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HIDRAULICOS (INDRHI)

UNIVERSIDAD DEL
ESTADO DE COLORADO
(CSU)

ESTUDIOS SOBRE LA OPERACION Y SEGURIDAD DEL SISTEMA DE EMBALSES DE VALDESIA

SECOND TECHNICAL REPORT [1/]

VOLUME IV

INSPECTION, MAINTENANCE AND SAFETY STUDIES

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June
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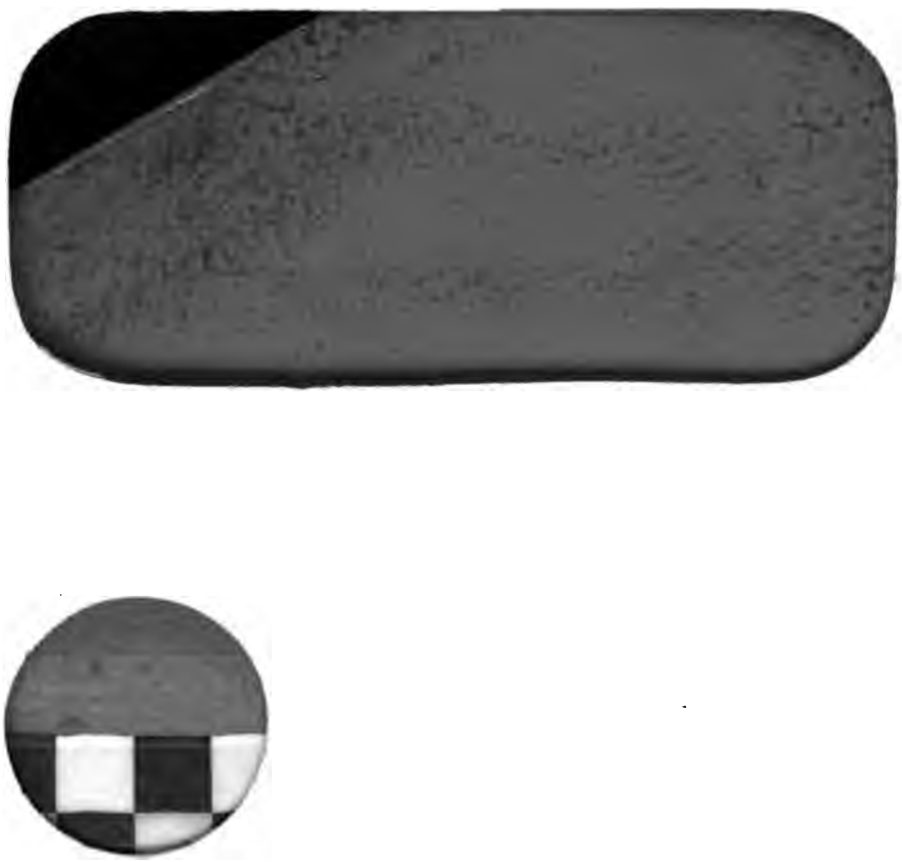

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INSPECTION, MAINTENANCE AND SAFETY STUDIES

28 June 1986

1/ Additional comments to this report are included in Addendum (Document No. 32)

Technical Report on the Project

OPERATIONAL AND SAFETY STUDIES OF THE VALDESIA RESERVOIR

for

Contract IICA/INDRHI/CSU
(Loan 1655-DO from World Bank)

VOLUME IV

INSPECTION, MAINTENANCE AND SAFETY STUDIES

by

Hseih Wen Shen
Consulting Board: C. F. Corns, Chairman
J. H. Douma, W. G. Holtz,
A. L. O'Neill and H. W. Shen
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Joyce Regenstreif
Cesar Mendoza

VOLUME IV

DAM SECURITY ANALYSIS

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VOLUME IV

DAM SECURITY ANALYSIS

4.1 INTRODUCTION

Dam failures have occurred since dam building began. One of the earliest accepted accounts of a failure dates back to around 2900 B.C., to a masonry dam in Egypt. It was probably built without a spillway and failed by overtopping shortly after it was built. The International Commission on Large Dams (ICOLD) conducted a survey in 1965 which indicated that since 1830 at least 466 incidents to dams have occurred worldwide. About 200 of these incidents were failures.

In United States, the National Dam Inspection Act P.L.92-367 of 1972 was implemented to set up a national program of inspection of non-federal dams. There were three purposes for the committee. The first purpose was to compile an inventory of dams in the United States. The second purpose was to inspect the non-federal dam inventoried and to provide the inspection results and advice for remedial measures to the state governments. The third purpose was to provide a report to the U.S. Congress on the activities performed under the Act and to give recommendations for a comprehensive national dam safety program.

Although this Act was put into law in 1972, no dam was inspected until 1977, half a year after the failure of Teton Dam in Idaho. The inventoried dams were classified as high, significant or low hazard dams. Dams where failure would cause the loss of more than a few lives or result in excessive economic losses to communities, industries or agriculture, were classified as high hazard dams. About 9000 dams in United States fell into this category.

Of the 6632 inspections to high hazard structures, completed by the end of 1980, 1927 dams, or 29 percent, were found to be unsafe. Ninety-seven dams were found to need emergency work, including eighteen that were breached. The inspections concerned unsafe attributes of the dams, rather than causes of actual incidents from the other studies previously discussed. Of the dams found to be unsafe, inoperable control components and defective structural component were the primary deficiencies, accounting for 2.7 percent each. Instability of structure accounted for 6.2 percent and seepage for 9.0 percent. The majority of unsafe dams, 78.1 percent, had inadequate spillway capacity cited as the primary deficiency. The final 1.3 percent were listed as having other deficiencies. A major reason for inadequate spillway capacity which accounted for 78.1 percent of the unsafe high hazard dams, was the change of the criteria for spillway size of high hazard dams used by the Corps of Engineers in the national program. The spillway design flood that a high hazard dam project should be capable of safely passing, to be in compliance with the COE's spillway capacity guidelines, is the probable maximum flood (PMF) for dams greater than 40 feet in height or with a storage capacity greater than 1000 acre-feet. The 1/2 PMF is considered adequate for smaller dams. These guidelines were modified to 1/2 PMF for any size high hazard dam, in most cases, when it became apparent that the majority of high hazard dams would not meet the requirements. Of course, with more flood data collected, the magnitude of PMF would also increase.

For more detailed discussions of dam incidents and dam failures, readers are referred to a separate report titled "Review and Analysis of

Dam Safety Inspection Guidelines from Governmental Agencies" by Regenstrif and Shen (1986), under the same contract.

As more dams have failed, the public has begun to pay much closer attention to dam security analysis. Detailed dam safety analysis were made for most of the major dams. A great deal of analysis and constructions are currently underway in United States to enhance the safety of many major dams.

For the security analysis of Valdesia Dam, we assembled a team of consultants to conduct a visual inspection of Valdesia Dam security in May 1985; a review and analysis of dam safety inspection guidelines from U.S. governmental agencies; analysis from existing data for dam safety monitoring; a recommended procedure for dam safety inspection; a recommended procedure for emergency operation; and a recommended organization plan for both normal and emergency reservoir operations. The first three items are described in this volume and the last three items are also briefly described in this volume. Detailed descriptions of the last three items are given in Volume 5.

4.2 DESCRIPTION OF THE TWO DAMS

4.2.1 Description of Location and Area

The Valdesia Reservoir system, located on the Nizao River in the Dominican Republic (see Figure 4.1), was designed to provide irrigation water to Nizao agricultural areas and hydroelectric energy to the national electric power network. As shown in Figure 4.2, the system consists of the Valdesia reservoir with a concrete buttress dam, a spillway, and a 60 MW hydropower plant, and the Las Barias afterbay (a short distance downstream from Valdesia) with a diversion and spillway

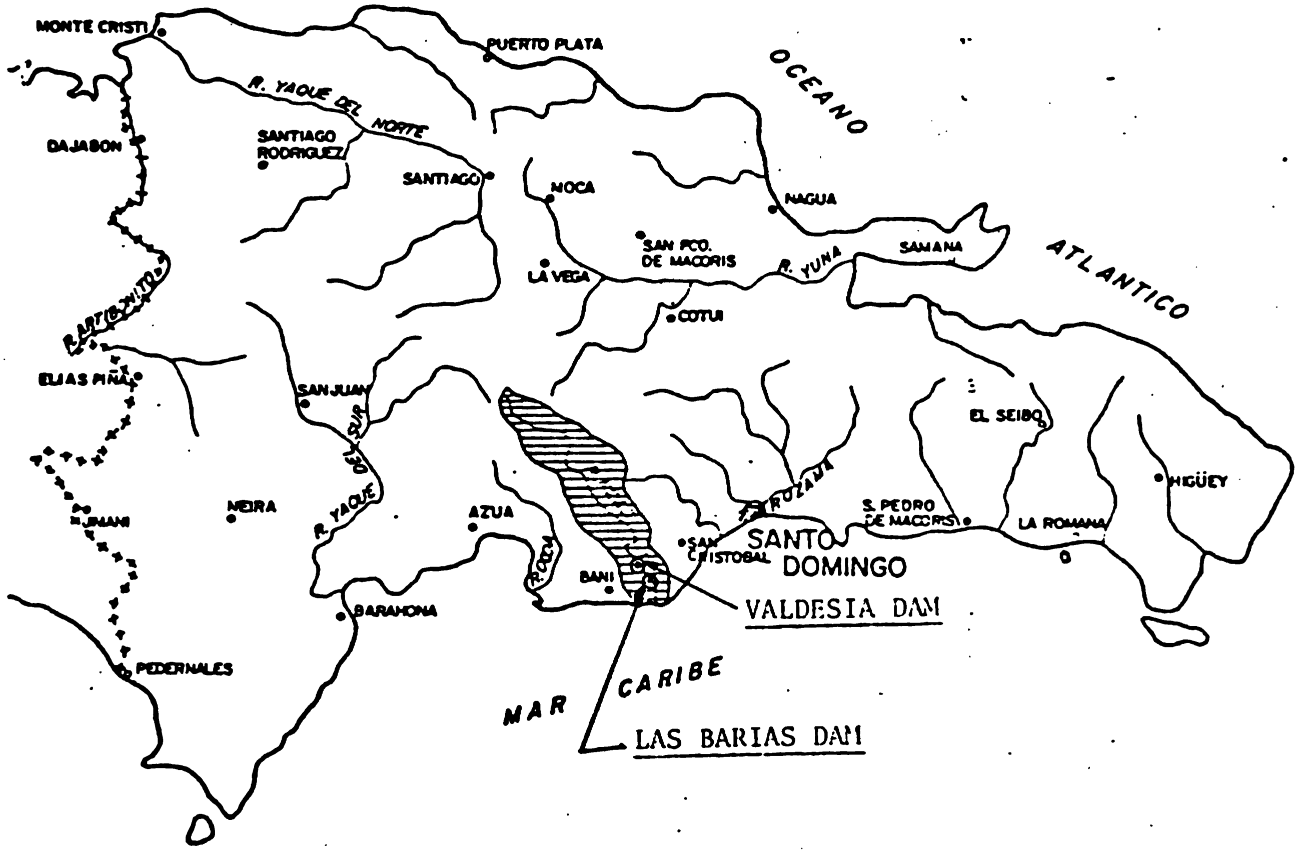

Figure 4.1 Location of the Nizao River Basin in the Dominican Republic

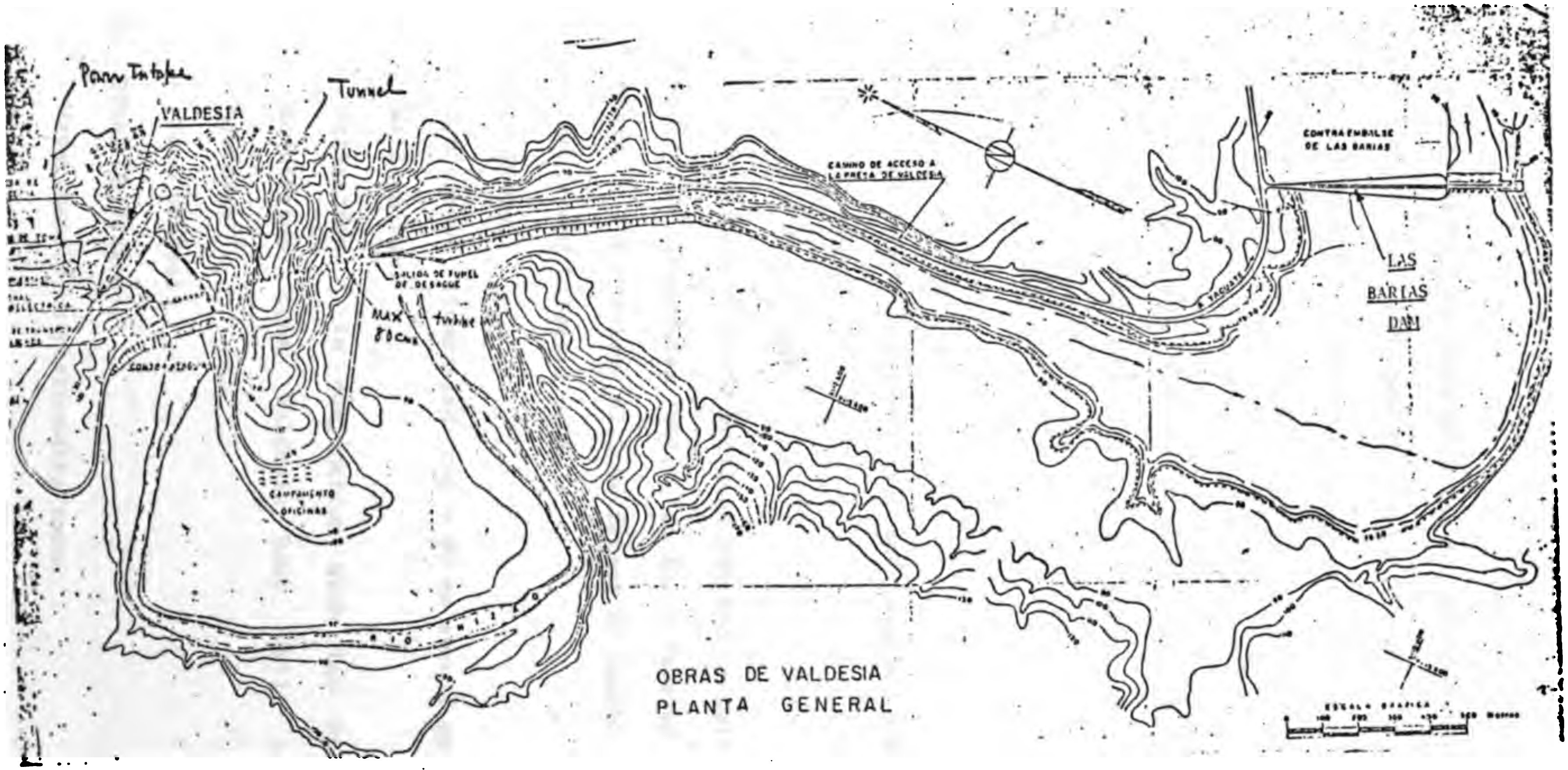

Figure 4.2: Valdesia Reservoir System

system. Future water resources planning for Nizao basin includes three additional reservoirs with power plants (Rancho Arriba, Jiguey and Aguacate) upstream from Valdesia reservoir (see Figure 4.3).

The Nizao basin upstream from Valdesia Dam covers approximately 900 sq. km. in area, and has an elongated shape (see Figure 4.4). Most of the head water areas of the basin have high slopes with a drop in elevation of about 2500 meters from the highest point to the Valdesia Dam site.

4.2.2 Description of Dams

General information, objectives, and detailed specifications for the dams are given below:

(1) General Information:

Valdesia is a concrete buttress dam and is part of a system of hydraulic structures built to fully develop the Nizao river basin. The system will be formed by Rancho Arriba, Jiguey, Aguacate and Valdesia dams.

(2) Objectives:

- Hydropower (installed cap - 60 mw annual generation of 110 million kwh)
- Irrigation - in conjunction with Las Barias Dam (5 km downstream from Valdesia Dam). Will irrigate 19,000 hectares
- Flood control

(3) Other Objectives:

- Water supply to surrounding towns
- Tourism

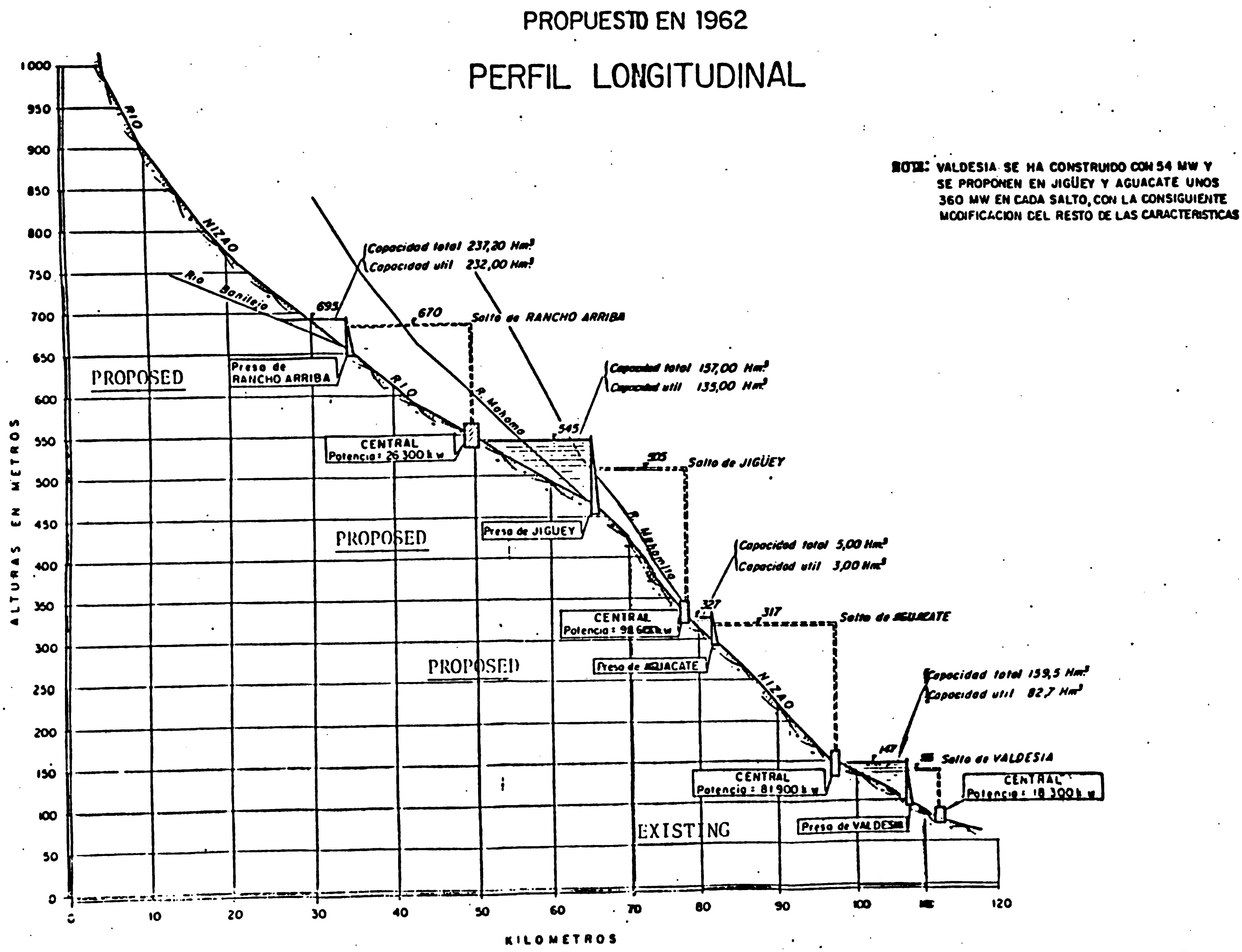

Figure 4.3 Existing and proposed reservoirs in the Nizao basin

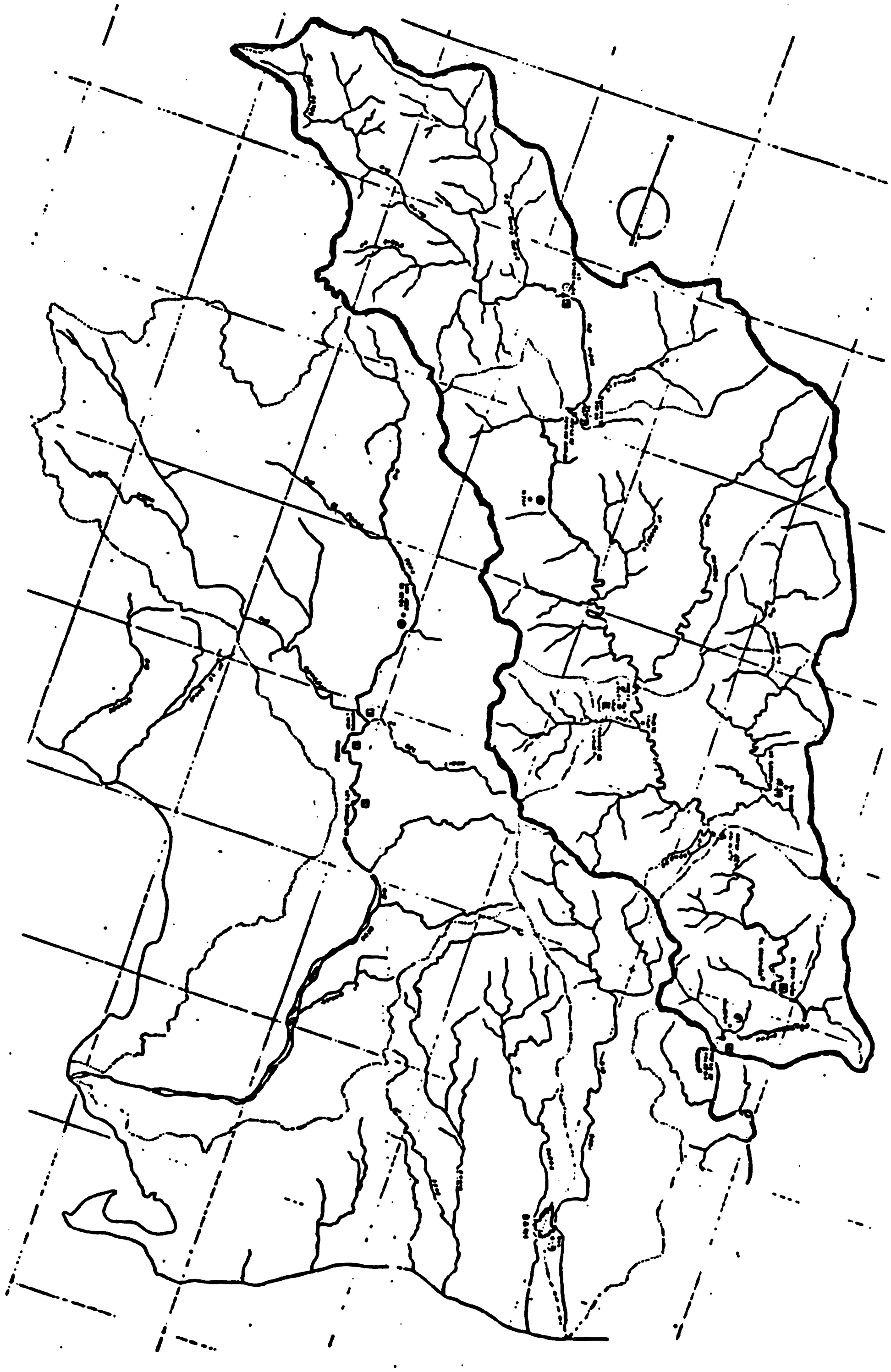

Figure 4.4. Nizao basin upstream of Valdesia reservoir

- Fishing

(4) Specifications

Valdesia Dam: (see also Figure 4.5)

Top of the dam	156	masl
Max. extraordinary level	154	masl
Free board	2	m
Max. operation level	150	masl
Elev. spillway crest	145	masl
Min. operation level	130.75	masl
Height of dam	76	m
Length of reservoir	7	km
Capacity to level 154	221	MCM
Capacity to level 150	186	MCM
Capacity to level 130.75	58	MCM
Capacity between levels 150-154	35	MCM

Spillway

Max. discharge capacity	7200	m/sec
5 radial gates of dimension	24 x 5	m
Width of piles (approximate)	40	cm

Hydroelectric Plant

Length of tunnel	900	m
Diameter of tunnel under pressure	6	m
Diameter of discharge tunnel	6.75	m
Installed capacity	60	MW
Discharge through intake	80	m^3/sec

Las Barias Dam: (see also Figures 4.6 and 4.7)

Top of the dam	81.6	masl
Max. extraordinary level	79.5	masl
Total length	664	m
7 radial gates 15 m width x 8 m high and one radial gate 13 m width		
Elev. spillway crest	69	masl
Capacity to bottom of spillway	0	
Capacity to top of gates (level 77.00)	0.6	MCM
Capacity to level 79.5	1.11	MCM
Height of the dam	22.6	m

4.2.3 Related Information

(1) During the passage of Hurricane David in September 1979, all of the spillway gates at Valdesia Dam were not fully opened and these

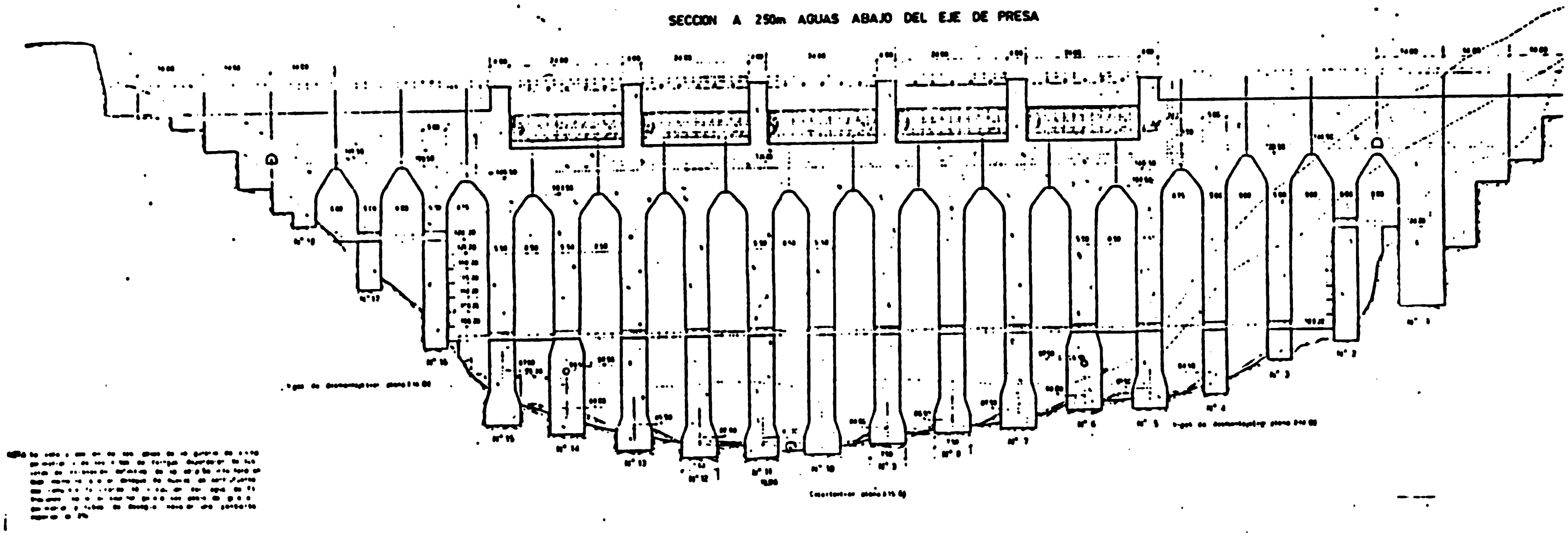

Figure 4.5. Front View of Valdesia Dam

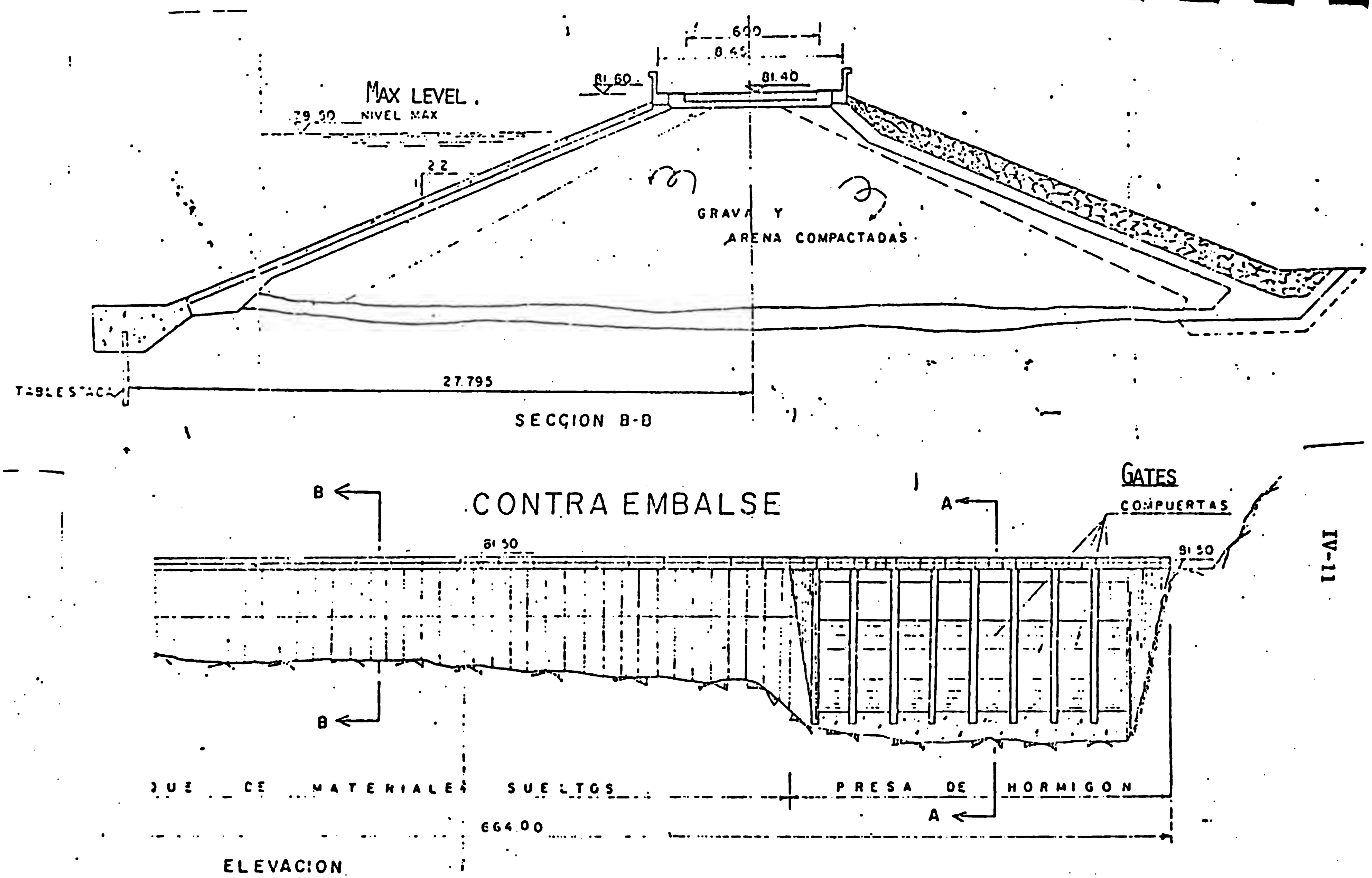

FIGURE 4.6 LAS BARIAS AFTER BAY

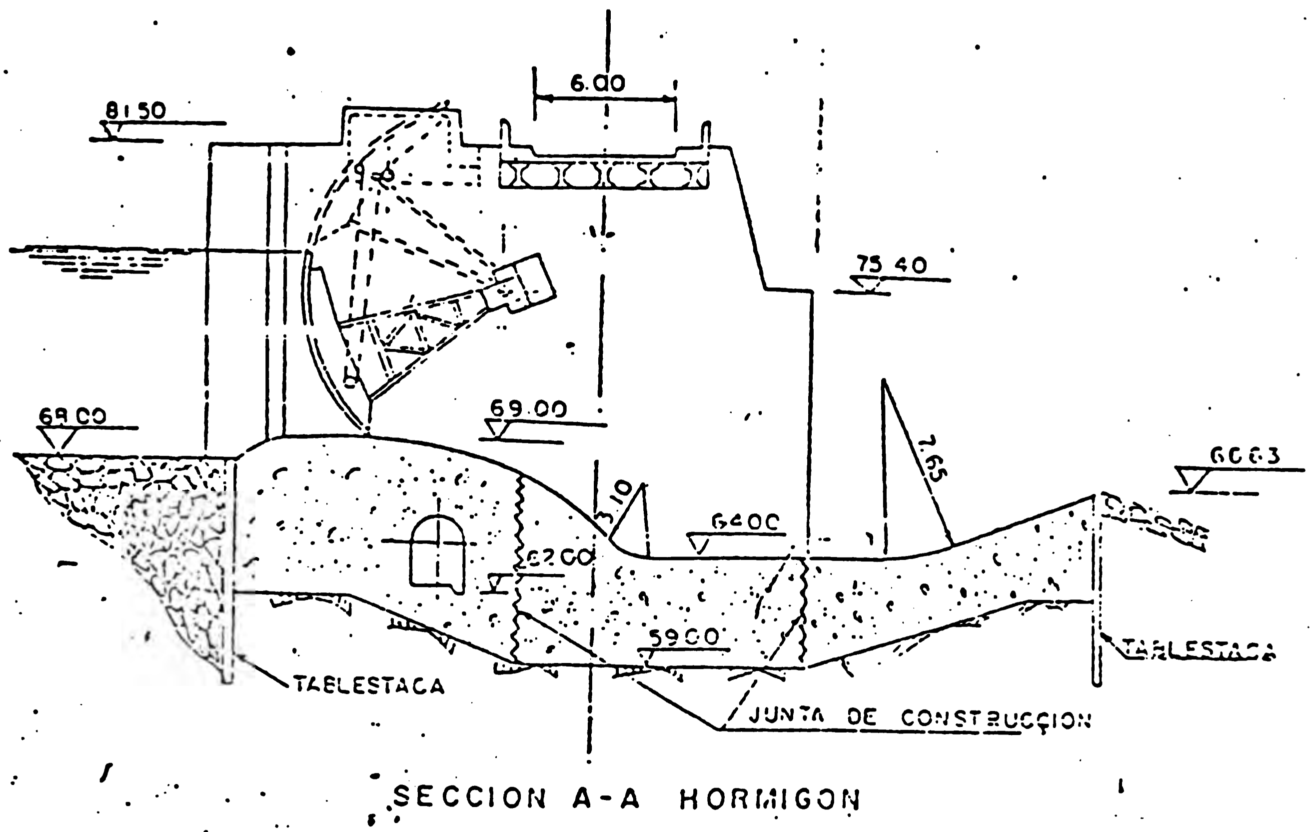

FIGURE 4.7 GATES IN LAS BARIAS AFTER BAY

gates washed away. Spillway gates for the Dam Las Barias were also damaged.

(2) A great deal of sediment deposition occurred in Valdesia Reservoir after Hurricane David. Figure 4.8 indicates the sediment deposit level in Reservoir Valdesia. This top sediment deposit level is rather close to the power intake. The excavation of these sediment deposits in this reservoir will begin soon.

(3) There are five gates over the spillway of Valdesia Dam. With the reservoir level at 154 meters, a total of 5000 cms can be passed through the five gates. For a maximum level of 156 meters, a total of 7000 cms can be passed through the five gates of Valdesia spillway.

(4) There are eight gates over the spillway of Las Barias Dam. With the reservoir level at 80 meters, a total of about 7200 cms can be passed through Las Barias Dam spillway. The height of this dam is 81.6 meters.

4.3 VALDESIA DAM SECURITY INSPECTION BY A CONSULTANT BOARD

The Board consists of Charles F. Corns, Consulting Structural Engineer, Jacob H. Douma, Consulting Hydraulic Engineer, Wesley Holtz, Consulting Geotechnical Engineer, Alan L. O'Neill, Consulting Engineering Geologist, and Hsieh Wen Shen, Hydrologist and Hydraulic Engineer, Colorado State University.

The Board performed its mission during May 13 to 18, 1985, and its itinerary was as follows:

May 13. Discussed the projects with personnel from IICA, INDRHI, and CDE.

May 14. Site visit.

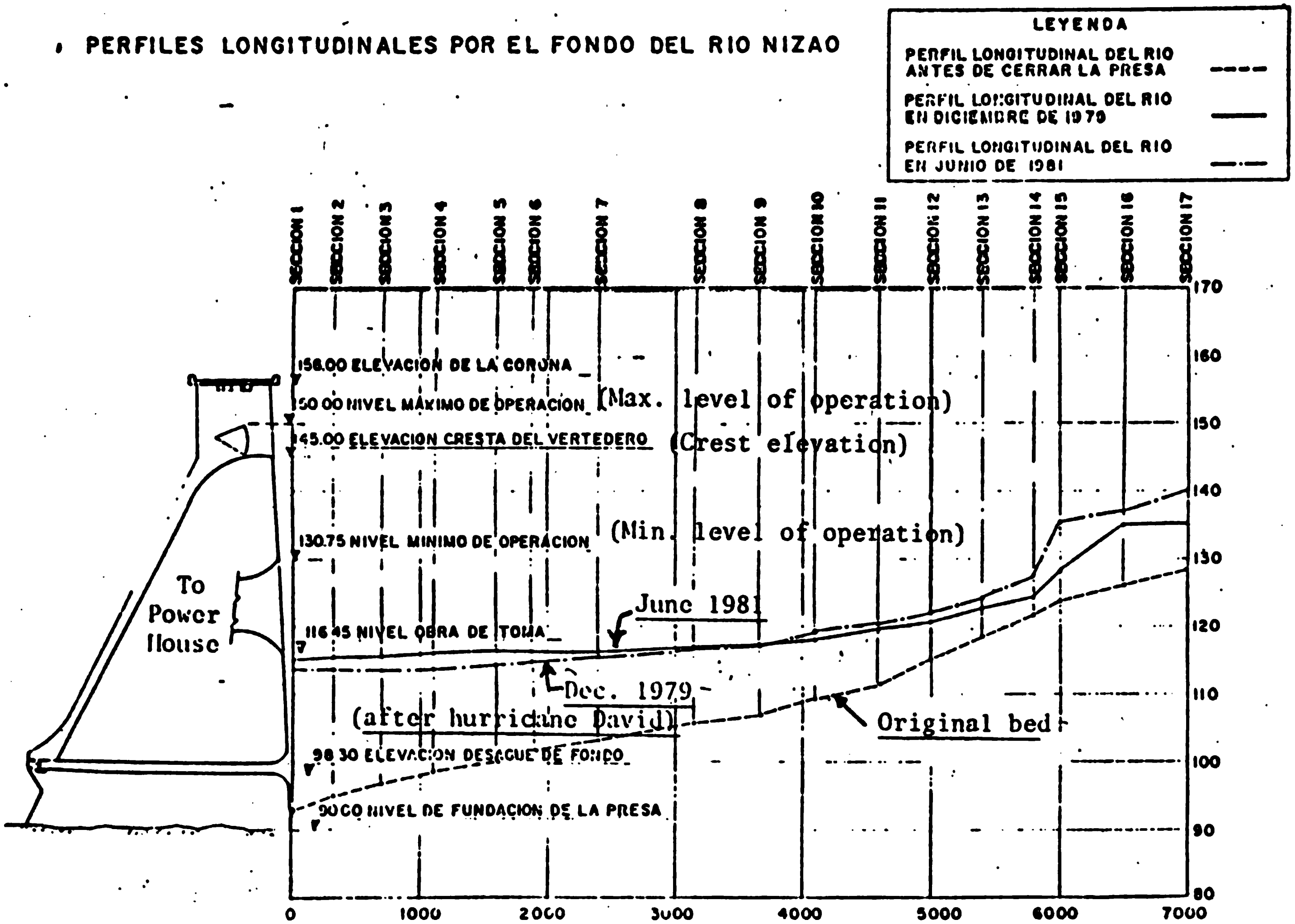

FIGURE 4.8. SEDIMENT DEPOSITION IN VALDESIA

May 15. Discussed projects with personnel from IICA, INDRHI, and CDE.

May 16, 17 and 18. Preparation and completion of this report.

The purposes of the review were: (1) to identify project defects that are apparent by visual inspection and to recommend remedial measures on the investigations needed to develop remedial measures; (2) to develop recommendations for the initiation of a formal inspection program to promote project safety; (3) to develop recommendations for emergency operations and for a warning and evacuation plan; and (4) to recommend a plan for organizational control of project operations during normal and emergency situations. The report discusses these items in the foregoing order, followed by the Board's recommendations. The section on PROJECT DEFECTS is based upon observations of the Board during its visit to the project and upon discussions with INDRHI and CDE personnel.

