 5. The headrace channel for ph.5 will be enlarged to cater for the necessary water. Because ph.5 has less capacity than ph.6 there is planned a bypass tapping construction. Our suggestion is that the water already in the channel should be utilized by constructing a new pipeline, and by replacing one of the old units by a new and larger one. Both units in ph.5 should be replaced by units with improved technology and metallurgy in order to get maximum efficiency. The upgrading of ph.5 with one unit of approximately 440 KW, refurbishing of one old unit and the construction of a new pipeline, will cost approximately 5 million NOK. The total new output of ph.5 will be approximately 550 KW. The cost each KW is approximately 9000 NOK, which is feasible (App.7, fig 5,6).

Upstream the intake of phase 5 power plant there is a new scheme under construction with maximum output of 1 MW.
The two power plants under construction will be commissioned in 1989. The situation for the power generating in Kargah water-course will be as shown in the sketch within 1989.




More power plants upstream in the catchment area can be constructed. According to our informants, there is a lake which could be regulated to give more firm power during low flow season. There is, however, no access roads and there is a wildlife sanctuary for mammals in this area. The existing plants and the suggested modifications will not lead to any further environmental conflicts.

## 6.2 HASSANABAD phase 1 and 2 hydel stations

### 6.2.1 General

Hassanabad Phases 1 and 2 provide the only source of electrical supply for the west bank of the Hunza valley, i.e. the former kingdom of Hunza. The land is intensively terraced and irrigated, and a variety of food grains, vegetables, fruit trees and other crops are cultivated, as well as extensive poplar plantations along the irrigation channels for roofbeam materials. The population is Ismali and Burushaski-speaking, with a unique culture and great discipline and thrift. Various minor industries, and tourist developments are already under way, but depend on the rehabilitation of electrical supplies for their continuation.

The hydro power plants are constructed in a nullah where analysis of flow sediments carried out by the team shows that the possibility of turbine wear is great. When planning sedimentation chambers the accumulation of these particles must be considered. The chambers and the channel have to be constructed with this in mind. Key-words are slow stream velocity, optimal shape of the sedimentation chamber, knowledge of size and amount of actual particles and their sedimentation rate.

### 6.2.2 Hassanabad ph.1

This power plant has not been operated for 1 1/2 years, due to a destroyed headrace channel, caused by the construction of an irrigation channel above in the hillside. This construction is now completed and the refurbishing work on the power channel has started. There is a plan for the upgrading of the powerplant by making the channel wider and longer. The existing Francis turbines from Drees Co (Germany) have runned in 22 years and should be investigated for refurbishing to be used in other schemes.

### 6.2.3 Hassanabad ph.2

This is a new scheme commissioned in 1986 with two crossflow turbines manufactured in Japan. The power plant was out of order because the silty water in combination with high runner speed had destroyed the runners. New runners installed five months ago were also destroyed (Appendix 7, fig 7,8,9).

Since both power plants were out of operation, the village of Hunza had no electricity, and there was no fast solution to the problem. What first should be done is to get the old plant in operation. The crossflow turbines chosen might be wrong due to head and discharge. If new turbines must be installed, the planning, ordering, manufacturing and mounting will take 10-12 months. In the meantime Hunza will have no electricity available unless a diesel unit is installed. This unit should cover the most critical demand until Hassanabad ph.1 and 2 is in operation. In future this unit can be used for peak power production or cover the electric demand concerning the implementation of other schemes mentioned in this report.

Data for existing and proposed power plants at Hassanabad:

| Name of plant | head | discharge | turbine | | commissioned |
|---|---|---|---|---|---|
| | m | M/s | units | output KW | year |
| Hassanabad ph.1 | 52 | 0,50 | 1 Francis | 160 | 1965 |
| Proposed scheme | 67 | 0,85 | ? | 450 | ? |
| Hassanabad ph.2 | 114 | 0,57 | 2 Cross Flow | 400 | 1986 |

## 6.3 SKARDU hydel stations and SADPARA Lake

### 6.3.1 Sadpara Lake

The lake supplies Skardu with irrigation water an water for domestic use. The lake is regulated 1,8m to day. There exist plans to regulate the lake 15 m by a new earthfill damconstruction and a tap tunnel.

Steep talus and fans characterize two of the sides of the lake, and the inlet river has accumulated a large delta. In this connection it is important to point out at least two possible important geophysical effects of the regulation to come:

**Unstable side materials**

**Slides in the delta.**

The lowering of water may cause changes in the pore pressure leading to instability and slides. Regulation of the water level up and down will result in wave erosion causing undercut in the slopes and slides. The erosional processes will continue until a new equilibrium is established or an armouring layer is created.

By lowering the water level, the delta, which is built up of silty particles, will slide out due to instability caused by changes in the pore pressure. In addition, the stream on the delta platform will establish a new equilibrium related to lowered watertable. Deltas consist of alluvial sediments which are easily erodible. The result is a tremendous erosion continuing for several years. This effect is known from several places in Norway and is well documented. A side effect is all the silt and the clay particles which are brought in suspension. Because of the slow settling velocity, these particles will drift through the lake and enter the irrigation and the drinking water for several years.

Examination has shown that a regulation of more than 10 m has a strong negative effect on the biotopes in lakes. In Sadpara Lake it must be expected that the quantity of trout will be reduced.

### 6.3.2 Skardu phase 1 and 2

In SADPARA nullah there are two small hydro electric power plants named Skardu phase 1 and Skardu phase 2.(320 KW, 640 KW).
The Sadpara Lake secure firm power during low flow season. The

situation today is that there is available head between the lake and the intake for Skardu ph.2. In addition there is available head between Skardu ph.1 and 2 (approximately 15m).

The described increased regulation of the lake is justified by the need for water for irrigation and water supply during the low flow season. The regulation will make it feasible to utilize the head between the lake and the intake for Skardu ph.2. This scheme will give 4 MW additional power to Skardu. WAPDA is responsible for the planning of the multi purpose scheme which will be constructed in the near future.

Skardu ph.1 is running with approximately 60% efficiency, and the power plant needs refurbishing work (App. 7, fig. 11). After the regulation of Sadpara Lake, it is probably feasible to increase the head for Skardu ph.1 by constructing a new intake at the tailrace channel of Skardu ph.2, a new headrace channel and a new power station downstream the old existing power station. In any case, the old turbines should be refurbished. If the existing plant is upgraded, these turbines could be utilized in nearby schemes.

Data on existing and proposed power plants:

| Name | head | discharge | turbine | | | commissioned |
|---|---|---|---|---|---|---|
| | m | M/s | units | type | KW | year |
| Skardu ph.1 | 37 | 1.47 | 2 | Francis | 320 | 1972 |
| Upgraded | 76 | 2.0 | ? | ? | 1300 | ? |
| Skardu ph.2A | 60 | 1.0 | 2 | Cross Flow | 320 | 1981 |
| Skardu ph.2B | 60 | 1.0 | 2 | Cross Flow | 320 | 1988 |
| Skardu ph.3 | ? | ? | ? | ? | 4000 | ? |

## 6.4 Conclusion from the information on the existing SHP

There is energy to be gained by improved maintenance and operation and by refurbishing and upgrading the old power plants. Before new schemes are started, the work on improved utilizing of available water in existing power plants should be started. As earlier mentioned, very soon there will be more than 75 small hydro electric power plants in operation in the Northern Area, and many of them could be improved.

The team will strongly recommend that the following program is given first priority concerning the possible contribution from NORAD on power production in the Northern Area :

> To give examples on improved intake and el/mech solutions, refurbish and upgrade the following plants: Skardu phase 5, Hassanabad phase 1 and 2, Skardu phase 1. This means contribution from Norwegian industry in Norway.
>
> Establish a workshop near Gilgit as soon as possible with necessary facilities for proper maintenance on el/mech equipment. Among the employees there should be at least two trained in Norway. Preferably, they should be trained while the equipment for the above mentioned projects is under construction in the workshops in Norway. The Norwegian contribution should also include two years of training at the Gilgit workshop.

# 7 DESCRIPTION OF SITES ACCORDING TO TOR

## 7.1 Overview

In TOR for the October mission the following sites should be visited and evaluated for later studies:

| | | |
|---|---|---|
| TANGIR | 1 MW | Diamar District |
| NOMAL | 1 MW | Gilgit district |
| DARMADAR | 0.5MW | " |
| MEDIAHBAD | 1 MW | Baltistan District |
| GHOWANI | 2 MW | " |
| KACHURA | 1 MW | " |

From the Northern Area Public Works Department PC-1 documents are prepared for all schemes. A questionnaire from WAPDA gives information on sites, consumers, construction cost and feasibility of each scheme. These documents are available at WAPDA and at The Norwegian water Resources an Energy Administration.

## 7.2 TANGIR small hydro electric power scheme

### 7.2.1 Population, cultural position and socio-cultural effects

The Tangir Valley is an isolated valley about 25 Km from Karakoram Highway. A narrow, jeepable road gives access to the villages in the valley. A new road is under construction and will be completed in the near future. Tangir composes a culturally and socially distinct population of presently 24 000 persons. Until recently extremely isolated, little is known of the history of this community. Converted to Islam only some 8 generations ago by holy leaders from Swat, the population is Sunni, and has been constituted as a stateless society of free farmers, each household occupying a house with a fortified tower. Around 1900 AD, Pukhtun Wali, a refugee nobleman from Yasin, was able to set up a state in Tangir with himself as a ruler; but in 1917 the population successfully rebelled, killed Pukhtun Wali, and reconstituted itself as a stateless society. Contact during British

Indian and the first years after Pakistan's independence was minimal; but progressively Pakistan has established civil authority by non-violent means, and Tangir is now fully integrated in the state. Currently, considerable investments have been made in road and bridge construction, domestic water supply, irrigation, primary education, and other public institutions.

The area around the subdistrict (Tahsil) headquarters in Shumal has since 1982 been served by a 160 KW hydel plant which supplies limited domestic lighting to 730 houses. Appendix 7, fig 22. The proposed project will meet the demand from 2 000 consumers in different villages like Shumal, Juglot and Luruk. The settlement of Luruk is the largest with about 500 houses/4 000 persons. The population also looks forward to establish a small workshop for minor welding and automobile repairs, to serve the valley which is presently without any such facility.

Production in Tangir derives from agriculture, stockbreeding and forestry. Due to local circumstances planting does not start till the second week of March, whereas spring meltwater starts swelling the stream by the end of February. There is thus no anticipated conflict between a hydel plant utilizing the whole minimal flow of the stream, and irrigation interests. Tangir thus scores very high in terms of socio-economic and cultural criteria: the project supplies presently unelectrified settlements which fervently desire electricity; significant benefits will reach the whole population of woman and children as well as men; immediate effects in economic development can be expected in the form of electricity-powered auto-workshop and sawmill.

It can also be expected that when time comes the electricity will contribute to reduced use of firewood and deforestation. This use will also improve the standard of living by reduction of open fires in the houses, as soot and smoke from lights and open fires are a major source of inconvenience (Appendix 7, fig 15).

### 7.2.2 Energy and Power Production

To cover the electric demand, the electricity must be produced in the valley as a transmission line from a countrywide network is unthinkable in the foreseeable future.

As the gradient of the river gives possibilities for high head plants, it is possible to construct a 1.8 MW powerstation on the right hand side of the river. This plant should be a multi purpose scheme and the feeder channel should be constructed to cater for necessary irrigation water to irrigate new land at Luruk. On the left hand riverbank side, an even bigger plant can be constructed. Locally they have proposed to enlarge the existing irrigation channel to a small village. The construction on this side will give a road to this village. This solution should include the enlargement of the proposed channel on the left hand side for irrigation purposes (App. 7, fig 14).

There are great boulders in the river where the intake to both projects will be located. There is moraine/loose material in the penstock area and powerplant area on both sites. The plant on the right hand side, however, has a better channel site concerning the danger of landslides, and the construction of channels will be easier (Appendix 7, fig 13). The length of the channels will be approximately the same. Information on hydrology is scarce and the installation of an automatic gauging station should be given priority. There are reasonable good sites for measurement.
The necessary construction of transmission lines will be the same for both alternatives.

Data on the existing and the new scheme:

| Name | head | turbine discharge | channel length | output | trans-mission line 11KV | distribution line |
|---|---|---|---|---|---|---|
| | m | M/s | m | KW | km | km |
| TANGIR PH1 | 42 | 0.84 | 3416 | 160 | 19 | 34 (ext.) |
| TANGIR PH2A | 135 | 1.6 | ? | 1800 | ? | ? (plan) |
| TANGIR PH2B | 180 | 1.4 | ? | 2100 | ? | ? (plan) |

By using local experience on the construction of the channel and local workers and construction equipment, Norwegian el/mech equipment in the powerstation, locally made transformers and transmission lines, the worst case budget is estimated to 40 mill NOK. Cost each KW is approximately 19,000 NOK. Cost each KWh is approximately 2,5 NOK/KWh. The planning and construction period will be 2 to 3 years.

### 7.2.3 Environmental aspects

Planned as a multi purpose scheme the new hydel project can result in enough irrigation water to a large area of barren land (App. 7, fig 14). There are fishes such as trout and sia fish in the stream. Only the trout, which is introduced by man, is of interest for the inhabitants of the valley. The building of the powerplant will strongly reduce the discharge about 2 km of the nullah during low flow periods in wintertime. Along this stretch there are some deep pools where the fish can survive during this period.

The construction of the hydel plants on the left hand river bank requires a road to a nearby village. For access to the site a bridge has to cross the river close to two old pittoresque bridges in Tangir village. It is suggested that one of them are improved by using same layout and materials. Thus this bridge can be used as access to the new road for the hydel plant.

The evaluation of the environmental effects of the scheme in Tangir shows that there seems to be no serious conflicts between the projects and the environment. Implementation of the project may instead have positive effects on the forests and the cultivation of barren land. The latter will reduce erosion and increase the cultivated area, thus giving more food for people and livestock.

## 7.3 NOMAL hydro electric power scheme

### 7.3.1 Population, Cultural Position and Socio-cultural Effects

Nomal is a community on the west bank of Hunza river 35 km from Gilgit town. The population is about 4 500. The hydro electric plant to be located there is intended to supply presently unelectrified settlements, with an additional 4 500 inhabitants, on the east bank. The present 108 KW hydel plant in Nomal can supply only a minority of the houses in the community.

The community is mainly composed of settlers from Hunza and Gilgit valleys who have arrived over the last 30 years. It is thus about equal proportions Ismailis and Shiahs. Extensive terraces and irrigation channels have been constructed, and the suitable area is now intensively cultivated. The community nucleus contains a small bazar commercial area. In the higher part of the valley, outside the reach of electrification from the existing hydel plant, are also some Gujar settlements.

There is presently pressure on land in Nomal, and a reluctance on the part of established owners to sell land to recent settlers. The new hydel scheme has one alternative which will require the purchase of a small cultivated area as site for the powerhouse and penstock. There is also a potential conflict of interest between hydrogenerating use and irrigation use of water from the nullah in the low flow months of February and March, when sowing and irrigation have started but melting has not set in the Nomal nullah watershed. A division of these water resources must be such as to secure the irrigation interests. One alternative is to construct lift irrigation schemes to lift the necessary amount of water from the tailrace water level to the existing irrigation channels and operate them during low flow season (App. 7, fig 17).

Electricity production from Nomal can be developed to provide additional supply to Gilgit city. This is of great importance as Gilgit's supply is presently inadequate, and heavily based on a 3 MW diesel generating plant. Gilgit has a pressing need for enhanced supply, since it is a growing town and centre of administration, commerce and industry in the region. The workshop and maintenance facility suggested by the team (cf. 3.1.3.) to maintain and repair the 75 hydro electric installations which will be in operation in the Northern Area by the end of 1991, must therefore **not** be allowed to infringe on domestic and commercial supplies presently delivered to Gilgit. This can only be avoided by developing Nomal hydel scheme to a 2 MW capacity as part of the package proposed by the NORAD team.

### 7.3.2 Hydro Electric Power Production

The objective of the SHP projects is to provide electric energy for domestic consumption and illumination of 2000 houses, and power for small industries. About 10,000 people living in the villages Rahimabad, Jutal, Juglote and Chilmis Das will benefit from this project. A truckable road exist from Gilgit town to Nomal.

The estimated minimum flow in Nomal nullah is 1.8 M/s. An existing hydro electric powerplant of 108 KW is hardly sufficient to meet the power requirement of about 500 consumers. This plant utilizes a head of 33m and a flow of 522 l/s in Cross flow turbines.

