MANAGEMENT OF 1992 FLOOD THROUGH MANGLA RESERVOIR

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SUMMARY

The primary function of Mangla Dam Project constructed on Jhelum river as part of the Indus Basin Project (IBP) is to conserve over 5 MAF of surplus river flows and then utilize them for supplementing the natural flows during scarcity periods. Its secondary function is to generate electric power from the water released for irrigation purposes. The project has no storage capacity exclusively provided for flood regulation and it is thus incidental to the main functions.

Due to geographical and locational constraints, very limited timely information on floods generated in Mangla catchment can be obtained. Firstly out of total catchment area of 12870 square miles, only 5737 square miles (about 45%) is under control of Pakistan. Secondly, the time lag from upstream most gauging station at Domel on upper Jhelum to Mangla is about 8 hours. Thirdly, on Poonch river, the gauging station at Kotli has only a time lag of one hour. Further out of 1630 square miles catchment drained at Kotli, 950 square miles (about 58%) lies under Indian control.

A network of 8 hydromet stations in Mangla catchment has been provided by WAPDA for the purpose of reservoir operation including the period of flood. All of them are equipped with manually operated HF Wireless System while some of them are also provided with VHF telemetric communication facility. However, due to serious financial and some technical constraints, the automatic VHF telemetric communication from some of the stations was disrupted even before the flood season of 1992. Notwithstanding this, the manual HF wireless facility was operative during 1992 season.

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1992 flood was caused by the extremely unusual and freak meteorological event of the combined effect within 24 hours of monsoon depression (over Rajasthan) and westerly (over Afghanistan), which resulted in intense rain in Mangla catchment within a very short period.

September 1992 flood developed into a super event with some unique features. Previously all major floods had occurred till end August (previous record flood was experienced from August 27-31, 1929). In this case the event took place on September 9 and 10, when Mangla reservoir had already been filled to its maximum conservation level of 1202 on August 29 and entered the normal low season operation. Historically high floods, in excess of 700,000 cusecs had single peak with generally sharp fall, this was double peaked. The first peak of 987,000 cusecs (second largest on record), was formed within a short duration of 11 hours on September 9. Within the same period the second peak of 1,090,000 cusecs (against previous record of 1,040,000 cusecs in 1929) followed on September 10. In quantitative terms this flood was 2.70 MAF as against 2.24 MAF record flood of 1929.

At this stage Mangla had virtually no flood regulating capability, basically due to design limitations. In addition, the inflow forecast provided by Met. Department was not so reliable. Inspite of these limitations WAPDA managed the first peak of 987,000 cusecs on September 9, within an outflow of 645,000 cusecs thus providing a substantial flood peak attenuation of 342,000 cusecs. In succession, the second peak of 1,090,000 cusecs on September 10, was also managed within an outflow of 933,000 cusecs with a significant peak reduction of 157,000 cusecs. (Incidentally this provided the unique opportunity of prototype testing of the spillway at its design discharge). During this process of flood routing 6 feet surcharge storage available above the maximum conservation level of 1202 was utilized and the reservoir level actually rose to 1207.83. But for further drop in inflows the reservoir could have overtopped the erodible bund at elevation 1208 and automatically triggered operation of the Emergency Spillway.

Notwithstanding the super flood, manual HF telecommunication system of WAPDA successfully withstood the severest test and provided constant communication with Mangla even when some of the hydromet stations were physically washed. Therefore, while routing the flood the related warning information as per prescribed procedures was continuously provided by WAPDA to the Flood Forecasting and Warning Centre (FFWC) at Lahore and the concerned downstream functionaries of Punjab Irrigation Department. In addition, on the initiative of the project authorities, timely warnings were provided to the immediate downstream districts of Mirpur and Jhelum and the concerned army authorities.