For detailed discussions of the findings of the Consulting Board, the readers are referred to "Review of Valdesia and Las Barias Dams, Nizao River," by Corns et al. (1985). The specific recommendations are as follows:

1. An underwater inspection should be made of the Valdesia power intake trash rack and it should be cleaned of debris, if necessary. Similar inspections should be made periodically when the reservoir water level is low.
2. Consideration should be given to the need for providing a vortex suppressor with a larger trash rack at Valdesia Dam to reduce pressure fluctuations in the penstocks when the racks are partially blocked with debris.

3. The left low-level outlet at Valdesia should be made operational in the same manner as adopted for the right outlet. Larger and stronger trash racks should be installed to prevent debris blockage at the intakes.
4. The Valdesia stilling basin should be unwatered and cleaned, after which the concrete surface should be inspected. Any damage should be repaired before the basin is placed back into operation. Similar inspections should be made periodically.
5. Sediment deposits at Valdesia should be monitored carefully and removed when necessary to insure that coarse sands and gravels do not pass through the low-level outlets and power intake.
6. To provide greater assurance of power to operate the Valdesia spillway gates, the generator station should be protected from the intrusion of rain runoff and the power cables from the 450 KW emergency generator should be adequately protected from the elements.
7. All design and construction data for Valdesia Dam should be reviewed to estimate a conservative, but reasonable shear strength for the foundation rock and an analysis to determine the dam's resistance against sliding should be performed. If an adequate factor of safety is not obtained by using an estimated foundation shear strength, the foundation rock should be tested by laboratory and/or in situ methods to determine the proper shear strength.
8. An earthquake study of the Valdesia Dam site area should be made to provide input data for a dynamic analysis. The

dynamic analysis of the dam should be made using ground motions from the Safety Evaluation Earthquake.

9. All foundation drains at both Valdesia and Las Barias dams should be located and identified. Each drain should be inspected for openness and cleaned where necessary. Observations of flow from each drain should be recorded and a record of discharge volume from the sump pumps should also be maintained.

10. A study should be performed to assess the adequacy of the existing foundation drainage system at Valdesia.

11. The piezometer system should be investigated to determine if the measurements being obtained are accurate. All piezometers and other measuring devices should be checked at three to four month intervals to assure that they are operating properly.

12. Instrumentation data should be maintained on time plots, also showing associated data such as reservoir level and temperatures, as appropriate.

13. A line of survey monuments should be installed across the Valdesia and Las Barias dams for measuring horizontal and vertical movements.

14. An emergency power generator should be installed at the Las Barias spillway to ensure capability to operate the gates.

15. The sump pump in the Las Barias spillway gallery should be maintained in an operable condition so that the gallery can be unwatered for inspection and maintenance of drains.

16. At Las Barias Dam, reservoir sedimentation should be monitored to insure that large quantities of coarse sediment do not pass

over the spillway to cause excessive damage to concrete surfaces. Removal of reservoir sediment deposits may be required in the future.

17. The Las Barias stilling basin should be unwatered, cleaned, inspected for excessive concrete erosion and repaired, if necessary. Similar inspection should be made periodically.

18. The Las Barias spillway crest gates should be operated as uniformly as is practical to reduce downstream channel erosion and minimize the amount of coarse sediment which may be trapped in the stilling basin.

19. A survey should be made of the scour hole downstream of the Las Barias stilling basin to assess the stability of the end of the stilling basin, the sidewalls and the outlet structure for the earth embankment toe drains. If stability is threatened, consideration should be given to placing large stone in the scour hole adjacent to the structures.

20. A formal schedule of inspections for the Valdesia and Las Barias dams should be adopted, as follows:

    a) Operations personnel should make frequent inspections of all features.

    b) An annual maintenance and structural inspection should be made by engineers and/or supervisors not directly involved in day to day operation and maintenance of the dam. The inspection should be documented by an internal report.

c) A formal technical inspection by a multidiscipline team familiar with design and construction of dams should be made at intervals no greater than 4 years.

d) Special technical inspections should be made following major problems or unusual events such as earthquake, hurricane, flood, and monitoring data indicating adverse behavior.

21. An emergency forecasting procedure should be developed based on modern techniques and equipment.

22. An emergency operating plan should be developed to assign responsibilities and include specific instructions and alternatives for different situations as agreed upon by both CDE and INDRHI.

23. A warning system should be devised to warn dam tenders and the public in downstream areas of an impending emergency.

24. An evacuation plan should be developed to move people from the downstream areas expected to be flooded by discharges from the dams or by potential dam failure.

25. The emergency communications system should be improved by adding more redundancy to the system, strengthening the existing microwave tower, and possibly replacing the existing radio equipment.

4.4 VALDESIA DAM SAFETY DATA ANALYSIS

Five different types of data collected by CDE to monitor the behavior of Valdesia Dam. These five types are (1) piezometers to measure the variation of uplift pressure, (2) temperature gauges, (3) pendulum to measure the dam movements, (4) extensómetros to measure concrete deformation, and (5) accelerometers to measure sudden movements

of the dam. The first four types of data collected during years 1982, 1983 and 1984 were provided to us in October 1985.

4.4.1 Piezometers

Piezometers are used to measure uplift pressure underneath the dam. If excessive seepage should occur below the dam, the large uplift pressure underneath the dam could overturn the dam. Eighteen cuerda vibrante (vibrating wire) type of piezometers were installed at blocks 5, 11, 15, 17 and 18. The locations of these blocks are shown in Figure 4.5. This type of piezometer is satisfactory, providing the equipment are properly maintained and the engineers, taking the readings, have been properly trained for making the observations. Piezometers should be checked every to to three months to insure that these equipments are functioning properly.

All the piezometer data are plotted on Figures 4.9 through 4.22. Pore pressures wre used on the vertical axes because piezometers are installed at different datum and it is convenient to analyze results at this form. Each line on the figure indicates data taken on the same day.

As stated by Rodriguez, Octavio and Franklin Ramirez in their October, 1985 report titled, "Sistema de Auscultacion de la Presa de Valdesia," that not all the piezometer readings can be trused. It is recommended that all piezometers should be investigated at once according to the procedure recommended in Section 4.5 of this report. The particular trouble piezometers are No. 1 (P5-1), No. 7 (P17-a) and No. 8 (p17-b) because these readings did not respond to the change of reservoir level (see Figures 4.11 and 4.18). Piezometers No. 4 (P11-2) gave constant pore pressure readings which might be valid. If all the existing piezometer data should be correct; uplift pressure underneath