The proposed scheme from NAPWD is located upstream the existing plant. This is planned to produce 1000 KW at a head of 90m and discharge of 1.6 M/s. Our visit resulted in the suggestion of utilizing the existing feeder channel to the old power plant for the new plant. The channel must be enlarged to cater for approximately 2 M/s. The existing intake and silting basin must be improved and there must be constructed a new forebay upstream the existing in the channel. A hundred meters upstream the existing forebay there are rapids in the channel of approximately 10 m head (App. 7, fig 1). A new underground pipeline can be constructed from the new forebay to the powerstation which can be located about 300 m downstream the existing plant. It is roughly estimated that the head can be 100 - 125 m, and with a discharge of 2M/s the output is estimated to 2000 KW (App. 7, fig 16, 17). The existing plant can be used during high flow season. An even better alternative is to disassemble it and rebuilt it on another site close to a village where no electricity is available.

In the Nomal nullah watercourse there has also been carried out studies on a medium scaled high head hydropower scheme. According to WAPDA this has not proved to be feasible. A high head scheme can also be in conflict with the environment in the catchment area.

Data on existing and planned power plants:

| Name | Head | Turbine discharge | Output | Transmissionline |
|---|---|---|---|---|
| NOMAL PH1 | 33m | 522 l/s (1 unit) | 108 KW | 11 KV (exist.) |
| NOMAL PH2A | 92m | 1530l/s (2 units) | 1000KW | 11 KV (planned) |
| NOMAL PH2B | 120m | 2000l/s (2 units) | 2000KW | 11/33 KV (plan) |

If a 2 MW powerstation is feasible at Nomal, 1 MW should be transferred to Gilgit to serve new industries as the proposed workshop for el/mech maintenance of hydro power plants in the Northern Area. The distance is 35 km and a 33 KV line is required. The scheme shall include all necessary transmission and distribution systems.

As worst case, the cost of NOMAL PH2B is estimated to be 45 mill NOK. This include local transmission line (11KV), distribution line and step down transformers. It also include the 33 KV line to Gilgit. It is assumed that local experience and workers will be used. The planning and construction time will be two to three years.The cost/KW is 22.500 NOK, and the cost/kWh is approximately 3 NOK.

### 7.3.3 Environmental Aspects

The new project will affect the Nomal nullah an additional 300m compared to the existing small hydro power plant. During the dry months, February and March, the flow in the stream will be very small. The valley is, however, narrow and there seems to be no vital environmental interests affected along the project part of the stream (App. 7, fig 16).

## 7.4 DARMADAR hydro electric power scheme

### 7.4.1 Population, Cultural Position - Socio-cultural Effects and Estimates of Demand.

The objective of the project is to provide electric energy for domestic consumption/illumination of 4 500 houses of 12 nearby villages like Sumal, Yengal, Hatoo, Damas, Ghakuch, Anwarabad, Silpi, Yeshi and Hayim. 18 000 people will benefit from this project.

The population is composed of Shina-speaking cultivators of Shiah and Ismaili persuasion, interspersed with some hamlets of tran-shumat Gujars. Agriculture is less intensive than in many other parts and settlements are scattered and indifferently terraced; natural vegetation is sparse and the numerous small stock are dependent on high mountain summer pastures.

The population in this stretch of valley is presently entirely without electricity, and in great need of this as well as other developments. The potential for growth in the area, however, seems limited. There is also a conflict of water use as between irrigation and power generation in the period February-April. There are, however, different alternatives to solve this problem.

### 7.4.2 Hydro Electric Power Alternatives

The site is located about 90 km from Gilgit in Ghizar valley. A jeepable road leads up to the site, and a new road along the valley bottom is under construction. The construction work sometimes blocks the existing road. The construction is scheduled to be completed within two to three years.

The project site lies across the Ghizar river on the north bank. For the proposed project it is necessary to construct a suspension bridge and an approach road to the intake structure. The proposed project of 500 KW will not cover the demand from 4 500 households. At least a 1 MW scheme should be proposed. The data for the 500 KW scheme was presented in 1985. The estimated minimum waterflow in the nullah is approximately 1 M/s. The steep gradient in the river makes it possible to construct a 1-2 MW scheme in the nullah close to the main river. Further up in the mountains it is a waterfall which could be developed for 2-4 MW. The development of this scheme will give access road to villages in the mountain area.

The following alternatives should be investigated:

**DARMADAR 1A:** Same site as the proposed project with longer channel and higher head to produce 1-2 MW. This solution requires the construction of a suspension bridge and an access road to the intake site.

**DARMADAR 1B:** This solution has intake in the nullah close to Darmadar village. An existing irrigation channel can be enlarged to cater for additional 1200 l/s. The powerstation can be constructed close to an existing suspension bridge crossing the main river some 2 KM downstream of the confluence of Ghizar river and the Darmadar nullah. This solution can give approximately 1MW and requires no construction of suspension bridge or access road. The cost for the construction of the suspension bridge is equivalent to the construction cost for an enlarged channel.

**DARMADAR 2** : The utilization of a waterfall further up in the nullah. This solution can give 2-4 MW and require the same infrastructure as DARMADAR 1A, but a longer access road has to be constructed.

Data on the different projects:

| NAME | HEAD | TURBINE DISCHARGE | CHANNEL LENGTH | OUTPUT | TRANS-MISSION L. | DISTRI-BUTION L. |
|---|---|---|---|---|---|---|
| | M | M/S | KM | MW | KM | KM |
| DARMADAR 1A | 150 | 1.2 | 2 | 1.5 | 40 | 55 |
| DARMADAR 1B | 100 | 1.2 | 2 | 1.0 | 40 | 55 |
| DARMADAR 2 | ? | 1.0 | ? | 3 | ? | ? |

The intake in the nullah is difficult with gravels and boulders (App. 7, fig 12). Hard rock in the riverbeds, however, can make a weir crossing the nullah feasible. A worst case construction cost between 30-40 mill NOk must be expected for 1 or 1,5 MW output. The cost/KW is approximately 30.000/KW, and the cost/kWh is approximately 4,5 NOK.

### 7.4.3 Environmental Aspects

The existing plans of construction of a hydro power plant in Darmadar seems not to affect or be in serious conflict with the environment. The possible alternative scheme in the mountain was not visited.

## 7.5 MEHDIABAD small hydro electric scheme

### 7.5.1 Population, Cultural Position, Socio-cultural Effects and Estimates of Demand

The village Mehdiabad is presently served by an existing hydro power plant of 108 KW. 3000 people are connected, however load shedding occur frequent due to increase in maximum power demand. The villages Tolti Brooq, Chatra, Katisho and Dapa, upstream Mehdiabad town in the nullah, have a total population of 5000. So far they have had no electricity facilities. The implementation of the proposed scheme will together with the existing plant give electricity to 8000 people. A regular power supply without load shedding may uplift socio-economic conditions of the people of the area.

The population is Shiah, and locally famed for their level of education, both in modern terms and in traditional fields of religious studies. Electricity is envisaged to replace watermills for grinding flour (App. 7, fig 23) and handsaws for producing planks for building materials, as well as for welding, workshops and other modern developments beyond its main uses for domestic consumption (App. 7, fig 22). There is here, as everywhere, a strong public interest in obtaining enhanced electric power. Winter cold is severe, and there is a great potential for use of electricity for spaceheating and waterheating in cold season. As in most areas, there is however a need to accommodate the simultaneous uses of water during late winter low flow to both irrigation and hydro electric generation.

### 7.5.2 The Hydro Electric Scheme

The construction site is located about 50 KM from Skardu town in Kharmong valley on the left bank of the Indus river. A truckable road goes up to 40 KM. The remaining distance, about 10 Km, is jeepable.

The intake site in the nullah consists of boulders. It is located upstream an existing watersupply and irrigation intake. Hence the watersupply intake must be moved to the Hydel channel intake where a weir will be constructed. Lift irrigation schemes must be constructed in the tailrace of the power station to deliver the necessary water for irrigation during late winter low flow. The channel will run through sites where landslides can occur, and the forebay must be constructed in a steep hillside. The pipe can be foundated on rock.

The minimum water flow in the nullah is said to be 1.1 M/s, hence the powerstation cannot run on maximum output during low flow periods. During low flow periods only 75 % of maximum output can be expected. In addition, this will be reduced in late winter when there is a need for irrigation.

Data on existing and planned schemes:

| NAME | HEAD<br>M | TURBINE DISCHARGE<br>M/S | OUTPUT<br>KW | CHANNEL LENGTH<br>KM | TRANSM-ISSION LINE KM | DISTRI-BUTION LINE KM |
|---|---|---|---|---|---|---|
| MEHDIABAD PH1 | ? | ? | 108 | ? | ? | ? |
| MEHDIABAD PH2 | 80 | 1.5 | 1000 | 1000 | 80 | 68 |

The worst case construction cost of Mahdiabad ph2 is roughly estimated to 30 mill NOK.
The cost/KW is approximately 30.000 NOK, and the cost/kWh is roughly 5 NOK.

### 7.5.3 Environmental Aspects

During low flow season, approximately 1km of the stream will dry up, because of hydro power production, watersupply and irrigation. Drying up a stretch of a river will to some extent affect the life in and around the stream. In this case, however, the landscape and the stream itself indicate that there are no serious conflicts in relation with the environment.

## 7.6 GHOWARI hydro electric power scheme

### 7.6.1 Population, Cultural Position, Socio-cultural Effects and Power demand

Ghowari is a strip of river bank settlement along the Shyok river 80 km from Skardu town (App. 7, fig 10). Socially and culturally similar to Mehdiabad, but perhaps with a somewhat lower level of education, initiative and community solidarity. Since the scheme is based on water from the main river by a long channel, there is no serious conflict of interests between irrigation and hydro electric uses. It is possible that the scheme can improve the irrigation of the area.

### 7.6.2 The Hydro Electric Scheme

The road to Ghowari from Skardu is jeepable, but will be improved and become truckable in the near future.
The Ghowari scheme has intake in Shyok river where the waterlevel varies 4-5m from low flow to high flow season. The proposed channel of 5 km will pass through villages and the forebay will be constructed in the hillside. The head will be approximately 36m. The rapids in Shyok river at the powerstation site should be included, thus the head will be approximately 44 m. Appendix 7, fig 10. The scheme is planned as a 2 MW scheme, but could easily be upgraded to 10 MW.

The intake structure will be expensive because retaining walls must be constructed to prevent flood water to damage the channel. The channel itself will also require land. Constructed as a 2 MW plant it will be an expensive scheme. A 10 MW plant would be more feasible because there is enough water in Shyok river. A 10 MW plant, however, has to deliver energy to Skardu. This means the construction of a 80 km long 33 KV transmission line.

### 7.6.3 Environmental Aspects

Dependent on the technical solutions at the intake in Shyok river, there might be a minor effect on natural life in the river. This will only occur if a weir across the stream is built, an alternative which is unlikely. These possible negative effects, however, can easily be compensated if they are taken care of in the planning. The construction of a channel along the banks of Shyok river will require land, but is expected to have no vital effects on the environment.

## 7.7 KACHURA hydro electric power scheme

The proposed project is located in Kachura village and is situated 32 km from Skardu town. The site of the powerhouse is 1 km from the existing jeep road. Two 1 MW generating sets are planned to be installed and the generated power will be transmitted to Skardu through a 33 KV 3 phase transmission line. Here the power will be distributed to Skardu town and nearby villages by existing 11 KV system. This project has already been included in the Northern Area's Annual Development Programme 1988/1989 and is planned to be constructed by NA PWD. The el/mech equipment in the power station has not yet been procured.

Data on the scheme:

Installed capacity two units of 1MW
Turbine discharge 1.6 M/s (each unit)
Working head 81m
Headrace channel length 750 m
Transmission line 33 KV 32 km
Estimated cost 12 mill NOK (NA PWD)

A rough worst case cost estimate (1988) including training etc. gives a construction cost of approximately 40 mill NOK. This proves that our cost estimate is high, and that a close co-operation between NA PWD and the Norwegian consultant is necessary on the other schemes. Especially NA PWD's experience on the construction of transmission lines, roads, powerhouse and channels is interesting. The Norwegian consultant can improve solutions on intake, channels, pipeline and equipment in the powerhouse.

## 7.8 Conclusions

Socio-cultural effects of electrification, rough technical/ economical and environmental evaluation of each scheme leads to the following priority :

TANGIR
NOMAL
DARMADAR
MEHDIABAD
GHOWARI

In the rural areas presently supplied, electric power for domestic use has had a marked welfare effect, benefiting woman and children equally with men in their daily lives. It is also a stimulus to the development of cottage industries and small enterprises. There is no doubt that extension to further areas would be beneficial.

The implementation of Tangir and Nomal SHP will give the best spin off effects thinking of electrification for the benefit of poor people, multipurpose aspects and future maintenance of all hydel plants in operation in Northern Area.
These two plants should also be given priority due to investment cost and construction time schedule. From an environmental point of view, Tangir and Nomal seems to be the best projects. According to NORAD's checklist for initial screening projects, Chapter 6, hydro power projects, the answer is **negative** to all the questions for the five evaluated projects. None of the projects seem to implicate serious environmental effects in their surroundings. Tangir may lead to the most positive side effect by development of barren land and a possible reduction in the pressure on the forest reserves. There is no other electric production alternatives to hydro power than diesel powered units.

# 8 PRESENT POWER DEMAND AND POWER PRODUCTION - THE NEED FOR MEDIUM SCALED POWERPLANTS

## 8.1 GENERAL

Present power demand at Gilgit city is 10 MW and connected load is 6 MW. The total hydel power generated is 1.12 MW. During peak load time, small diesel generators located at different places of Gilgit town are also run. The total output of such generators is 0.5 MW. A new diesel generating station of 3 MW is constructed by WAPDA. Of the six generators installed in this power station only three are running during peak load time. The output available from this power station is 1.2 MW.

**To cover the connected load of 6 MW during peak load times only 2.82 MW is available for the moment.**

Of the totally available power, 1.7 MW is produced from diesel generator units, which is very costly. One unit of energy generated through diesel generators costs more or less 1.1 NOK and the revenue per unit is 0.1 NOK only. It is therefore not advisable to operate the diesel generators for long time periods.

The only hydro electric power of Gilgit is produced from KARGAH watercourse. In 1989 another two SHP plants will be commissioned producing a total of 5 MW.

These new schemes will not cover the present demand of Gilgit city. There are plans for more shops, workshops (welding, car repair), street lightning, electric heating to reduce the need for firewood, electric facilities in domestic use as refrigerators, television etc. Thus the power demand in the near future is much higher than what can be covered by the implementation of small hydel plants. A stronger utilization of the nullahs for hydro electric generating can some places be in conflict with wildlife or other environmental conservation plans. It is therefore natural that NA PWD and WAPDA are looking for a chance to construct medium scaled hydro power plants in order to meet the power demand of the area.

A survey of the domestic, commercial and industrial demand in the Northern Area indicates a total requirement of about 78 MW electric power. At present 8.5 MW electricity is generated by the existing 40 small/mini hydel stations. 35 small hydel projects are under construction. These will generate an additional power of about 22MW by 1991. Hence, to meet the power demand, it is our opinion that the construction of only small hydel schemes will be insufficient.

There are limitations concerning the use of power in the whole area, and there are several suitable sites for power plants with output 10-20 MW. The capital of the area, Gilgit city, should have first priority when it comes to the construction of a 10-20 MW plant.

## 8.2 Hydro Electric Power Schemes in GILGIT River.

### 8.2.1 The Hanzal Medium Scaled Hydro Electric Power Scheme.

Hanzal is located 15 km upstream Gilgit on Gilgit river. A shingle truckable road leads to the site.

A feasibility study has been carried out by WAPDA. The result is presented in GILGIT HYDRO POWER STATION, PUBLICATION NO 260 dated January 1982. The conclusion is that the scheme is not feasible. It was planned with a large intake dam where the damsite consists of loose moraine, and landslide on the left riverbank could occur (App. 7, fig 21). A 3 km channel would lead the water to a power-plant on the surface. Output during wintertime was estimated to 6MW, and 18 MW during summertime.

Local interests have thought of a less sophisticated project with only a small weir crossing the river. This project could give 6-10 MW output.

The head for both projects is 25-35m and the minimum flow in Gilgit river is 32 M/s. Hence the channel has to cater for at least 40 M/s, which means a cross section of approximately 50 square meter.

The implementation of the scheme will dry up the river over a distance of approximately 3,5 km during low flow periods in wintertime. A medium scale scheme like this will cause less damage than the combined effects of several small scale hydro electric power schemes. The implementation of Hanzal scheme will be an opportunity to transfer knowledge on effects which require interdisciplinary work connected to middle sized run of the river low head hydro power plants. Actual subjects are effects on biological life in rivers, sedimentation, wave erosion and effects on the surroundings when new land is submerged.