It is evident that under the prevailing circumstances WAPDA managed the flood through Mangla reservoir quite effectively as per prescribed flood management procedures, design limitations and safety requirements of the structures. However experience such as 1992 floods always provide opportunities for augmentation/finetuning of flood forecasting, warnings and management procedures. Such an exercise is now getting underway in Federal Flood Commission as part of World/Asian Development Bank assistance. WAPDA will keep a close liaison with this activity and render all relevant assistance/inputs to particularly improve Manga flood management procedures. It is therefore WAPDA's considered view that any significant improvement consistent with design, locational and state-of-art limitations, would have to focus on the improvement of 12-24 hour flood forecast reliability in quantifying the peak (within $\pm$ 10%) & inflow volumes (within $\pm$ 20%).

INTRODUCTION

Mangla Dam Project on river Jhelum is an important component of the Indus Basin Project (IBP) implemented by Pakistan as a consequence of Indus Waters Treaty consummated between India and Pakistan in 1960. As depicted in the Schematic Diagram (Fig.1), Mangla Dam is ideally suited to sustaining irrigation supplies to canal commands of about 8.5 million acres which were being fed by the headworks located in India.

The primary function of Mangla Dam is to conserve over 5 MAF of surplus river flows and then utilise them for supplementing the natural flows during scarcity periods. Its secondary function is to generate electric power from the water released for irrigation purposes. As no storage capacity has been reserved for flood control, its accrual is only incidental to its main functions.

II THE PROJECT

Major structures of the project are: Main Dam, Intake Embankment, Main and Emergency Spillways, the Tunnels and the Power Station. Their location is as shown in Fig.2.

Its initial gross storage capacity was 5.88 MAF with corresponding live capacity of 5.34 MAF. The maximum conservation level is 1202 feet above mean sea level while the dead storage level is 1040 feet. The lake created behind the dam at full pool covers an area of about 100 square miles.

The lake of the reservoir, though continuous at maximum conservation level of 1202. gets separated into two parts at elevation below 1' 10. This is due to the presence of Jari Ridge on left reservoir rim. To confine this separate part of the lake. another sizeable embankment known as Jari Dam has also been constructed as part of the project. It has an independent arrangement for evacuation of the lake below elevation 1110 through an irrigation outlet valve.

Capacity of major project outlets has been designed with the objective of ensuring dam safety against overtopping under conditions of record or probable maximum floods.

The project has a power potential of 1000 MW out of which 800 MW has since been harnessed while remaining 200 MW is now under exploitation through installation of 2 x 100 MW units. These units are due for commissioning in 1994.

Water flow diagram of the project is at Fig.3 whereas salient project figures are in Table 1.

III HYDROLOGY RELATED DESIGN CONSIDERATIONS

At the time of project design, hydrologic data was available from 1922 onward. This also included the major floods experienced at Mangla during 1928, 1929, 1958 and 1959. Out of these, the record flood was of 1929 with a peak discharge of 1,040,000 cusecs. Based on this data and the related meteorological information. a probable maximum flood (PMF) of 2,600,000 cusecs was computed.

As already mentioned, Mangla Dam Project has no storage capacity exclusively reserved for flood. Hence any flood mitigation is incidental to the primary requirement of safely handling the flows resulting from the conditions under record or probable maximum floods.

Dams are required to be safeguarded against overtopping by very large floods through provision of either a spillway or surcharge storage capacity above maximum pool or a combination of both. At Mangla, the optimal scheme lay between these two extremes. It was not economical to provide spillway with capacity equal to the PMF of 2,600,000 cusecs. Though provision of sufficient surcharge storage capacity for accommodation of

single flood was feasible, the volume of succession of floods in monsoon season could be so great that cost of providing storage either by raising of the dam or lowering the conservation level would have been quite excessive. Future sedimentation was another complicating factor.

