Paper No.520

EXPERIENCES OF INSPECTION OF DAMS IN PAKISTAN

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SYNOPSIS

Pakistan has 47 dams which are considered to be large dams as defined by ICOLD (International Congress on Large Dams). Only 7 dams are being looked after according to International Requirements for Dam Safety as set by ICOLD and by Law in most of the developed countries and quite a few of under developed countries. There is increasing awareness for safety of dams, with old dams not designed/constructed according to developments in engineering of dam viz homogeneous dams with chimney filters, hydraulic fill dam. Inspection by a team of experts independent of O&M of the project has contributed largely to the continued safety of dams and reservoirs. Experiences of the inspection, have been described and illustrated with a view to point out the usefullness of this institution and share the knowledge gained, so that the same can be applied to the Project under design, construction and maintenance.

INTRODUCTION

Every dam which impounds water, presents a potential danger which should neither be under nor over estimated. The risk of sudden disaster is for ever inescapable, although knowledge and vigilence may reduce such a risk, it can never be entirely banished. Recent failure of 110 meter high Teton Dam in U.S.A., which was designed by U.S. Bureau of Reclamation (A pioneer in engineering of dams in the World and a prestigious organization), illustrates that disasters have overtaken dams which were built by those who were in their day acknowledged master of their Profession. Pakistan can ill afford loss of any of its dams and has some of the largest structures in the world, whose malfunctioning can cause significant economic loss to its economy and failure would be catastrophic. Most of the developed countries have enacted laws to regulate Safety of Dams and some of the non developed countries have followed the example. In Pakistan, promulgation of Dam & Reservoir Safety Laws have been under discussion since 1970. However WAPDA being owner of major dams, has setup Dams Monitoring Organization (DMO) since 1973, to look after its

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own dams. The safety of the dam is ensured by a three tier system with function as described hereafter:

TIER-I **Surveillance Staff at Site** who carry out observations of instrumentation and related data, its plotting and initial interpretation. Coordinate with routine inspection team of O&M staff at site. Study any abnormality reported and advise as necessary, investigations and timely actions.

Keep tier II informed by supplying all observed information.

TIER-II **Dam Monitoring Organization** which has large expertise covering the full spectrum of engineering of dams with function of:

Analysis and interpretation of all data observed as reported by Tier-I.

Study and advise on all problems however minor.

Assure continued safety by visits to site and be in close liaison.

Carry out annual inspections so as to assure that nothing has been missed.

Keep informed Tier-III and concerned including agencies of the Government of Pakistan about performance of dams and ancilliary structures.

TIER-III is the periodic inspections which are necessary according to the spirit of all safety laws, at intervals of five years or earlier if necessary. This function is also being looked after by DMO (Tier-II) for WAPDA dams till such time an institution is formed at Federal level.

ICOLD has defined a large dam, as any water impounding structure of more than 15 meter (50 ft) height above general stream level but also has included structures between 10 to 15 meters height but having difficult foundation or holding more than 50 Acre foot of stored water, have large spillway capacity. Pakistan suffered failure of Nari Bolan Dam in 1976 and the more recent incident of gate failure of Sukkur Barrage. It has therefore been proposed to include all barrages in the purview of proposed safety law which should be applicable to all water impounding structures above 6 meter height. Finland has in 1984 enacted law to ensure safety of dams as low as two meter height.

Pakistan has 15 large dams on the register of dams with ICOLD but has actually at the present 47 dams which are large dams according to definition by ICOLD. It is indeed alarming, that even after listening to news of disasters of dams elsewhere in the world (recently Kotmali dam Sri Lanka, Carsington dam U.K.), only dams owned by WAPDA are monitored for safety (6 WAPDA dams plus Simly Dam owned by C.D.A.) and subjected to Periodic Inspections. In 1986 Wali Tangi dam near Quetta, Baluchistan was almost near failure with its downstream shell washed off due to overtoping by a flood.

Experiences of inspection of dams in Pakistan are described and illustrated with a view to share the knowledge and experience gained, so as to act as a guidance for future inspections.

Inspection Procedures

Inspection of all major dams owned by WAPDA are being carried out periodically. The present schedule of inspections requires that any dam built is inspected a year after its construction. Subsequent two inspections are carried at two years interval. Further inspections are at 5 yearly interval, unless the condition of the structure requires an earlier inspection. The inspection report usually recommends the timing of the next inspection. In Pakistan, all first inspections have been carried out by the Designer viz Mangla in 1973 by Binnie & Partners; Tarbela Dam in 1986/87 by TAMS, Hub Dam and Khanpur Dam by M/S A.C.E. in 1985, 1986 and Simly Dam by WAPDA, (Being the Designer) in 1985. Terms of reference have been set out as under, however additional clauses are added for each inspection as considered appropriate according to the current state of health of the dam, its ancilliary structures and reservoir.

a) "Terms of Reference"

Inspection of the Project excluding Electrical and Mechanical installation relating to the Hydro-electric works in order to determine whether there are any deficiencies or potential deficiencies in the condition of Project structures, in the quality and adequacy of maintenance or in the method of operation which might endanger safety of the Project.

b) Review and comment on data relating but not limited to such matters as settlements, movements, seepages, leakages, crackages, hydrostatic pressures in structures, the foundation and abutments and function of foundation drains and wells.

Inspection Team

Inspection team is constituted keeping in view the state of health of the dam & the current problem/potential problems known on the basis of performance reports. Major causes of incidents with dam and ancilliary structures have been enumerated by ICOLD Exhibit 1,2,3, however, each dam has unique features and careful planning of the inspection is necessary. The team has to have a multi discipline expertise as well as generalists for the overall safety review of the Project. Even the generalists have limitations for such large structures as Mangla & Tarbela, so an expert board has been considered instead of the generalist member. More than one member in each discipline is necessary so as to have a continuous dialogue during the inspection of each feature and component of the project structures. The team constitution for different inspections have been

fortunate in having all the top level talent as can be judged from the inspection team proposal for Mangla Exhibit-4. A look at the team constitution would reveal that the problems of the structures were carefully thought/studied/recorded. These are:

i) Mangla was redesigned during construction when shear zones were found in almost all the clay strata on excavation. Shear strength of clays used in design was residual strength. Later Kalabagh foundation bedrocks have been investigated for design. These are also of Siwalik origin and about the same age as Mangla however residual strengths have been found to be much lower. It has to be seen how this situation will affect the safety of structures at Mangla.

(ii) Design of structures for earthquake loading was not so developed at time of Mangla construction. Also higher seismic acceleration may be experienced. Review of the same has been left to the proposed team for IV-inspection of Mangla, as information on design of Kalabagh structures under similar loading is now available.

iii) Mangla may not be raised in the fore-seeable future and it is necessary to find ways and means of sluicing of sediments so as to prolong the life of reservoir and avoid delta to approach and obstract the confluence of Jhelum with Kanshi & Poonch Pockets of reservoir.

iv) Project behaviour has been satisfactory without incident so far and it is all the more necessary to have a detailed comprehensive physical inspection after 5 years.

v) The safety of the project is the 'Keyword' for the inspection team however such relative subjects as sedimentation of reservoirs, environmental aspects of reservoir are also examined. Lately "Safety of the Project" has also included, a review of the budgeting, staff and preparedness for emergencies.