### 8.2.2 Alternative Sites in GILGIT River.

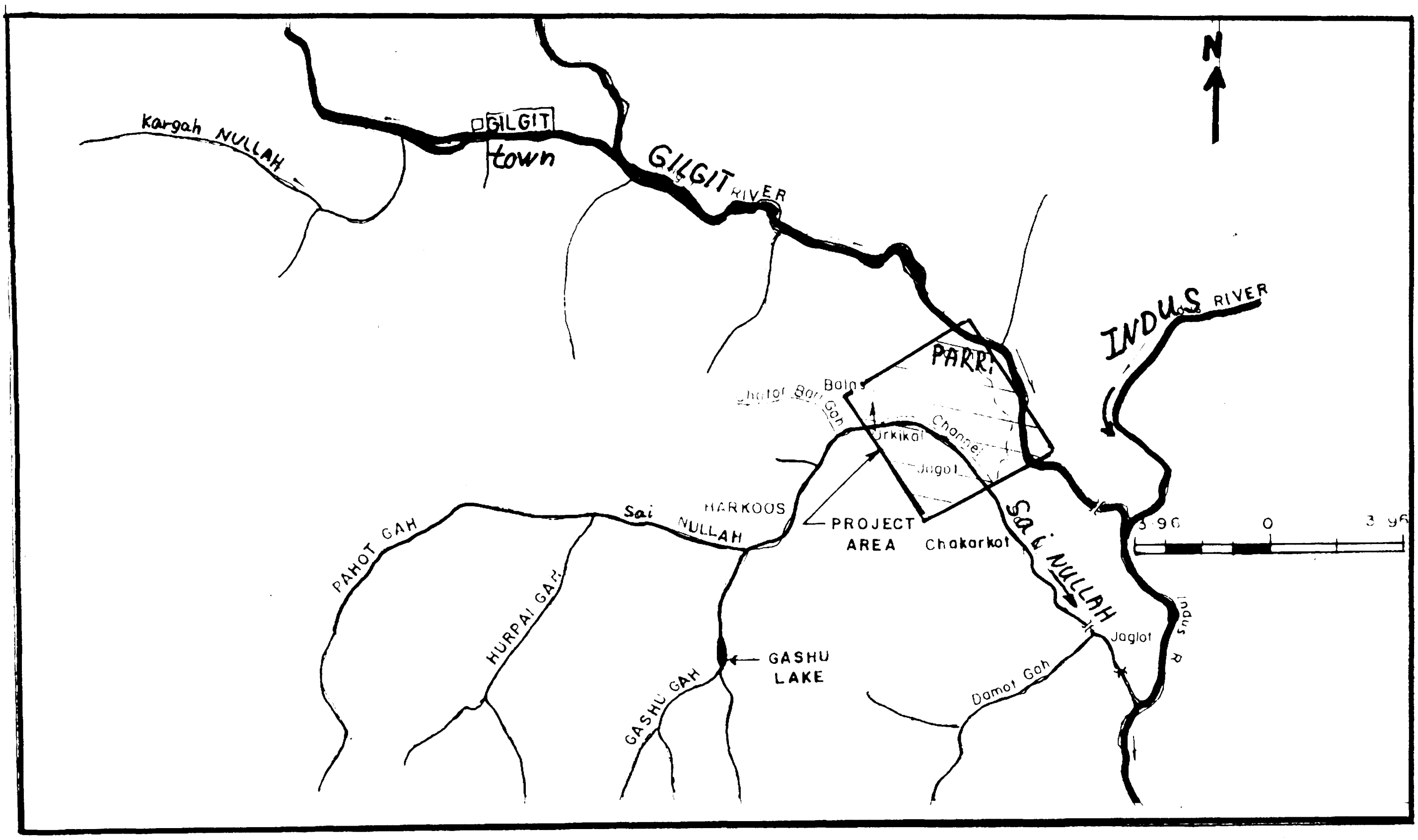
There are other more promising sites upstream Hanzal and downstream Gakuch in Gilgit river. App. 7, fig 20 shows an interesting site. Since there is solid rock on both riverbanks, it is technically feasible to construct a small concrete dam. A hydro power plant should utilize the head in the river oxbow by a headrace tunnel and a tailrace channel.
The same comments on environment is given to this site as to the Hanzal site.

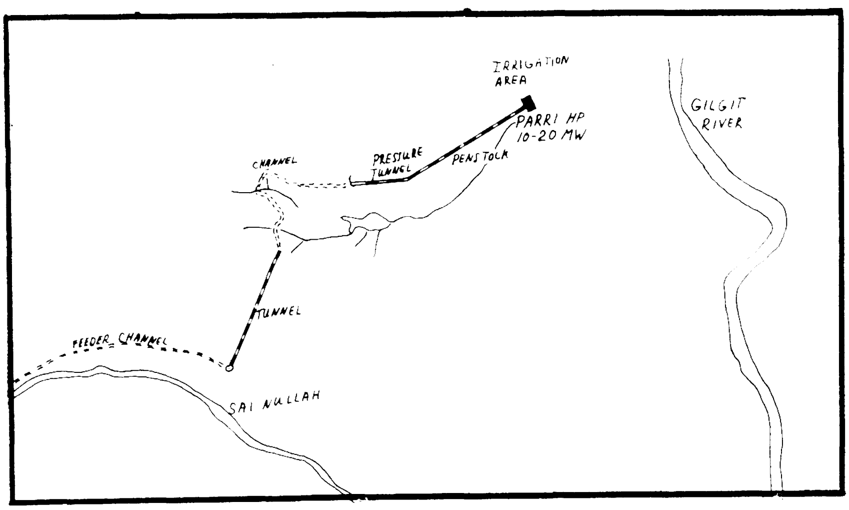
## 8.3 The PARRI Multi Purpose Scheme.

As shown on the sketch, the Parri scheme utilizes the water from Sai Nullah to Gilgit river. The aim of the project is to carry irrigation water to 20 000 acres of land to be cultivated and to produce power for electrification of Gilgit valley.

Parri forms a large, high terrace by the Indus and was the site of the first overnight stage for the old Kashmir-bound caravans out of Gilgit. Originally devoid of water, it was in 1937 provided with a long channel from Sai nullah for drinking water, in 1956 expanded for partial irrigation of the land. The settlement is small and mixed, including also Khirgiz refugees from Sinkiang. There are still large land areas (20 000 acres) of dry land, and equally large level areas of dry land across the Indus

(App. 7, fig 19). Water from a medium scaled hydro power plant placed high up on this terrace could be reused for irrigation; otherwise there might be a conflict of interests between irrigation and hydro electric use in the months of low flow of the Sai nullah water source during February-April.




The scheme consists of an intake structure in Sai nullah, a 1 km long diversion tunnel to a possible site for a reservoir, and a pressure pipe from this site to the top of the irrigation area (about 250m above Gilgit river).

As the estimated minimum flow in Sai nullah is 1.9 M/s and the head is 500 - 700 m depending on the alternatives, the firm power without a reservoir will be approximately 7MW. Because the tunnel can cater for a large amount of water, it is possible to produce 18 MW during the high flow season. The water which is not needed for irrigation can be utilized in a second power station situated at the bank of Gilgit river, giving another 4 MW. This scheme includes an intake in the tailrace channel from Parri 1 and the construction of a pipeline to utilize the head of approximately 250m to Gilgit river.

This second scheme can give power for lift irrigation schemes to irrigate large areas of dry land across the Indus river using water from Gilgit river (App. 7, fig.19).

The scheme will dry up the Sai nullah for a long distance (App. 7, fig 18), and it seems to have many elements known from Norwegian hydro power developments. Examination of the environmental effects of this project has to be interdisciplinary and seems to give a good opportunity for training and transfer of knowledge.

A feasibility study has been carried out by WAPDA on the Parri scheme. China and Canada have been interested in the scheme which will cost approximately 300 mill NOK. Norwegian knowhow is considerable in this type of scheme. We therefore suggest that a Norwegian consultant should carry out a review of the existing plans.

## 8.4 Conclusions

A continuous development of small scaled hydro power schemes to meet the future demand of electricity in more populated areas like the town of Gilgit (approx. 60 000 inh.) may lead to more severe environmental effects. The low flow during winter and early spring limits hydroelectric output. The number of perennial streams in the Gilgit area are few. This means that several small schemes have to be constructed in each of them and the pressure on each perennial stream system will increase. Sooner or later these developments may threaten the wildlife and bird biotopes in more fertile zones of the mountains.

To meet the power demand in populated areas like Gilgit, the development of medium scaled power plants (10-20 MW) appears therefore to be a better solution than the building of the required number of small plants.

Hanzal and Parri projects are examples of medium scaled schemes in the Gilgit area. Hanzal is a low head project in the Gilgit river, while Parri is a high head multipurpose project in a tributary to the Gilgit river. The environmental effects of these schemes are unknown and the conflicts may be greater than for each of the small ones considered separately. There is, however, within WAPDA a wish for transfer of both knowledge and training in the environmental field. These projects will provide such an opportunity.

## 9 VISIT TO PAKISTAN ENGINEERING COMPANY (PECO) 22-10-88

PECO is a state enterprise situated in Lahore. They are producing steel pole structures for transmission lines from 11 KV up to 500 KV. Most of the steel pipes for Small Hydro Power stations is produced by PECO. They are producing all kinds of pumps and electric motors. They also have some experience in producing turbines, especially Francis turbines. Ten years ago they co-operated with DREES company in W. Germany in a large programme which was called "the one hundred small hydro project". 50% of the turbines were produced by PECO. All the turbines were small with a maximum head of 45m.

PECO can carry out any kind of welding work, and has produced flywheel, draftubes, dam gates etc.

At PECO-KOTLAKHABAT WORKS (producing gates, transmission poles) the manager of structure division is Mr.Syed Sohail Hasnat.

At PECO-BADAMI WORKS (turbines, pumps, motors etc.) the General Manager is Mr. Abdul Wahid Rana. Phones off: 286236, telex:44750 PECO Pk.

# SMALL HYDRO POWER MISSION TO PAKISTAN

*TERMS OF REFERENCE*

## BACKGROUND

In March 1988 NORAD sent a delegation to Pakistan to evaluate possible Norwegian participation in rural electrification development in Pakistan. One of the conclusions is that Norway should assist Pakistan in the planning and development of small hydro power (SHP) plants in the Northern Region, Gilgit, Diamar and Baltistan districts.

Based on the recommandations in the draft mission report from April '88, and comments made by NORAD's Board of Directors has been decided to define the project further by sending another mission to Pakistan. Together with representatives from WAPDA the mission's aim is to improve NORAD's background for decisionmaking and to prepare TOR and bid documents for consultency services for the implementation of two or three of the six Pakistan identified SHP-projects.

## SCOPE OF WORK

The visit will be organised and headed by the Norwegian Resident Representative to Pakistan, Mr. Per Skogstad. The other mission members will be:

Mr. Torodd Jensen, Hydro Power Engineer
Mr. Fredrik Barth, Professor Social Anthropolgy
Mr. Sverre Husebye, M.Sc. Physical Geography

The mission shall be carried out in full understanding and participation from WAPDA or any other representative assigned by the Pakistan authorities.

The mission shall during the stay in Pakistan deal with the following:

- Meetings with WAPDA in order to discuss and evaluate the PC-II documents on the six SHP-projects in question.
- Together with representatives from WAPDA undertake a site visit to the six SHP-projects in NA and discuss logistics etc. with NAPWD.
- Socio-culturel and environmental aspects together with a technical/economic evaluation shall be the main issues for the project selection.
- Based on the given information, discussions and site visits try to reduce the number of SHP-projects which should be included in the TOR for later Norwegian consultancy services.
- Together with WAPDA work out and agree upon TOR and costs for the feasibility study as well as mode of implementation for the selected projects. The TOR should take care of the need for transfer of technology during the planning and the construction period.

- The mission shall seek clarification on the organizational aspects in Pakistan of the Norwegian assistance, both in respect of support to the national programme of electrical grid extension and to the SHP-projects.

The TOR for the implementation of the SHP-projects and a written report from the mission, shall be presented in English language not later than November 5th 1988.

APPENDIX 2

6 PAGES

List of meetings:

| date | time | meeting with / visits to |
|---|---|---|
| 11/10 | 0930-1030 | WAPDA General Manager Hydel<br>MR.SAEED AKHTAR NIAZI |
| 11/10 | 1330-1530 | WAPDA<br>Chief Eng.Hydel, Mr.MUHAMMAD ZAKRIA<br>Deputy Director,Hydel,<br>Mr.SHAHID HUSSAIN |
| 12/10 | 0800-1230 | WAPDA. Mr.S.HUSSAIN<br>Miss.BUSHRA PARVEEN<br>Research officer (environment)<br>Hydro Electric Projects |

These first meetings in Lahore were general meetings were the purpose of our mission was explained. WAPDA's policy and interest in the six named projects were discussed. It was focused on spin off effects by implementation some of the hydropower schemes and the possible contribution from local contractors and Pakistan relevant industry. The need for practical training of WAPDA engineers was emphasized, as well as the chance to give practical training to those who had attended the one year Norwegian Hydel course at Norwegian Technical Highschool.

No maps were available to give sufficient information on potential head and size of catchment area. The maps are restricted of political reasons. They will, however, be available for each site when the planning works starts.

| | | |
|---|---|---|
| 13/10 | 1600-2100 | WAPDA representative Gilgit<br>Mr. ABDUL WAHID<br>Visit the new 3MW diesel generating station. |

Mr. A.WAHID is besides being the WAPDA representative also the head of the construction of the 4MW scheme at Kargah.

14/10 0900-1030 NORTHERN AREA PUBLIC WORKS DEPARTMENT
GILGITA (NAPWD)
Chief Engineer
Brigadier NAJEEB ULLAH KHAN,

Superintending Engineer,Gilgit Circle
Lt.Col JAWAID AHMED

Superintending Engineer (Works)
Chief Eng.'s office
Lt. Col RASHID AHMAD

Executive Eng. Water&Power Division
Gilgit
Mr. SULEMAN WALI KHAN

Executive Eng. (Works)
Chief Eng. office
Mr. ALI AMAN SHAH
Executive Eng. (E&M) Chief Eng. off.
Mr. MIHAMMAD NABI

Assistant Executive Engineer (civil)
Ghizar Division
Mr. MUHAMMAD BASHIR

Resident Engineer (HEP) WAPDA Gilgit
Mr. ABDUL WAHID

The meeting with the Chief Engineer and his staff gave a brief introduction to the situation in the Northern Area concerning electricity production, demand, maintenance problems and available local workforce. The existing small hydro power plants, transmission and distribution net required heavy maintenance work which stressed the people employed. Concerning the development of small hydel plants planning, construction and operation is carried out by NAPWD. There is local knowledge on hydrology, sedimentation, el/mech. equipment, civil works and land survey.

| | | |
|---|---|---|
| 14/10 | 1100-2000 | Visit the plants existing and under construction in Kargah watercourse. Visit Nomal project site and the existing plant at Nomal. |
| 15/10 | 0830-1200 | Visit The PARRI MULTIPURPOSE SCHEME Power station area and Sai nullah. |
| | 1200-2000 | Visit Hassanabad small hydel plants phase 1 and 2 in Hunza.Meeting with Executive Engineer Hunza division Mr.DARVESHALI |
| 16/10 | 0800-2300 | Visit to Darmadar project site. Meeting with Chizar Division Mr. ALI AHMED JON Mr. MUHAMMAH BASHIR Mr. TAJWAR KHAN WAZIR |
| 17/10 | 0800-1500 | Gilgit - Skardu |
| | 1500-2130 | Site visit to Skardu hydel plants phase 1 and 2. and Sadpara lake.<br><br>Meeting with NAPWD Skardu Superintending Engineer Baltistan Circle Lt.Col SAIFUR REHMAN<br><br>Executive Engineer Water & Power Division Mr. NASIR ALI |
| 18/10 | 0700-1400 | Visit to Mehdaibad and Gowari hydel schemes |
| | 1400-2100 | Skardu - Chilas |

19/10  0700-1000  Meeting NAPWD Chilas

Chief Engineer NAPWD
Brigadier NAJEEB ULLAH KHAN

Superintending Engineer
Colonel MUMIR AFGAL

Executive Engineer Water & Power
Division Chilas
Mr. JUMA SAEED

In this meeting our conclusions so far were discussed. The meeting concluded that it is a must to improve the maintenance procedure of the existing hydel stations, and that the implementation of a mech/el workshop to carry out maintenance work should be given priority. To meet the energy demand from people presently without electricity and the demand of the capital in the area, Gilgit, it is necessarily both to develop local nullahs and the main rivers for energy production. As regards medium scaled power plants, the NAPWD would give priority to studies on the Gilgit river. The argument was that this river could give the electricity to cover the demand during wintertime without serious environmental damages. It would also imply solutions with possibilities for the utilization of present local knowhow and workforce. The technological solutions on construction and equipment which have to be introduced would not be too far a step.