In view of these considerations, a surcharge storage of 26 feet (upto elevation 1228) was provided above the maximum conservation level. This would have a capacity of 1.8 MAF initially but could reduce to 1.5 MAF due to sedimentation over time. At that stage, maximum conservation level would be reduced correspondingly to maintain a surcharge storage of 1.5 MAF below elevation 1228. The top of the dam was kept at elevation 1234 to provide a free board of 6 feet. The resultant design criteria for flood routing through the reservoir was as below :

i) At maximum pool of 1202 for all floods upto combined outflow capacity of about 900,000 cusecs from the main spillway and power station.

ii) With some involuntary encroachment above elevation 1202 in case of flood greater than 900,000 cusecs occurring at full pool, as it would exceed the combined capacity of various outlets.

iii) With a nominal surcharge (of upto 6 feet) in case of 1929 record flood (1,040,000 cusecs) occurring at full pool using the main spillway and power station and simultaneously reducing the reservoir outflow to about 900,000 cusecs.

iv) Maximum record flood (1929) occurring at full pool through emergency spillway in case of main spillway becoming inoperative, with surcharge storage upto elevation 1228 without any danger to the safety of the dam with top elevation 1234.

v) PMF of 2,600,000 cusecs at full pool, through the two spillways and power station with surcharge storage upto elevation 1228.

Flood routing corresponding to conditions (iv) and (v) both for without and with sedimentation are depicted in Fig.4.

Federal Flood Commission (FFC) has the overall responsibility for flood management in the Indus River System. In pursuit of this, Flood Management Procedures, including role of IBP reservoirs, have been evolved in consultation with all concerned. Regarding Mangla, these duly consider the above mentioned design criteria.

IV. FLOOD MANAGEMENT CAPABILITY OF MANGLA.

Mangla reservoir does not have any storage specially reserved for flood control. However, during the filling season upto end of August, it can help in flood peaks attenuation particularly if they occur in the early part of the season. Therefore, the reservoir is operated according to pre-determined criteria to ensure, as far as possible, its filling even in the year of low inflow and at the same time keeping some capacity for absorption of flood peaks except those occurring very late in the flood season.

During evolution of flood routing procedures of Mangla, the possibility of drawing down the reservoir in advance of floods to create some regulation storage was recognised. However, it was not prescribed as the method because, in that case, the flood forecasting has to be very reliable to obviate the possibility of accentuating rather than alleviating the conditions.

A system of hydromet stations in Mangla catchment was established before its completion in 1967. This was retained after commissioning of reservoir and is still providing useful data for day to day operation. This system was further augmented as part of WMO/UNDP Project from 1977 - 1985 , particularly in the context of flood forecasting based on real time hydromet data from the upper river catchment . The resultant forecasts were prepared by Pakistan Meteorological Department (PMD) but their accuracy, particularly in case of Mangle, remained limited due to serious locational and geographic constraints including the fact that about half of the catchment lies outside Pakistan control.

V. HISTORIC FLOOD MANAGEMENT THROUGH MANGLA RESERVOIR

Since commissioning of Mangla Dam Project in 1967, five major floods occurred in the Jhelum River before 1992 super flood. These floods occurred in 1973 (August), 1975

(August), 1976 (August), 1978 (March) and 1988 (July). Corresponding hydrographs are shown in Figs. 5 — 9 respectively, while a summary is given below:

Year	Occurrence	Reservoir Level (Feet) Start	Maximum	Peak Inflow (1000Cusecs)	Peak Outflow (1000 Cusecs)	Flood Volume (MAF)
1973	August 9-11	1196.9	1199.2	331	220	0.75
1975	August 28-30	1201.6	1203.5	455	117	0.48
1976	August 1-5	1186.7	1201.4	588	201	1.88
1978	March 16-18	1113.0	1129.5	490	28	0.57
1988	July 15-17	1191.8	1197.2	426	243	1.07

It is evident from this data that except for 1975, the resultant reservoir level remained below 1202. Hence, flood management was achieved without much problem within the conservation level. However, in 1975 slight encroachment into the surcharge storage had to be made for flood mitigation of about 338,000 cusecs. The maximum and minimum flood mitigation during these floods was 462,000 and 111,000 cusecs respectively.