Conduction of Inspection

Know the Structure

It is very important to know the structure before you can talk about it, especially its problems and evaluation of its performance. A list of all available reports including design reports, completion reports, performance reports is compiled and circulated to team members, so that they are prepared for the job by referring to any reports which concern their assignment during inspection. Complete set of record is made available at site and at DMO to give a proper tempo to the inspection, a pre-inspection visit has become a feature to familiarize the members of the team with the project and its current state of health, problems and potential problems with any componant structure of the project. It also sets the ball rolling for inspection and starts the thinking process for the members of the team. Earlier several site visits are made to make arrangements for the

inspection. Arrangements include not only such requirements as reference markers along crest and toe of dams to facilitate inspectors but also re-observation and updating of surface survey movement control network, instrumentation data on pore-pressures, seepages, leakages, deformations, crackages, operation of reservoir, sediment distribution within reservoir, degradation downstream of structures and in the river, it has to be seen and decided which componants of structure will be available for physical inspection and whether dewatering and cleaning is required. Inspection of wells by C.C.T.V. borehole camera and underwater inspection by diving of features likely to remain submerged, may be required. Detailed discussions are also held with site organization on performance of the Project and any particular feature requiring attention of the inspection team.

Each group carries out inspection as entrusted to them by team leader and submits daily reports. These reports are reviewed and discussion held including intergroup discussions where interest overlaps. Principal findings are discussed with site organization on the last day of inspection and points requiring immediate attention are brought to their notice. Within two weeks the principal findings and recommendations are circulated to concerned in the form of a report. Group reports are compiled by each group and submitted as a report. Usually it is necessary to have meeting of the inspection team to thrash out any controversy. Compilation and printing of report of inspection is entrusted to selected members from the inspection team.

Experiences of Inspection

What is important for the inspection, how to achieve the objectives of the inspection and not to miss any feature, is highlighted.

(i) Eyes of the Inspector

How the inspector reacts to what he sees, is important and is illustrated by examples:

Mangla intake embankment has a system of drainage wells-Exhibit-5. During inspection, it was found that seepage was occuring downstream of the line of wells, which meant that drainage wells are inadequate.

Warsak Dam spillway-Exhibit-6 was being eroded by heavy sand loaded flows, during the high flow session from April to September. Every body was looking at the exposed face of dam showing minor attrition action, however under-water photography and subsequent inspection by diver, dramatically revealed that stilling basin horizontal floor had lost most of its steel which was not washed down but was churning within the basin, causing accelerated erosion.

Sukian riprap was damaged over considerable length between chainage 335-342. Beaching had occured which was revealed dramatically as the routine inspection team thought it to be normal construction profile-Exhibit-7.

(ii) **Use Your Ears - Even Feet/Hand**

During inspection of Sukian Dam Chainage 190-195,Exhibit-7, noises of water falling was noticed. Development of seepage from foundation sandstone was located and treated.

Even feet/hand can detect irregularities. Walking on compacted filter gave the feeling of over compaction. Grading tests showed that rejected material with too much fines had been put which felt harder. The filter criteria not only requires prevention of migration but also enough capacity to pass the seepages and not to hold, to have undesirable hydrostatic pressure in the fill protected. Several thousand Cu.Ft. of filters had to be removed.

Consistency of concrete, soil moisture, clay fraction of soil can be easily judged by an experienced inspector sufficiently accurately for construction control.

iii) **Sometimes you are scared.**

It is important not to be scared and also not to cause sensation before careful thinking and discussions. If the problem requires prompt action, it should be immediately brought to the notice of concerned site staff. Readings of instruments sometimes causes scare, however immediate action is to inspect the site to find out any collaborating signs of malfunction supporting the instrument readings. Some time, the instrument observation reveals their limitation.

Tarbela Dam Auxiliary Dam-I developed a sinkhole through its core-Exhibit-8. The downstream inclinometer casings showed continued rise even at depleting reservoir levels. It seemed a case of piping to foundations, with increasing leakages which were being recorded as increasing water levels under downstream shoulder. It was thought that reservoir be lowered immediately to stop this continuous rise. By the time a decision could be taken, further rise stopped. It took more than a year to understand the ambiguity of observation of water table in open-jointed inclinometer casings.

(iv) **Look at Data Carefully**

It may be noted that instrument installation are done at location which are likely to show abnormalities if any. Piezometers across a grout curtain show its effect in lowering the pressure downstream of the curtain.

A careful appraisal of data often points out, ambiguities/malfunctioning/potential problems. Piezometers downstream of water supply tunnel of Simly Dam, Exhibit-9 showed higher

pressures than possible according to the position of the piezometers. This showed that possibly the tunnel lining was not satisfactory and leakages were occuring. Dye test was not recommended as water is used for drinking and brine test was done for confirmation.

(v) You cannot play with a Major Structure

While inspecting and evaluating safety of a dam, keep in mind its importance viz-a-viz, damages likely downstream. Mangla Main Embankment-Exhibit-10 developed very minor boiling at toe. Much severer boiling was taking place downstream of Sukian but was only being kept under watch, however boiling for main dam was recommended to be treated immediately, although this was not necessary.

(vi) Do not make Recommendation which are too Costly.

Keep the factor of cost in mind and do not be liberal in your recommendation. A typical case is the thickness of various layers of filters for treating an area subject to boiling/large seepages. A foot of additional filter would cost several lacs of rupees in some cases.

(vii) Think long term

The time of inspection of a dam, is not only the time to review all its problems/likely problems/carry out a thorough and comprehensive physical inspection but is the time to think of its longterm behaviour/performance and utility. Sedimentation of Mangla and Tarbela are longterm problems. How to increase the life of these reservoirs is a longterm problem. Another aspect is its longterm behaviour vis-a-vis monitoring instrumentation available and functioning at a future date.

(viii) Investigations are top priority Recommendation

Recommendations following an inspection, are usually in the form of remedial measures to various features requiring treatment. However some recommendations are suggestions, how to investigate/to provide more information on some problem, before safety of the project can be assured and recommendation for remedial measures can be made. You cannot budget for all the recommendations/measures in the year following the inspection and these have to be phased. Obviously the immediate safety hazards are the top priority items to be treated, however investigation required should also be in the list of items in the top-priority as these may reveal

potential hazards.

(ix) Sometime You cannot solve a Problem

This is a situation which has to be faced sometimes. Some problems take years to resolve, viz Khanpur Dam - Turbidity of flows from wells provided at toe of the Dam-Exhibit-11, Wells discharged mud which amounted to over 50,000 cft in 1986 at reservoir level of 1928 S.P.D. (Conservation level is 1982). The material needed to process and produce this amount of fines would be of the order of 2,50,000 cft. However there is no physical damage to Main Embankment Dam. Several hypothesis have been formed and are still being investigated.