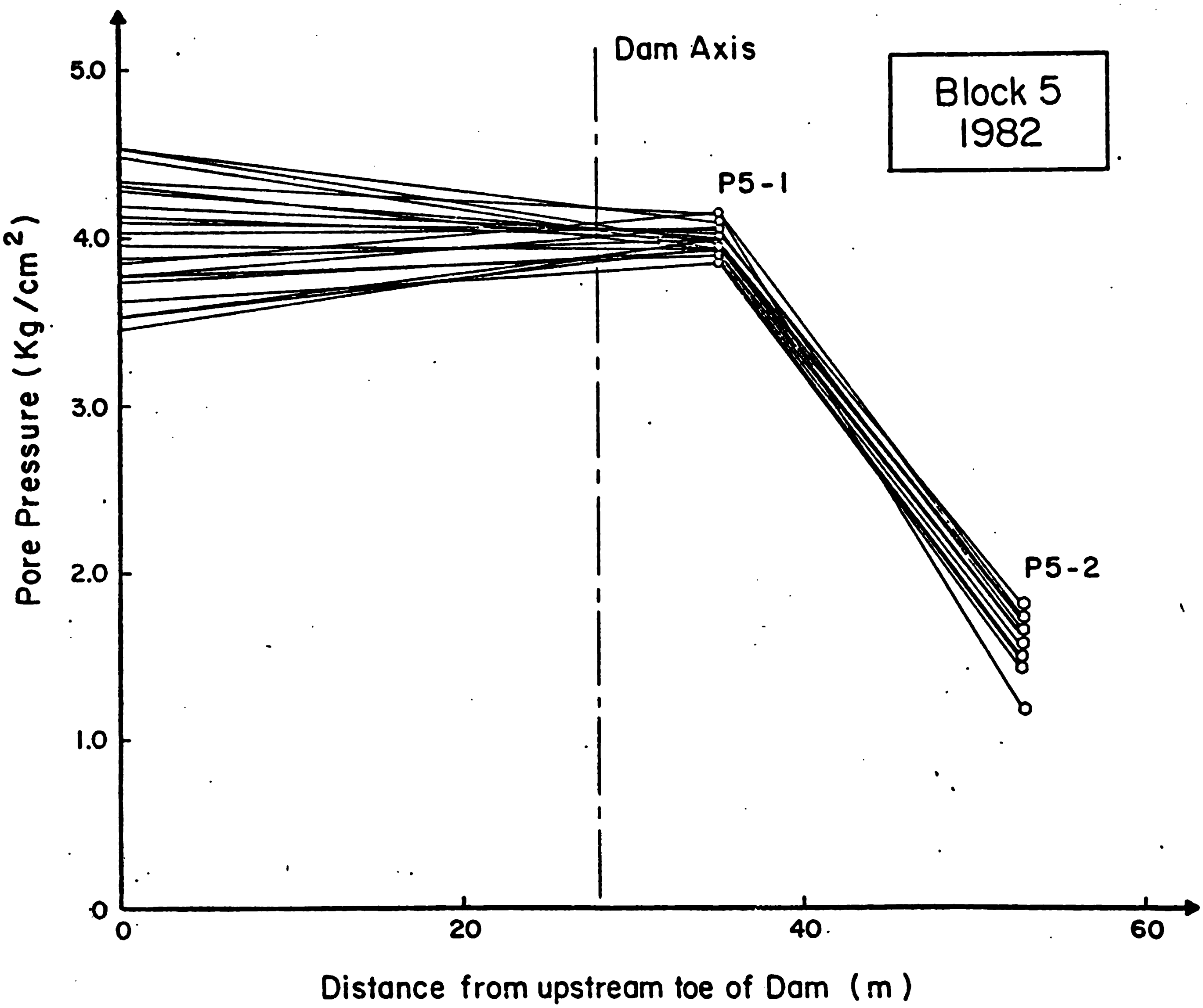

Figure 4.9 - Por Pressure Distribution for Block 5 - 1982

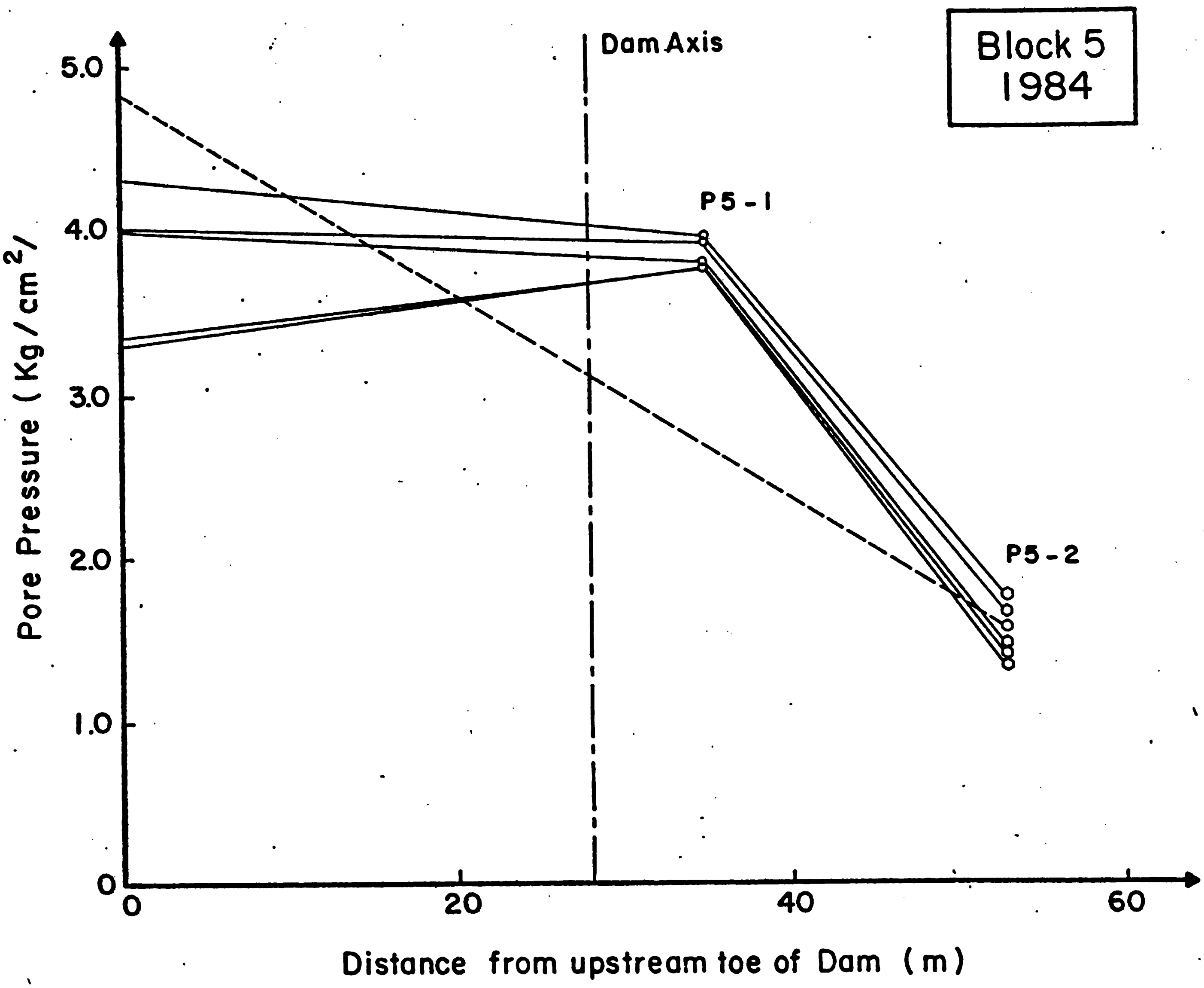

Figure 4-11: Pore Pressure Distribution for Block 5-1984

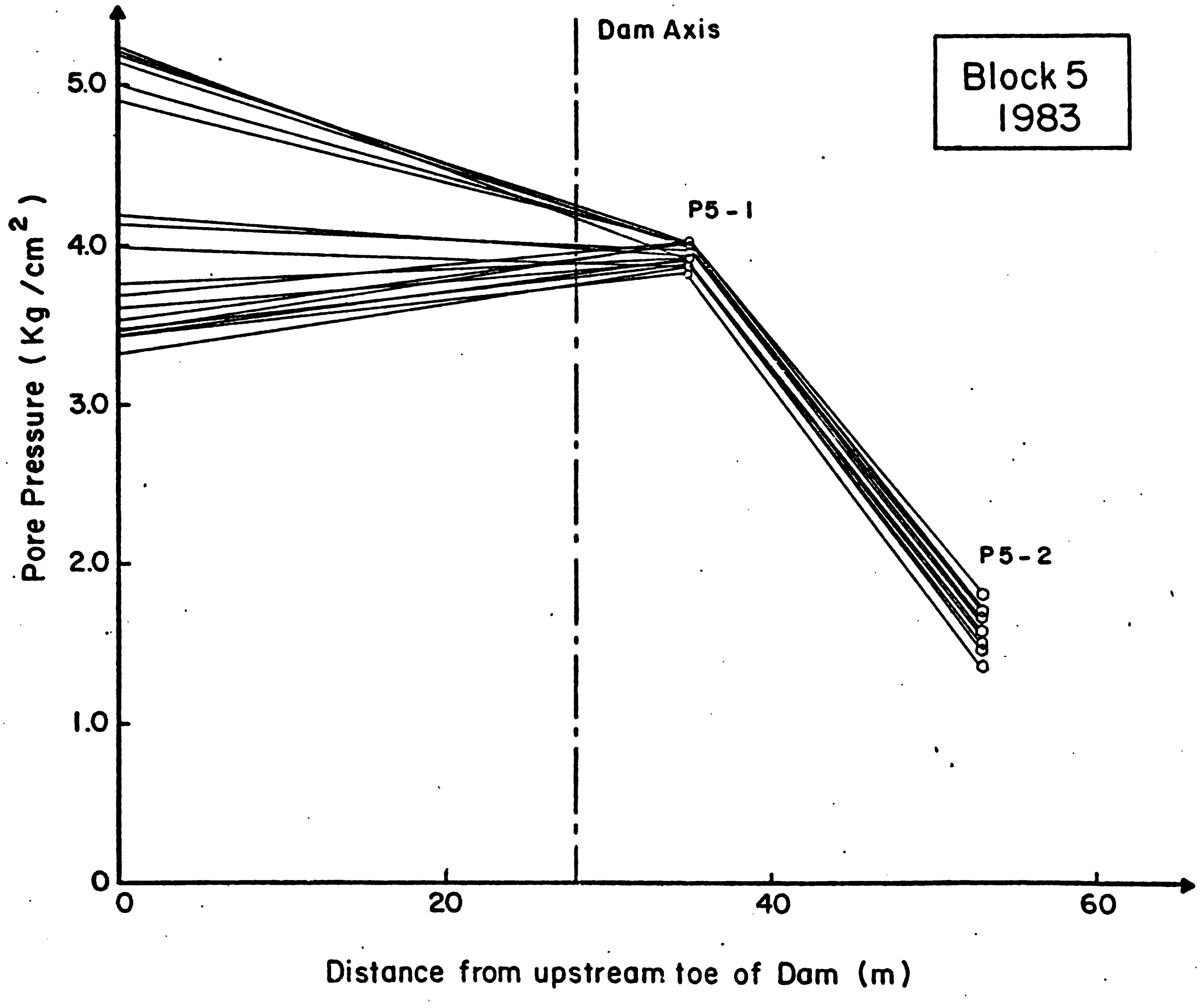

Figure 4-10: Pore Pressure for Block 5-1983

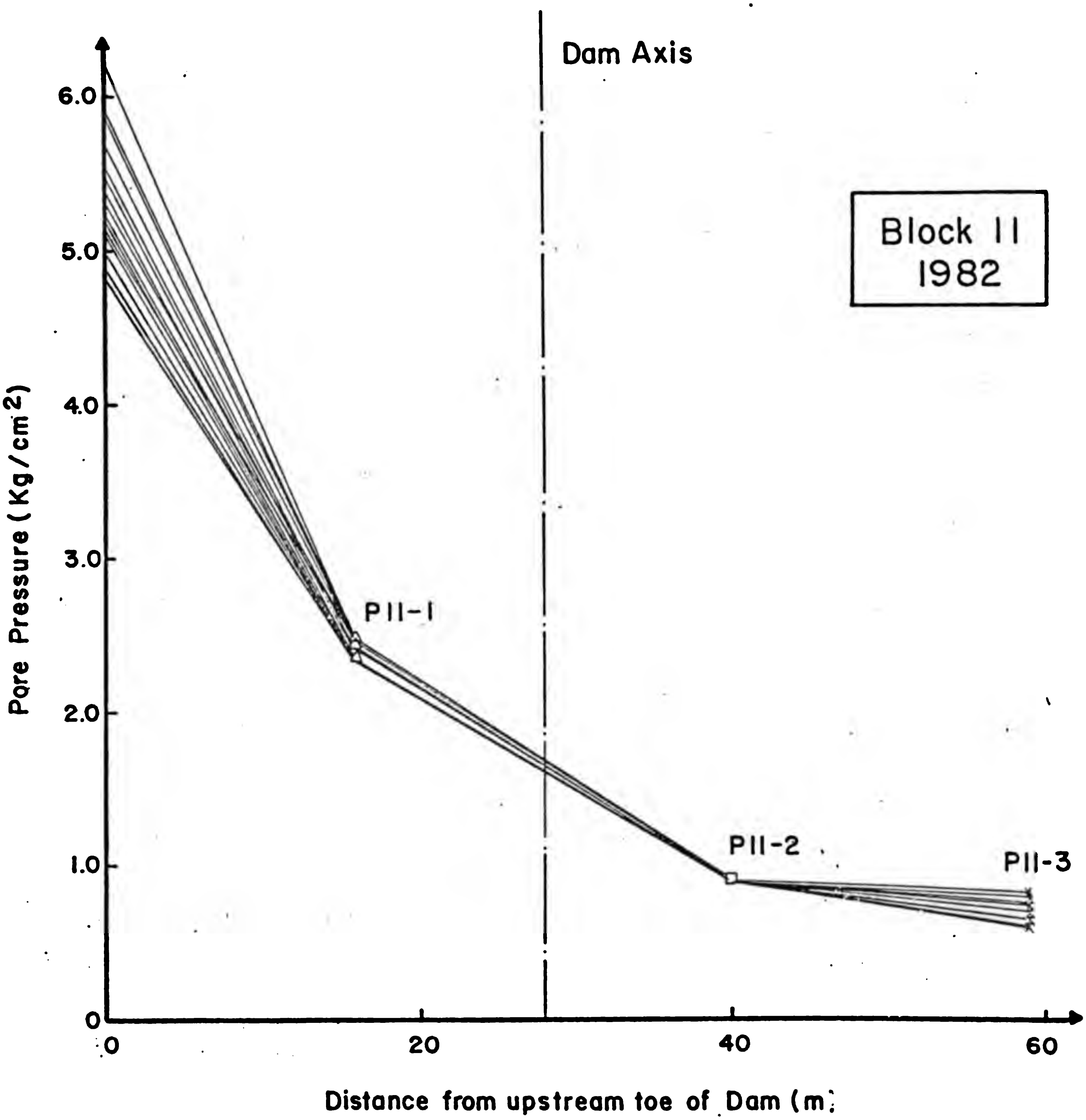

Figure 4.12: Pore Pressure Distribution for Block 11-1982

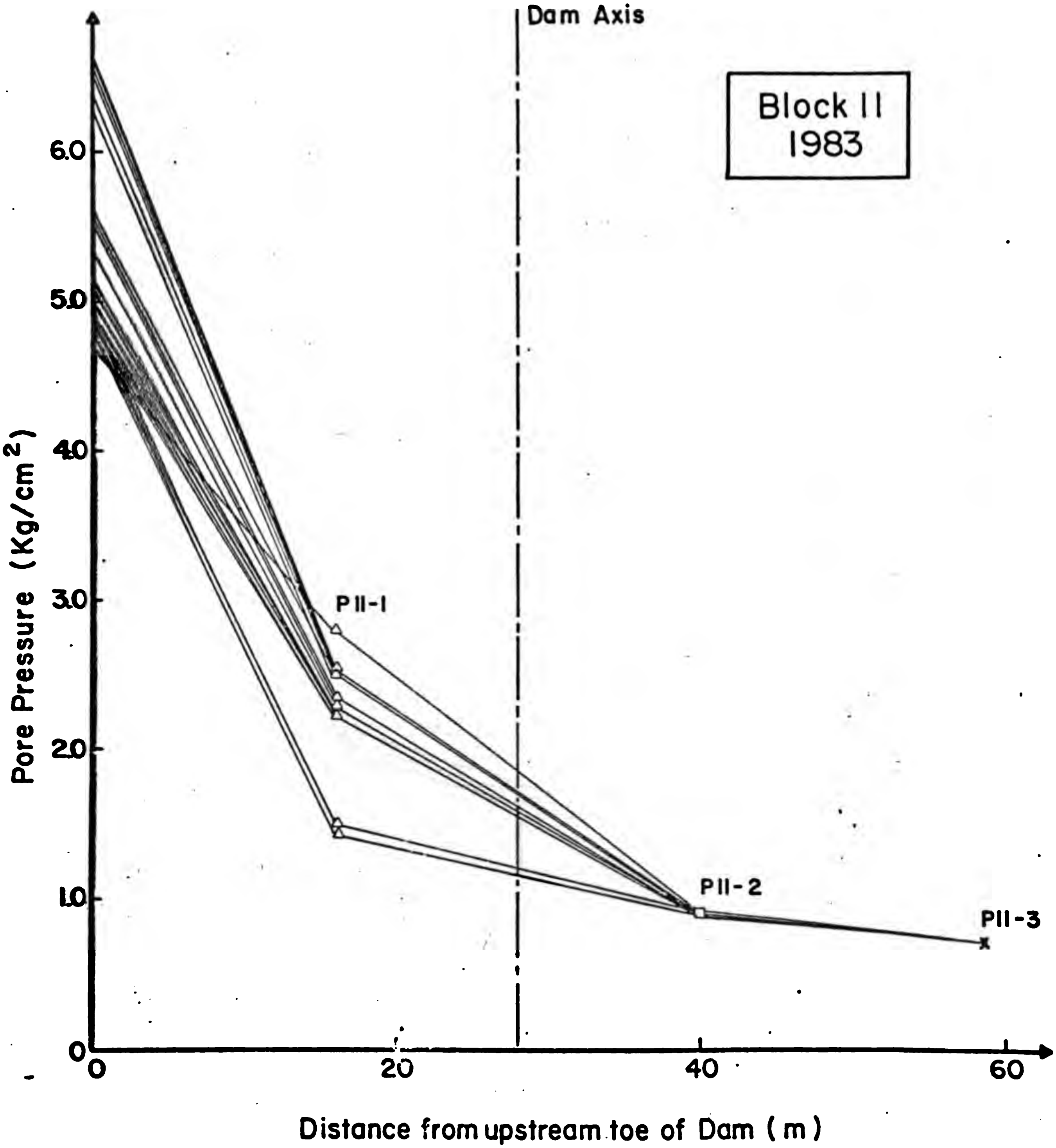

Figure 4-13: Pore Pressure Distribution for Block 11-1983

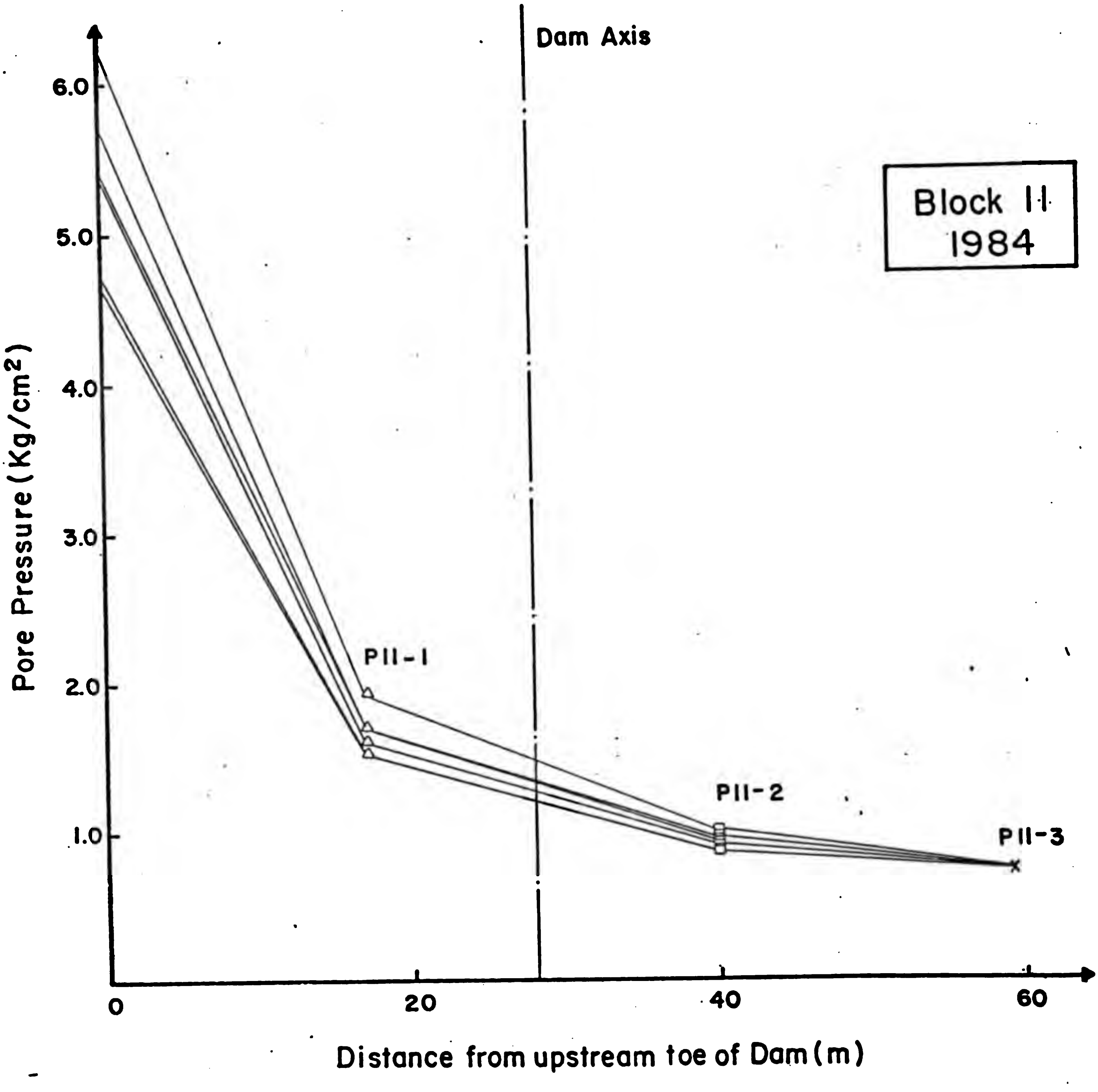

Figure 4-14: Pore Pressure Distribution for Block 11-1984

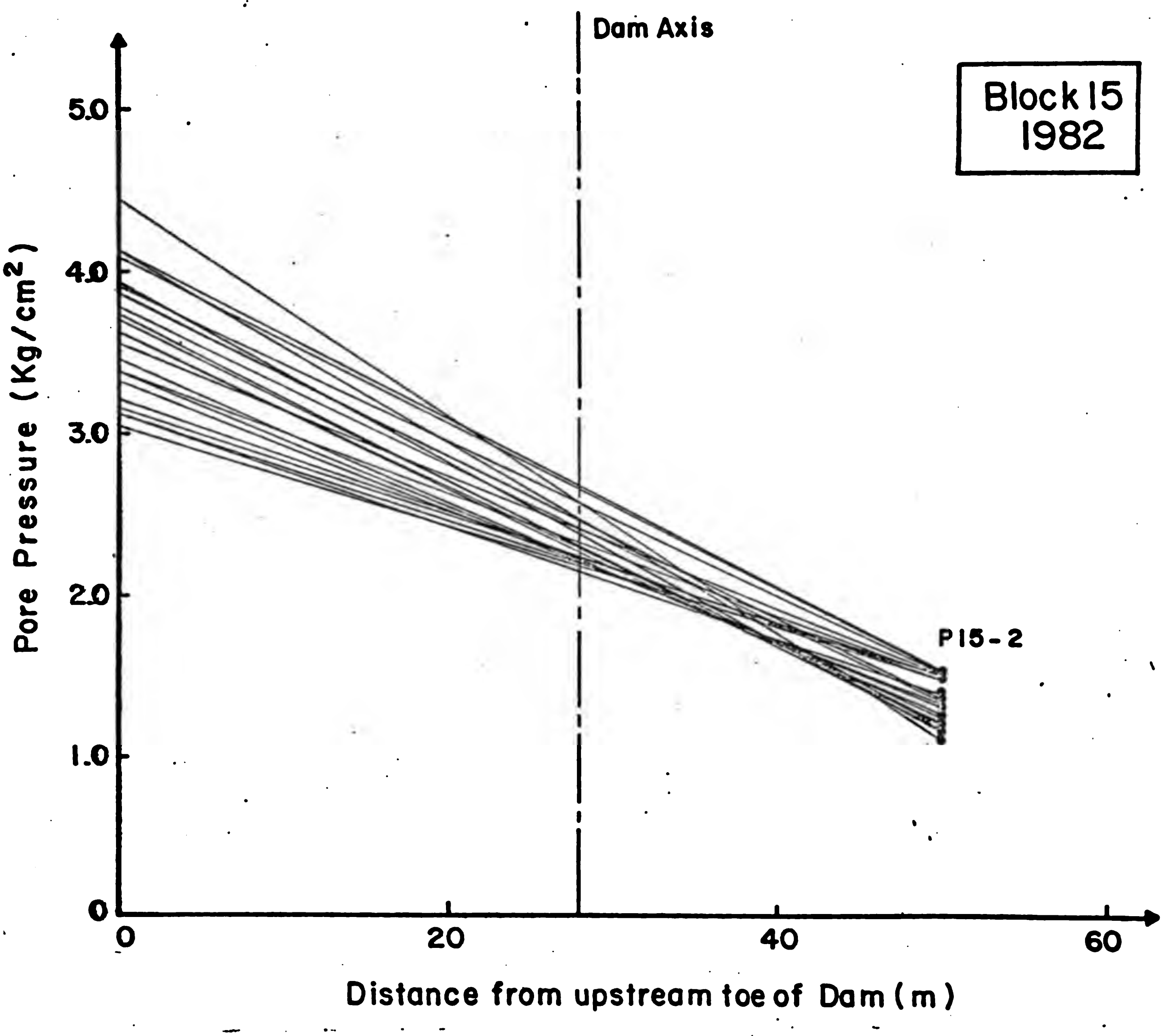

Figure 4-15: Pore Pressure Distribution for Block 15-1982

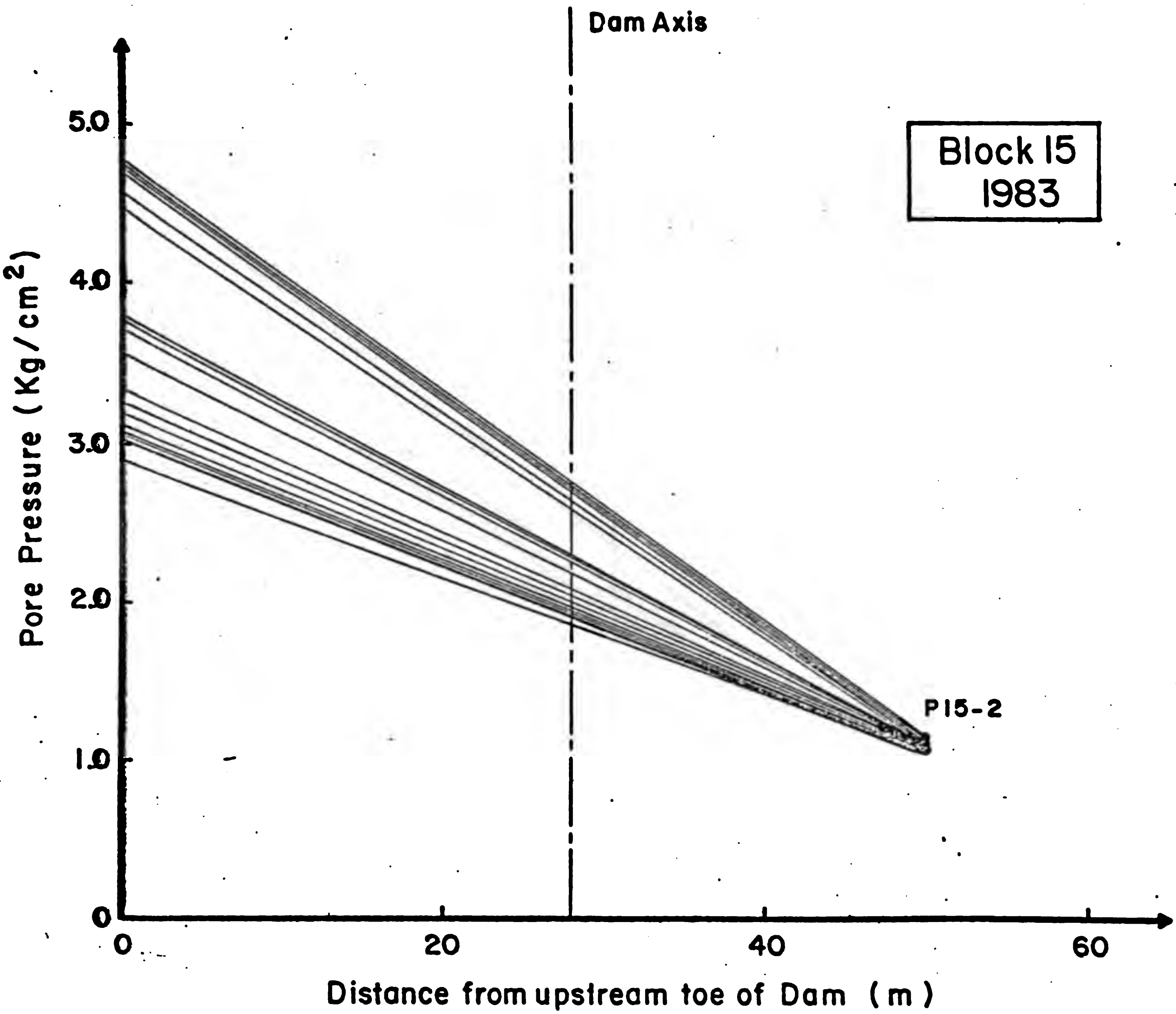

Figure 4-16: Pore Pressure Distribution for Block 15-1983

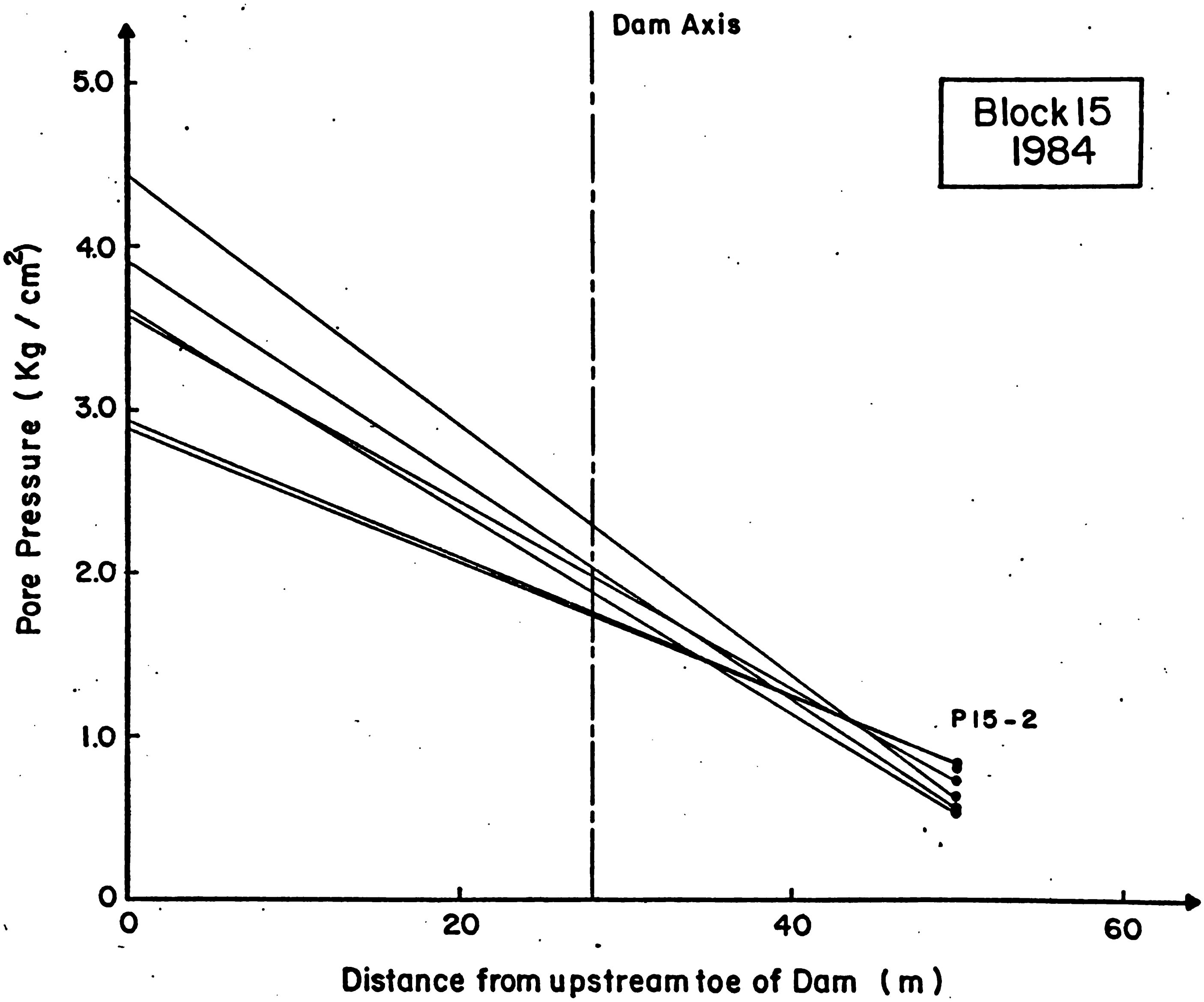

Figure 4-17: Pore Pressure Distribution for Block 15-1984

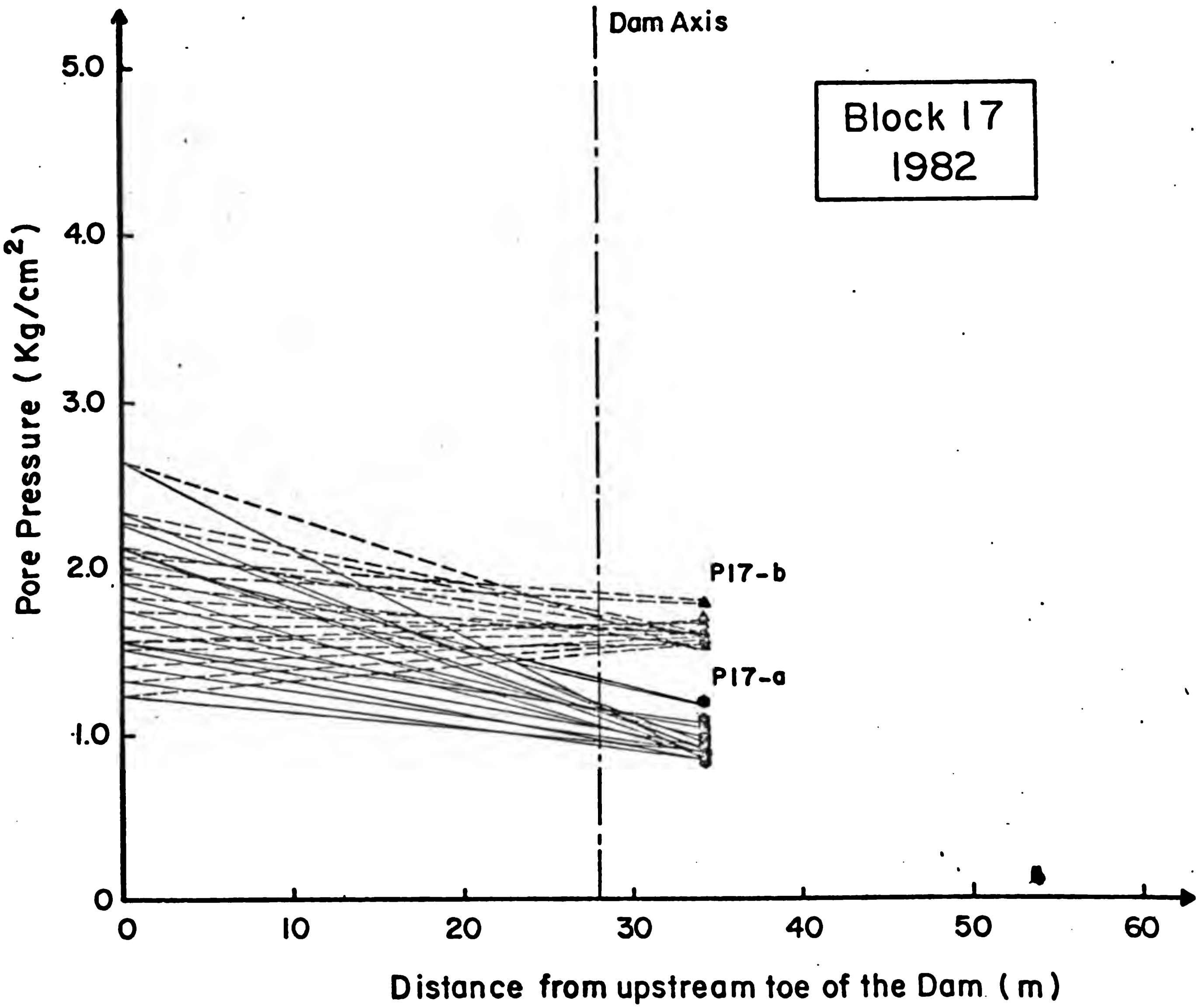

Figure 4-18: Pore Pressure Distribution for Block 17-1982

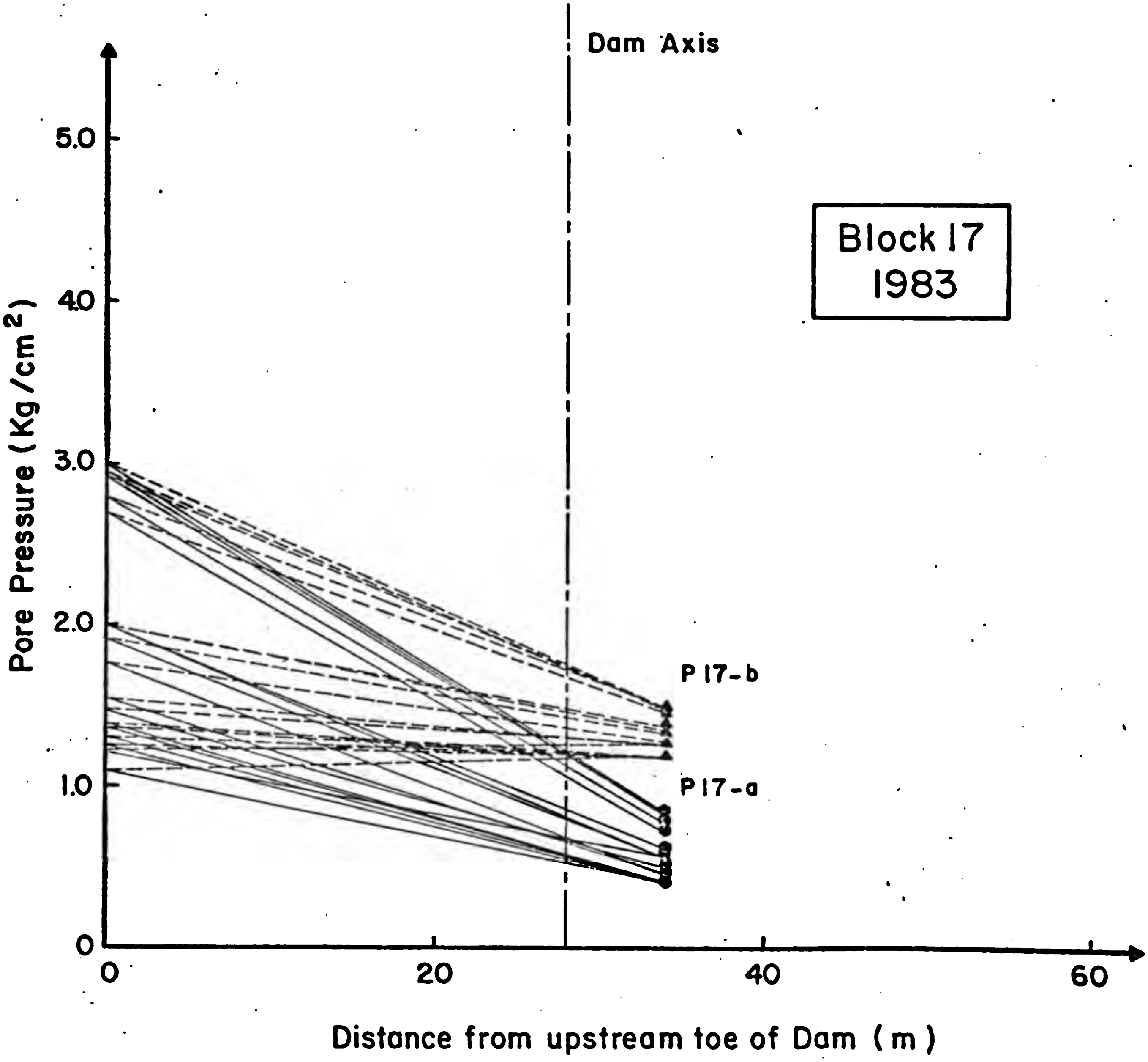

Figure 4-19: Pore Pressure Distribution for Block 17-1983

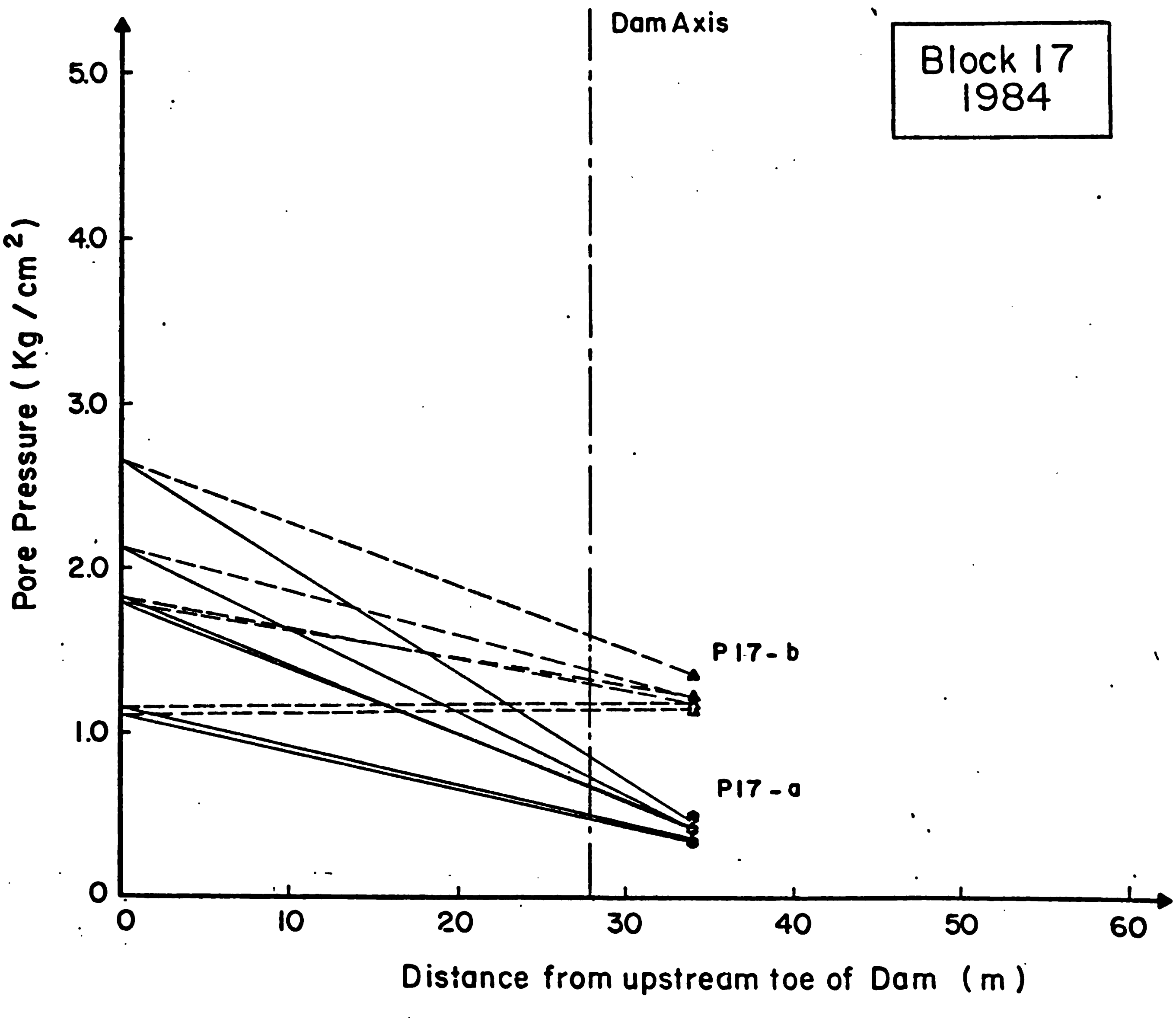

Figure 4-20: Pore Pressure Distribution for Block 17-1984

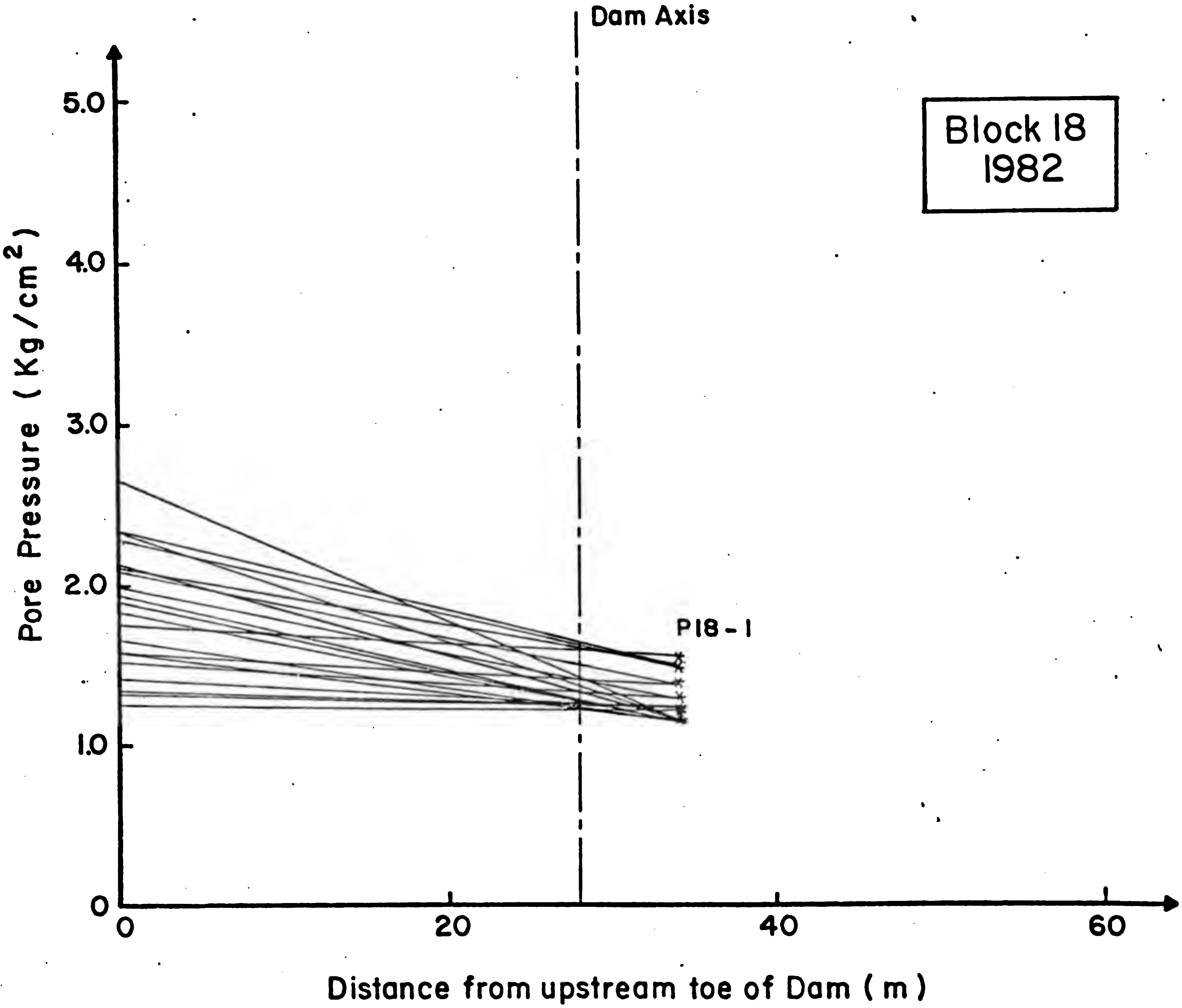

Figure 4-21: Pore Pressure Distribution for Block 18-1982

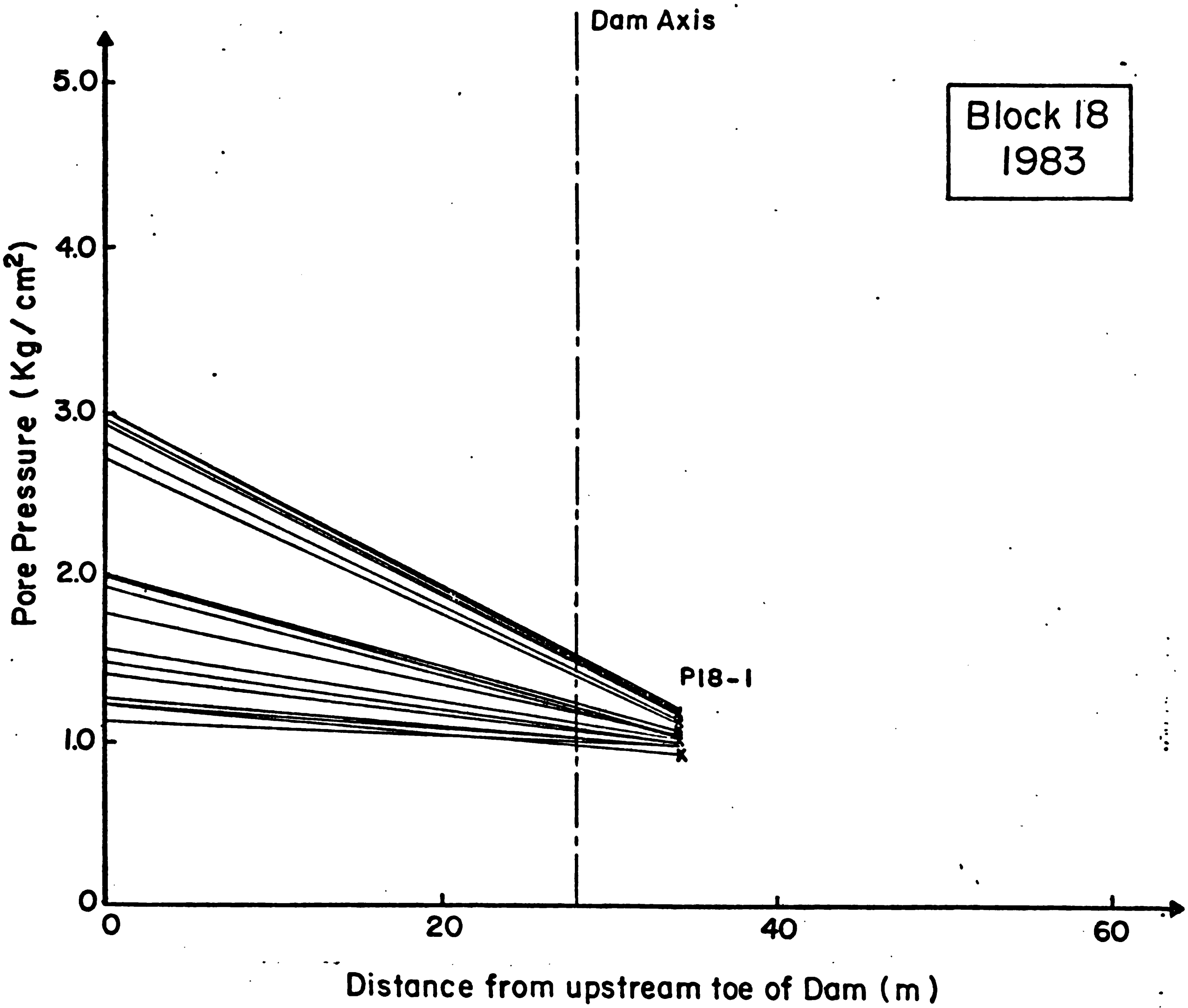

Figure 4-22: Pore Pressure Distribution for Block 18-1983

