INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT

INDUS WATERS SETTLEMENT PLAN

April 18, 1960

Department of Technical Operations
CURRENCY EQUIVALENTS

4.762 rupees - U.S. $1.00
1 rupee - U.S. $0.21
1 million rupees - U.S. $210,000
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Annexure 1
Annexure 2
1. The Indus Basin system of irrigation is the largest single system in the world. The irrigated area is equal to the total irrigated area in the United States and is one-eighth of the total irrigated area in the world. A map of the Indus Basin is annexed as Annexure 1.

I. Objectives of the Plan

2. Under the provisions of the proposed International Water Treaty, the use of the Indus waters would be divided between India and Pakistan. With some exceptions provided for in the Treaty, the waters of the three Eastern Rivers (Ravi, Beas, Sutlej) would be available for the use of India and the waters of the three Western Rivers (Indus, Jhelum, Chenab) would be available for the use of Pakistan. The areas in Pakistan now irrigated from the Eastern Rivers would, in future, be irrigated by supplies transferred from the Western Rivers by a system of link canals, backed up by a volume of reservoir storage.

3. These areas are located in The Sutlej Valley, and along The Ravi in the area of the Central Bari Doab. In extent, they amount to about five million acres, which is approximately equivalent to the area in Egypt irrigated from the Nile. To supply these canals from the Western Rivers would require the transfer of about fourteen million acre feet of water.

4. Most of the difficult problems experienced in irrigation projects are found in the Indus system. The rivers themselves, fed by glacier and snow melt and by torrential monsoon rains, are subject to great variations in flow, seasonally and annually. At certain times floods occur which result in large losses of crops and cattle and breaches of irrigation canals. Moreover, there is a large spill to the Arabian Sea, equivalent to about the average annual discharge of the Nile River. But during the periods of seasonal low flow, acute shortages occur on all canals at critical times during germination or maturing of crops. For these reasons the construction of storage reservoirs to capture water during the periods of high flow for release during the periods of low flow is a necessary element in the future development of irrigation throughout the basin.

5. Waterlogging and salinity are a serious menace in Pakistan. As irrigation has increased, the water table has been progressively rising with the result that several million acres of land have become waterlogged. Because of the high water table and lack of drainage, millions of acres are severely saline or are becoming so, and consequently unfit for cultivation. Tens of thousands of additional acres are being affected each year.
6. The Engineering Plan which is to be adopted, not only effects the necessary "replacement" of Pakistan's present irrigation uses from the waters of the Eastern Rivers necessitated by the proposed division of the waters, but also contemplates remedial measures for the problems mentioned in paragraphs 4 and 5 above. Moreover, while the primary purpose of the reservoir capacity to be constructed by Pakistan is to meet the requirements of irrigation, advantage would be taken of the hydro-electric potential for the generation of power to meet Pakistan's growing needs.

II. Projects to achieve Objectives

7. The Engineering Plan would be the largest program of its kind ever to be undertaken anywhere in the world. It would involve a gigantic system of works requiring 10 to 12 years to construct. In West Pakistan it would consist of the following Projects:

. Two large Dams and storage reservoirs on The Jhelum and The Upper Indus;
   Hydro-electric power installation at The Jhelum Dam;
   Six new major inter-river link canals joining The Indus to The Jhelum, The Jhelum to The Chenab, The Chenab to The Ravi, and The Ravi to The Sutlej;
   Three new barrages at points where a new canal crosses a river;
   Remodelling of five existing barrages;
   Remodelling of four existing inter-river canals;
   Remodelling of four existing canals;
   Tubewell and drainage works.

1. Dam and Reservoir with Power on The Jhelum

8. The Jhelum River Dam would be an earth-fill dam, and create a reservoir which, with the crest of the dam at El 1220, would have a gross capacity of 5.35 MAF and a usable or live storage of 4.75 MAF. The power plant is designed to consist initially of four units of 75,000 KW each, a total of 300,000 KW.

9. Pakistan has requested that the dam should include the necessary structures for raising the crest level at some later date to increase the storage capacity from 4.75 MAF to some 8 or 9 MAF. This would increase the quantities of fill and therefore the cost. This incremental cost will not be met out of the Fund.