(x) Nothing is un-important.

This is well said, rather than actually practised. Very minor boils are not considered important. Boiling, however insignificantly minor reveals, that there is residual pressure at the point of boiling.

Minor leakage was noticed through core wall of Wali Tangi Dam, Quetta. Exhibit-12. This was ignored, however it actually means that the core wall of concrete is cracked and hence structurally unsafe. It was recommended to be supported by a butteress.

(xi) Even silly questions are welcome

Any question asked, starts the process of thinking. Even a silly question requires explanation to refute. Thinking is the key to solution of any problem.

(xii) Collection of Experts at Site.

It is known that concentrated thinking accounts for 80% of the solution of problems. Gathering of expertise at a dam is like focussing all the energies towards safety problems of the dam and structures. It usually happens why this was not thought before, why it did not occur. During 1986 inspection of Khanpur Dam, omission in detail for the upstream previous zone was pointed. Amendment of original section of main embankment for achieving acceptable safety factors against siesmic loading, resulted in placing the previous shell in direct contact of foundation rock. Consequently reservoir water would enter the left abutment limestone at a greater head as no blanket was placed in this pocket. Remedial action was proposed on observational approach.

Lessons & Conclusions

Inspections provide an opportunity to gether expertise at site which is not possible otherwise. Problems at the project are resolved and continued health of the project structures is ensured. It may not be possible to completely resolve, some of the problems however there is better understanding and by further investigation, solutions are usually possible. Inspection provide the project a thorough review and it is not embarassing to the project if omission in O&M of the project are revealed.

There is no doubt that the team should have the best talent available. Independent members have proved invaluable. As many disciplines as required by project condition should be included, with more than one person on each subject, so as to have dialogue on each feature/problem of the project structures.

Inspection of all dams and barrages in Pakistan should be made compulsory by law or executive order as elsewhere in the world. Continuous satisfactory performance as reported by site organization should not be taken as all is well. Dam not owned/designed/constructed by WAPDA/established consultants in dam engineering/built long time ago when this branch of engineering depended on empirical approach to design, need an early inspection so as to provide review of their safety

EXHIBIT - I

DAM INCIDENTS

THE DISTRIBUTION OF INCIDENTS OF DAMS OF DIFFERENT TYPES AND WITH DIFFERENT FOUNDATIONS IS AS FOLLOWS

	Number of incidents						
	A	B	G	E	R	M	Total
	Arch	Buttress	Gravity	EarthFill	Rockfill	Misc.	
Earth Foundation							
Failures		3	8	39	6	3	59
Accidents		1		82	1		84
Rock Foundation							
Failures	7	4	21	35	6	8	81
Accidents	11	5	14	65	8		103
No information about Foundation	3	3	23	101	6	3	139
Total	21	16	66	322	27	14	466

THE DISTRIBUTION OF INCIDENTS TO DAM - TYPES AND VARIOUS HEIGHTS IS AS FOLLOWS

Height (m)	Number of incidents						
	A	B	G	E	R	M	Total
5 – 15			21	59	4	9	93
15 – 30	5	8	22	168	11	4	218
30 – 50	9	6	14	73	7	1	110
50 – 100	6	2	7	17	5		37
More then 100	1		2				3
No information				5			5
Total	21	16	66	322	27	14	466

EXHIBIT-2

STATICS OF FAILURES OF DAMS

DAM	Country	Year of Disaster	Lives Lost
Otov	Brazil	1960	Unknown
Ponsher-Khadakwasla	India	1961	Unknown
Kuala Lumpur	Malaya	1961	600
HYokiri	South Korea	1961	250
Babii Yar	USSR	1961	145
Vaiont	Italy	1963	2600
Quebrada la Chapa	Colombia	1963	250
Baldwin Hills	USA	1963	5
Sempor	Indonesia	1967	200
Nanaksagar	India	1967	100
Frias	Argentina	1970	42 +
Buffalo Creek	USA	1972	125
Bolan	Pakistan	1976	24 +
Teton	USA	1976	11

EXHIBIT - 3

DAM INCIDENTS

Location of occurrence or cause	Visible sign of the occurrence	Cause The visible occurrence is probably due to inadequacy in the following aspects	Lesson Errors in one or more of the following activities can be concluded from the cause
Foundation Dam ; main Other dams Spillway Channel Tunnel Ancillary works Reservoir	Displacement settlement heaving horizontal movement Other deformations Slide cracking breakage Water action (excl. flow discharge) wave action surface erosion leakage internal erosion internal water pressure (incl. uplift) boiling Flow discharge blocking of water discharge inoperable gate flowing or falling water action overtopping blowout Deterioration of steel concrete rock or earth	Stability concerning overturning sliding strength deformation total or differential Durability concerning internal water-action surface water action weathering deterioration Function concerning flow discharge free board water level variation total leakage ; economic ally acceptable Other conditions earth quake resistance	Site-exploration and field test Investigation and choice of material Planning, layout and hydrology Design and structural Construction Measurement and instrumentation Operation Maintenance and supervision