VI. MANAGEMENT OF 1992 FLOOD

General

Generally, Mangla reservoir is filled to maximum conservation level of 1202 each year by the end of August under the pre-determined operational criteria concurred by the concerned Federal and Provincial agencies. In keeping with basic functions of this storage and design criteria, during the impounding stage below conservation level of 1202, significant flood control can be exercised in the early part of filling season till end July. However, at the fag end when the reservoir is at or near the full stage, only incidental mitigation through peak shaving is possible.

For the purpose of reservoir operation including flood period and related hydrological studies, WAPDA is maintaining in Mangla catchment a hydromet network of

eight stations. All of these are equipped with manually operated wireless system to transmit the data to Mangla. Some of those are also provided with telemetric facility. A schematic diagram along with time lag of each station to Mangla is given in Fig.10.

During the flood season, guage/discharge from Mangla catchment network stations is normally received at 6-hourly intervals. However, in case of river stage above medium flood, the frequency is increased to hourly interval.

It may be worth mentioning here that due to geographical and locational constraints, very limited timely information on floods generated in Mangla catchment can be obtained. Firstly, out of total catchment area of 12870 square miles, only 5737 square miles (about 45 %) is under control of Pakistan (details indicated in Fig.11). Secondly, the time lag from upstream most gauging station of Domel on upper Jhelum to Mangla is about 8 hours. Thirdly, on Poonch river, the gauging station at Kotli has only a time lag of one hour. Further, out of 1630 square miles catchment drained at this point, 950 square miles (about 58 %) lies under Indian control.

Conditions up to September 9

In 1992, the conservation level of 1202 was finally attained on August 29. Following this, it started operating with Main Spillway closed to pass the incoming flows through the power station. This level almost remained steady since the inflows were hardly enough to meet the power station requirements uptil 0100 hours of September 9.

Reported rainfall data from September 6-10, 1992 from various stations of WAPDA network is listed in Table 2. This indicates that from September 6-8, 1992, there was nominal rainfall with scattered distribution. To convert this information into corresponding runoff, the only reliable information was the discharge at the river gauging stations located downstream of the rainfall stations. Hourly discharge data for various Mangla catchment stations is listed in Table 3. It can be seen (from sheets 1 to 3 of Table 3) that from September 6-8, 1992 the flows were normal without any indication of the impending major flood. Another check on this was the hourly inflow data of Mangla reservoir. This data from September 6-13, 1992 is listed in Table-4. It is evident from sheets 1 to 3 of Table 4 that hourly inflows in Mangla reservoir, as late as September 8, varied between 27,000 to 113,000 cusecs with a mean daily value of 38,000 cusecs These inflows were hardly sufficient to run the power station fully. This conclusion of non-formation of any major flood

was further supported by daily rim-station flood forecasts prepared by Pakistan Meteorological Department (PMD) and issued from the Flood Forecasting and Warning Centre (FFWC) at Lahore. Comparative information on rainfall/flood forecasts of FFWC and actual is listed in Table 5. This brings out the following picture regarding Mangla flood flows from September 6-8, 1992;

Date	Mangla Reservoir Inflow (1000 x Cusecs)	
	PMD Forecast	Actual
September 6	20-40	10-69 (Mean 27)
September 7	25-50	10-136 (Mean 34)
September 8	25-50	22-113 (Mean 38)

September 9

Till morning (0100 hours) of September 9, Mangla reservoir was being operated with Main spillway closed and a discharge of 33,000 cusecs passing through the power station. On the other hand a very unusual and freak meteorological phenomena had taken shape in late hours of September 8. This resulted in combining over Mangla and lower Chenab catchments of the monsoon low (over Rajasthan) and westerly (over Afghanistan). Consequently, from 0100 hours onward, the hourly rainfall data of various catchment stations (Table 2) started showing continuously heavy precipitation. This persisted throughout the day without any respite and basically caused the super flood of 1992. The intensity of September 9 rainfall can be judged from the following comparison with accumulative figures of the previous three days:-

Station	Catchment	Total Rainfall (Inches)	
		Accumulative September 6-8	September 9 only
Domel	Upper Jhelum	1.93	9.45