Block 5 is certainly dangerous, and uplift pressure underneath Block 17 is rather marginal. Detailed stability analysis to investigate the overturning of dam must be conducted at once. Figures 4.21 and 4.22 are for pore pressure distributions of piezometer P18-1.

4.4.2 Pendulum

There are six pendulums installed inside the dam to measure the movements of the dam. As shown by Figures 4.24 and 4.25 for "direct pendulum", the maximum movements for each pendulum was less than 2 millimeters between 1982 and 1984 and also in 1984 the pendulum readings were very stable. The No. 1 and No. 2 inverted pendulum fluctuated within 2 millimeters between 1982 and 1984. However, No. 3 inverted pendulum, inserted at Buttress Block 15, had moved considerably (about 4 mm) between March to July 1982 both in transverse and longitudinal directions. Figures 4.26 and 4.27 show the pendulum wire movements. One must note that No. 3 direct pendulum is also inserted at Buttress Block 15 and had not moved considerably between March to July 1982. This discrepancy should be investigated at once. It appears that the dam movements could certainly be caused by thermal stresses due to temperature fluctuations. In the future, its pendulum should move more than 5 mm which was the maximum movement recorded in the past four years, one must employ a specialist to investigate this matter. Fluctuation of readings within narrow limits are certainly better than progressing movements in one direction.