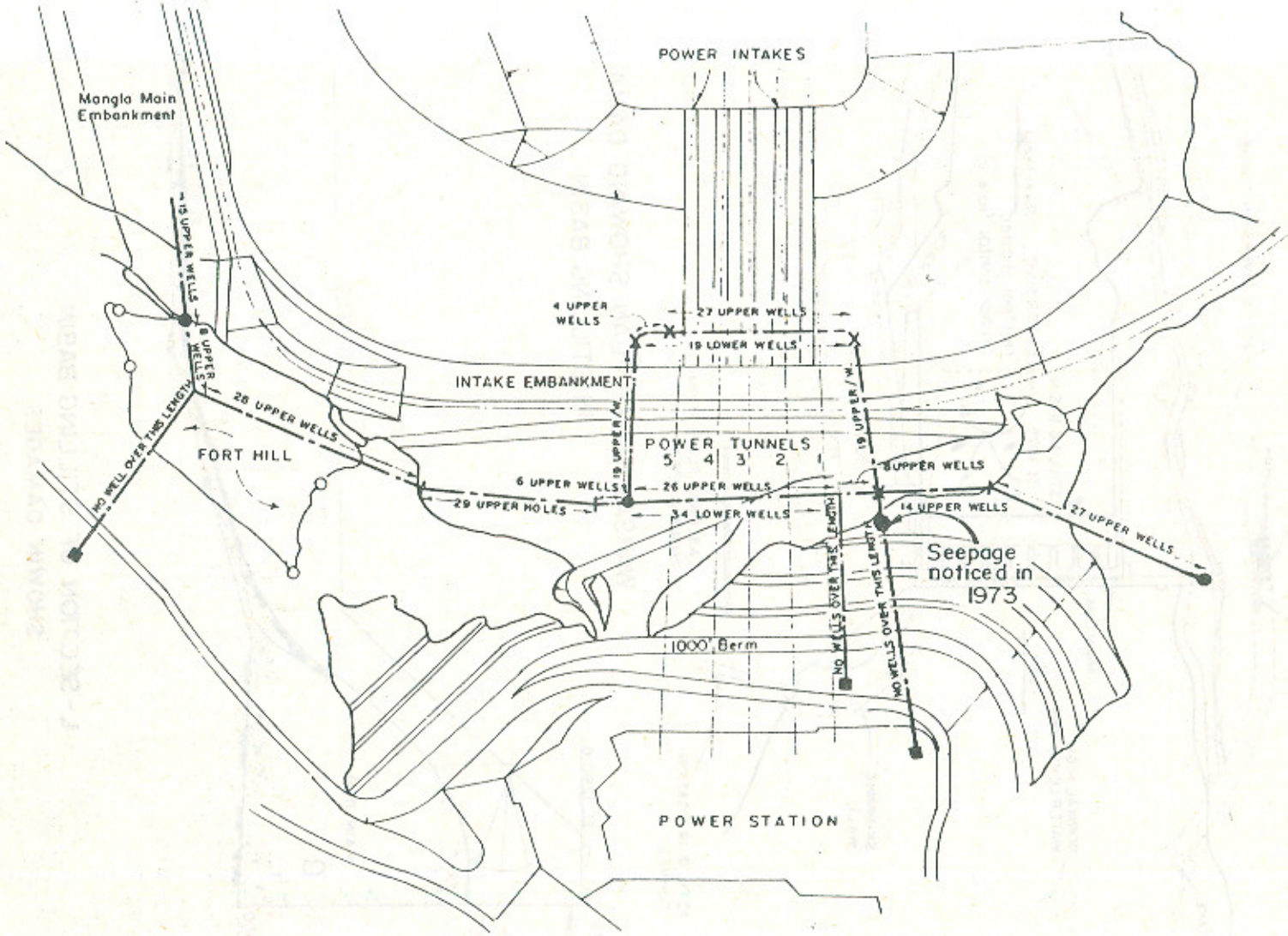
EXHIBIT-4

MANGLA DAM - 4TH PERIODIC INSPECTION OCTOBER, 1988

INSPECTION TEAM

Team Leader.	M. I. Chishti	45 days
Experts Boards	Asghar Ali Abidi	15 days
	Fayyaz Ahmad	15 days
	Aslam Rashid	15 days
	H. D. Bangash	15 days
	Altaf-ur-Rehman	15 days

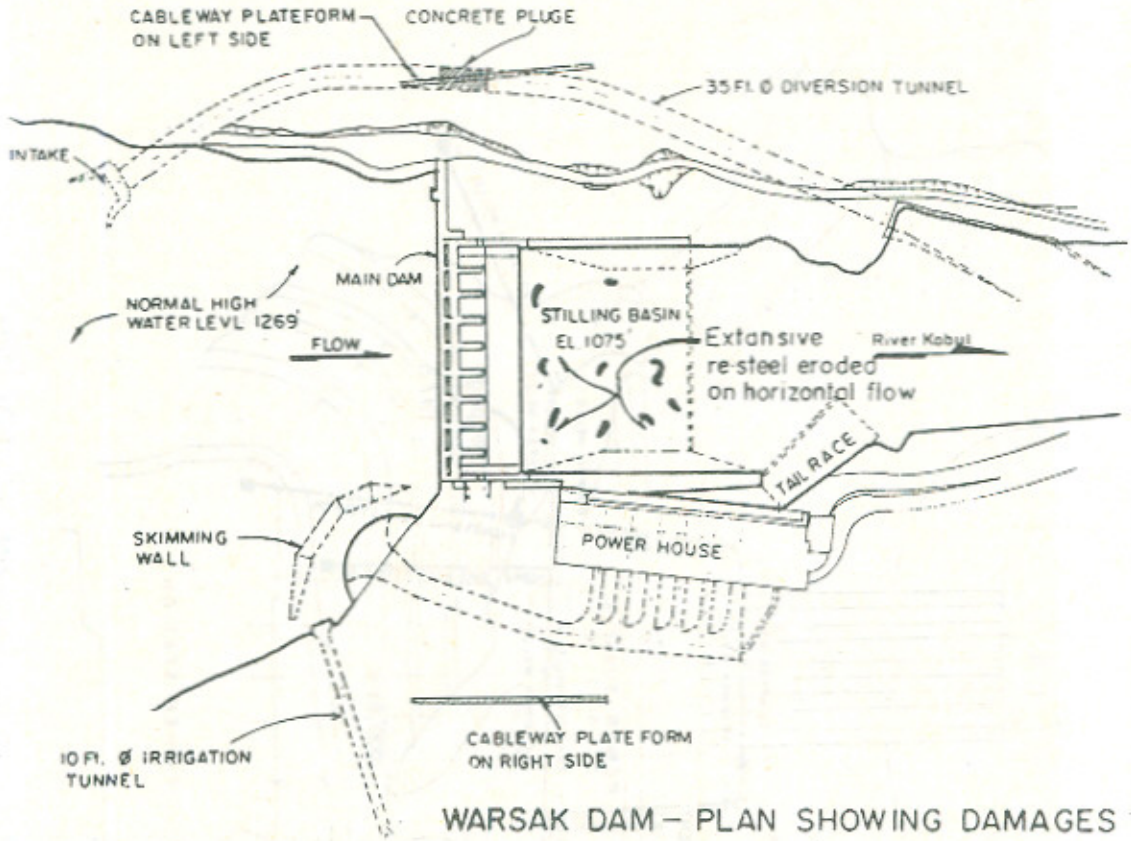
	WAPDA	NESPAK / ACE	
Siesmic Re-Design		Jamil Hasan	15 days
Shear Strength stability of Slopes Reservoir Rim stability.	Arshad	Arif Ejaz Javaid Akhtar	20 "
Sedimentation, Sediment Sluicing Hydrology.	Dr. Younus K. F. Sheikh	Dr. Ashraf Akhtar	15 " 15 "
Geology, Siesmic Risk Factors Report Compilation.	Baqir Hassan	Mansoor Ahmad	55 "
PHYSICAL INSPECTION			
Embankments	Dr. Izharul Haq	Dr. Arif Ejaz	45 "
Hydraulic Structures Concrete.	Mumtaz / Mushtaq	S.M. Zafar	45 "
Rim Seepages	Masud / Anzarul Hossain	Naqib	30 "
Instrumentation	Qazi M. Ishaq	—	
Geotechnical	Bhatti / Jawed Ahmad	Khalid / Mansur	15 "
Survey	S.M. Tariq	Waheed Mir	15 "
Mechanical	Ashraf Akbar / Zubair	R.U. Sheikh	15 "
Electrical	Anwar Zai	—	
Watershed	Jaleel Qureshi	—	
Environmental	Rashid Ali Salaam Ansari		10 " 10 "