1000-1700  Visit to Tangir valley and the possible sites for a 2 MW hydel scheme

Meetings with:
Sub divisional officer
Mech/el engineer
BDR division NAPWD
Mr. SHER DIL
SDO Darrel/Tangir
Civil Engineer

| | | |
|---|---|---|
| | | Mr. GHIAS KHAN |
| | 1700-2100 | Tangir - Besham |
| 20/10 | 0800-1400 | Besham - Islamabad |
| 21/10 | | Islamabad - Lahore |
| 22/10 | 0800-1300 | Meeting WAPDA<br>Chief Eng. MUHAMMAD ZAKRIA<br><br>Director Hydro electric project<br>Engr. M. A. A. NOMANI<br><br>Deputy Director<br>Mr. SHAHID HUSSAIN<br>Research Engineer<br>Miss. BUSHRA PARVEEN |

In this meeting we discussed our conclusion and we got information on the PARRI multi purpose scheme and the HANZAL (Gilgit) scheme. We also got information on hydrological, sedimentations and environmental problems in the Northern Area. TOR for possible Norwegian Consultant were also discussed in principal. It was appreciated that the team would work for spin off effects of the Norwegian contribution to improved electricity production in the Northern Area. Our conclusions were met by positive comments and it was stressed that it is a need for the mech/el workshop at Gilgit.

| | | |
|---|---|---|
| 22/10 | 1400-1600 | Visit to Pakistan Engineering Company<br>PECO<br>Meetings with:<br>General Manager Badami Magh Works<br>Engr. ABDUL WAHID RANA<br><br>Manager Structure Division<br>PECO-Kotkakhbat Works<br>Mr. SYED SOHAIL HASNAT<br>Return to Islamabad |

24/10 1000-1300 Visit to the TARBELLA dam after one night stay in Peshavar.

Meeting with:
General Manager
Mr. RASHID A.CHAUDRY

Chief Engineer
Engr. ABDUL KHALIQ KHAN

In this meeting we got information of the transport of sediments in the catchment area to the Tarbella dam. We also got the sediment budget for different rivers as the Gilgit river, Hunza river etc. The measuring methods were discussed with the Chief Engineer, who was very well informed since the sediment problems were his main interest. He can later be reached in the Dams Monitoring Organization, 8C, Bahawalpur House Lahore.

VISIT NORAD TEAM

Anx-A

EXISTING HYDEL STATIONS

| GILGIT DISTRICT | CAPACITY IN KVA | NO OF GENERATING SETS | REMARKS |
|---|---|---|---|
| 1. Gilgit Phase-I | 400 KVA | 2x200 KVA | |
| 2. Gilgit Phase-II | 560 " | 1x200, 1x360 KVA | |
| 3. Gilgit Phase-III | 375 " | 3x125 KVA | |
| 4. Gilgit Phase-IV | 375 " | 3x125 " | |
| 5. Dormoshko-V (Gilgit) | 250 " | 2x125 " | |
| 6. Juglote | 135 " | 1x135 " | |
| 7. Singal | 125 " | 1x125 " | |
| 8. Sherqillah | 135 " | 1x135 " | |
| 9. Nomal | 135 " | 1x135 " | |
| 10. Naltar | 100 " | 1x100 " | Required replacement. |
| 11. Chalt | 50 " | 1x50 " | -do- |
| 12. Hassanabad Ph-I (Hunza) | 200 " | 1x200 " | -do- |
| 13. Minapin | 125 " | 1x125 " | |
| 14. Sumayar | 125 " | 1x125 " | |
| 15. Chatorkhand | 200 " | 1x200 " | |
| 16. Hassanabad Ph-II | 500 " | 2x250 " | |
| 17. Danyour | 200 " | 1x200 " | |
| 18. Khyber | 500 " | 1x500 " | |
| 19. Gupis | 750 " | 6x125 " | |
| 20. Dudalas | 750 " | 3x250 " | |
| | 5990 KVA<br>4.8 MW | | |

| DIAMAR DISTRICT | | | |
|---|---|---|---|
| 1. Chilas | 200 KVA | 1x200 KVA | |
| 2. Astore | 270 " | 2x135 " | |
| 3. Thore | 125 " | 1x125 " | |
| 4. Tangir | 200 " | 1x200 " | |
| 5. Darel | 250 " | 1x200 " | |
| 6. Parishing | 250 " | 1x200 " | |
| 7. Rattu | 200 " | 1x200 " | |
| 8. Gorikot | 250 " | 2x250 " | |
| | 1695 KVA<br>1.4 MW | | |

| BALTISTAN DISTRICT | | | |
|---|---|---|---|
| 1. Skardu Phase-I | 400 KVA | 2x200 | Two gen sets required replacement. |
| 2. Skardu Phase-II | 800 KVA | 4x200 KVA | |
| 3. Khaplu | 135 " | 1x135 " | |
| 4. Parkuta (Mehdiabad) | 135 " | 1x135 " | |
| 5. Sirmik | 125 " | 1x125 " | |
| 6. Shigar | 135 " | 1x135 " | |
| 7. Kachura | 250 " | 2x125 " | |
| 8. Tolti | 250 KVA | 2x125 KVA | |
| 9. Olding | 125 " | 1x125 " | |
| 10. Hoshopi | 100 " | 1x100 " | |
| 11. Stak | 200 " | 1x200 " | |
| 12. Mendi | 200 " | 1x200 " | |
| | 2855 KVA<br>2.3 MW | | |
| G.Total: | 8.5 MW | | |

VISIT NORAD TEAM

Anx B

UNDER CONSTRUCTION HYDEL PROJECTS

| GILGIT DISTRICT | CAPACITY IN KVA | NO OF GENERATING SETS | REMARKS |
|---|---|---|---|
| 1. Danyour Hydel Project(for additional one Unit) | 200 KVA | 1x200 KVA | Chinese |
| 2. Rehabilitation Kargah Phase-VII | 1250 " | 2x625 " | English |
| 3. 1 MW Hydel Project at Jalalabad | 1250 " | 2x625 " | Chinese |
| 4. 1 MW Hydel Project at Nazbar (Yasin) | 1250 " | 2x625 " | " |
| 5. Hydel Project at Ishkoman | 1250 " | 2x625 " | " |
| 6. Hydel Project at Singal Phase-II. | 250 " | 1x250 " | Switzerland |
| 7. Hydel Scheme at Juglote | 1250 " | 2x250 " | Yet not procured. |
| 8. Hydel Scheme at Misgar (Hunza). | 200 " | 1x200 " | " |
| 9. 1 MW Hydel Scheme Nagar. | 1250 " | 2x625 " | " |
| 10. 1 MW Hydel Scheme Phander | 1250 " | 2x625 " | " |
| | 9400 KVA<br>7.520 MW | | |

DIAMAR

| | | | |
|---|---|---|---|
| 1. 1.5 MW Hydel Project Thack Chilas | 2000 KVA | 4x500 KVA | 1x500 KVA Swiz made<br>3xTo be procured. |
| 2. 1 MW Hydel project at Bunner. | 1250 " | 2x625 " | Chinese |
| 3. 1 MW Hydel project Ph-II Darel. | 1250 " | 2x625 " | " |
| 4. Loas Hydel Project. | 1250 " | 2x625 " | " |
| 5. Shankargrah Hydel Project. | 250 " | 1x250 " | " |
| 6. Hydel Scheme Gudai Astore. | 800 " | 2x400 " | To be procured. |
| 7. Hydel Scheme Harcho Astore. | 300 " | 1x300 " | " |
| | 7100 KVA<br>5.68 MW | | |

BALTISTAN

| | | | |
|---|---|---|---|
| 1. Hydel project Manthoka | 250 KVA | 1x250 KVA | Swis made |
| 2. Hydel Project Kayo. | 125 " | 1x125 " | Australia. |
| 3. Hydel Project Garbuching | 250 " | 1x250 " | Swis made. |
| 4. Hydel project Keris | 200 " | 1x200 " | Japan |
| 5. Hydel Project Thalley | 200 " | 1x200 " | " |
| 6. Hydel Project Ph-II Kachura | 250 " | 2x125 " | Country made. |
| 7. Hydel Project Gondus | 200 " | 1x200 " | Chinese. |
| 8. 1 MW Hydel project at Kharko Daghony. | 1000 " | 2x500 " | Chinese |
| 9. 1.5 MW Hydel project Balagond. | 1500 " | 3x500 " | Yet to be procured. |

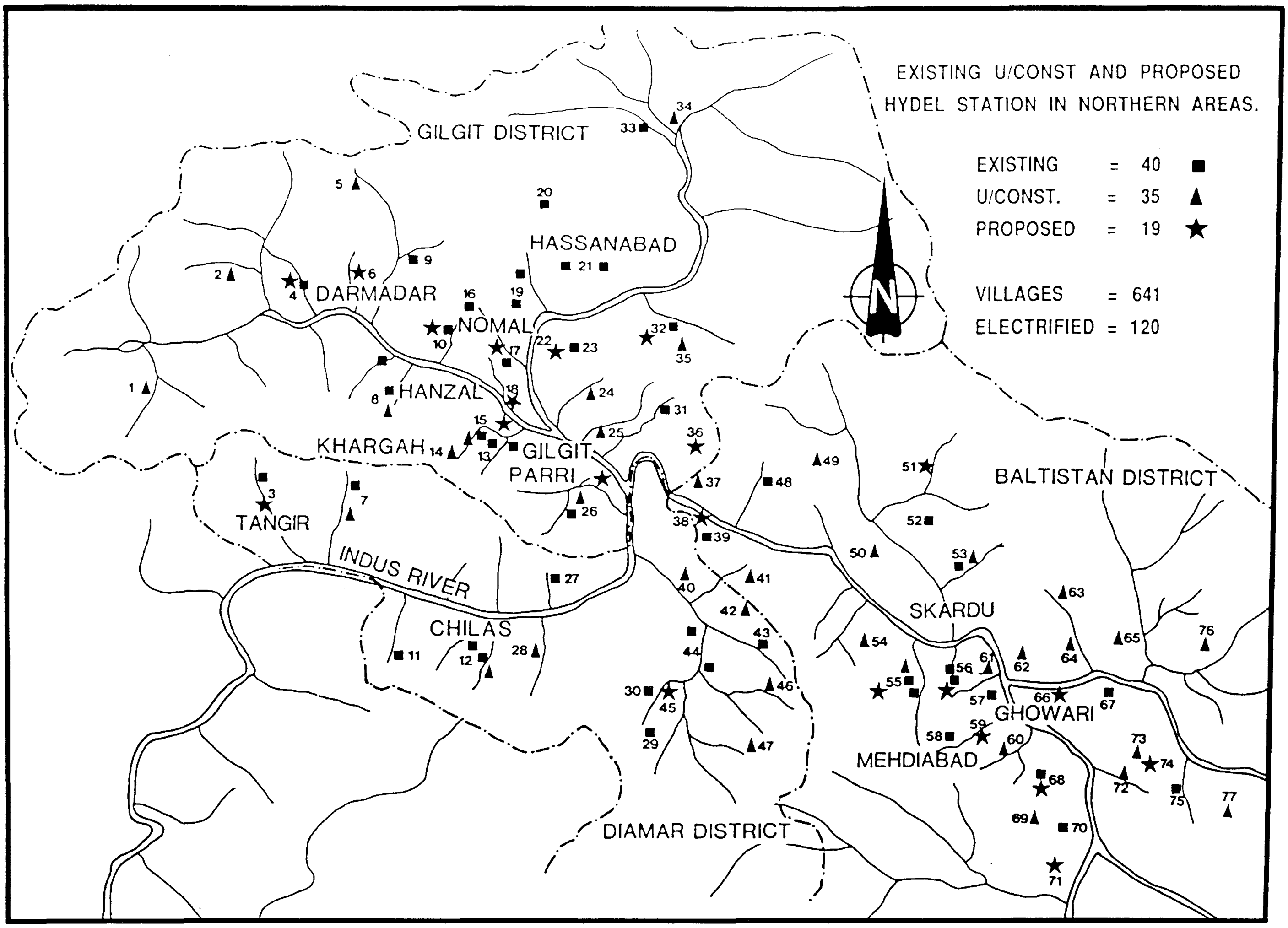
VISIT NORAD TEAM

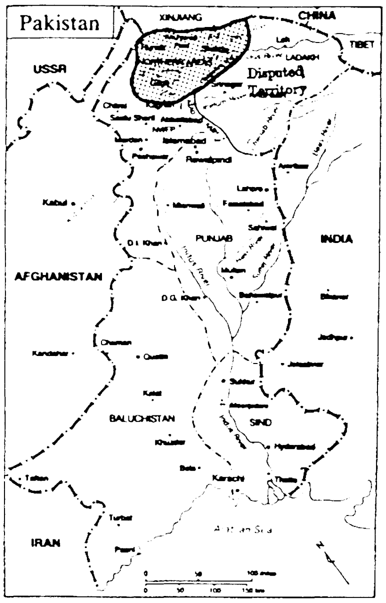
Anx C

HYDEL PROJECT IDENTIFIED FOR FUTURE CONSTRUCTION

| S.No. | Name of Project | Capacity |
|---|---|---|
| **GILGIT DISTRICT** | | |
| 1. | 750 KVA Hydel Scheme Darmadar (Ghizar) | 750 KVA |
| 2. | 5 MW Hydel project Hanzal ( Gilgit) | 6250 " |
| 3. | Const of 250 KVA Hydel scheme Phase-II Sumayar (Nagar) | 250 " |
| 4. | Const of 500 KVA Hydel scheme Pisson (Nagar) | 500 " |
| 5. | Const of 1250 KVA Hydel Scheme Sherqillah Phase-II (Ghizar) | 1250 KVA |
| 6. | 200 KVA Hydel Scheme Bargo (Gilgit) | 200 " |
| 7. | Const of 500 KVA Hydel Scheme Haramosh(Gilgit) | 500 " |
| 8. | Hydel project Gupis Ph-II (Ghizar) | 2000 " |
| **DIAMAR** | | |
| 1. | Tangir Phase-II(Tangir/Diamar) | 1000 " |
| 2. | Const of 800 KVA Hydel Scheme Bulashber (Astore) | 800 " |
| **BALTISTAN** | | |
| 1. | 2 MW Hydel Scheme at Kachura | 2500 " |
| 2. | 1 MW Hydel Scheme at Mehdiabad | 1000 " |
| 3. | Hydel project Gowari | 4000 " |
| 4. | Satpara Dam Project. | 4000 " |
| 5. | Const of Hydel Scheme at Tolti Ph-II (Kharmong) | 250 " |
| 6. | Const of Hydel Scheme at Barald Shigar. | 500 " |
| 7. | Const of 500 KVA Hydel Scheme Ganji | 500 " |
| 8. | 500 KVA Hydel Scheme at Hussainabad (Khaplu) | 500 " |
| 9. | Const of 1 MW Hydel Scheme at Hargosil (Kharmong) | 1000 " |
| | | 27750 KVA |
| | | 22.20 MW |

| | | | | |
|---|---|---|---|---|
| 10. | 1.5 MW Hydel project Dumsum | 1500 KVA | 3x500 KVA | Chinese |
| 11. | 1 MW Hydel project at Basho | 1000 " | 2x500 " | " |
| 12. | 500 KVA Hydel project Harpo | 500 " | 2x250 " | " |
| 13. | Hydel Project Niasolo | 250 " | 1x250 " | " |
| 14. | Hydel Project Turmic | 1000 " | 2x500 " | Yet to be procured. |
| 15. | Hydel project Pion | 1000 " | 2x500 " | " |
| 16. | Hydel project Shiriting. | 1000 " | 2x500 " | " |
| 17. | Hydel project Shigar Ph-II | 1000 " | 2x500 " | " |
| 18. | Hydel project Gole | 500 " | 2x250 " | " |
| | | 10720 KVA | | |
| | | 21.776 MW | | |




| | KVA |
|---|---|
| 1. PHANDAR | 1250 |
| 2. NAZBAR | 1250 |
| 3. TANGIR | 2500; 200 |
| 4. GUPIS | 2000; 750 |
| 5. ISHKOMAN | 1250 |
| 6. DARMADAR | 750 |
| 7. DAREL | 1250; 250 |
| 8. SINGLE | 125; 250 |
| 9. CHATORKHAND | 200 |
| 10. SHERQILLAH | 1250 ; 250 |
| 11. THOR | 200 |
| 12. CHILAS | 1250; 500; 2000 |
| 13. KHARGA N | 4000 |
| 14. DORMUSHKO | 250; 1250 |
| 15. HANZAL N | 6250 |
| 16. NALTAR | 100 |
| 17. NOMAL | 250; 135 |
| 18. BARGO | 200 |
| 19. CHALT | 125 |
| 20. BODALAS | 750 |
| 21. HASSANABAD | 200; 500 |
| 22. PISAN | 500 |
| 23. MINAPIN | 125 |
| 24. DAYOUR | 250 |
| 25. JALALABAD | 1250 |
| 26. JAGLOTE | 250; 135 |
| 27. GOHARABAD | 200 |
| 28. BUNAR | 1250 |
| 29. RATTU | 200 |
| 30. GORIKOTE | 250 |
| 31. BAGROTE | 800 |
| 32. SUMAYAR | 250; 125 |
| 33. KHYBER | 500 |

| | KVA |
|---|---|
| 34. MISGAR | 200 |
| 35. NAGAR | 250 |
| 36. HARAMOSH | 500 |
| 37. TURMIK | 1000 |
| 38. GANJI | 500 |
| 39. MENDI | 200 |
| 40. HARCHO | 800 |
| 41. HARPO | 500 |
| 42. LOUS | 1850 |
| 43. PARISHING | 200 |
| 44. ASRORE | 135; 135 |
| 45. BULSHBAR | 800 |

| | KVA |
|---|---|
| 46. GUDAI | 250 |
| 47. SHANKORGARH | 250 |
| 48. STAK | 200 |
| 49. NIALSO | 250 |
| 50. KAYO | 125 |
| 51. BARALDO | 500 |
| 52. HASHOPI | 100 |
| 53. SHIGAR | 1000 |
| 54. BASHO | 1000 |
| 55. KACHURA | 250; 2000<br>2500; 250 |
| 56. SKARDU | 3000; 800 |
| 57. SIRMIK | 125 |
| 58. PARKUTA | 135 |
| 59. MEHDIABAD | 1000 |
| 60. MANTHAKA | 250 |
| 61. GOL | 500 |
| 62. KIRS | 200 |
| 63. THALY | 200 |
| 64. BALAYGOND | 1500 |
| 65. KHARKOO | 1000 |
| 66. GHOWARI | 4000 |
| 67. KHAPLU | 135 |
| 68. TOLTI | 250; 250 |
| 69. SHIRTING | 1000 |
| 70. OLDING | 125 |
| 71. HERGOSIL | 1000 |
| 72. GUNDAS | 200 |
| 73. GARBUCHING | 250 |
| 74. HASANABAD | 500 |
| 75. SIKSA | 200 |
| 76. DANSAM | 1500 |
| 77. PION | 1000 |

## ANALYSES RESULTS OF SEDIMENTS FROM THE NORTHERN AREA

### Mineral analyses

The analyses were carried out by counting particles under a stereo microscope. An average of 323 particles were counted in each fraction. In samples 1, 2 and 3 the sand fraction between 0.075 and circa 1 mm has been analysed. All samples have been analysed between 0.250 and circa 1 mm.