4.4.3 Extensómetros

Extensómetros are used to measure the deformation of the concrete base of the dam. As stated in report titled: "Auscultacion de la Presa de Valdesia by OFITECO (date unknown), that all the extensómetros were

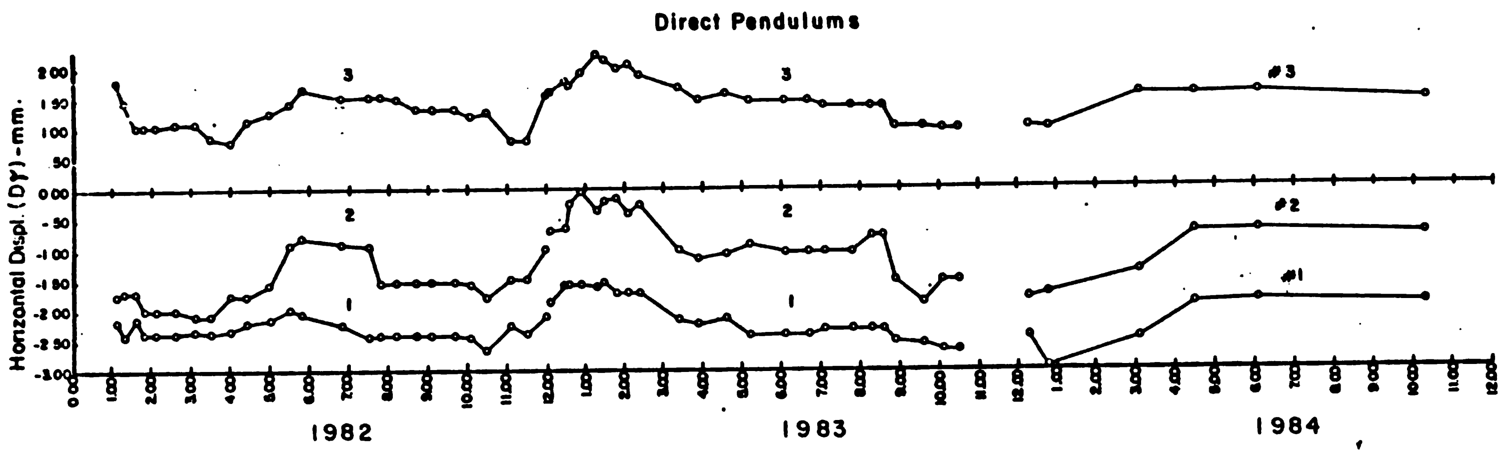

Figure 4.23 Direct pendulums transverse movement in 1982-1984.

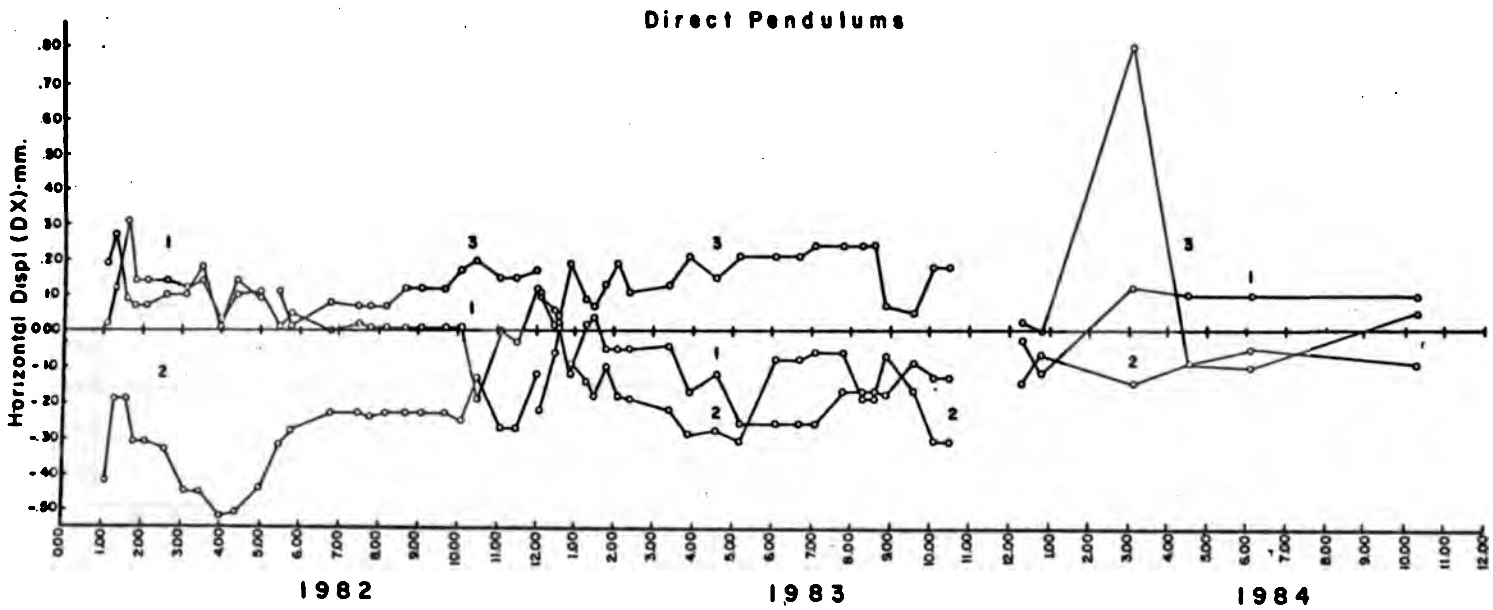

Figure 4.24 Direct pendulums longitudinal movement in 1982-1984.

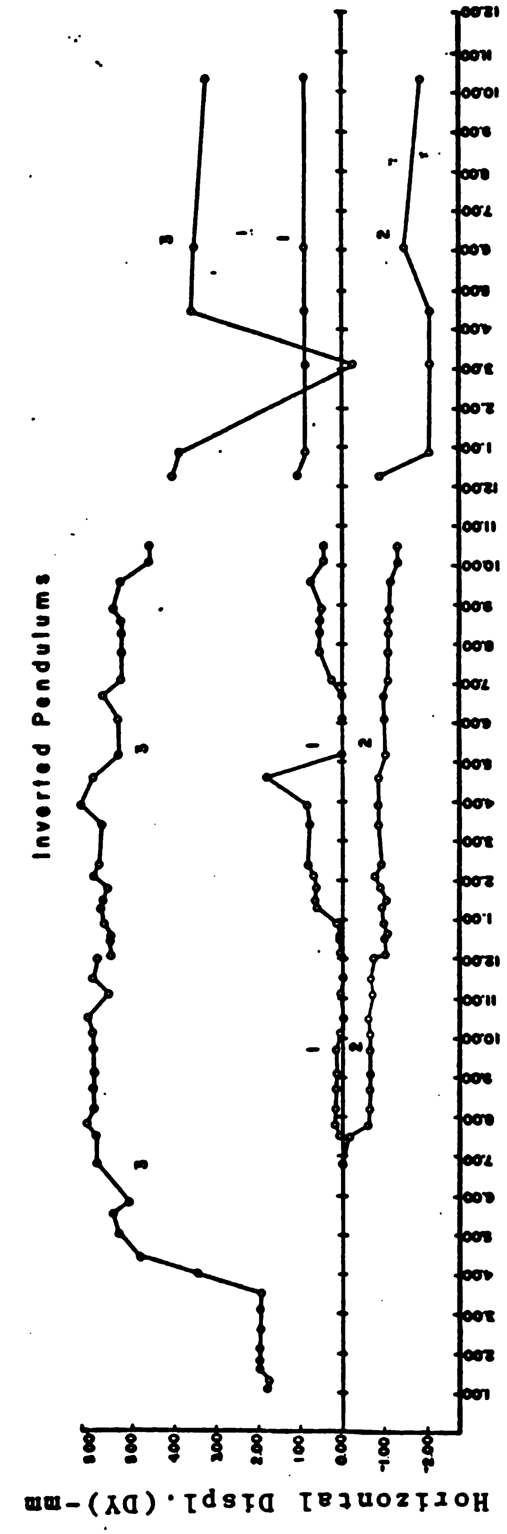

Figure 4.25 Inverted pendulums transverse movement in 1982-1984.

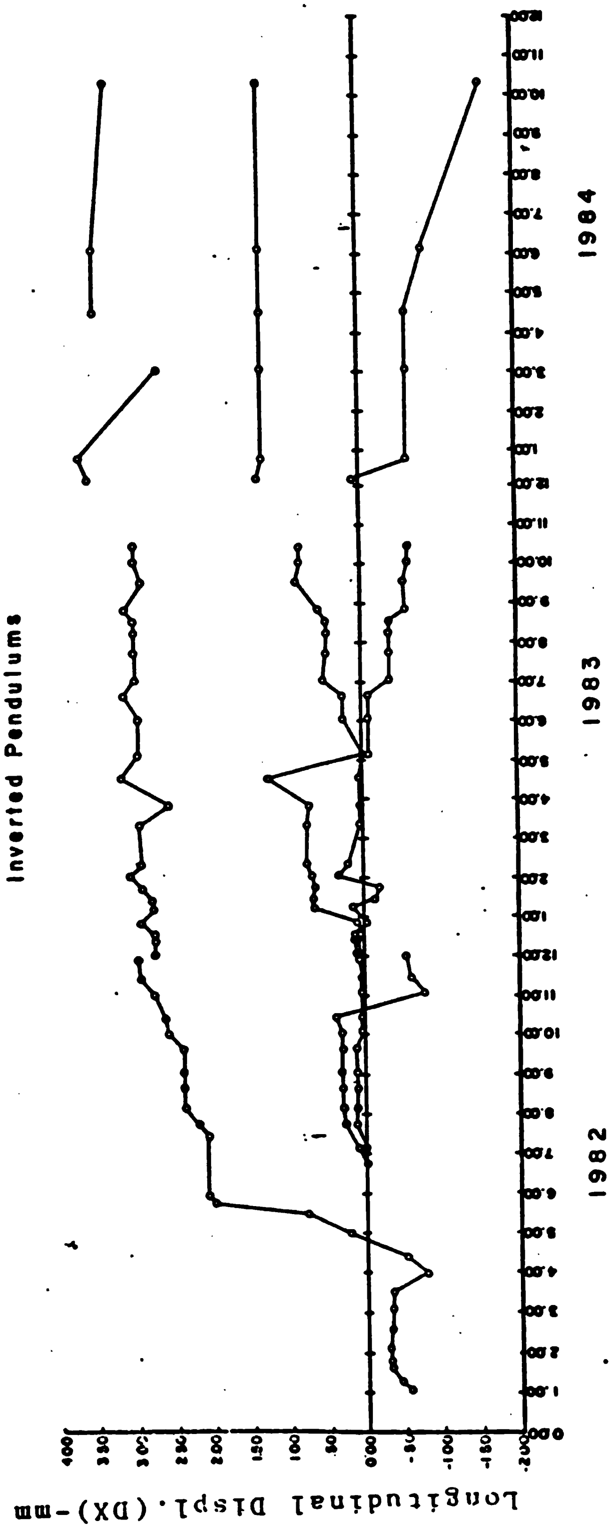

Figure 4.26 Inverted pendulums longitudinal movements in 1982-1984.

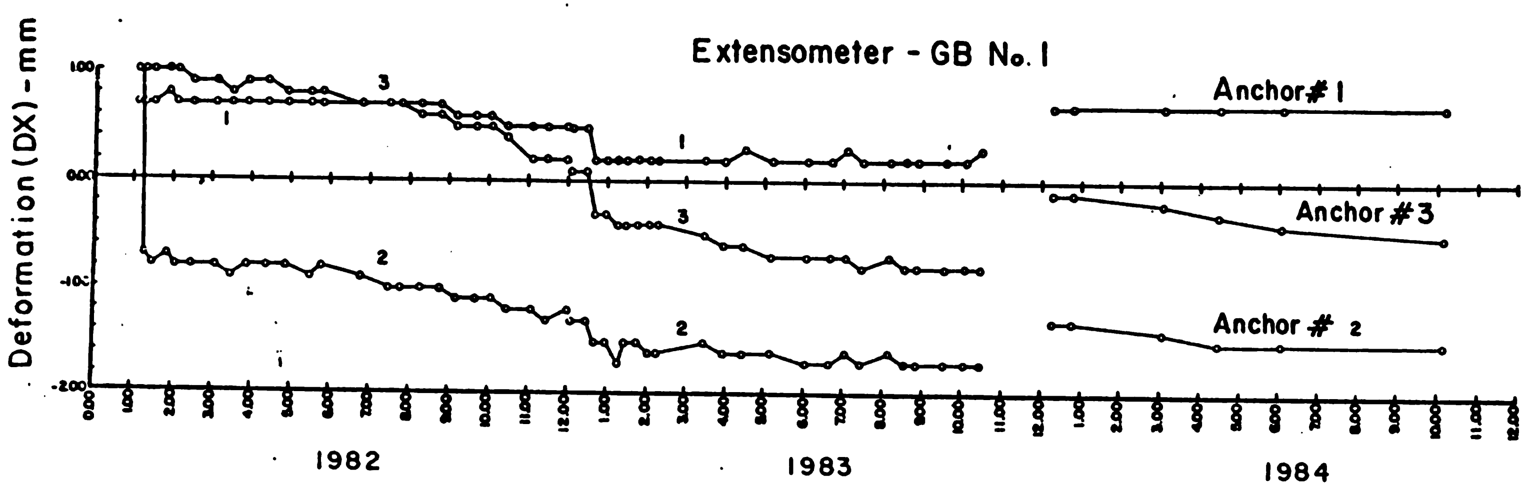

Figure 4.27. Deformation (DX), Extensometer GB No. 1, 1982-1984.

in bad shape during the flooding by Hurricane David and repairs were made for all these extensómetros. Data collected during 1982, 1983 and 1984 are plotted in Figurs 4-27 through 4-34 and summarized in Table 4.1.

Table 4.1. Deformation measured by extensómetros.

Base Ext. No.	Anchor No.	Deformation DH (mm) 1982	1983	1984	Deformation DX (mm) 1982	1983	1984
1	1	0.4	0.1	0.4	0.7	0.2	0.7
	2	-0.5	-0.9	-0.8	-1.0	-1.5	-1.5
	3	0.4	-0.4	-0.1	1.0	-0.7	-0.4
2	1	19.0	19→21	20	55	55→58	59
	2	6.0	6.0→8.0	9.0	2.0	2.0→2.5	3.0
	3	-5.0	-4.0→-1.0	-0.8	-1.8	-1.8→-0.4	-0.4
3	1	-0.3	-0.3	-0.2	-1.0	-0.9	-0.5
4	1	1.0→0	Missing	Missing	1.4→0	Missing	Missing
	2	1.0→0.6	0.4	0.8	1.0	0.8	1.2
	3	4.0→3.0	2.6	2.6	6.0→4.0	4.0	4.0→4.5

As indicated in Table 4.1, the anchors in Base No. 1 moved within 1 mm; the anchors in Base No. 2 moved within 3 mm; the anchor in Base No. 3 moved within 0.5 mm and the anchor in Base No. 4 moved within 2 mm. These movements appear to be normal. Readings taken from extensómetros Group No. 11 installed in the upstream face of dam shell near elevation 116 meters indicated that very little movements occurred between January 1982 and October 1983.

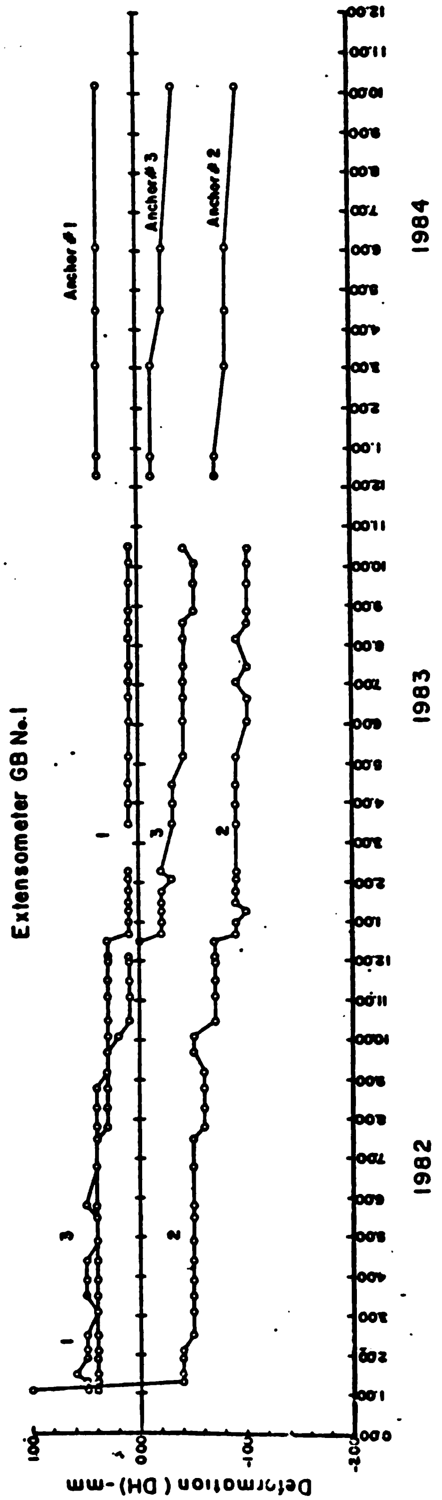

Figure 4.28. Deformation (DH), Extensometer GB No. 1, 1982-1984.

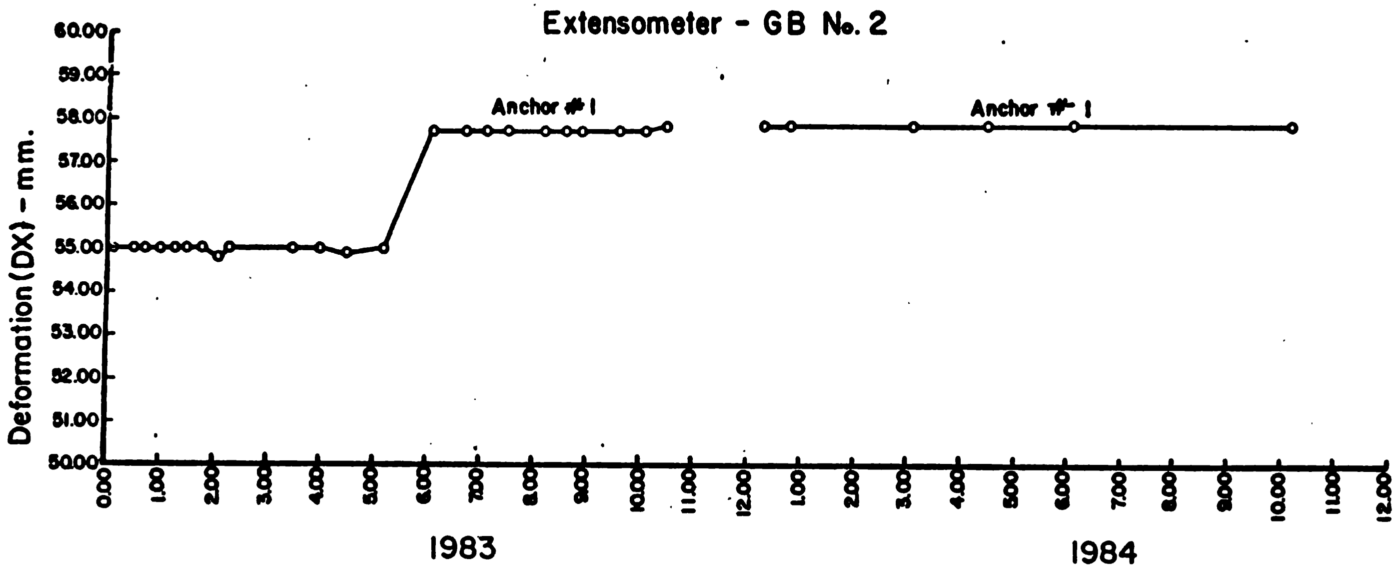

Figure 4.29. Deformation (DX), Extensometer GB No. 2, 1983-1984.