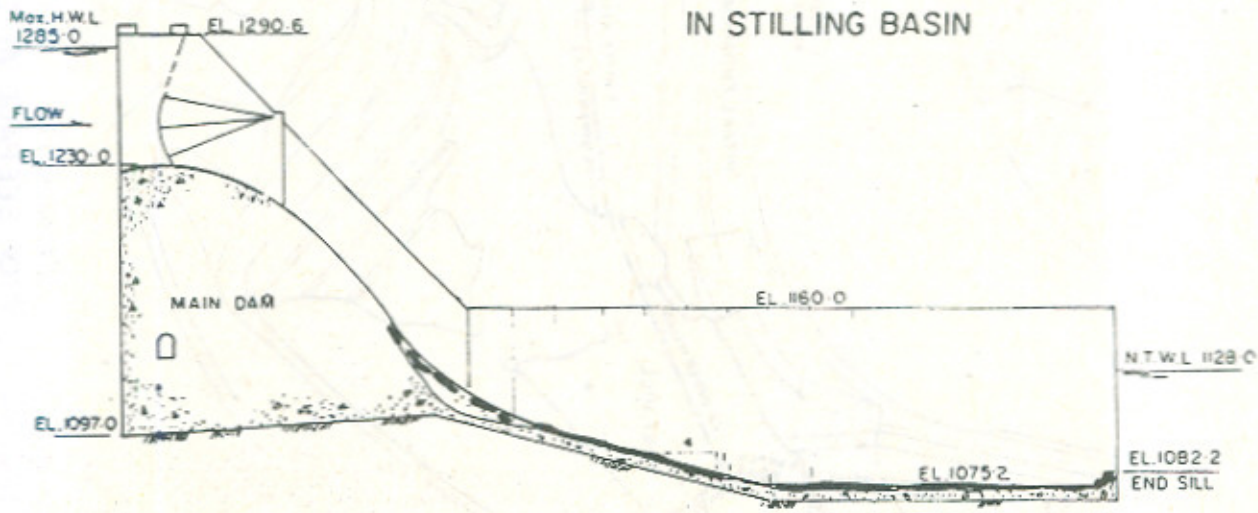
INTAKE EMBANKMENT - PLAN SHOWIN THE POSITION OF SEEPAGE AT THE DOWNSTREAM LINE OF WELLS