Kallar	Kanshi	0.60	9.38
Palandri	Lower Jhelum	1.83	7.90
Kotli	Poonch	1.06	7.83
Mangla	Reservoir Vicinity	0.40	2.60

With start of continuous rainfall from early hours of September 9, close watch of hourly reservoir inflows was started. Mangla inflows were fluctuating like a freshet (refer sheet 4 of Table 4) jumping from 32,000 cusecs at 0100 hours to 74,000 cusecs at 0200 hours and 114,000 cusecs at 0300 hours but dropping again to 74,000 cusecs at 0400 hours. Then these again increased to 115,000 cusecs at 0500 hours and stabilized at this discharge at 0600 hours. The first real indication of an impending flood came at 0700 hours when the inflow suddenly jumped to 235,00 cusecs. This was further confirmed at 0800 hours when the inflow touched high value of 274,000 cusecs. Consequently the project authorities decided at 0830 hours to start routing of the flood by opening Main Spillway gates which process was completed by 1000 hours.

By 1300 hours inflow touched 348,000 cusecs when the reservoir operation was switched over to the emergent flood routing. This involved instant institution of hourly flood routing activities.

Mangla catchment accumulative rainfall and the corresponding reservoir inflows for the period September 7-10, 1992 are depicted in Fig. 12.

As already mentioned, Mangla reservoir is designed to route the floods at the maximum pool level of 1202 upto combined outflow discharge of 900,000 cusecs from the Main Spillway and the Power Station. However, in view of the emergent situation resulting from sudden large flood and need to absorb as much of it as possible, the criteria for routing the record flood with nominal surcharge (of upto 6 feet) over 1202 elevation was resorted to. As can be seen from hourly reservoir data (sheet 4 of Table-4) an extremely high peak of 987,000 cusecs was managed within outflow of 645,000 cusecs thus providing

a substantial flood peak attenuation of 342,000 cusecs. Also, the increase in reservoir outflow was gradual and it took 14 hours to raise it from 141000 to 645000 cusecs. In this deliberate flood mitigation process the reservoir level rose to about elevation 1207.

September 10

Due to recurrence of intense rainfall in some parts of the catchment, the reservoir inflow, which had reduced to 658,000 cusecs at 2400 hours of September 9, started rising rapidly again. Unfortunately by this time, all the river gauges on Jhelum Main and Kunhar had overflown due to onslaught of the super flood. Hence, it was not possible for the project authorities to monitor the flood build-up in the upper catchment and instead the only reliance had to be on the actual reservoir inflows.

Within four hours (from 0000 hours to 0400 hours) reservoir inflow rose to a record figure of 1,090,000 cusecs compared to 1929 maximum of 1,040,000 cusecs. Consequently, starting from 0100 hours outflows had to be further increased. Ultimately all the Main Spillway gates were fully opened which enabled managing this unprecedented second peak, within 11 hours of the first, with an outflow of 933,000 cusecs. While effecting a significant peak attenuation of 157,000 cusecs it resulted in raising the reservoir level close to elevation 1208 but without triggering the operation of Emergency Spillway. But for fortunate drop in reservoir inflow from 1,090,000 cusecs at 0400 hours to 1,013,000 cusecs at 0500 hours and further reduction to 933,000 cusecs at 0600 hours, the reservoir would have overtopped the erodible bund of Emergency Spillway at elevation 1208 and thus automatically triggered its operation.

As soon as the flood inflow started dropping the reservoir outflow was throttled and by 1300 hours it was reduced from 933,000 cusecs to 774,000 cusecs. The process was vigorously continued and by 24000 hours of September 10 the reservoir outflow was brought down to 210,000 cusecs.

September 11 to 13

Having reduced the reservoir outflow to a modest 210,000 cusecs at 0100 hours further reduction continued throughout the day by reservoir manipulation within 0.4 feet. Thus by 2400 hours of September 11, outflow was only 144,000 cusecs.

Further gradual reduction in outflow continued and at 2400 hours on September 13, the reservoir level was 1203.08 with outflow of 122,000 cusecs.