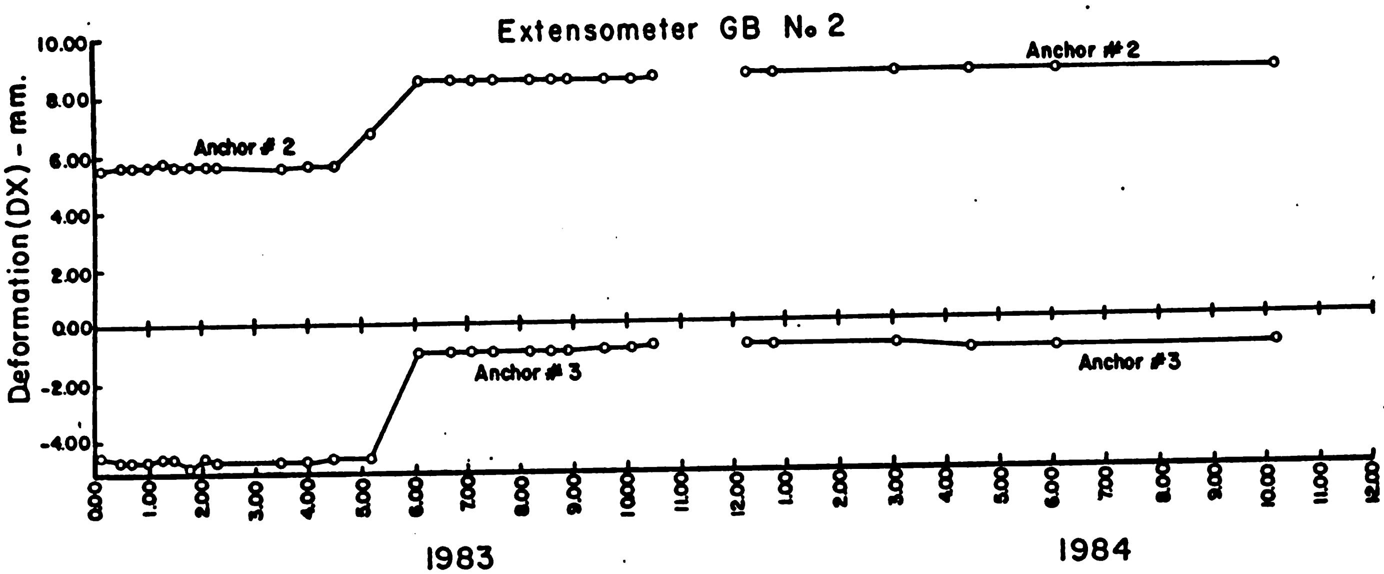

Figure 4.30. Deformation (DH), Extensometer GB No. 2, 1983-1984.

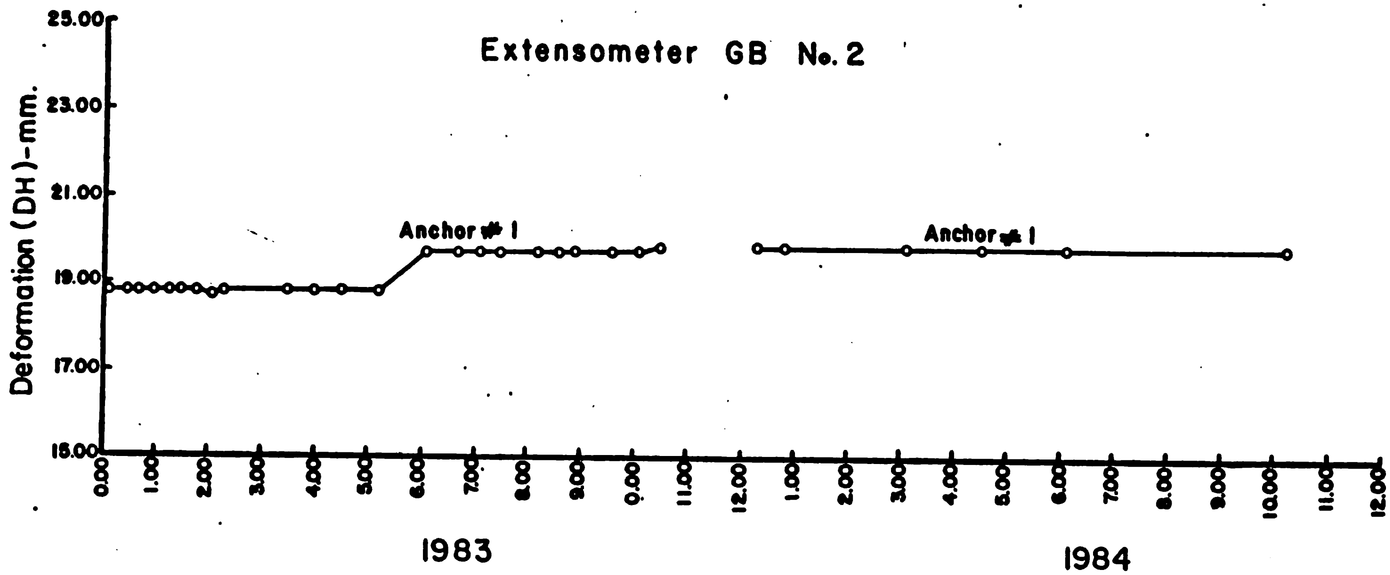

Figure 4.31. Deformation (DX), Extensometer GB No. 2, 1983-1984.

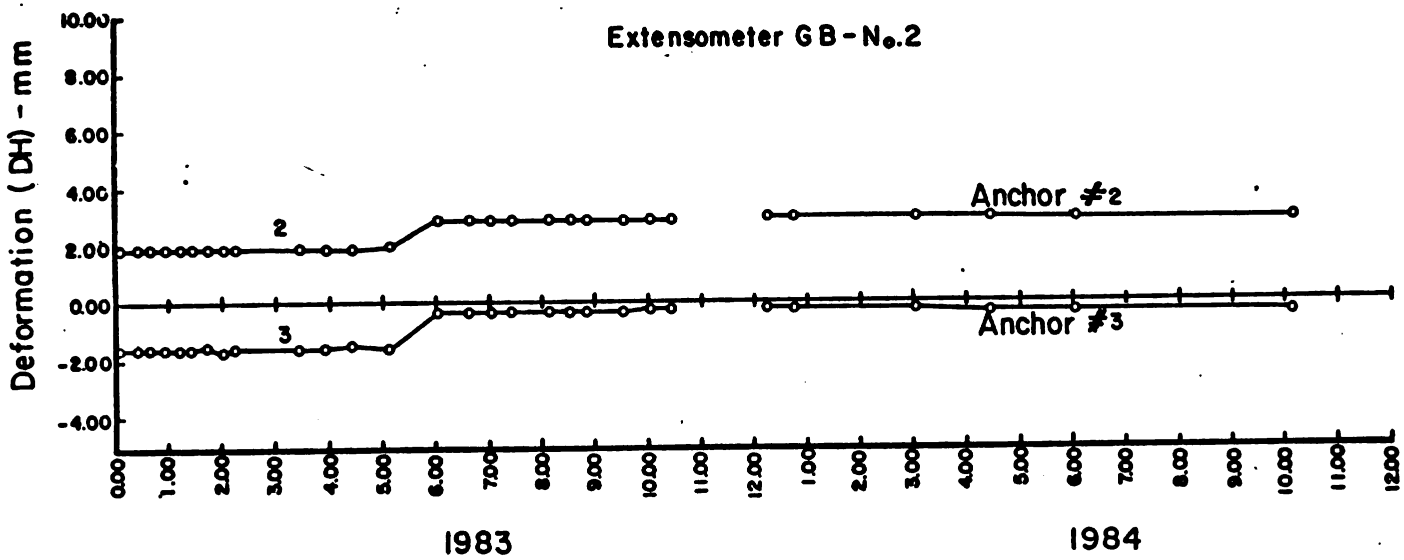

Figure 4.32. Deformation (DH), Extensometer GB No. 2, 1983-1984.

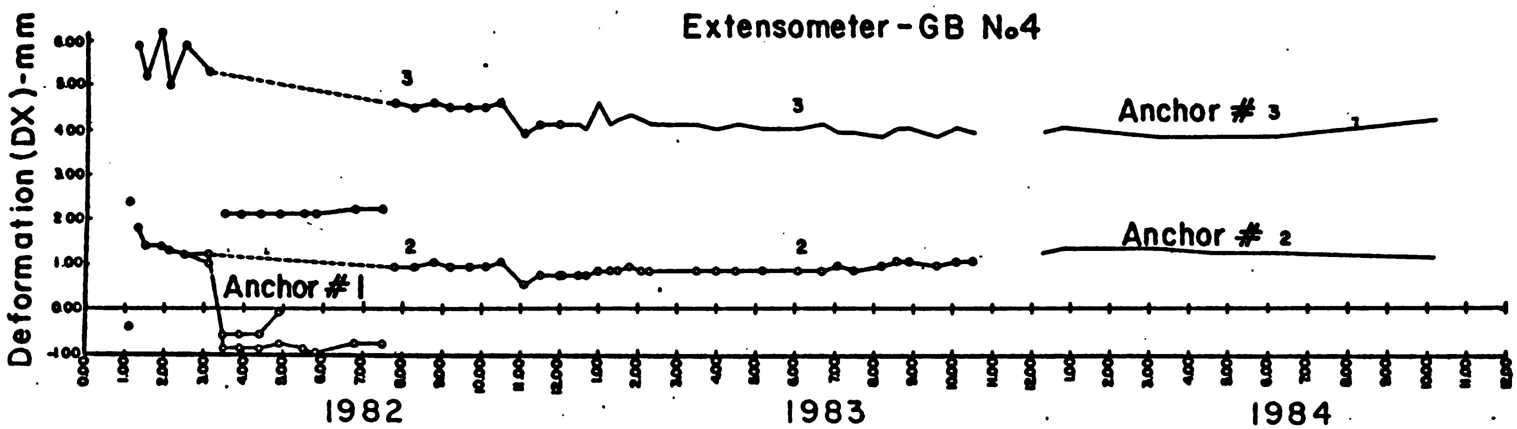

Figure 4.33. Deformation (DX), Extensometer GB No. 4, 1982-1984.

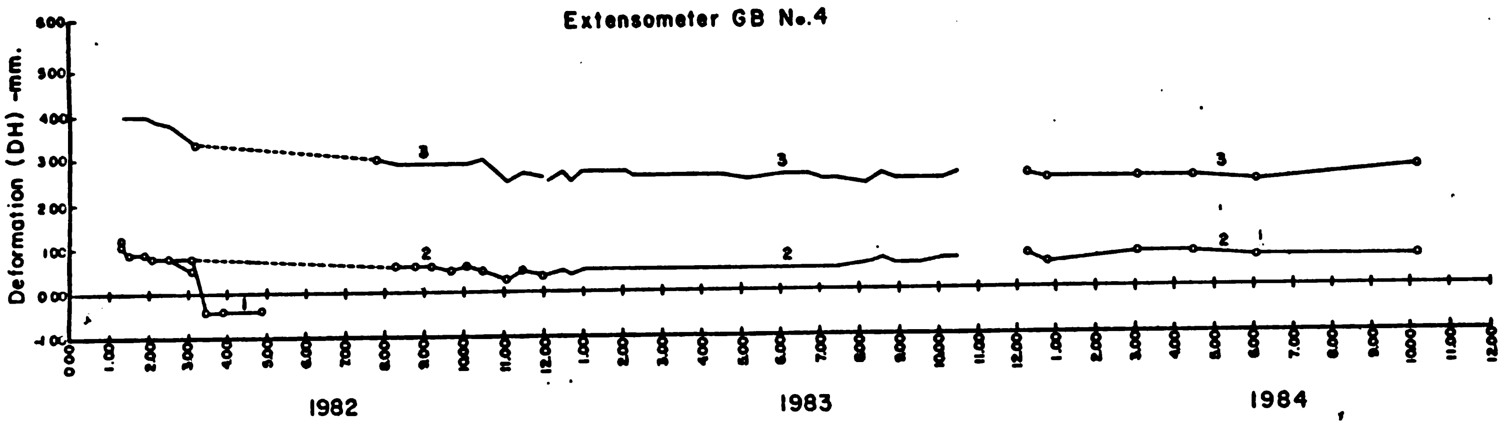

Figure 4.34. Deformation (DH), Extensometer GB No. 4, 1982-1984.

4.5 REGULAR INSPECTION AND MAINTENANCE PROGRAM

Regular inspection and maintenance program is rather critical to the dam security. During Hurricane David in 1979, spillway gates were not operable and considerable damage occurred. In this section, the supply inspection guidelines from U.S. Government agencies were reviewed first and recommended procedures for regular inspection and maintenance program are given.

4.5.1 Review of Regular Inspection and Maintenance of U.S. Governmental Agencies

A report titled, "Review and Analysis of Dam Safety Inspection Guidelines from U.S. Governmental Agencies" prepared by Regenstrif and Shen was submitted for this project in April, 1986. Their conclusions are given below.

Safety inspections of dams are necessary to help maintain the safety and livelihood of those living near a structure. The historical incidence of failures and accidents to dams has repeated examples of incidents that could have been prevented. Not all problems leading to incidents can be detected in advance by inspections, but there are enough that can be to make inspections worthwhile.

A statistical study of failures and accidents to dams, based on information gathered by the United States Committee on Large Dams (USCOLD) and the International Commission on Large Dams (ICOLD), showed durability problems as prevalent in leading to incidents, accounting for over 40% of incidents. The USCOLD report cites seepage problems to embankment type dams and deterioration to concrete structures as the most frequently encountered problems. Stability problems follow durability problems, accounting for over 30% of problems. Functional problems accounted for approximately 20% and other types of problems

accounted for the remainder. The studies also indicated that the early years of a dam's life are when most of the incidents occur. Overall, around 60% occur within the first ten years of operation.

Governmental programs on dam safety can help to protect the public by requiring that inspections are done and by generally promoting responsible practices concerning dams. The owner of the dam is ultimately responsible for his structure, but guidelines to ensure that he is being held responsible are a prudent measure. The Corps of Engineers (COE) rated the states in 1980 on the basis of their dam safety programs. Thirty states were found to have adequate dam safety programs. These states were contacted and asked to send information and documents concerning their program. Several federal agencies with dam safety programs were also contacted. The formats used by several states indicated an individual approach that met each state's needs and legislative requirements as the way to set up programs. Most of the states' organizations were centralized, working from one department. However, decentralized programs were also encountered. Programs for dam safety cover several aspects of the dam; they concern a project from its inception through operation and maintenance and finally, in some cases, its demolition. Periodic inspections of the dam are an important part of this program.

A program exerting the most direct control the dams is a direct surveillance program. In this case, the state is responsible for inspecting the dams. An alternative program uses the quality assurance approach, where the owner is responsible for the inspections, and assures the state authorities that inspections are being conducted. The choice of program approach is up to each state based on its resources.

As with almost any program today, obtaining funding for implementation can hinder the program from meeting its goals. The National Dam Inspection Act of 1972 (P.L. 92-367) was enacted to help the states improve or enact their own dam safety programs. Federal funding under the Act provided for inspections of high hazard structures, compiling an inventory of the dams in each state, training of state personnel and publishing documents on guidelines for inspection programs. Many states indicated that when the federal funding was withdrawn, they would not have sufficient state funding to continue the program. However, for those states with some funding, P.L. 92-367 provided an opportunity to improve their programs. When the COE rated the states as having adequate programs in 1980, states were not required to have adequate funding. In the 1982 report, only sixteen states of the twenty-four rated as having adequate programs included funding.

Besides using the expertise and guidance supplied by the COE through P.L. 92-367, the completed inspections pointed to an area of disagreement between inspectors and dam owners. This area concerns the spillway capacity requirements. Many dam owners feel the criteria is too strict and are supported by the low incidence of problems due to inadequate spillway capacity. A method for evaluating this criteria on a case by case basis, based on the damage estimates, with varying spillway improvements can be used to arrive at a solution that is acceptable to both parties.

Guidelines for safety inspections are not usually part of the legislated program. It would be too hard to cover all of the areas to look at on all of the dams under a program's jurisdiction. However, often generalized guidelines are included as additional material. But

to conduct a thorough inspection on an individual dam, an individualized guideline would be most appropriate.

In addition to individual characteristics of a dam project that help in choosing the inspection items for a guideline, the level of inspection being conducted can be used. Multiple levels of inspections are used to help minimize the cost of ensuring a safe structure while checking it frequently. A program of four levels of inspections, used by the Tennessee Valley Authority (TVA), describes this approach. The four levels of inspection are formal, intermediate, informal and special. The first three levels are conducted at set periodic intervals. The longer the interval between inspections, the more thorough the inspection is and the higher the level of inspectors. The formal inspections are the most thorough, conducted by engineers and geologists in the field of dam safety, at intervals of three to five years. Informal inspections are often conducted by damtenders on a daily or weekly basis. The special inspections are conducted when an abnormal event occurs, and can be as thorough as a formal inspection.

4.5.2 Inspections for Valdesia and Las Barias Dams

Four levels of inspections should be immediately put into effect for Valdesia and Las Barias Dams. These four levels of inspections are informal, intermediate, formal and special. Informal (or routine) inspection is for all proper personnel at the dams to make routine inspections of all features of the project on a routine basis that some designated personnel (at the dam) are required to inspect their dams at least once a month. The main purpose is to detect any visual evidence of distress or weakness. The lists of these weaknesses are given later in this section. Intermediate inspection should be conducced jointly by

responsible personnel in the Operation Divisions of both CDE and INDRHI. A formal inspection at about 5-year intervals should be conducted by specialists in structure, geotechnical, hydraulic machinery, hydraulics and others. Special inspection shall be conducted after the occurance of an abnormal event such as hurricanes, large floods, earthquakes, etc. If certain weaknesses should be discovered in any of these four level of inspections, consultants must be employed to make specific detailed analysis.

Weakness conditions may be described by the following condition.

1) Piping of boils in the area of any structure such as the embankment, downstream from the embankment, outlet works, or spillway.

2) Slides or sloughs on slopes of the embankment, spillway, stilling basin, discharge channel, or embankment abutments.

3) Increase in seepage quantities through or under the embankment, abutments, spillway area, or stilling basin.

4) Increase or decrease of flow from the structural joints, weep holes, or drains in the outlet works, stilling basin, or spillway.

5) Unusual vertical movement, horizontal movement, or cracking of the embankment or abutment.

6) Significant cracking of the outlet works, conduit, stilling basin, or spillway.

7) Sinkholes or localized subsidence within 500 feet of the embankment, outlet works, or spillway.

8) Excessive deflection, displacement, or vibration of the outlet works tower, service bridge piers, stilling basin retaining walls, and spillway monoliths or elongation/abrupt settlement of the conduit.

9) Erratic movement, excessive vibration, or operating failure of outlet works gates.

10) Excessive displacement, benching, or degradation of riprap and/or exposure of the embankment or bedding materials.

11) Unexpected increase or decrease in piezometer readings for embankments or foundations.

12) Occurrence of an earthquake.

13) Any other evidence of distress or potential failure that could inhibit operation of the project or endanger life or property.

4.6 REGULAR MAINTENANCE PROGRAMS

During Hurricane David, spillway gates could not be opened and severe damage occurred. It is important to keep all instruments in working condition through a strictly enforced maintenance problem. In addition, all monitoring systems for dam safety should be read regularly at every two week intervals and after each abnormal event. These data should be examined at least once every two weeks and also after each abnormal event. If significant change should occur in any of these readings, special consultants should be employed immediately to investigate the cause of these changes. Regular maintenance programs should include the following items.

4.6.1 Communication Systems

The communication systems available at Valdesia Dam and CDE in Santo Domingo are (1) through a UHF radio transmission system and (2) a micro-wave telephone system. Neither of these proved to be fail-safe during Hurricane David. Additional redundancy needs to be built into these systems because emergency communications between the two facilities are extremely important for (1) forecasting events, (2) starting emergency operating procedures, and (3) putting evacuation plans into operation.

During Hurricane David, the micro-wave tower was blown down. This tower must be strengthened to withstand the most severe storms. Consideration also might be given to constructing a second auxiliary tower located nearby at a more protected location, if this is possible. The radio station also was not operable during the storm. Apparently, the equipment for this stations is in poor condition and should be replaced.

There should be operators at both ends of the system available in some form at all times to transmit and receive critical information and instructions.

The communications system must be closely examined before June of each year (before hurricane season) and once a month during hurricane season.

4.6.2 Gate Operating System

The major defect in the dam emergency operating system was vividly demonstrated during Hurricane David when the gates could not be operated. This resulted in the destruction of all five gates at Valdesia and two gates at Las Barias Dams, accompanied by other damage at the dams and in the downstream river channel. The principal reason for gate opening failures was the lack of electric power from the primary powerhouse source and the emergency source. Although substantial improvement has already been made, it is strongly suggested that additional modifications be made to provide greater protection to primary and backup power systems.