EXHIBIT - 5

EXHIBIT – 6



WARSAK DAM – PLAN SHOWING DAMAGES IN STILLING BASIN



L-SECTION OF STILLING BASIN
SHOWIN DAMAGES

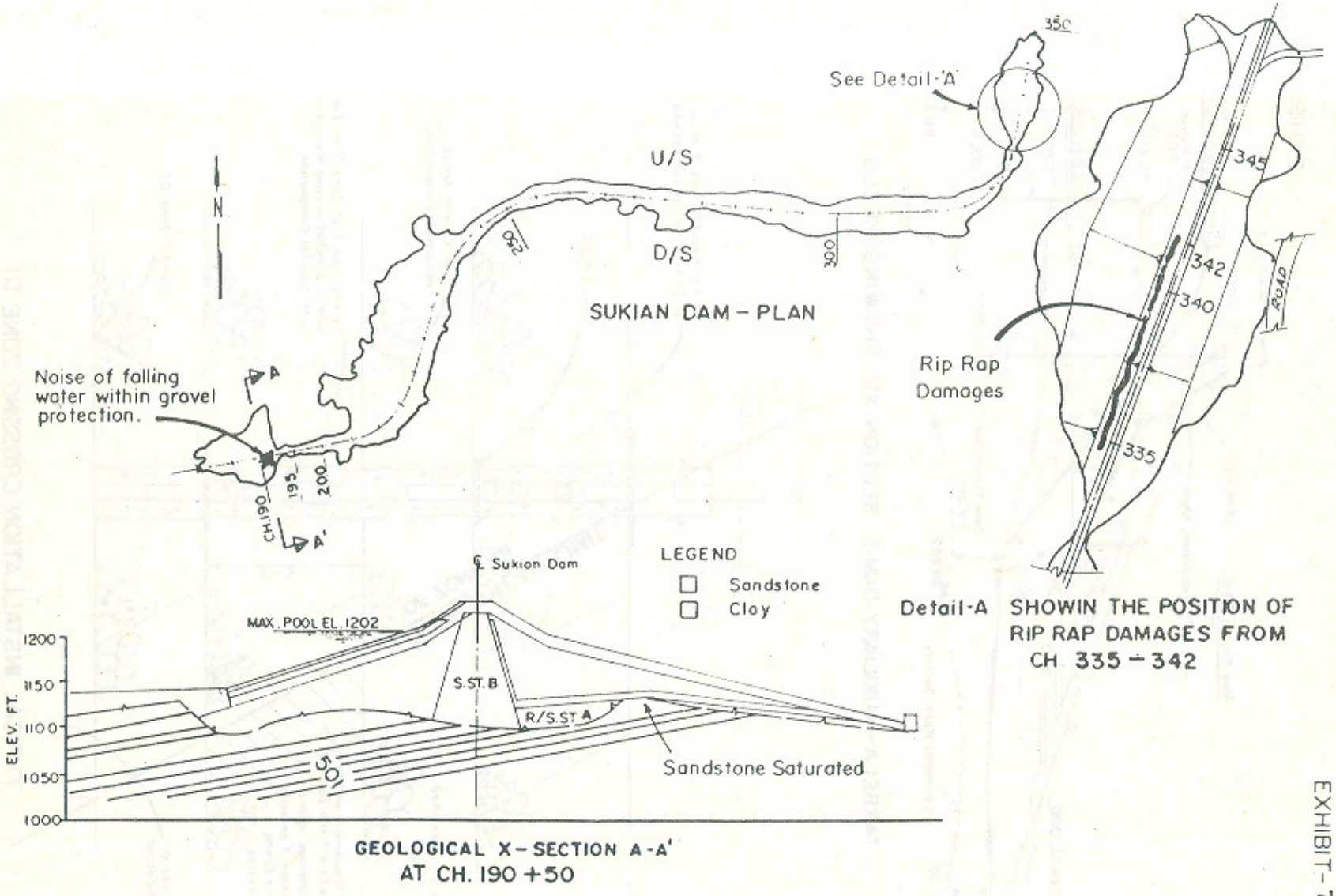
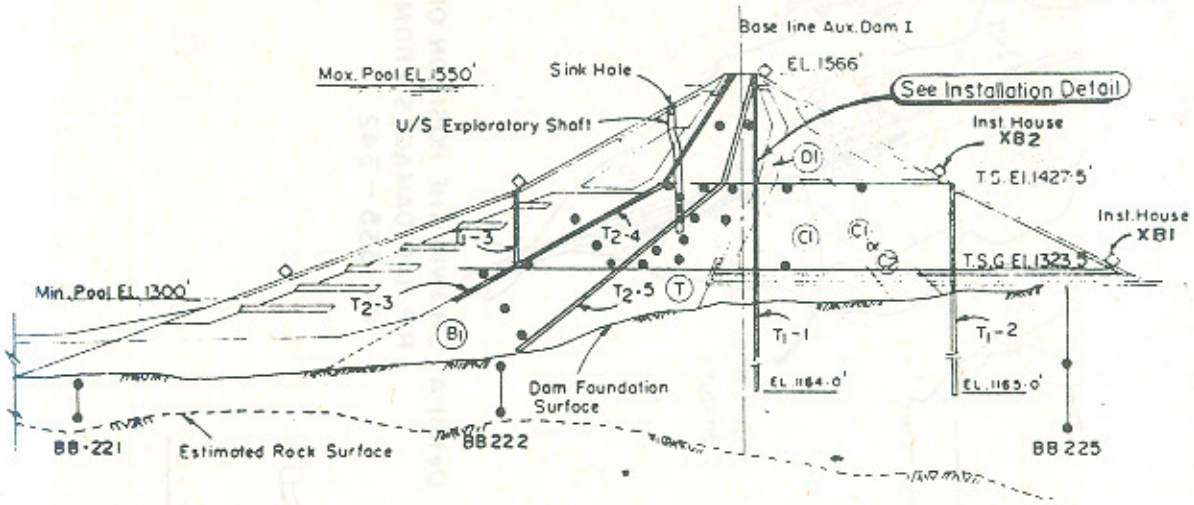
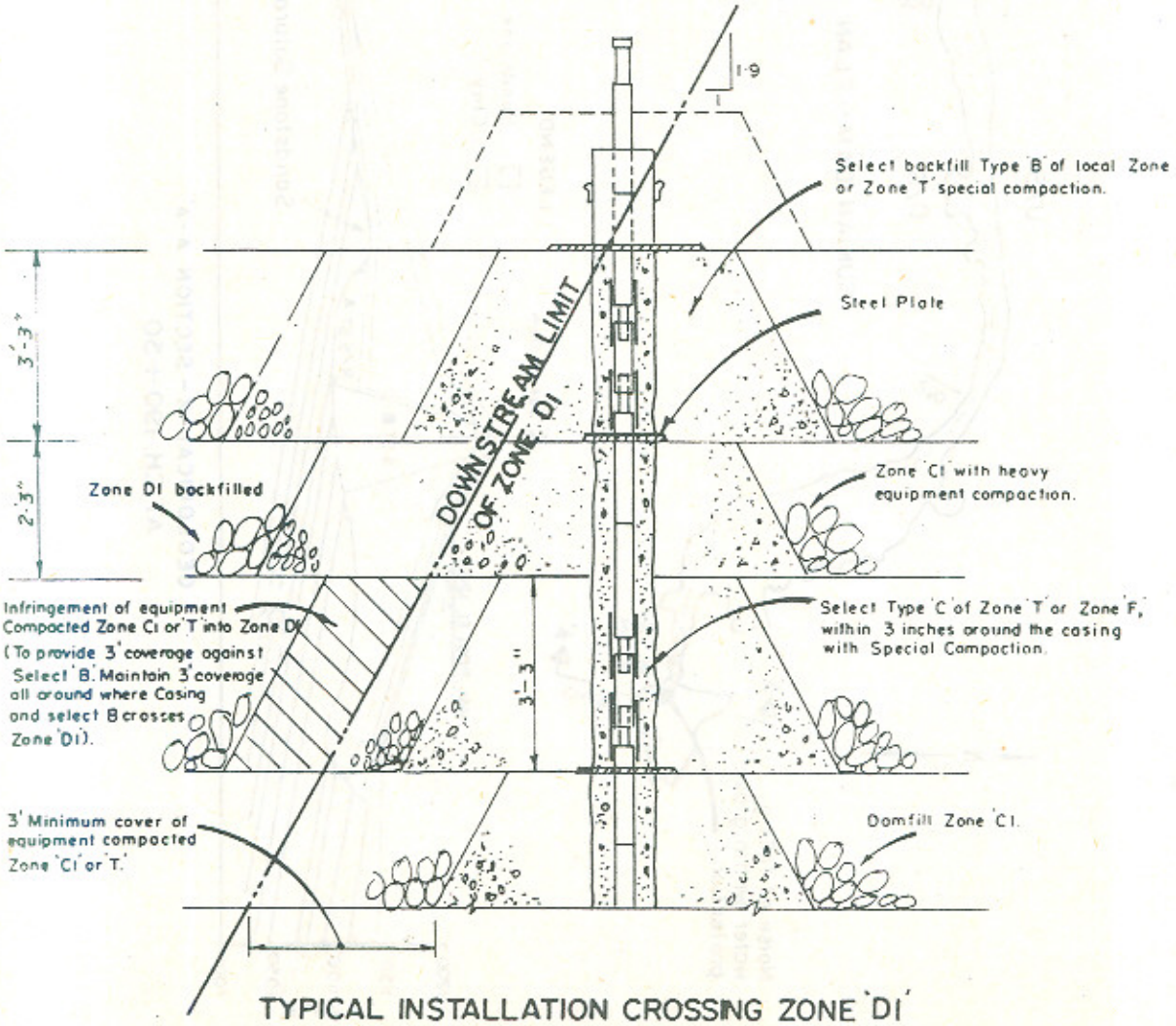

See Detail-'A'
U/S
D/S
N
SUKIAN DAM – PLAN
Noise of falling water within gravel protection.
A
A'
CH.190
195
200
250
300
350
Rip Rap Damages
345
342
340
335
ROAD
Detail-A SHOWIN THE POSITION OF RIP RAP DAMAGES FROM CH 335 – 342
℄ Sukian Dam
LEGEND
Sandstone
Clay
MAX. POOL EL. 1202
S.ST.B
R/S.ST.A
Sandstone Saturated
ELEV. FT.
1200
1150
1100
1050
1000
GEOLOGICAL X – SECTION A-A'
AT CH. 190 +50