Routing of the flood through Mangla reservoir during the critical flood days of September 9-11, 1992 is shown in Fig.13.

Conjunctive Operation For Flood Mitigation

Due to heavy rainfall in the lower contiguous catchment of Chenab , the discharge at Marala also started registering very sharp rise. From 255,000 cusecs at 1800 hours on September 9, it touched a peak of 839,000 cusecs at 1100 hours on September 10. By this time WAPDA had already resorted to throttling of Mangla peak outflows. Consequently this conjunctive operational mode of Mangla and Marala helped in somewhat reduced synchronisation of Jhelum and Chenab peaks at downstream locations of Trimmu and Panjnad.

Recapitulation

It can be appreciated from the foregoing that :-

a) This super flood was caused by the unusual and freak meteorological event of combining monsoons and westerlies essentially over Jhelum catchment. As this occurred very late in the season on September 9 and 10 (previous record flood was experienced from August 27-31, 1929) Mangla reservoir had already been filled to its maximum conservation level of 1202.

b) On the morning of September 9, 1992 there was a sudden rise in reservoir inflow due to heavy cloud burst in Poonch catchment of Mangla followed closely by the upper Jhelum basin. To cope with this emergent situation, flood routing through Mangla reservoir was immediately started in accordance with the prescribed procedure. This also included utilizing 6 feet of surcharge storage available above the maximum conservation level of 1202.

c) As a consequence of intense rainfall staring from early hours of September 9, the reservoir inflows jumped from 115,000 cusecs (0600 hours) to a peak of 987,000 cusecs (1700 hours) within a very short period of 11 hours. However, due to effective flood routing a peak reduction of 342,000 cusecs (from 987,000 to 645,000 cusecs) was achieved.

d) After initial peak of 987,000 cusecs the reservoir inflows dropped to 543,000 cusecs by 1900 hours of September 9. Unfortunately, at this stage, due to recurrence of heavy rainfall in some parts of catchment, the inflow started rising again and registered the second record peak of 1,090,000 cusecs at 0400 hours on September 10, 1992. As by this time the reservoir level was at elevation 1207.73 (very close to the surcharge storage limit of 1208), Main Spillway was fully opened. In this process a discharge of 933,000 cusecs passed downstream with corresponding reservoir level of 1207.83. But for further drop in inflows, the reservoir could have overtopped the erodible bund at elevation 1208 and automatically triggered Emergency Spillway in operation.

e) As soon as the flood inflows started receding further reservoir outflows were throttled and by 2400 hours on September 10, these were brought down to a modest discharge of 210,000 cusecs.

f) This process continued through September 11 also and by the end of day only a discharge of 144,000 cusecs was flowing out of Mangla.

g) In addition to substantial attenuation, about 0.2 MAF flood flows were impounded in the reservoir at a very critical juncture when Chenab river was concurrently in a condition of exceptionally high flood. But for this, the flood peaks from Jhelum (Mangla) and Chenab (Marala) would have fully synchronized at the downstream locations of Trimmu and Panjnad further aggravating the flooding.

Salient features of routing 1992 super flood through Mangla reservoir, including flooding in the catchment and transmittal of flood warning information to the concerned quarters, are contained in Table-6.

VII. CRITICAL EVALUATION OF FLOOD MANAGEMENT BY WAPDA

Necessity

Exceptionally high, rather super floods, were generated almost concurrently in Jhelum and Chenab during early September 1992 as consequence of freak and unusual meteorologic events. Whereas significant flood attenuation was effected through Mangla, Chenab floods flowed down uncontrolled. Synchronization of these flows resulted in unprecedented flood peaks at the two downstream locations of Trimmu and Panjnad.

The floods of 1992 caused extensive damage: 10,000 people lost their lives and about 13,000 villages with more than one million houses were destroyed. Over 5 million acres of land were inundated resulting in loss of about 15% of both cotton and rice crops and 10% of sugarcane crop. The nationwide damage is estimated around US $ 2.2 billion.