The most frequent minerals are quartz, feldspar, mica, pyroxenic and amphibolic minerals. An unidentified black, soft mineral was observed, particularly in sample 3 but also in samples 5 and 6. Since the mineral has low hardness it most likely has little or no abrasive effect.

Circa 65% of sample 1 is composed of quartz. The mean for the other samples, except number 5, is circa 45%. Sample 5 is the only one of the 6 that contains more feldspar than quartz. It has not been specified which amphibolic and pyroxenic minerals were observed but they all have relatively equal hardness and can be considered to have relatively equal abrasive effect.

In the group "other minerals" circa 10 types were observed. Of these only zircon and possibly titanite and epidote have an abrasive effect. The amount of these minerals is, however, very limited. The mineral garnet, which has a high abrasive effect, was not detected with certainty in any of the samples.

### Particle shape

The particle shape was only visually observed. Quartz has in all of the samples a very sharp-edged shape. Particularly sample 1 was found to be such in this sharp-edged quartz. The quartz appeared to be least sharp in sample 5. The feldspar showed a few round shapes in samples 2, 3 and 5. The pyroxenic and amphobolic minerals varied more in shape. They were often found to have the shape of sterns/stalks and to be relatively sharp-edged.

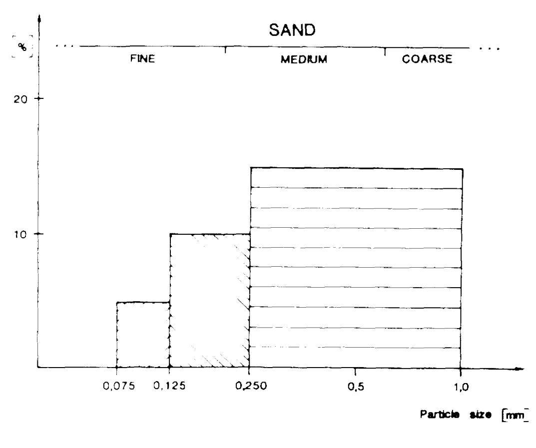
Small fragments of rock species were observed in samples 2, 4 and 5. They were all too small to identify with certainty. However, judging by the mineral composition, parts of the sediments originate from certain types of gneiss and others from eruptives.

# Mineral analyses

| NR | PARTICLE SIZE | SPECIES OF ROCK | QUARTZ | FELD-SPAR | MICA | PYROX-ENIC AMPHI-BOLIC MINER. | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | HASSANABAD | | | | | | |
| | 0.075-0.125 | - | 66.6 | 16.2 | 1.2 | 12.0 | 4.0 |
| | 0.125-0.250 | - | 66.6 | 17.7 | 6.0 | 8.0 | 1.7 |
| | >0.250 | - | 60.6 | 21.1 | 8.4 | 9.1 | 0.8 |
| 2 | TANGIER 19.10.88 | | | | | | |
| | 0.075-0.125 | - | 42.1 | 27.0 | 3.3 | 25.0 | 2.6 |
| | 0.125-0.250 | - | 37.7 | 34.7 | - | 23.6 | 4.0 |
| | >0.250 | 10.4 | 39.6 | 38.8 | 3.2 | 6.8 | 1.2 |
| 3 | HENZEL INTAKE | | | | | | |
| | 0.075-0.125 | - | 40.1 | 32.2 | 24.7 | 2.0 | 1.0 |
| | 0.125-0.250 | - | 39.8 | 30.7 | 22.1 | 0.9 | 6.5 |
| | >0.250 | - | 36.9 | 33.2 | 26.6 | 0.7 | 2.6 |
| 4 | SHI NALLAH, INDUS | | | | | | |
| | >0.250 | 5.0 | 53.4 | 25.3 | 5.5 | 9.9 | 0.9 |
| 5 | DARMADAR DOWNSTREAM | | | | | | |
| | >0.250 | 2.4 | 24.4 | 31.8 | 36.9 | - | 4.5 |
| 6 | DARMADAR | | | | | | |
| | >0.250 | - | 45.0 | 39.9 | 12.0 | 1.2 | 1.9 |

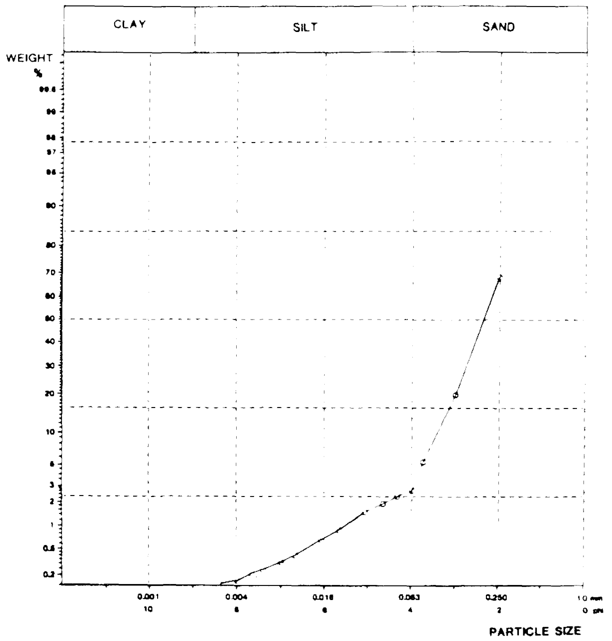
| LOC | MINERAL | QUARTZ | FELD-SPAR | MICA | PYROX-ENIC AMPHI-BOLIC MINER. | OTHER |
|---|---|---|---|---|---|---|
| PK 1 | - | 60.6 | 21.1 | 8.4 | 9.1 | 0.8 |
| PK 2 | 10.4 | 39.6 | 38.8 | 3.2 | 6.8 | 1.2 |
| PK 3 | - | 36.9 | 33.2 | 26.6 | 0.7 | 2.6 |
| PK 4 | 5.0 | 53.4 | 25.3 | 5.5 | 9.9 | 0.9 |
| PK 5 | 2.4 | 24.4 | 31.8 | 36.9 | - | 4.5 |
| PK 6 | - | 45.0 | 39.9 | 12.0 | 1.2 | 1.9 |

PARTICLE SIZE EXAMINATION

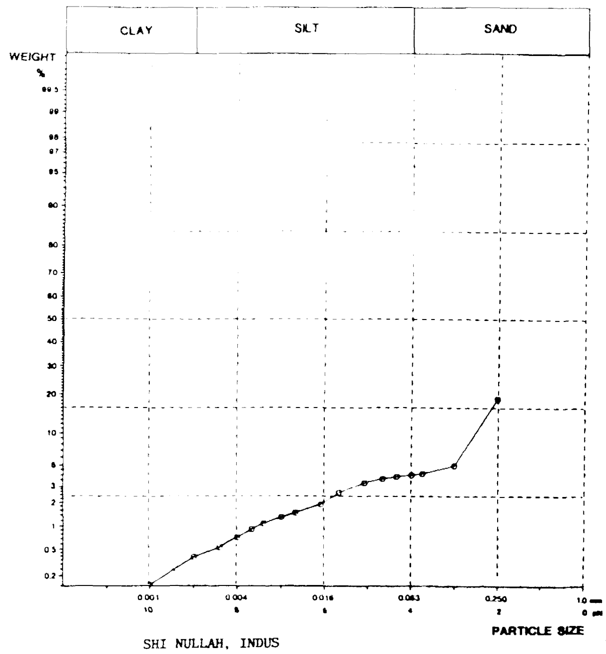


# PARTICLE SIZE DISTRIBUTION

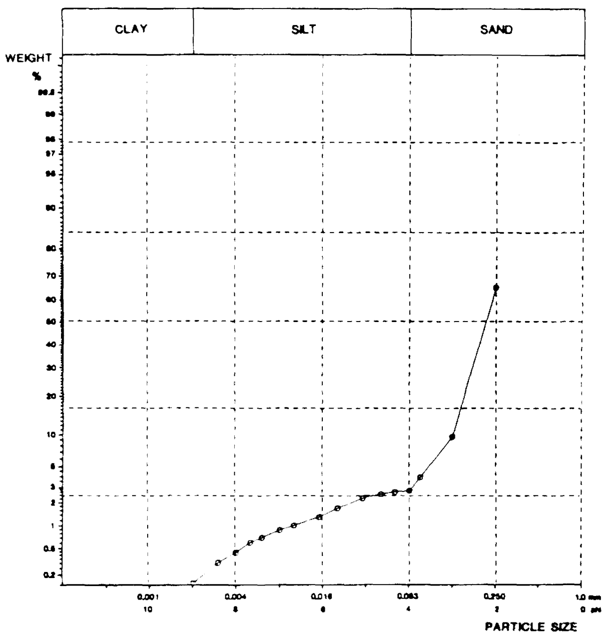
HASSANABAD



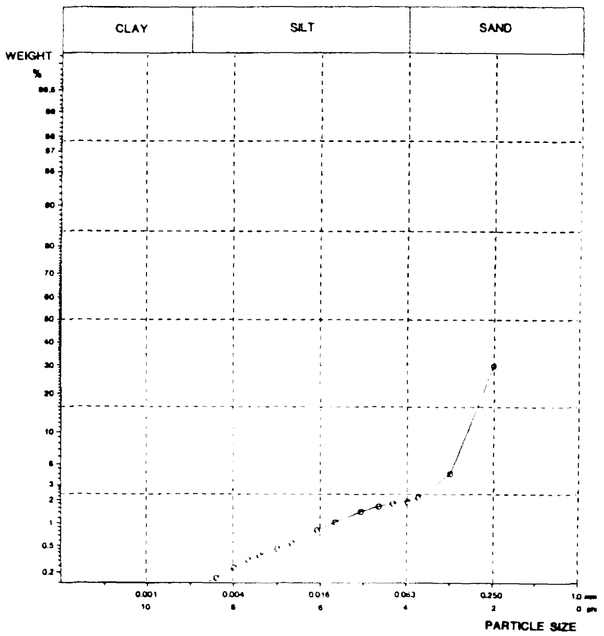

TANGIER



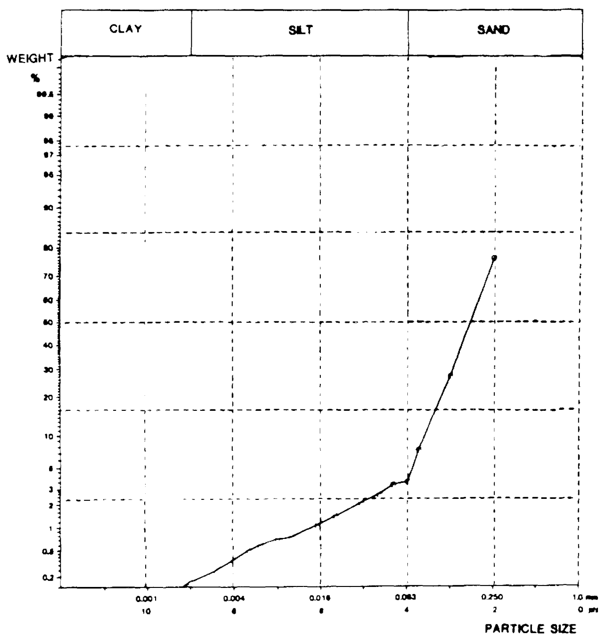

HENZEL



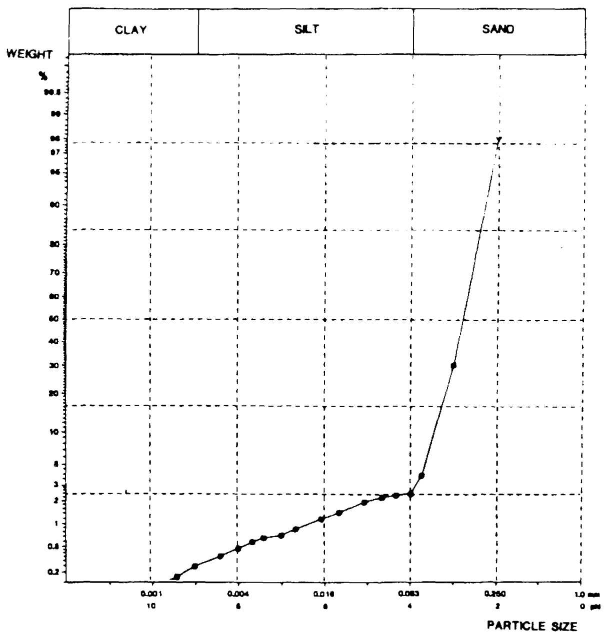

SHI NULLAH, INDUS




DARMADAR, DOWNSTREAM




DARMADAR



# IMPLEMENTATION OF PROJECTS IN THE NORTHERN AREA

**Project Schedule**

| | ACTIVITY | -88 | 1989 | | | | | | 1990 | | | | | | 1991 | | | | | | 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dec | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ |
| 1. | Decision MDC | ■ | | | | | | | | | | | | | | | | | | | | | |
| 2. | Preparation TOR for refurbishing upgrading mission | — | | | | | | | | | | | | | | | | | | | | | |
| 3. | Mission visit | | - - | | | | | | | | | | | | | | | | | | | | |
| 4. | Preparation TOR for Kvaerner Serv. | | | — | | | | | | | | | | | | | | | | | | | |
| 5. | Award of contract | | | | - | | | | | | | | | | | | | | | | | | |
| 6. | Construction workshop | | | — | — | — | — | — | | | | | | | | | | | | | | | |
| 7. | Equipment workshop Purchasing Mounting | | | | | — | — | — | | | | | | | | | | | | | | | |
| 8. | Refurbish Skardu 1 Runner fabrication Mounting Commissioning | | | | | — | — | — | — | — | — | — | — | — | | | | | | | | | |
| 9. | Refurbish Hassa-nabad 1 Runner fabrication Mounting Commisioning | | | | | — | — | — | — | — | — | — | — | | | | | | | | | | |



APPENDIX 6
6 PAGES

| ACTIVITY | | -88 | 1989 | | | | | | 1990 | | | | | | 1991 | | | | | | 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dec | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ |
| 10. | Refurbish Hassa-nabad 2<br>Turbine/generator<br>Civil works<br>Mounting<br>Commissioning | | | | | | | | | | | | | | | | | | | | | | |
| 11. | Upgrade Kargah 5<br>Civil works<br>Pipeline<br>Turbine/generator<br>Refurbish 1 unit<br>Mounting<br>Commissioning | | | | | | | | | | | | | | | | | | | | | | |
| 12. | NAPWD training in workshop in Norway | | | | | | | | | | | | | | | | | | | | | | |
| 13. | Supervision worksh | | | | | | | | | | | | | | | | | | | | | | |
| 14. | Preparation TOR, bid.dosc.for. Consultancy Serv. | | | | | | | | | | | | | | | | | | | | | | |
| 15. | Bid preparation | | | | | | | | | | | | | | | | | | | | | | |
| 16. | Bid evaluation | | | | | | | | | | | | | | | | | | | | | | |
| 17. | Consultancy Serv. Award of contract | | | | | | | | | | | | | | | | | | | | | | |