EXHIBIT-7

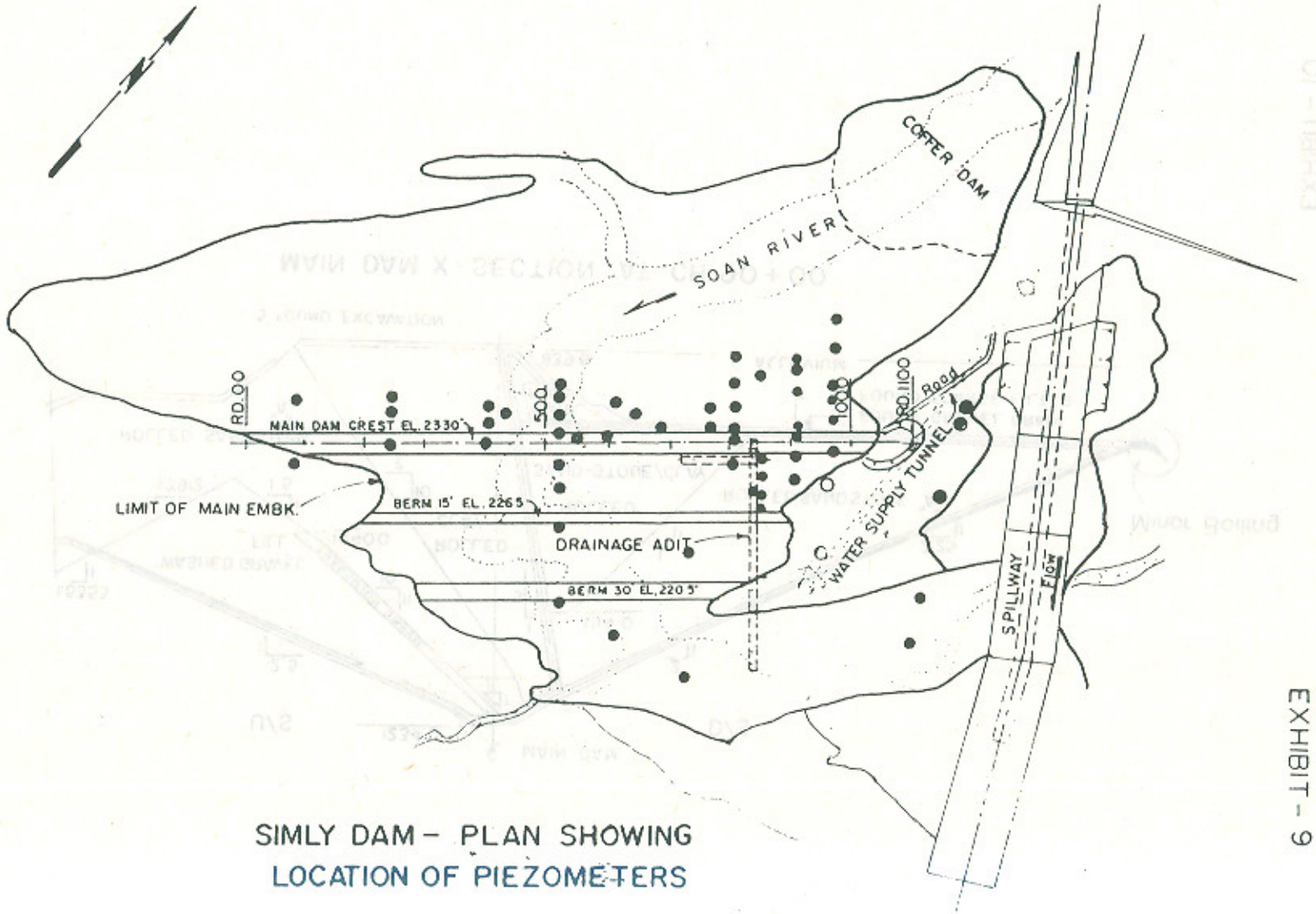
EXHIBIT – 8



TARBELA – AUXILIARY DAM-I SECTION-XB SHOWING PIEZOS.

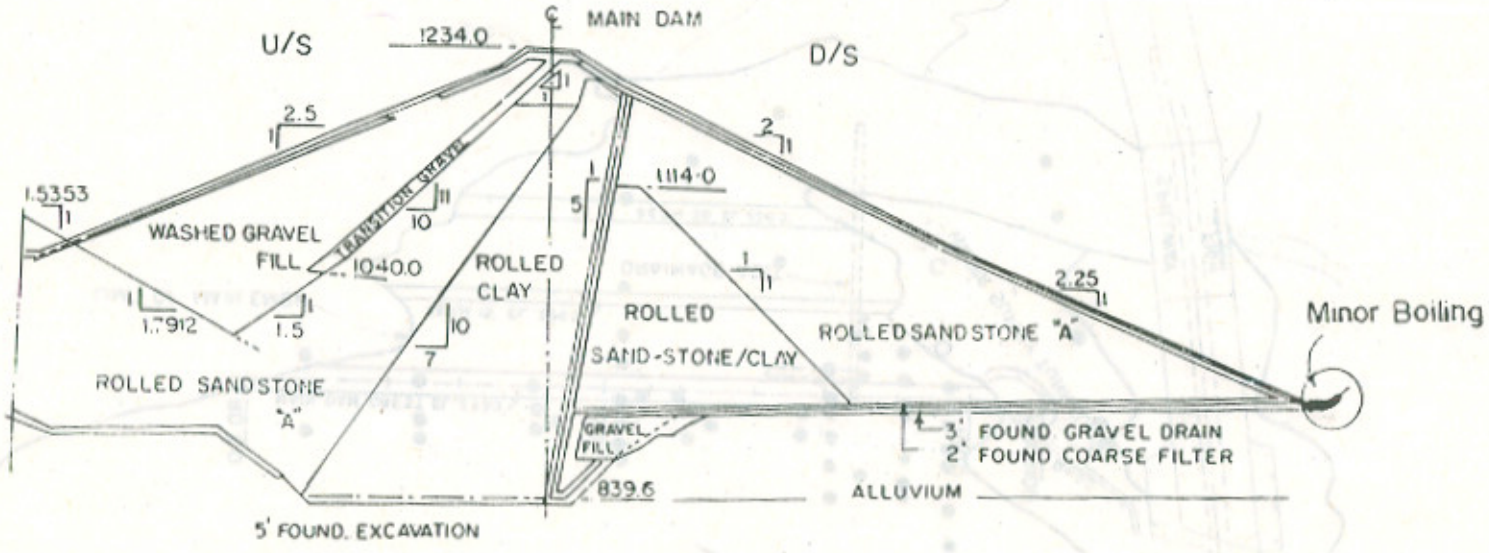


TYPICAL INSTALLATION CROSSING ZONE 'DI'