In the wake of national tragedy caused by 1992 floods, a lot criticism was targeted at WAPDA by the press and public. This implied that but for, "mismanagement of flood in Mangla" the situation could have been much better. The issue was so agitating that the Government of Pakistan immediately constituted a ministerial level Enquiry Sub Committee. This was followed by a Parliamentary Committee which, besides the overall flood management in the country, particularly went into Mangla flood routing. The technical information and related data were presented by WAPDA to both these official enquiry committees. This amply demonstrated that under prevailing conditions, WAPDA managed the flood through Mangla reservoir quite effectively. To clarify the position WAPDA also went to the press.

For further elaboration at technical level WAPDA also participated in two one day specific seminars conducted soon after the floods under the auspices of 'Friends Forum' and 'Pakistan Engineering Congress'. During these deliberations WAPDA convincingly established that implicating WAPDA in flood "mismanagement" was wrong and based on disinformation spread by the vested interests. Notwithstanding this, still there may be some lingering impression against WAPDA. Thus it seems desirable that various specific points raised at national/government level and WAPDA's responses there to be brought on record.

Main Points of Criticism

The following specific points were agitated in the aftermath of 1992 flood:

1. WAPDA did not make use of the facility of 24 hours advance quantitative forecasts of rain/flood.

2. Had WAPDA utilized these forecasts, Main Spillway could have been opened a day earlier, which would have caused lesser flooding downstream by reducing the peak reservoir outflow.

3. WAPDA did not make use of the flood information/ data being received from India under the standing arrangements.

4. Catchment area of Mangla does not have sufficient gauging stations. During 1992 flood even the existing WAPDA network did not perform satisfactorily. Hence the required information on reservoir inflows was not available in time.

5. Mangla Dam was not used deliberately for flood control over its conservation level when it could absorb flood upto elevation 1228 without endangering safety of the dam.

6. As historically no two-peak flood above 700,000 cusecs had been experienced at Mangla, WAPDA had presumed that no such flood would occur in future.

7. First flood peak of 987,000 cusecs was managed properly. But after this it was thought that second peak would not come and Mangla management felt relaxed. Thus the second unprecedented peak could not be managed properly.

8. On the basis of hindsight information, Mangla reservoir operation could have been better.

9. People of Jhelum city complained that they were not informed in time about the flood. Mangla Corps Commander also complained that he was not informed by WAPDA well in time.

10. There was lack of coordination between WAPDA and the concerned army/civil authorities which resulted in delayed communication of flood warning to the downstream areas.

11. Based on 1992 experience, immediate further improvements should be undertaken for the flood forecasting and warning system.

Factual Position

The responses to explain factual position regarding main criticism in handling 1992 flood through Mangla were brought out by WAPDA before the official enquiry committee, public, press and technical fora as explained earlier. A resume is given in the following :-

1. Non-utilization of 24 Hours Advance Forecasts

For the purpose of advance flood flow forecasting at Mangla, quantitative precipitation data for the upper catchment is essential. Its accuracy can be further enhanced from the river gauging data from the upstream stations provided sufficient time lag till the flood waters reach the dam site is available.

As mentioned earlier, for the improvement of flood forecasting/routing through the Indus River System, a WMO/UNDP Project was implemented after 1977. Its component of improved forecasting also included installation of a quantitative precipitation measurement radar for providing input to the computer based mathematical models to convert this information to flood flows.

For the purpose of actual forecasting at present, the following facilities/procedures are being used:-

i) A quantitative precipitation measurement (QPM) radar has been installed at Sialkot by Pakistan Meteorological Department (PMD). This radar has a wave length of 5.2 CM and a range of about 230 KM. It is operated through linked computer system by which the rainfall of each sub-catchment of the river is evaluated.

ii) This radar only provides some inforrnation with regard to lower catchments of Chenab and Ravi in India. In particular, this radar is not at all in a position to cover the Jhelum river catchment above Mangla.

iii) The rainfall data evaluated by QPM radar at Sialkot is passed on to FFWC Lahore through a dedicated telephone link for further processing and utilisation in forecasting.

iv) Information regarding other radars in Pakistan is also obtained by PMD where necessary.