Project Schedule

| ACTIVITY | | -88 | 1989 | | | | | | 1990 | | | | | | 1991 | | | | | | 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dec | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ |
| 18. | Detailed study Tangier Civil work/El/Mech | | | | | — | — | — | — | | | | | | | | | | | | | | |
| 19. | Detailed study Nomal Civil work/el/mech | | | | | — | — | — | — | | | | | | | | | | | | | | |
| 20. | Review Parri | | | | | | | | — | — | | | | | | | | | | | | | |
| 21. | Review Hanzal | | | | | | | | — | — | | | | | | | | | | | | | |
| 22. | Prefeasibility study. Gilgit River | | | | | | | | — | — | — | — | | | | | | | | | | | |
| 23. | Review WAPDA/NAPWD MDC Tangier Nomal | | | | | | | | — | — | | | | | | | | | | | | | |
| 24. | Review WAPDA/NAPWD MDC Parri/Gilgit | | | | | | | | | | | | — | | | | | | | | | | |
| 25. | Civil works Tangir | | | | | | | | | | | — | — | — | — | — | — | — | — | — | — | — | — |
| 26. | El/Mech Tangir | | | | | | | | | | | | — | — | — | — | — | — | — | — | — | — | — |
| 27. | Civil works Nomal | | | | | | | | | | — | — | — | — | — | — | — | — | — | — | — | | |

| | ACTIVITY | -88 | 1989 | | | | | | 1990 | | | | | | 1991 | | | | | | 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dec | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ | JA | SO | ND | JF | MA | MJ |
| 28. | El/mech Nomal | | | | | | | | | | | | | | | | | | | | | | |
| 29. | Commissioning<br>Tangir<br>Nomal | | | | | | | | | | | | | | | | | | | | | | |

Project Schedule

**COST FIGURES**

**REFURBISH/UPGRADING HYDEL PLANTS**

Mission visit January 89..........0.4 mill NOK
Kargah ph 5.......................6.0 "
Hassanabad ph.1...................0.8 "
Hassanabad ph.2...................5.5 "
Skardu ph 1.......................1.5 "
Contingencies.....................1.8 "
Budget Refurbishing/Upgrading SHP plants.............16 mill NOK

**DEVELOPMENT OF MECH/EL WORKSHOP FOR IMPROVED MAINTENANCE**

Construction Workshop and
Equipment for the Workshop...... 13.0 mill NOK
Supervision two years.............2.5 "
Training of Pakistan Engineers at
Workshops in Norway...............1.5
Contingencies.....................2.0 "
Budget Workshop...................................19 mill NOK

**IMPLEMENTATION OF NEW SHP SCHEMES**

TANGIR SHP, 2 MW. Transmission lines
and irrigation channel.(worst case).40 mill NOK
NOMAL SHP, 2 MW. 33 KV transmission
line to Gilgit. (worst case)........45 mill NOK
Budget New SHP Schemes............................85 mill NOK

**MEDIUM SCALED HYDEL POWER PROJECTS-REVEIEW-STUDIES**

The Parri Multi Purpose scheme.
(Review of plans).................0.8 mill NOK
The Hanzal Low Head Hydel Scheme
Gilgit River..(Review of plans)...0.5 "
Alternatives in Gilgit river
Pre Feasibility study.............1.7 "
Budget medium Scaled Hydel schemes.................3 mill NOK
TOTAL BUDGET RURAL ELECTRIFICATION PROGRAMME .....123 mill NOK

**BUDGET 1989**

THE FOLLOWING FIGURE SHOWS USE OF MONEY IF THE PROGRAMME IS ACCORDING TO OUR RECOMMENDATIONS AND UPSTARTING SUMMER 1989

WORKSHOP...............................12.0 mill NOK
VISITS / TRAINING (WORKSHOP)...........2.0 "
VISITS TO NORWAY. PARTICIPANTS FROM
WAPDA AND NAPWD........................0.3 "
REFURBISH/UPGRADE PROGRAMME............5.0 "
DIESEL UNIT TO HUNZA, AND 33 KV LINE
GILGIT - NOMAL.........................1.7 "
CONSULTANCY SERVICES TANGIR/NOMAL......4.0 "
**BUDGET 1989...........................25.0 mill NOK**

**Altering the programme will be possible at several stages according to available budget or new information.**

**COST FIGURES**

**REFURBISH/UPGRADING HYDEL PLANTS**

Mission visit January 89..........0.4 mill NOK
Kargah ph 5.......................6.0 "
Hassanabad ph.1...................0.8 "
Hassanabad ph.2...................5.5 "
Skardu ph 1.......................1.5 "
Contingencies.....................1.8 "
Budget Refurbishing/Upgrading SHP plants.............16 mill NOK

**DEVELOPMENT OF MECH/EL WORKSHOP FOR IMPROVED MAINTENANCE**

Construction Workshop and
Equipment for the Workshop...... 13.0 mill NOK
Supervision two years.............2.5 "
Training of Pakistan Engineers at
Workshops in Norway...............1.5
Contingencies.....................2.0 "
Budget Workshop...................................19 mill NOK

**IMPLEMENTATION OF NEW SHP SCHEMES**

TANGIR SHP, 2 MW. Transmission lines
and irrigation channel.(worst case).40 mill NOK
NOMAL SHP, 2 MW. 33 KV transmission
line to Gilgit. (worst case)........45 mill NOK
Budget New SHP Schemes............................95 mill NOK

**MEDIUM SCALED HYDEL POWER PROJECTS-REVEIEW-STUDIES**

The Parri Multi Purpose scheme.
(Review of plans).................0.8 mill NOK
The Hanzal Low Head Hydel Scheme
Gilgit River..(Review of plans)...0.5 "
Alternatives in Gilgit river
Pre Feasibility study.............1.7 "
Budget medium Scaled Hydel schemes.................3 mill NOK
TOTAL BUDGET RURAL ELECTRIFICATION PROGRAMME .....133 mill NOK

**BUDGET 1989**

THE FOLLOWING FIGURE SHOWS USE OF MONEY IF THE PROGRAMME IS ACCORDING TO OUR RECOMMENDATIONS AND UPSTARTING SUMMER 1989

| | | |
|---|---|---|
| WORKSHOP | 12.0 | mill NOK |
| VISITS / TRAINING (WORKSHOP) | 2.0 | " |
| VISITS TO NORWAY. PARTICIPANTS FROM WAPDA AND NAPWD | 0.3 | " |
| REFURBISH/UPGRADE PROGRAMME | 5.0 | " |
| DIESEL UNIT TO HUNZA, AND 33 KV LINE GILGIT - NOMAL | 1.7 | " |
| CONSULTANCY SERVICES TANGIR/NOMAL | 4.0 | " |
| **BUDGET 1989** | **25.0** | **mill NOK** |

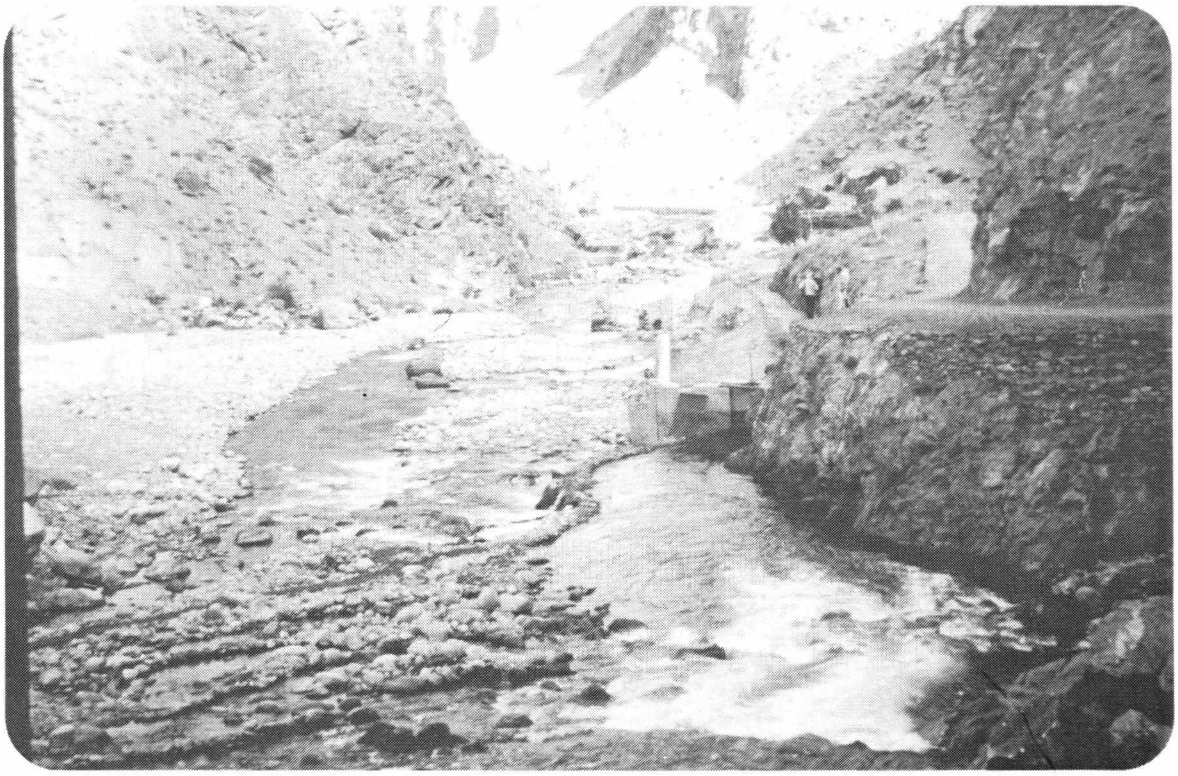
The budget for 1990, 1991, and 1992 will be approximately 35 mill NOK each.

**Altering the programme will be possible at several stages according to available budget or new information.**

1

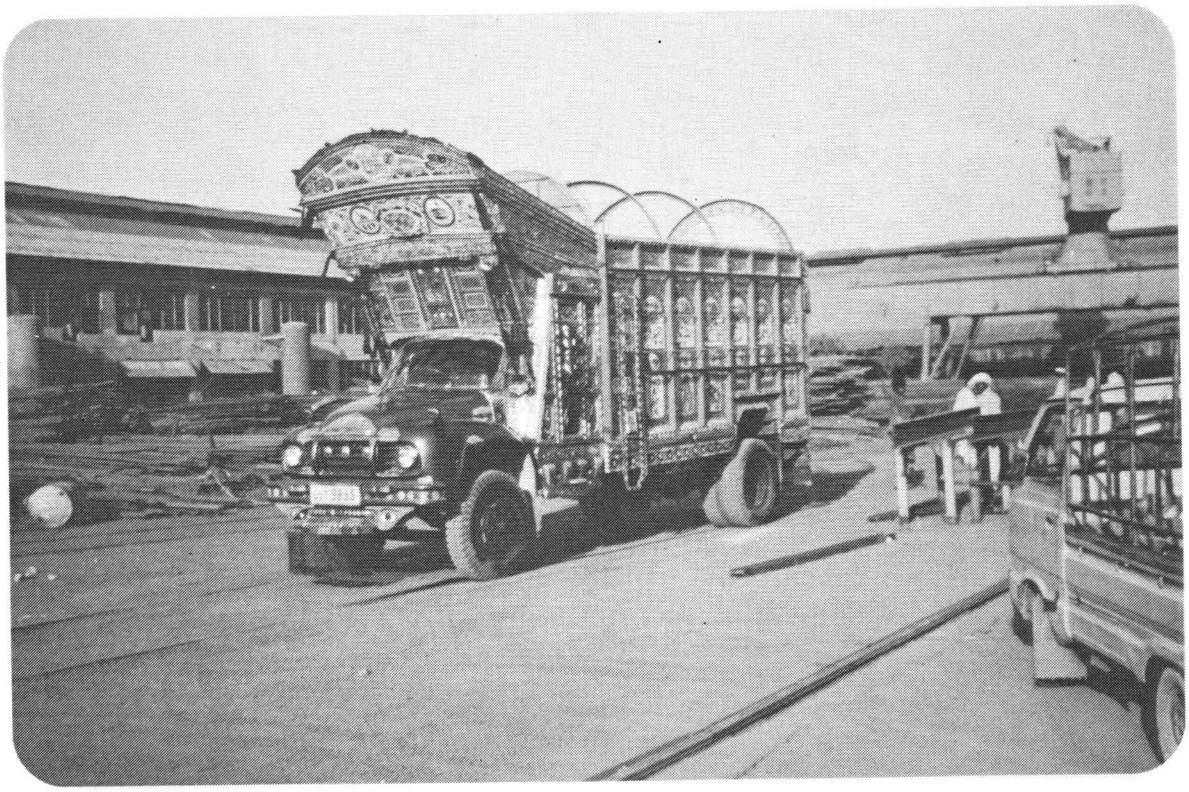
Cascade in feeder channel for Nomal hydel power plant.

2



Example of intake. Kargah, phase 1.

3

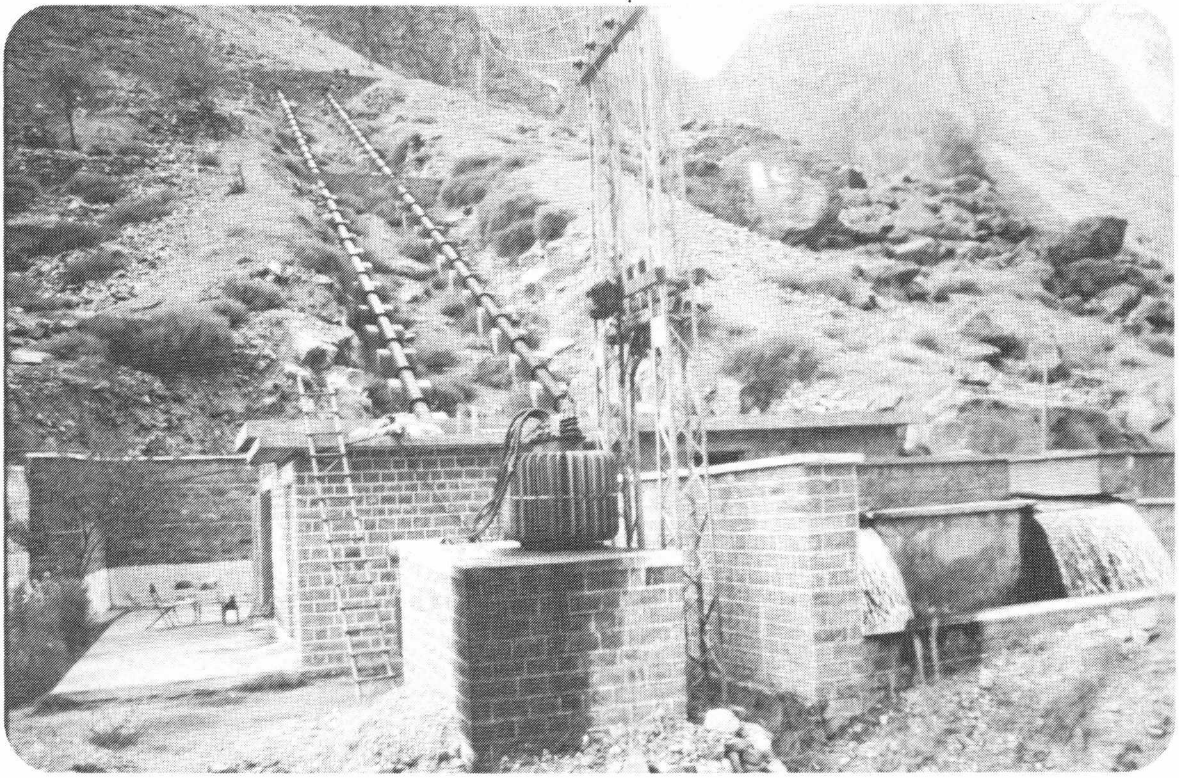


Pakistand Engineering Company, PECO. One of the lorries is ready for transportation

4

The roads to the construction sites normally are not truckable. Hence heavy equipment has to be transported by tractors.