The primary source of electric power for operating the gates, during normal operations, is from the CDE electrical network, that includes the Valdesia generators, and this is satisfactory under normal conditions. However, during Hurricane David, the network power was out and, reportedly, the Valdesia generators were shut down because of lack of operators, large flow of water from the hillside into the generator room, and/or equipment vibration. The powerline from an emergency 450 KW diesel generator, located in the adjacent hillside, was damaged or destroyed by the storm. Thus no power was available to operate the gates. Manual operations is not feasible during an emergency and should

not be relied upon. The Board believes that the main backup system should be more reliable.

First, the generator station should be protected from accumulation of outside water, and, as mentioned, the penstock inlet trashrack should be improved, if generator vibrations were due to unsteady flow.

Secondly, the 450 KW diesel generator power should be protected. This unit has been moved from the hill to the switchyard area. The power to the gates is now supplied by means of cables on an open, shelf type raceway, bracketed to concrete training and retaining walls. This outside system is subject to possible failure during a major storm. The cables should be placed in a concrete raceway placed on the ground and provided with a steel cover. Weep hole drainage of the structure should be provided if necessary. Also there is some chance that the transformer near the diesel generator house could possibly be damaged. This should be housed or otherwise protected.

Thirdly, a small generator has been added at the top of the dam. This can only operate one gate at any one time. However, in a rapid hurricane storm, the time to operate all gates with this unit would be excessive, and not practical in a storm as potent as Hurricane David.

Power to operate the Las Barias Dam gates is supplied over a power line from the CDE network. There is no emergency source of power to operate the Las Barias spillway gates in case of interruption to the normal power supply. During a storm emergency, it is essential to the integrity of the dam that a capability to simultaneously operate all gates be available. Thus an emergency power generator should be installed at the las Barias Dam to ensure that capability.

All power sources for gate operation should be checked each week. The actual gate operation with full reservoir head should be attempted about once every four months if possible, making an attempt to duplicate, as closely as feasible, the severe hurricane conditions.

Dam Safety Monitoring Instruments

1. Valdesia Dam:

Several types of instrumentation were provided for the Valdesia dam and foundation in 1980. These included electric piezometers of the vibrating wire type, pendulum type movement devices, extensometers and accelerometers (see publication "Auscultacion de La Presa de Valdesia, Proyecto de Instalacion de Acelerografos y Piezometros de Cuerda Vibrante" by OFITECO, dated April 1980).

It was reported in the publication "Control de la Subpresion" by OFITECO, dated December 11, 1980, that 18 piezometers were placed through the base concrete into the dam rock foundation. These were located at blocks 5, 11, 15, 17 and 18. The locations are shown in the above publications. There were 16 single piezometers (one elevation) and two installations with two piezometers (two elevations, each). The piezometers are placed in a hole drilled into the foundation conglomerate. Sand surrounds the piezometer unit which has a porous element and a cuerda vibrante (vibrating wire) with a cable to a central location for activation and readings. This type of piezometer is satisfactory, providing the equipment is properly maintained and the engineer taking the readings has been properly trained for making the observations. Piezometers should be checked every three months to insure that they are functioning properly.

All these data should be taken every two weeks to show uplift pressures acting on the base of the dam.

As discussed in Section 4.5, piezometer P5-1 did not function properly. A check should immediately be made of the piezometric P5-1 to determine if the measurements being obtained are accurate. This can be accomplished by either installing an additional piezometer of another type close to any piezometer whose measurements are suspect or by temporarily converting a nearby drain hole to measure uplift pressures. The latter method can be accomplished by inserting a packer with gage into the top of the drain hole.

The first referenced publication indicates that pendulo (pendulum) type movement measuring devices were installed at three locations as shown on Plan No. 1. Data from these were recorded about every two to four weeks. These data should be summarized by appropriate time-movement graphical plots. This must be done and be maintained continuously as data are obtained. We have received pendulum data for 1982, 1983, and 1984. Any change of basic datum must be clearly stated, see discussion in Section 4.5.

The first referenced publication also indicates that four extensometers were installed as shown on Plan No. 1. These data, also taken at about two to four week intervals, should be summarized by time vs movement graphical plots. This must be done and the records maintained up-to-date.

Measurement points were also inserted into the concrete at several joints. These consist of three points across which dial gauge measurements can be made. Records of measurements have been recorded and should be plotted continually.

Three accelerometers installed on heavy concrete blocks are located in the left abutment rock, on the upper part of the dam near midpoint and on the lower part of the dam at about the quarterpoint towards the right side. These are strong motion Terra Tech., Model RFT-350 accelerographs, which are activated and reactivated at certain levels of earthquake (or other) accelerations. This installation was discussed in "Auscultacion Presa de Valdesia, Sistema de Vigilancia Sismica" by OFITECO, dated October 3, 1980. These were not installed prior to the 1979 earthquake, therefore, no records of that event are available. We were shown the measured data during June, 1986. The accelerometer triggers a target when activated. The instrumentation engineer should check this while reading the other instruments, at the two to three week intervals. If triggered, or if a noticeable earthquake event occurs, the film should be removed and interpreted as to magnitude of strong ground motion. A purpose of the accelerometer is to register the time of any strong ground motion. One should then immediately check all the other measurements after this event. The correlation of the registered acceleration with dam behavior should be investigated after each major movement.

We did not see any physical measuring points (brass bench marks, steel imbedded rods or other fixed points) for surveying horizontal and vertical movements of the top surface of the Valdesia dam. This is normally done as a "fixed points" measuring system which is easy to install and inexpensive. One line of points anchored into the roadway concrete should be positioned longitudinally at the center of each block. Precise leveling and distance readings (to 1/1000 ft - 0.3048 mm) should be surveyed at three to four month intervals and be

correlated with other instrument readings. Later, readings may be made at one year intervals if justified by the data. The data should be plotted for horizontal and vertical movements on movement vs time graphical record sheets. It is unlikely that all points on the dam can move the same amount continuously. Even when fixed points can not be rigorously established, the survey should be carried out to measure at least the relative movements of dams.

2. Las Barias Dam:

We were advised that no instrumentation has been installed at the Las Barias Dam, either for the embankment section or the gate structure. As a minimum, one line of survey points for horizontal and vertical control should be established along the crest of the dam and gate works at horizontal intervals of about every 50 meters or between gates. Companion points should be established similarly in a line about one-half way down the downstream embankment slope. Precise level and distance measurements to 1/1000 ft (0.3048 mm) should be made about three times per year. The points could be brass caps, steel rods or other fixed points imbedded in concrete or drill holes filled with mortar in the embankment.

The toe drain outlet should be repaired. The toe drain manhole should be inspected regularly and the depth of drain water recorded. It would be advantageous to establish a flow measuring weir at the discharge end of the embankment drain, during the outlet structure repair work. A periodic record of the amount of seepage through the upstream concrete face and the embankment could then be monitored on a continuing basis.

4.7 WARNING AND EVACUATION PLANS

Emergency gate operations are discussed in Volume III and organization considerations are given in Volume V. Although it is not within the scope of this project, discussions on warning and evacuation plans are given below.

4.7.1 Warning System

There should be warning systems at the dams and critical locations downstream from the dams. Warning systems ar required during emergencies caused by hurricanes and other major precipitation events which require large passages of water through the open gates, or floods caused by breach of one of the dams due to earthquake or other causes. When large superflows are anticipated, a warning procedure is needed to warn workers and supervisory people at the dams and families and persons living within the flood plain downstream.

At the present time, the flood plain hydrology of the Nizao River below the dams, has not been developed. A detailed study is necessary to determine the inundation levels for various upstream discharge flows. The studies should show the inundation levels for normal flows, high precipitation flow events when dam gates are opened, excessive flows during hurricane events when dam gates pass their maximum capacity, and major floods in the event of full or partial breach of the dams.

Various types of warning systems should be considered for various flood levels. Less extreme flood dangers can be announced to the populace by army, police or others, because the events may be forecasted ahead of time, or, at least, there is adequate time for evacuation. Warning systems should be developed for the specific grade of the emergency visualized. Such emergencies include large flows with partial

to full gate openings, extreme flows caused by major hurricanes, and floods caused by a breach of the dam. Generally, the warnings would be initiated by the dam operators in accordance with the emergency operating plan based on reservoir elevations. In the case of high magnitude earthquakes, the quake itself would be the alerting mechanism. During the periodic readings of piezometers and the other instruments of the dam, the monitoring staff should be alert to any significant or major changes in readings which might indicate a buildup of failure conditions. These might be forewarnings of water pressure buildups, drainage failures or structure or foundation movements. If believed necessary for continuous surveillance, the instruments themselves could be so adapted to trigger a warning system when extreme differences of readings from the normal are developed. This, however, would be a very sophisticated system and is not ordinarily provided or recommended at this time.

4.7.2 Evacuation Plan

After the flood plain hydrology study has been made and the various type of warning systems have been established and proven, there will need to be an evacuation plan. Such a plan will have various goals depending upon the severity of the anticipated flood events, the terrain, and location of populace. For minor floods due to high precipitation events which require partial gate openings, people could be warned to move to higher ground. The passage of a hurricane event with full gate openings might require some of the populace to move to much higher ground and others to evaculate the valley. A dam breach probably would require valley evacuation. The army, police or emergency agency people will be required to enforce movement or evacuation of

people and to assist with transporation and other needs. Such evacuation emergencies should be well planned in advance and trial emergency operations scheduled.

4.8 SPECIAL PROBLEMS

Some problems were noticed by the Consultant Board during their dam inspection trip in May 1985 and then special problems must be taken care of immediately.

4.8.1 Valdesia Dam

Power Intakes:

During the passage of Hurricane David in August 1979, a single main generator was in operation for about one hour. It was closed down when its operation became irregular and noisy and drainage water entered the generator room. While the somewhat higher than normal reservoir water level and wave action during the hurricane resulted in increased penstock pressures, it is not likely that this was the major cause of erratic generator operation. Substantial blockage of the intake trash rack could have produced sufficient pressure fluctuations in the penstock to cause the irregular and noisy generator operation.

During the site visit, both generators were in operation with the reservoir at elevation 131 meters. There was a vortex at the power intake which contained a substantial amount of floating debris. The vortex appeared to be pulling some of this debris down to the trash rack which could cause partial blockage of the trash rack. For lower reservoir elevations, several smaller vortices could form.

It is suggested that an underwater inspection be made of the power intake trash rack to determine the extent of its blockage by debris.

The trash rack should be inspected periodically when the reservoir water level is low and cleaned of debris, if necessary. Consideration should be given to the need for providing a vortex suppressor with a larger trash rack to reduce pressure fluctuations in the penstocks when the rack is partially blocked with debris.

Low Level Outlets:

The two low level outlets could not be operated during Hurricane David as they were blocked with debris and sediment. In the right outlet, which has been opened and cleaned, the intake trash rack failed causing trash to lodge in the downstream Howell-Bunger valve making it impossible to operate the valve. The Howell-Bunger valve has been replaced with a slide gate which will prevent blockage of the outlet at the control valve. It is not known whether the trash rack has been replaced. If not, a larger and stronger trash rack should be installed to prevent blockage of the outlet at its intake. The left outlet should be made operational in the same manner as adopted for the right outlet as both outlets should be available to lower the reservoir level at the beginning of an emergency reservoir operation.

Spillway Stilling Basin:

The spillway stilling basin normally is filled with 10 meters of water when there are no flows through the low level outlets and over the spillway crest. The stilling basin has not been unwatered and inspected since completion of construction. During the site visit, it was stated that the stilling basin invert was covered with several meters of logs and other trash. The stilling basin should be unwatered and cleaned, after which the concrete surface should be inspected to determine whether the passage of logs or the crest gates during Hurricane David

caused any damage to the concrete. If so, the damage should be repaied before the stilling basin is placed back into operation.

Reservoir Sedimentation:

A large volume of sediment was deposited in Valdesia Reservoir during Hurricane David. A sediment survey made in December 1979 indicated that the top of the sediment deposit was near the bottom of the power intake. Most likely, a substantial amount of fine suspended sediment passed through the turbine unit which was in operation during the first part of the hurricane. Later inspection indicated that this sediment did not damage the turbine runner. A contract has been signed to remove much of the deposited sediment by dredging operations. Sediment deposits should be monitored carefully, particularly after each large flood, and removed when necessary to insure that coarse sands and gravels do not pass through the low level outlets and power intake.

Foundation Strength and Dam Stability

Data presented to the Board of Consultants included some drawings and written documents which indicate the extent of geologic and foundation explorations. These data, along with our observations at Valdesia Dam, suggest that the foundation for the dam consists mainly of conglomerate. The rock, as exposed on the abutments, contains gravel, ranging from pea to cobble size, in a matrix of medium to fine sand. Although the sandy matrix is only moderately well cemented, the rock is strong and forms massive bluffs in outcrops both up and downstream of the dam. Descriptions of geologic conditions encountered during construction were not available; however, from all indications, the rock remains the same conglomerate formation in the lower parts of the foundation. The Board was not presented any original design analysis,

assumptions, or parameters used for the design. It was noted in the report on the visit to the dam construction site on November 1972 by C.I.E.P.S. that a total shear resistance of 20 kg/cm^2 was used to compute sliding stability for design of the dam. In the Board's opinion 20 kg/cm^2 without any allowance for the angle of internal friction would represent a very conservative value for shear resistance of the conglomerate rock. Yet, the same report indicated that tests yielded strength values from 1 to 4.2 kg/cm^2 on the foundation rock without indicating how the tests were conducted or what material those results represent. An average value of 2 kg/cm^2 for shear resistance was used to review the stability of an average buttress with the finding that the vactor of safety was 1.2. Such a low factor of safety is considered unsatisfactory for safe performance of the dam. The Board questions the very low value of shear resistance used in the analysis and recommends that a future safety evaluation include: (1) a thorough review of the site geology to determine the nature of foundation materials, (2) a review of data to determine how the foundation was treated and shaped during construction, (3) an evaluation of shear resistance of the rock against sliding, and (4) a reanalysis of shear resistance against sliding utilizing the most critical buttress with uplift pressures as determined by measurements. The Board suggests that, after a good understanding of the type and nature of the foundation is obtained, experienced engineers can estimate conservative, but realistic, values for shear resistance of the rock. The dam's factor of safety against sliding can then be checked. If unsatisfactory values for factor of safety are obtained, it may then be necessary to conduct carefully

controlled laboratory and/or in situ tests of the foundation rock to determine a proper value for shear resistance.

Foundation Drains:

During the inspection of the interior of Valdesia Dam, the Board noted that some foundation drains situated in the spaces adjacent to buttress number 15 were plugged with wood or mud. Also, the drawings made available to the Board do not show all locations of the drains in plan view.

The proper functioning of the foundation drains is essential to the dam's stability and their effectiveness should be continuously monitored to assure their openness and a condition of free flow. As soon as feasible, the locations of all foundation drains should be determined and recorded by number and location. All drains should be inspected for openness and cleaned out where needed. A record should be kept of flow from each drain and date of last cleanout. The drain monitoring program should be correlated with uplift pressure measurements to help assess the effectiveness of the drainage system. It would also be beneficial to measure the discharge from the sump pump that evacuates all water inflow to the dam's interior and correlate the measurements with time and reservoir levels. That data would show any increasing or decreasing rates of leackage and drain discharges. Any sharp decreasing rate should be further investigated to determine if the cause is due to loss of drain effectiveness.

In addition to the foregoing, it is advisable that an assessment of the adequacy of the existing foundation drainage system be made based on stability analysis using uplift pressures as indicated by piezometers. Should results indicate that increased stability is desirable and that

improved foundation drainage would be beneficial from the viewpoint of reducing uplifts, then additional drains should be installed.

Seismicity and Dynamic Analysis:

The Dominican Republic is subject to recurrance of strong earthquakes. The largest earthquakes tend to be located on the north side of the island as evidenced by the 1946 Richter Magnitude M8.1, 1948 M7.3, and 1953 M6.8 events. Although the zone of strongest earthquakes is located some distance from Valdesia Dam, the seismicity is complicated by indications of an active, relict subduction zone which generally underlies the area of the dam site. Present day seismicity is related to active plate tectonics wherein the island of Hispaniola is at the northeast boundary of the Caribbean plate which is moving east with respect to the North American plate.

Seismicity of the island is well documented in a report titled "Technical Report, CDE Seismograph Network, December 13, 1979 - July 17, 1981" revised July 23, 1982 by Matumoto and Terashima of the Institute of Geophysics, Galveston Marine Geophysics Laboratory. The authors examined records of historic seismicity and estimated that the dam site area has experienced earthquakes with a Modified Mercalli Intensity IX-X during the period of 1567-1910. Intensity IX-X correlates approximately to Richter Magnitude 7-8 range. During the study period for the referenced report more than 1,500 earthquakes were recorded and based on the data, the authors proposed three seismic zones in the Dominican Republic. Zone 3 includes the area of Valdesia Dam. Statistical studies of earthquake recurrence for Zone 3 indicate the following return period for various levels of Richter Magnitude: M6.0 - 23 years; M6.5 - 43 years; M7.0 - 78 years; and M7.5 - 144 years.

The preceeding discussion illustrates that Valdesia Dam is subject to significant seismicity. The Board of Consultants was not presented data indicating the magnitude of the seismic factor selected for the original design or how it was applied in stability analysis. The Board recommends that the stability evaluation of the dam include a modern dynamic analysis similar to those conducted for safety evaluations of major dams in highly seismic areas of the United States. Such an analysis needs to be preceded by an earthquake study for the Valdesia Dam site in which a Safety Evaluation Earthquake (SEE) is selected along with appropriate ground motion parameters for the site. It should be mentioned that Professor Mete A. Sozen, in his report of April 25, 1979, "Report on Inspection of Valdesia Dam and Power House, Dominican Republic," recommended that a dynamic analysis of the dam be made following an earthquake site study.

4.8.2 Las Barias Dam

Reservoir Sedimentation:

The site inspection at Las Barias Dam indicated that sediment was deposited in the reservoir upstream of the dam and that some coarse sands and gravel have passed over the spillway crest and through the stilling basin. One sediment survey indicated the top of sediment deposit upstream of the spillway structure to be about 2 meters below the spillway crest. Concrete surface erosion on the spillway crest just downstream of the gate sills and on the end sill at the downstream end of the stilling basin indicates that coarse sands and gravels have passed over the spillway crest and through the stilling basin. This is also evidenced by freshly deposited gravel bars in the river channel a short distance downstream of the stilling basin. It is suggested that

reservoir sedimentation be monitored to insure that large quantities of coarse sediment do not pass over the spillway to cause excessive damage to concrete surfaces. To prevent this possibility, it may be necessary in the future to remove sediment deposited for some distance upstream of the dam. Removing sediment from the reservoir would also increase water storage in the reservoir and this benefits irrigation.

Spillway Stilling Basin:

It appears that the stilling basin has never been unwatered for inspection. It should be unwatered and the concrete surface should be inspected to determine whether excessive erosion has occurred or is likely to occur if coarse sands and gravels continue to pass through the stilling basin. Nonuniform gate operation would cause some gravels to remain in the stilling basin and be moved around by eddy currents to cause additional concrete erosion. Any abrasive material which may be in the basin should be removed when the basin is unwatered. The crest gates should be operated as uniformly as practical when coarse sands and gravels pass over the spillway crest in order to minimize the amount of these materials which may be trapped in the stilling basin.

Erosion Downstream of Stilling Basin:

The site inspection indicated that considerable erosion has occurred in the river streambed just downstream of the stilling basin. A large portion of the sheet pile cutoff at the downstream end of the basin has failed and is disconnected from the structure. Most of the original rock blanket downstream of the cutoff has been destroyed by downstream erosion which appears to be several meters deep in some locations. A survey should be made of the scour hole downstream of the stilling basin to determine whether there is a possibility of

undermining the end of the stilling basin; the side walls, particularly the left wall; and the outlet structure of the earth embankment downstream toe drains. If further deepening of the scour hole would endanger these structures, consideration should be given to placing a sufficient amount of large stone adjacent to the structures and into the scour hole to stabilize the whole area. The steel-sheet piling in place should be cut off at the stilling basin end sill top elevation and bent and displaced steel piling should be removed.

Gallery and Foundation Drains:

Board members could not inspect the spillway gallery at Las Barias Dam because is was flooded and could not be drained due to the inoperability of the sump pump. Thus, the sources of possible leakage and the foundation drain discharge into the gallery could not be assessed. It is essential that the gallery sump pump be maintained in an operable condition to permit the periodic inspection of the gallery and the foundation drainage system. As in the case at Valdesia Dam, the Las Barias Dam foundation drains should be inspected, cleaned out where needed, and monitored closely to assure their effectiveness.

4.9 CONCLUSIONS AND RECOMMENDATIONS

- All recommendations (including those by the Consulting Board as stated previously in this volume) should be implemented at once.