SIMLY DAM – PLAN SHOWING
LOCATION OF PIEZOMETERS

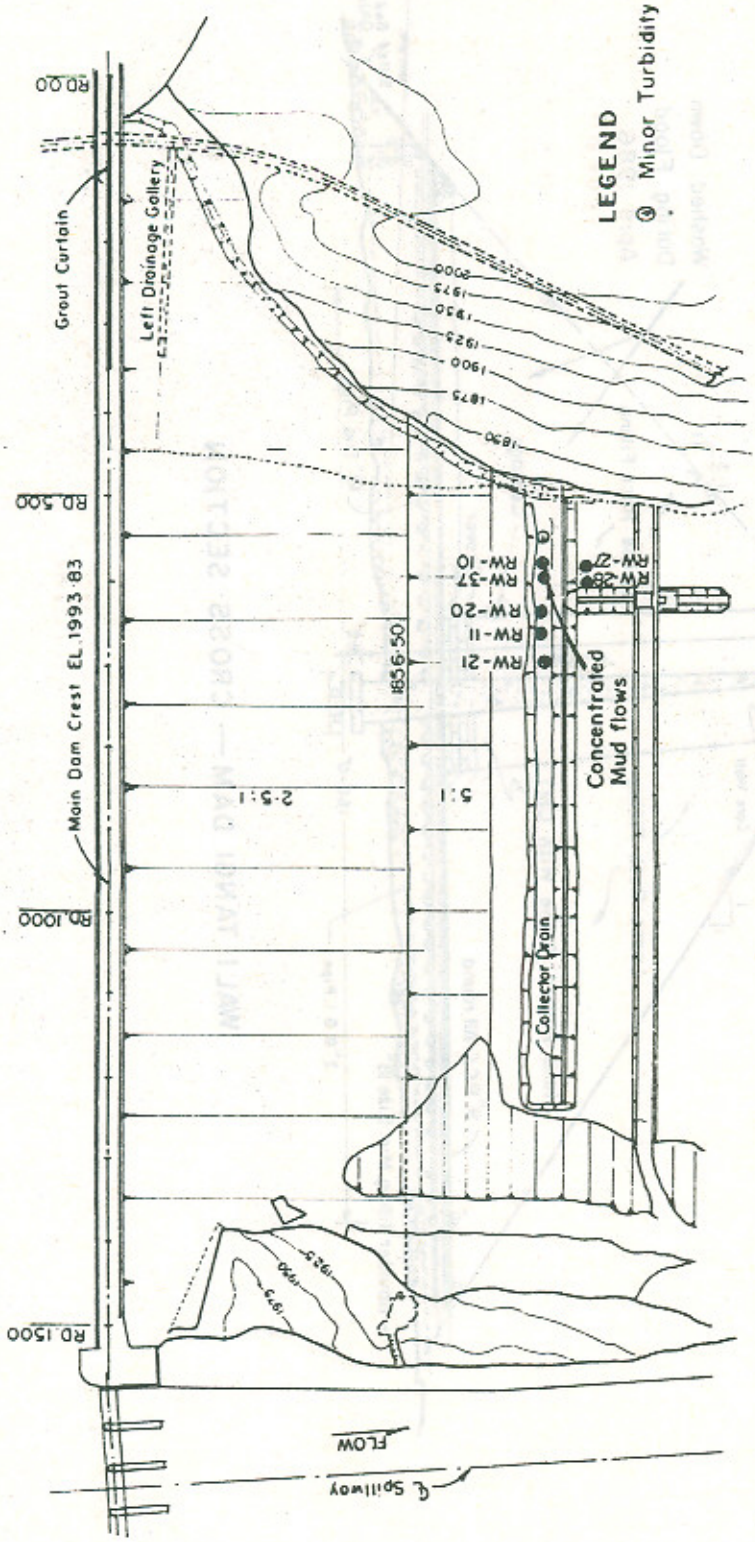
EXHIBIT - 9



MAIN DAM X-SECTION AT CH. 90+00

EXHIBIT-10

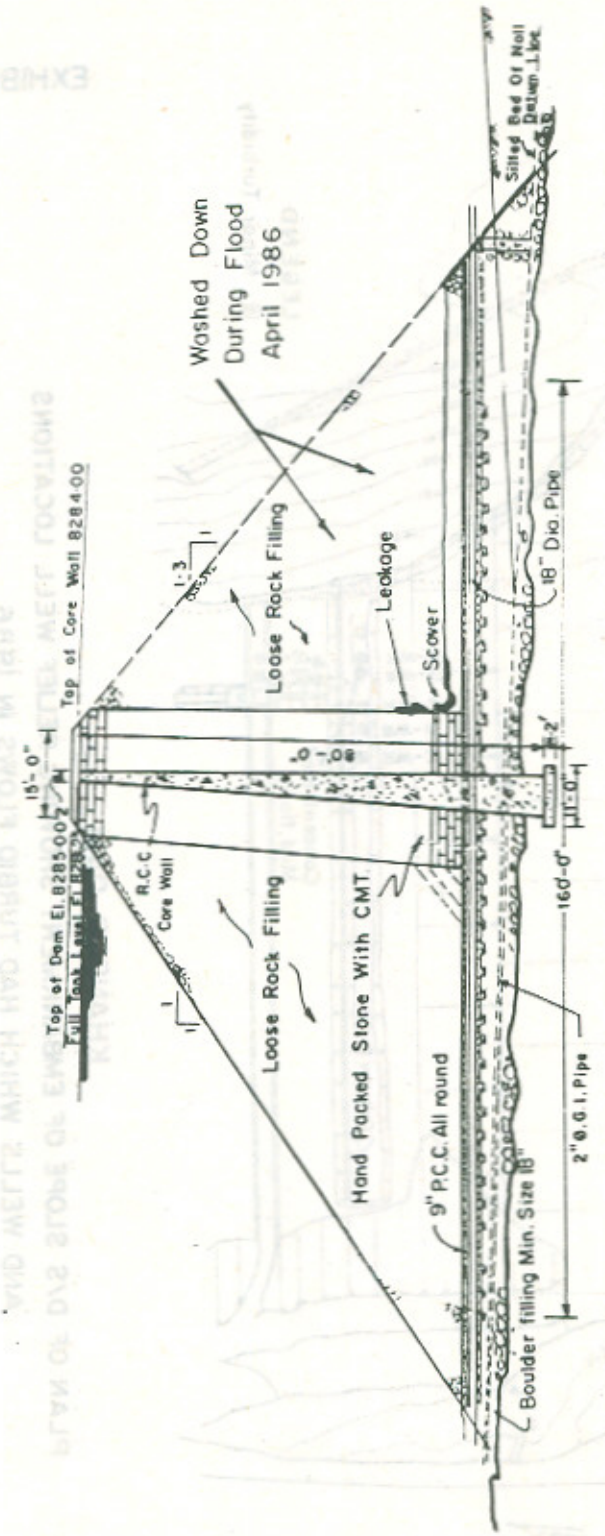
EXHIBIT - II



KHANPUR DAM

PLAN OF D/S SLOPE OF EMBANKMENT SHOWING RELIEF WELL LOCATIONS AND WELLS WHICH HAD TURBID FLOWS IN 1986

EXHIBIT - 12



WALI TANGI DAM — CROSS SECTION

LIST OF PUBLICATIONS ON DAM SAFETY

1. Safety of Dams Operation
   ICOLD - Conclusions of the session on question 52.
2. Dam Engineering and Dam Safety Capabilities in Dam Engineering Snow Mountains Engineering Corporation.
3. Recommended guidelines for safety inspection of Dams U.S. Army Corps of Engineers.
4. Dams, Their Safety and the General Public ICOLD.
5. The Evaluation of Dam Safety - ASCE 1976.
6. Dams and Public Safety
   A Water Resources Technical Publication
7. Dam Safety Guidelines
   ICOLD Bulletin No. 59, Paris 1987.
8. Safety of small Dams
   Engineering Foundation Conference Procedings ASCE.
9. Safety of Dams
   Proceedings of the International Conference on Safety of Dams, April 1984.
10. Automated Observation for the Safety Control of Dams ICOLD 1982, Bulletin 41.
11. Inspection of Dams
    Following Earthquake Guidelines ICOLD 1988, Bulletin 62.
12. Dam Monitoring General Considerations ICOLD 1988, Bulletin 60.
13. Safety of Existing Dams
    Evaluation and Improvement National Academy Press
14. A Private Owners Perspective of Dam Safety U.S. Committee on Large Dams.
15. Dam Safety and Rehabilitation
    Fourth Annual U.S. COLD Lecture.
16. Dam Safety Hazard Classification Guidelines U.S.B.R.
17. SEED - Safety Evaluation of Existing Dams ICOLD