5

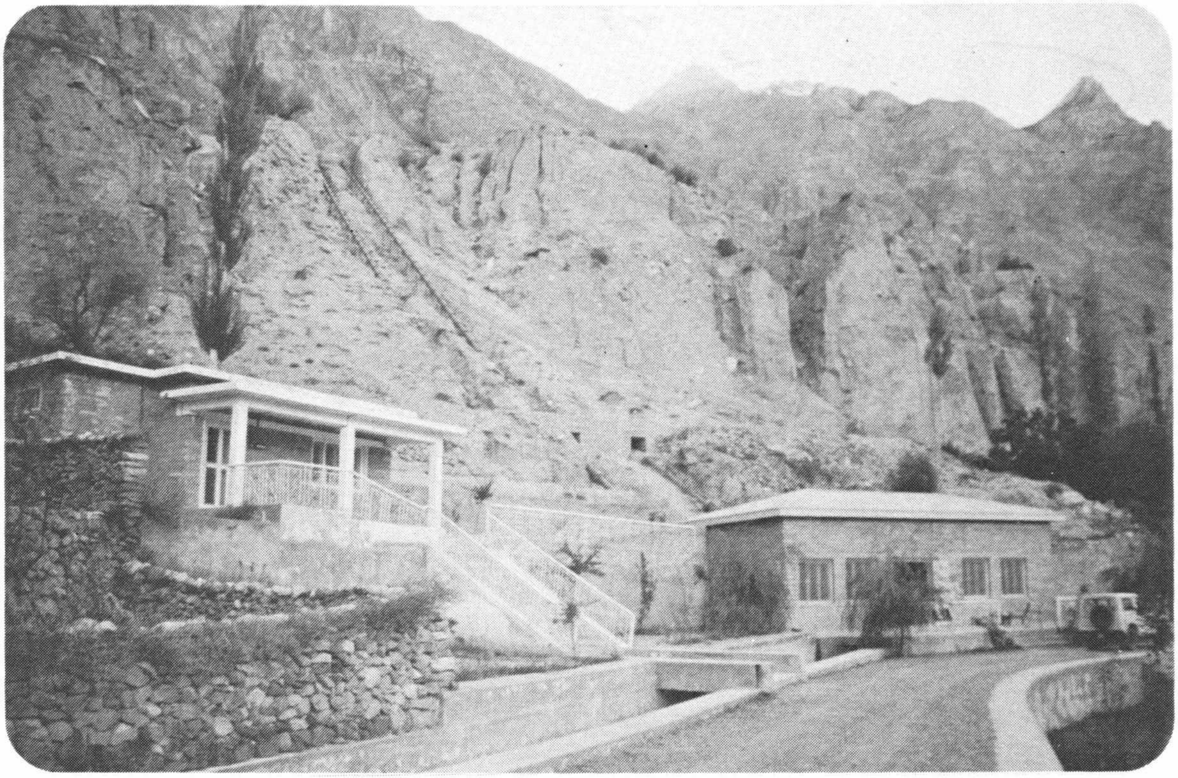


Kargah Phase 5, 200 kW. Can be upgraded to 550 kW.

6

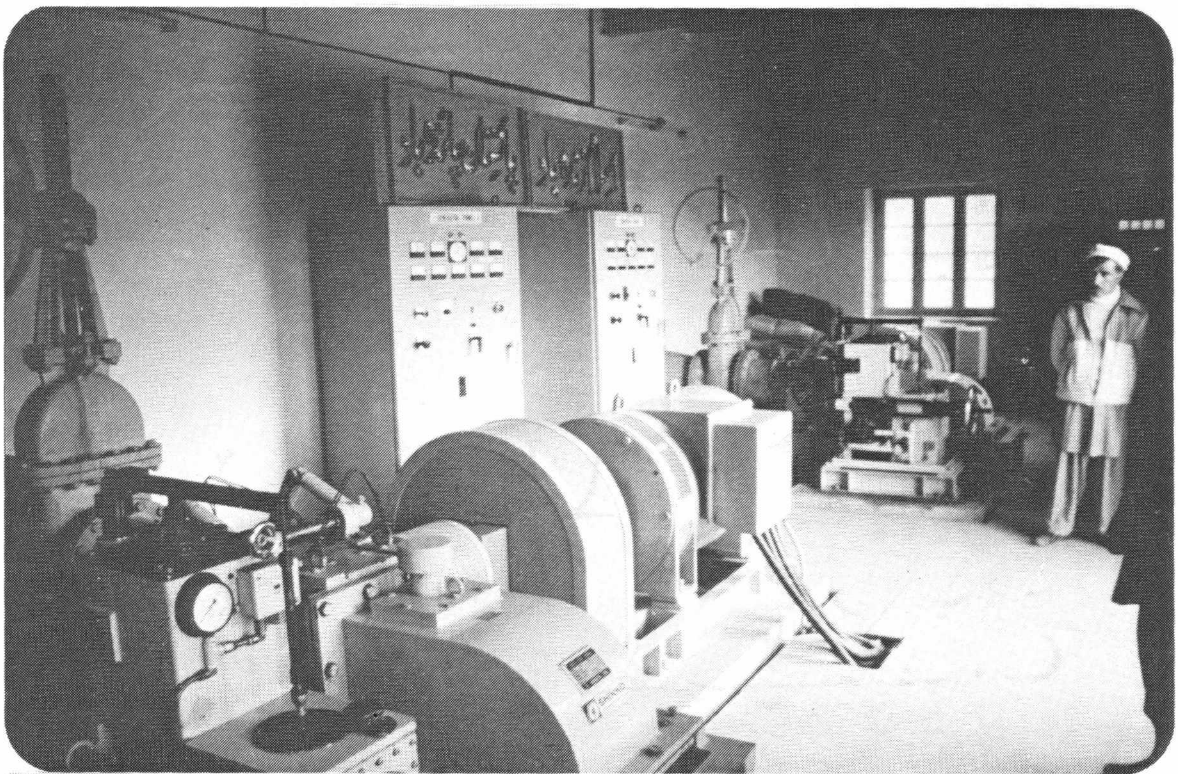
Intake Kargah, phase 5 and 6.

7

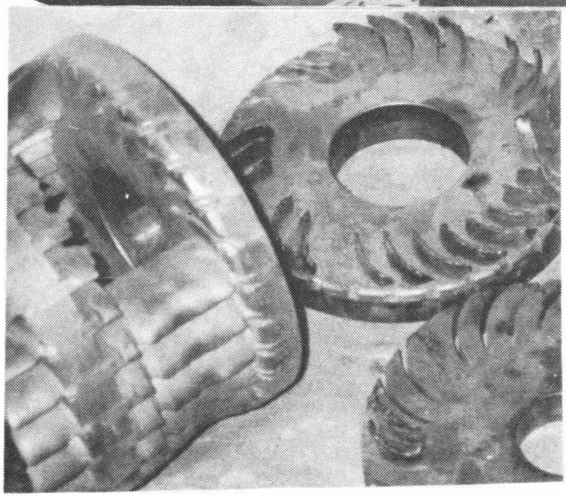


Hassanabad Phase II, 400 kW

8

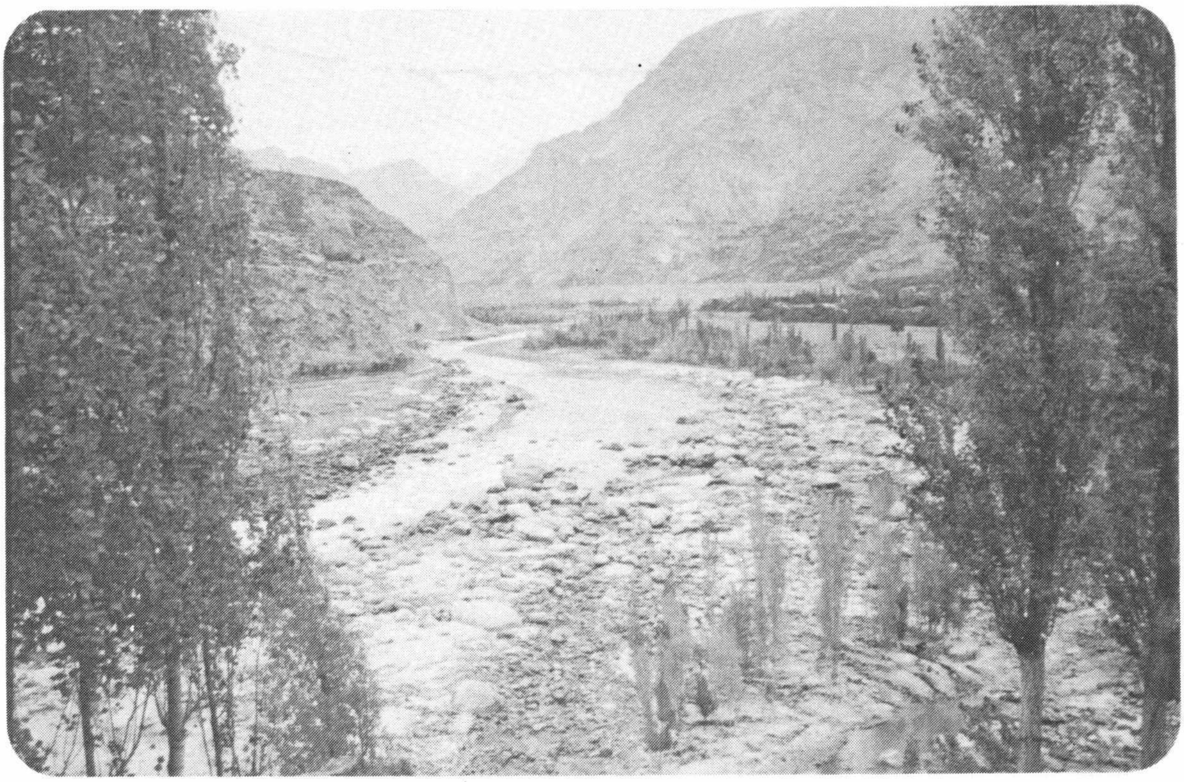


9



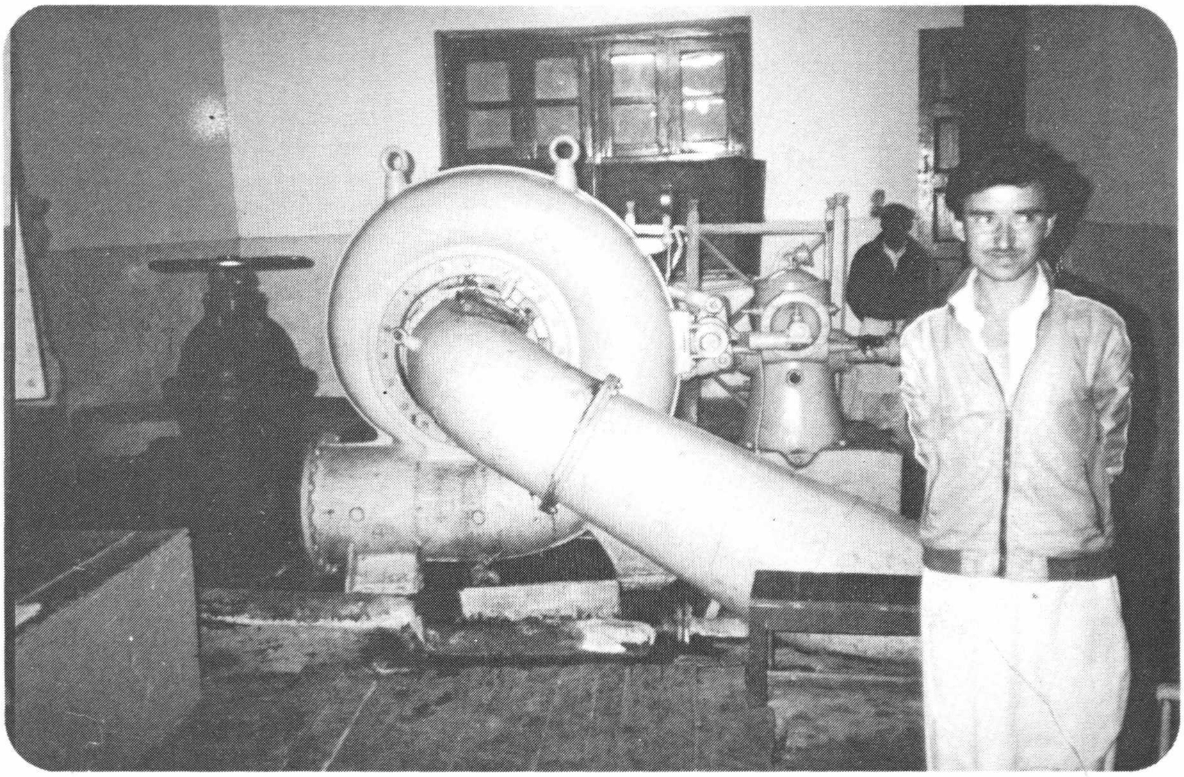
Hassanabad Phase II.
Commisioned 1986.
Runners destroyed twice caused by sand and high runner speed.
1500 RPM
H ca 113 m
Q ca 2 x 0.28 $m^3/s$

10



Ghowari Hydel Scheme 2-10 MW. A 5 km long channel has tobe constructed on the left river bank (Shyok River).

11

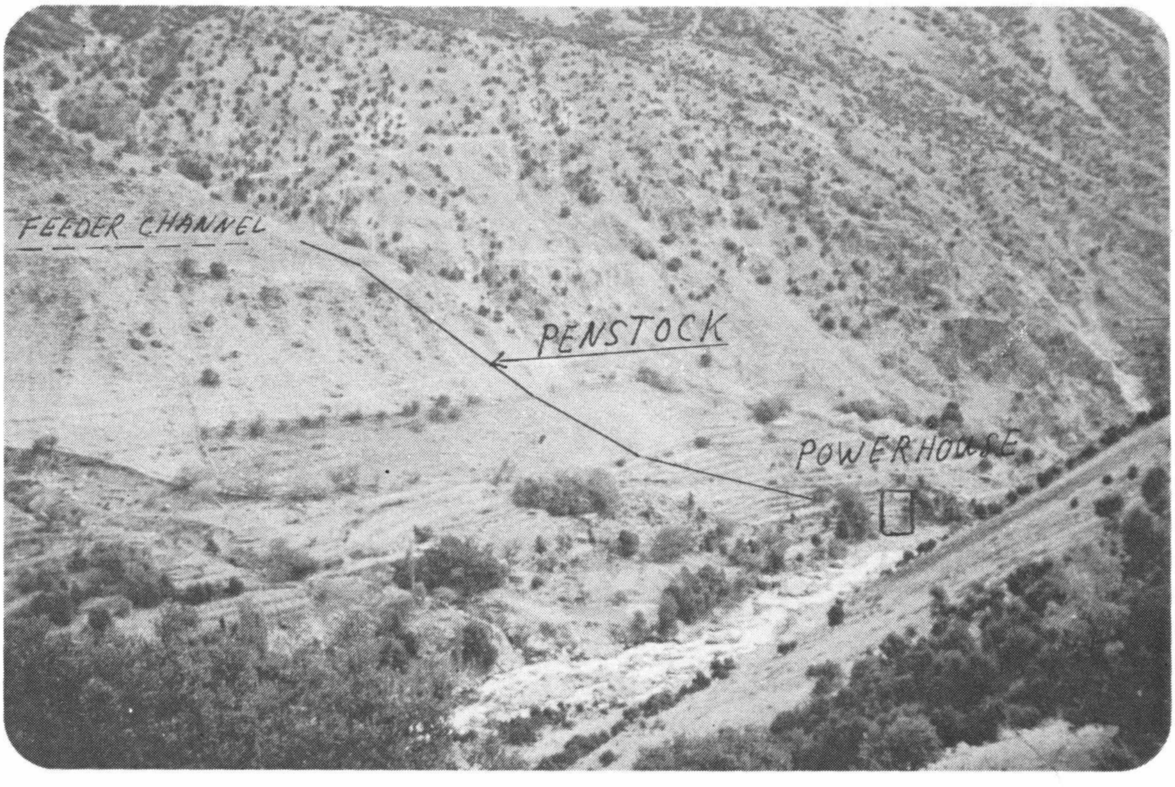


Skardu phase 1. Refurbishment of Francis-runner is needed.

12

Intake conditions for Darmadar small hydro-electric power scheme.