10. The total amount of fill would be approximately 83,000,000 cubic yards, and the spillway would require about 1,000,000 cubic yards of concrete.
2. **Dam and Reservoir on The Indus**

11. The Upper Indus River Dam would be a rock-fill dam and would create a reservoir which, with the crest of the dam at El 1420, would have a gross capacity of 5.1 MAF and a usable or live storage of 4.2 MAF. No power installation would be included in the initial project, although certain civil works needed for future power development would be incorporated.

12. The total amount of fill would be approximately 94,000,000 cubic yards and the spillway would require about 700,000 cubic yards of concrete.

3. **Rasul-Qadirabad Link Canal**
   
   **Capacity 19,000 cusecs**

   **Remodelling Rasul Barrage**

13. This link canal would carry water from The Jhelum to The Chenab and would draw from the pond above Rasul Barrage. The barrage would be raised 5.5 feet to provide a 2 foot working head from the pond into the canal and also achieve the necessary command at the outfall into The Chenab above the new Qadirabad Barrage. The canal, which would be un-lined, would have a total length of 27 miles and would be excavated by machine dredging.

14. Besides the construction of a head regulator, there would be 39 other structures to be built, consisting of 5 inlets, 6 canal crossings, 3 cross-drainage works, 1 outfall and 24 bridges.

15. The volume of earthwork would total some 45,000,000 cubic yards.

4. **Qadirabad-Balloki Link Canal**
   
   **Capacity 18,600 cusecs; Sub-link 5,000 cusecs**

16. This link canal would carry water from The Chenab to The Ravi. It would have a total length of about 80 miles. It would be a deeply-cut canal with a head capacity of 18,600 cusecs. It would take off at the new Qadirabad Barrage on The Chenab and outfall into an arm of The Ravi at a point a few miles upstream of Balloki. The canal would be excavated by machine dredging.

17. Besides the construction of a head regulator, there would be 125 other structures to be built, consisting of 2 cross regulators, 4 falls, 20 inlets, 25 canal crossings, 3 cross-drainage works and 71 bridges.

18. The volume of earthwork would total some 120 million cubic yards.
5. Balloki-Suleimanke II Link Canal  
Capacity B-S I increased 3,500 cusecs to 18,500 cusecs

Remodelling Balloki Barrage

19. This link canal would essentially be an enlargement of an existing link canal (B-S I), about 54 miles in length, to increase its capacity from 15,000 cusecs to 18,500 cusecs and would require modification of the Balloki Barrage. The combined canals would carry water from The Ravi to The Sutlej. They would take off from the pond at Balloki on The Ravi. As the groundwater level is generally below the proposed canal bed, the canal would be excavated largely in the dry.

20. Besides the construction of the cross regulator, there would be 40 other structures to be built, consisting of 2 falls, 10 canal crossings, 7 drainage crossings and 21 bridges.

21. The volume of earthwork would total some 13 million cubic yards.

6. Trimmu-Islam Link Canal  
Capacity 11,000 cusecs

Remodelling Trimmu Barrage

22. This link canal would carry water from The Jhelum-cum-Chenab into the lower reach of The Sutlej. It would take off at Trimmu Barrage on The Chenab just downstream of The Jhelum confluence. It would be about 106 miles in length. The Trimmu Barrage would have to be remodelled to provide for the new link.

23. A total of 147 structures would be needed, consisting of 7 regulators, 5 falls, 70 drainage works and 65 bridges.

24. The volume of earthwork would total some 62,000,000 cubic yards.

7. Kalabagh-Jhelum Link Canal  
Capacity 22,000 cusecs

Remodelling Kalabagh Barrage

25. This link canal would carry water from The Indus into the lower reach of The Jhelum. It would be about 84 miles in length and would take off from the pond above Kalabagh Barrage on The Indus. Remodelling of the barrage would be necessary to provide for the new link.

26. A total of 119 structures would be required, consisting of 2 regulators, 9 falls, 42 drainage works and 66 bridges.
The volume of earthwork would total some 88 million cubic yards.

8. Taunsa-Panjnad Link Canal
   Capacity 12,000 cusecs

This link canal would carry water from The Indus to the lower reaches of The Jhelum-cum-Chenab. It would be 45 miles in length and would take off at the Taunsa Barrage.

Besides a regulator, a total of 53 structures would be required, consisting of 5 falls, 22 drainage works and 26 bridges.