13

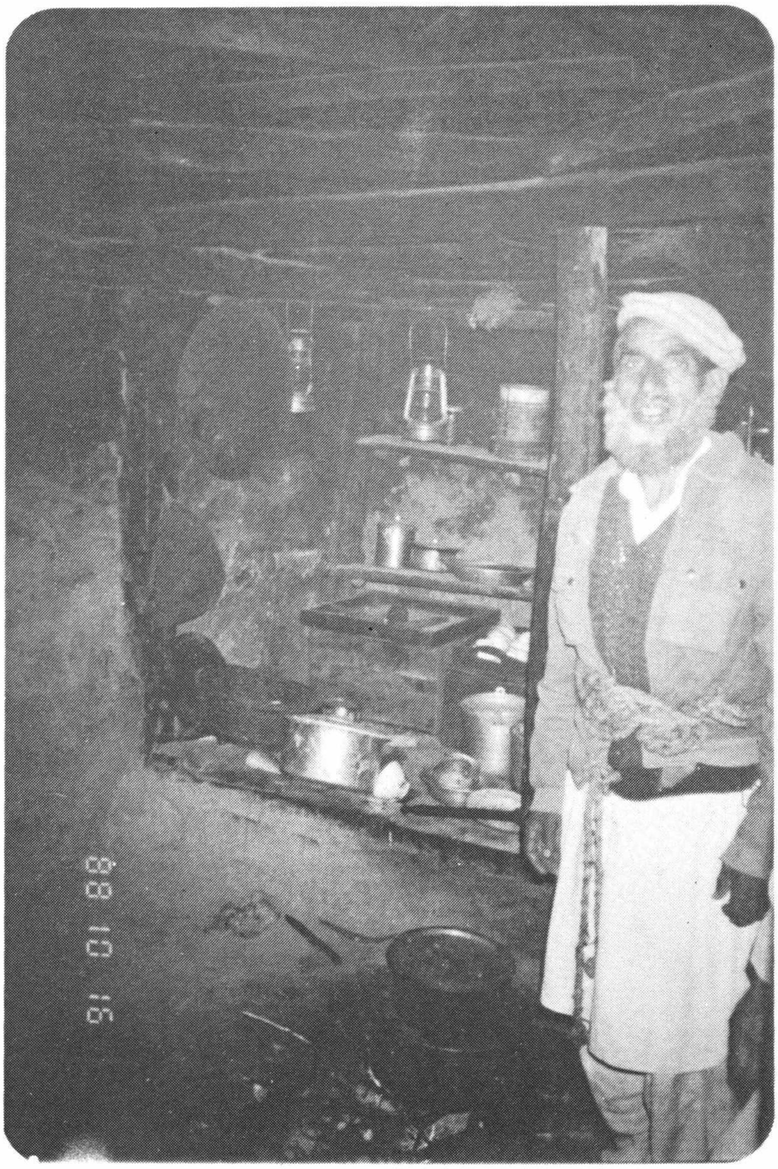



Site for power station Tangir.

14


The settlement of Luruk, Tangir. An irrigation channel is constructed in the hillside. The main channel from the river, however, cannot cater for the necessary amount of water for the whole area.

15

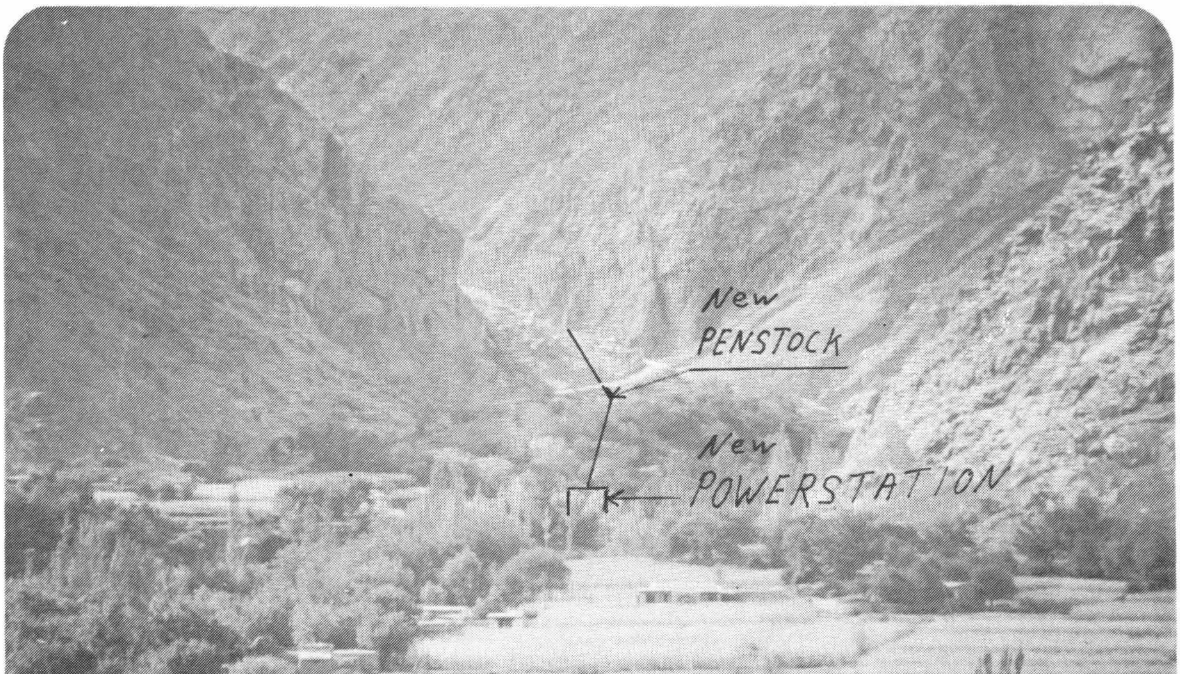



The interior of a traditional dwelling. Soot and smoke from lights and open fires are a major source of inconvenience

16

Nomal nullah downstream existing hydro-power intake.

17

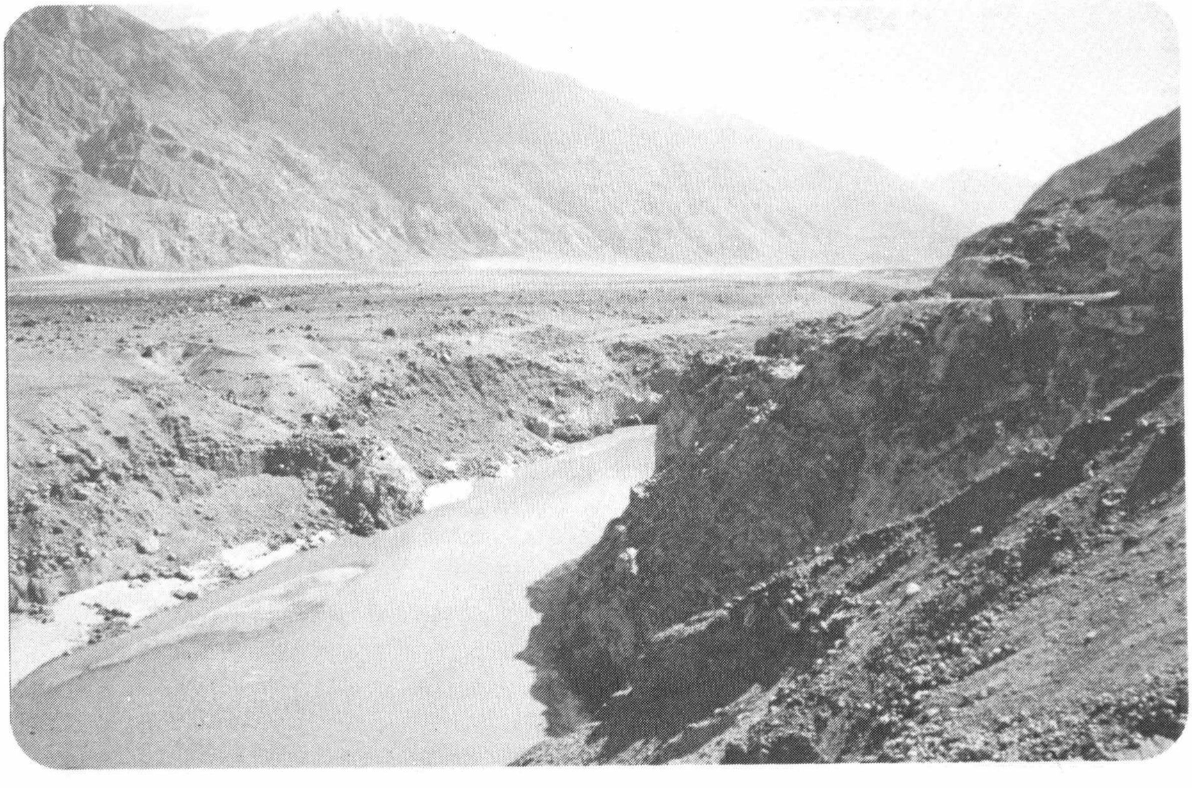



Nomal downstream site for the new power plant.

18

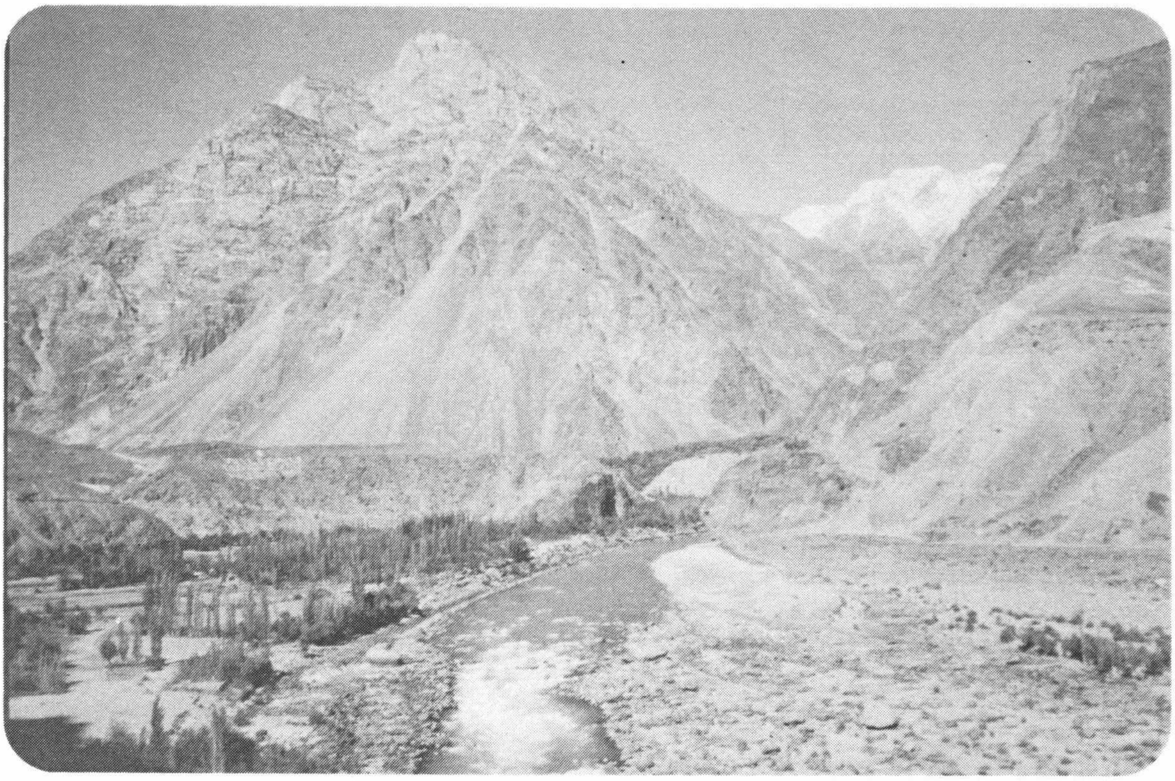
Parri multi purpose scheme. Sai Nullah before the confluence with Indus River.

19



Indus River downstream the confluence with Gilgit River.
View over possible land to be irrigated by the Parri scheme.

20

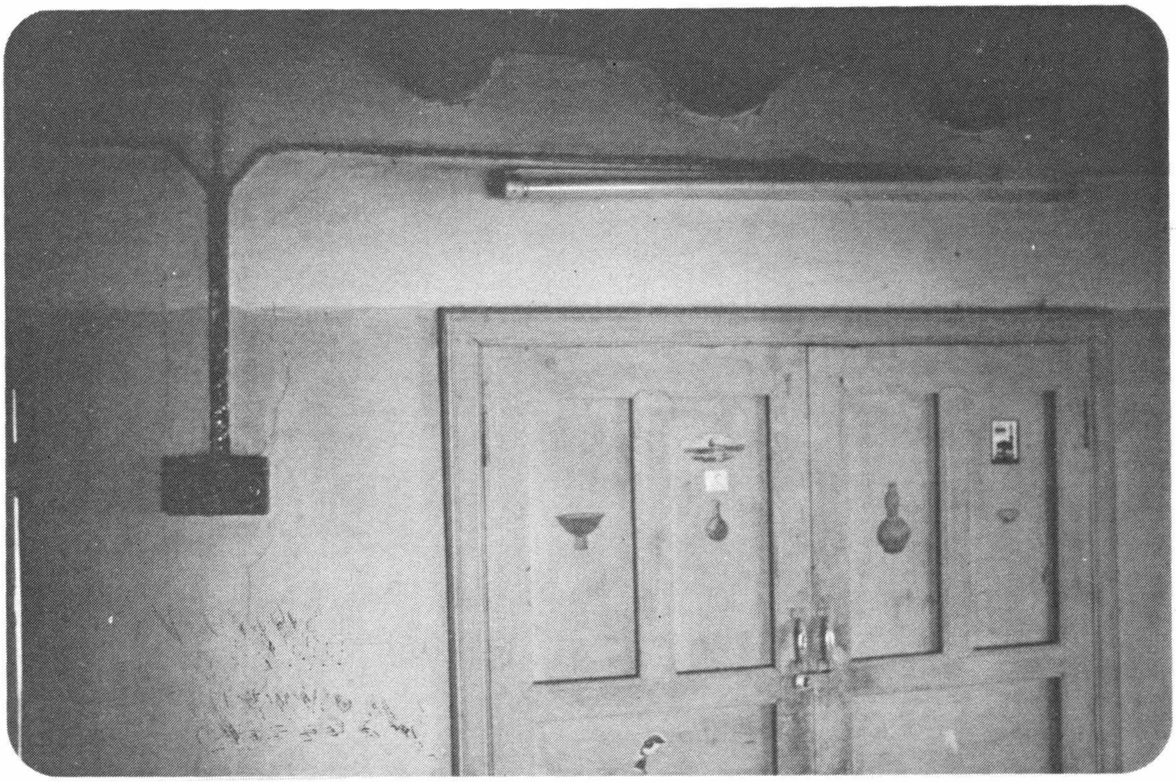


Intake site for another more promising medium scaled hydel scheme upstream Hanzal in Gilgit River.

21

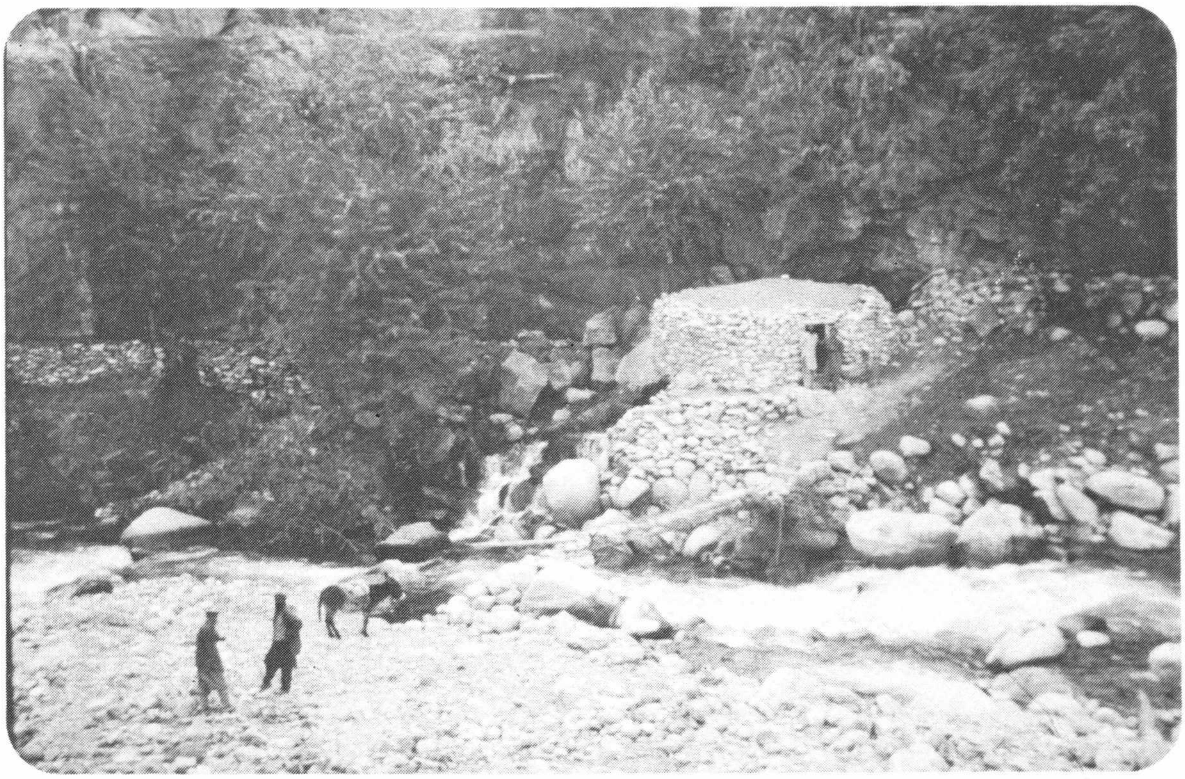
Intake site for medium scaled Hanzal low head hydel scheme. 6-10 MW. Gilgit River.

22



The available power is limited. For domestic use 100-500 W is available for each house. The power is used for illumination. The wirering is carried out by trained personell. The installation fee is 40 NOK, and the energy is available at 0.10 NOK/kWh.

23



Water is also used to operate flour mills.

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