The volume of earthwork would total some 23 million cubic yards.

9. Marala-Ravi Link Canal and Remodelling of Marala Headworks
   Capacity 22,000 cusecs

The construction of this link canal, whose length is 60 miles, has been completed. In view, however, of recurring heavy damage to the link from floods, the present capacity of cross-drainage works is inadequate and must be at least doubled to make the link safe against flood hazards.

In addition, remodelling of the Marala Headworks is essential because of difficulties experienced in regulation and silt control.

10. Bambanwala-Ravi-Bedian-Dipalpur Link Canal
    Capacity 5,000 cusecs

The construction of this link canal, whose length is 103 miles, has been completed. In view, however, of repeated high floods in The Ravi during the past few years causing large damage, additional cross-drainage works are necessary.

11. Modifications to Existing Canals

34. Balloki-Suleimanke I Link Canal,
    Haveli Link Canal,
    Dipalpur Canal,
    Sidhnai Canals,
    Pakpattan Canal,
    Fordwah Canal.

Minor works are necessary to improve the utility of the Balloki-Suleimanke I Link Canal, and on the other canals named above, to meet some or all of their requirements from sources different from the existing pattern of supply.
12. New Barrages

36. Three new barrages are needed at points where a new canal crosses a river.

37. Near Qadirabad on the Chenab, a new barrage is needed for the Qadirabad-Balloki Link.

38. Above Sidhnai, a new barrage on the River Ravi is needed to provide a crossing for the Trimmu-Islam Link.

39. Below Islam, a new barrage on the River Sutlej is needed for the crossing for the Trimmu-Islam Link.

40. For all three barrages, standard gates 60 feet in width would be incorporated. Qadirabad Barrage would have 54 spans of gates, Ravi Barrage, 20 spans, and Sutlej Barrage, 30 spans. The lengths of these barrages would be 3,558 feet, 1,314 feet and 1,974 feet, respectively.

13. Tubewells and Drainage

41. A tubewell program is planned, consisting of a total of some 2,500 tubewells, having an average capacity of three cusecs each. This program would develop an area of about one million acres, using about 1,000 tubewells with an annual yield of approximately 1.6 MAF. About 1,500 tubewells would be installed along the link canals, Taunsa-Panjnad, Rasul-Qadirabad, Trimmu-Islam, lower Balloki-Suleimanke and B-R-B-D.

42. Open and tile drains would be constructed for the drainage of the million acres in the 1,000 tubewell area and also for 1,600,000 acres of a larger tubewell area under a separate program, sponsored by the Development Loan Fund.

14. Construction Schedule

43. The construction schedule would give appropriate priority to the construction of those works which are related to "replacement", and it is of vital importance to Pakistan that these works should be completed and brought into effective operation before the end of the Transitional Period laid down in the Water Treaty.

44. The first work scheduled for completion would be the existing links, B-S I, M-R, and B-R-B-D. Next would be the Trimmu-Islam Link, to utilize Jhelum flow supplies and additional Chenab flow supplies, and the Qadirabad-Balloki Link to carry Chenab flow to Balloki, for Suleimanke. The Rasul-Qadirabad Link would be scheduled to be completed upon the completion of the Jhelum River Reservoir in the seventh or eighth year, to deliver stored water to the link system and to the Sutlej Valley. The Balloki-Suleimanke II Link would be required next to deliver maximum
supplies to Suleimank. The last links to be completed would be those from the Indus River. The Indus River Dam would be completed in about the twelfth year and would provide substantial additional supplies of stored water for irrigation development. The auxiliary canal work and the barrages incidental to each major link would be completed simultaneously with the links.

III. Engineering of Plan and Cost Estimates

A. General

45. The system of works for the Plan was drawn up by the Government of Pakistan in consultation with the Bank. The Government appointed an Indus Basin Advisory Board for this purpose, consisting of representatives of two American engineering firms and a British consulting engineer who was formerly a Chief Engineer in Punjab.

46. The Water and Power Development Authority, West Pakistan, (WAPDA) has been vested by the Pakistan Government with the responsibility for the implementation of the Plan. WAPDA's responsibility covers all irrigation development and a very substantial part of power development in West Pakistan.

47. The Authority has engaged a number of technical personnel, both Pakistani and foreign, to enable it to carry out its functions. In view of the magnitude of the Plan, WAPDA has also engaged the Harza Engineering Company of Chicago as coordinators and supervisors of the construction of the system of works.

48. A task of this magnitude will require the use of engineering and construction talent on a very large scale. The construction, procurement supply and transportation problems will tax every field of Pakistan's economy and administrative and technical competence.

B. Engineering

1. Jhelum River Dam

49. Several dam sites in the Upper Indus Basin, including sites on the Jhelum River and sites on the Indus main stem, have been under preliminary examinations for several years. In 1953, the Government of Pakistan established an organization for investigation of promising dam sites and appointed an advisory board of foreign consulting engineers. On March 1, 1953, the Government of Pakistan retained the American firm of Tipton and Hill, which had experience in the area, to assist in the investigations and to report on the feasibility of the several projects then contemplated.

50. After more than a year of investigation of the physical and economic conditions having material bearing on the feasibility of Jhelum
River Project, Tipton and Hill reported on May 31, 1954, that the Project on the Jhelum River was feasible of construction and had a high order of economic priority.

51. The Government of Pakistan thereafter requested proposals on an international basis for consulting engineering services for the Jhelum River. The British firm of Binnie, Deacon and Gourley was selected for the preparation of plans and specifications and for supervision during construction. Harza were also retained on design of the spillway. After about two years, their work was nearing completion and the Government appointed an international Panel of Experts to review the plans. Some revisions were suggested by the Panel, which have been adopted by the Project Consultant. The plans and specifications are likely to be ready for tender to international bidding in the near future.

2. Indus Dam

52. Preliminary reports on the Indus Dam have been prepared by the two American firms of Tipton and Hill and Harza.

53. For the preparation of plans and specifications and for supervision during construction, the Government of Pakistan has employed the American firm of Tippetts-Abbett-McCarthy-Stratton. This project has not yet reached the stage of detailed designs.

3. Link Canals

54. The design and construction of canals has been handled for many years by the Pakistan Irrigation Department engineers. The local engineers have become expert. Before Partition they had already constructed several link canals and at Partition were constructing one of the largest link canals in the world which now has become one of the important links in the Settlement Plan.

55. The Pakistan Government has employed the American firm of Tipton and Kalmbach for the preparation of the plans and specifications of the six new link canals and for supervision during construction. This firm has been associated with Pakistan throughout the technical discussions with the Indian and Bank engineers and are at present also retained on a large tubewell program in the Punjab.

4. Barrages

56. The existing barrages also were designed by Pakistan Irrigation Department engineers. Foreign consulting engineers were also employed from time to time for special features. The competence of the Pakistani engineers is recognized internationally. The largest barrage in the world today was designed and constructed by them under the guidance of British engineers.
57. For the preparation of plans and specifications and for supervision during construction of the three new barrages, the Government of Pakistan has employed the British firm of Coode and Partners. This firm has had experience in design of barrages and irrigation works in Egypt, Sudan and Iraq.

C. Cost Estimates

58. Annexure 2 attached contains the cost estimate of the projects in the Settlement Plan. These estimates aggregating the equivalent of $835 million were compiled by PWS during 1959.

59. The estimates were based upon agreed design and construction criteria and were derived from various sources. The estimates for the dam on the Jhelum River are based on the construction estimates prepared by the consultants on the project, Binnie, Deacon and Gourley of London.

60. The cost estimates for the dam on the Indus River were derived using a composite process. The construction quantities were taken from Tipton and Hill's data of 1954; the unit costs were assumed to be the same as those derived for the dam on the Jhelum River by Binnie, Deacon and Gourley.

61. In estimating the cost of the link canals the quantities were determined from maps, plans, profiles and other data furnished by Pakistan using designs which conform to the general local practice. Unit prices for all major items, notably excavation, canal lining, bridges and drainage crossings were developed by detailed study of the operations involved, of the sources and costs of materials and supplies, and of the labor required. These three items -- excavation, lining and structures -- account for the major part of the cost of the link canals.

62. The cost estimates of the three new barrages and the raising of the existing Rasul barrage, were prepared by TAMS, largely on the basis of comparison with the cost of two recently constructed barrages in Pakistan.

IV. Administration

A. Organizational Aspects

63. The Bank is designated in the Indus Basin Development Fund Agreement as Administrator of the Fund. Under this Agreement, it is the responsibility of the Administrator to exercise the same care in the administration and management of the Fund as it exercises in its normal loan operations.

64. Since, therefore, in addition to the supervision of the use made of its own funds, the Bank will be acting in a "trustee" capacity
for the participating governments and will have the responsibility of administering funds provided by them, it feels that the situation calls for special arrangements. In any case the Plan is so large that it would not be possible for the Bank properly to discharge its administrative functions under the Plan without supplementing its own forces.

65. The Bank, in its prospective role as Administrator of the Indus Basin Development Fund, has, therefore, retained the services of Sir Alexander Gibb & Partners of London to augment its own engineering staff. The Bank has also retained the firm of Coopers and Lybrand (a consortium of British, Canadian and American firms) to assist it in the accounting and financial aspects of the Project.

66. The Bank's responsibilities are, inter alia, to ensure that detailed cost estimates are prepared and that construction schedules are adhered to. For this purpose, in December of last year a Mission visited Lahore where meetings were held with WAPDA and the consulting engineers retained by Pakistan. At this meeting and at a further meeting held in Washington in January of this year, again with WAPDA and the Pakistan consultants, the need for further detailed engineering studies and cost estimates, and the various criteria to be applied in this connection were established. This will result in more detailed estimates of cost which are likely to be available during the second half of 1960.

B. Comments on Preliminary Estimates

67. It is not yet possible to say to what extent the 1959 cost estimates for the scheme as a whole will reflect the actual cost.

68. In the estimate of cost for the Settlement Plan the sum of $277 million was included for the dam on the Jhelum River, including a hydro-electric power plant with an installation of 300,000 KW. A more recent estimate in more detail by the consulting engineers, Binnie, Deacon and Gourley, indicates that the cost of this dam may be considerably higher than the above estimate.1/

69. When the more detailed estimates for all the projects in the scheme have been completed, which is expected some time during the second half of 1960, it will be possible to approximate with greater precision the total cost and whether increases in the cost estimates for some projects may be offset by reductions in the estimates for others.

70. The final cost figures will, of course, be known only when bids have been received for all the projects in the scheme. Only as the

1/ This revised estimate does not cover the cost of the additional work needed to allow the subsequent raising of the dam referred to earlier. This incremental cost will not be met out of the Fund.
different projects will be put out to bid successively, and contracts are let from time to time, will these final cost figures emerge.

V. Economic Aspects

71. The project consists of a system of works to transfer from the three Western Rivers supplies to meet the irrigation requirements in those areas of Pakistan which have hitherto depended on supplies from the three Eastern Rivers. The effect of this transfer would be to release the whole flow of the Eastern Rivers for irrigation development in India.

72. The system of works would also provide substantial additional irrigation development in Pakistan and, as well as irrigation, would develop 300,000 kW of hydro-electric power. It would also make an important contribution to soil reclamation and drainage by lowering groundwater levels in waterlogged and saline areas, and in addition would afford a measure of flood protection.

73. The additional water for irrigation development would amount to some $8 - 15$ AAF per annum and would be used to increase production in existing irrigation areas by making good previous inadequacies in the supply and to irrigate new areas to be developed. Some would also be allocated for the irrigation of land previously abandoned because of waterlogging and surface salinity which would be reclaimed through the operation of the tubewells and new drainage channels mentioned above.

74. The average present day water duty at canal head in the Punjab is approximately 2.7 acre feet per acre of crop, which now gives a gross annual return of the equivalent of about US$30. The gross annual return per million acre feet of water, under the present cropping pattern and at present prices, is therefore around $11 million equivalent. On the not unreasonable assumption that a return of the same order of magnitude would be obtained from the use of the additional water, the additional irrigation development would make possible an increase in agricultural production in Pakistan of the value of about US$90 - $150 million annually.
### COST ESTIMATES OF THE PROJECTS IN THE SETTLEMENT PLAN

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<th>Cost in millions of dollars equivalent</th>
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<td>Foreign Exchange</td>
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<td>Dam and Reservoir with Power on the Jhelum</td>
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<td>Dam and Reservoir on the Indus</td>
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<td>Link Canals</td>
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<td>Tubewells and Drainage</td>
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