Thus for the purpose of Mangla forecast, PMD has to essentially depend upon the actual rainfall data from WAPDA and its own stations lying within Pakistan. As time lag from these stations to dam site is quite short, according to the present state-of-art, it is not possible to have reliable quantitative flood forecasts for Mangla catchment. This is also evident from PMD's forecasts and actual reservoir inflows during September 1992 flood as listed in Table-5.

2. Advance Drawdown Based on Forecast

It was not called for because:-

i) Neither the rainfall nor the river flows of September 6, 7 and 8 indicated the formation of any major flood (refer Fig. 12).

ii) On the morning of September 9, even after reports of high rainfall in some catchment areas, the reservoir inflows were in a freshet (alternate rise/fall) mode till 0600 hourly with maximum discharge of 115,000 cusecs. The first real indication of an impending flood was at 0700 hours with a recorded inflow of 235,000 cusecs. It was further confirmed at 0800 hours when the inflow further increased to 274,000 cusecs. Consequently, the project authorities decided at 0830 hours to start routing the floods by opening Main Spillway gates, which process was completed by 1000 hours.

Thus it is evident that WAPDA's decision to open Main Spillway gates on the morning of September 9 was not delayed as well as opening of the gates (say) a day earlier was not warranted.

3. Non-utilization of Flood Warning From India

This information is obtained through Pakistan Commissioner for Indus Waters (PCIW) as per standing arrangements. However, as per 1989 agreement with India, 3-hourly data/information about flood flows only on Sutlej, Beas and Ravi is obtained on telephone; about Chenab at Akhnoor (75,000 cusecs or above), Jammu Tavi at Jammu (20,000 cusecs or above) and Ravi below Madhopur (30,000 cusecs or above), the information is broadcast by Radio Jammu. During the flood season, office of PCIW monitors/compiles all this information and it is passed on to Flood Forecasting and Warning Centre (FFWC) at Lahore for further utilisation.

It is, therefore, evident that no flood data regarding Jhelum catchment is received from India under the standing arrangements.

4. Insufficiency of WAPDA's Gauging Network in Mangla Catchment and its Actual Unsatisfactory Performance During 1992.

There are sufficient gauging stations of WAPDA in the catchment located in Pakistan (Fig. 10). However, due to geographical restraint it only covers 45% of the catchment as the remainder 55% is under Indian occupation.

A network of 8 hydroment stations in Mangla catchment has been provided by WAPDA for the purpose of reservoir operation including the period of flood. All of them are equipped with manually operated HF wireless system while some of them are also provided with VHF telemetric communication facility. However, due to serious financial and some technical constraints, the automatic VHF telemetric Communication from some of the stations was disrupted even before the flood season of 1992. Notwithstanding this the manual HF wireless system successfully withstood the severest test and provided constant communication with Mangla.

The position regarding actual performance of WAPDA network during 1992 flood is contained in Table-7. It may also be worth mentioning that whereas a number of stream

gauging stations (Garhi Habib Ullah, Kohala, Azad Pattan) got completely washed out due to unprecedented flood, communication except for Garhi Habib Ullah was still maintained with Mangla to pass on whatever visual information was available.

5. Non-utilization of Surcharge Storage upto Elevation 1228 to Control Flood

Adoption of this operational mode was not warranted in view of the following considerations:-

i) Rise of level to 1228 under the project design and flood management procedure could be involuntary and only when:

Flood of record occurs at full pool and the Main Spillway becomes inoperative. This would press into service the Emergency Spillway for routing the flood and utilising in the process surcharge storage upto 1228.

At full pool, probable maximum flood (PMF) conditions prevail (peak discharge of 2,600,000 cusecs) and inflow becomes more than the combined outflow capacity of both the main and Emergency Spillways and Power Station.

ii) As in case of this particular flood, the Main Spillway remained operative the reservoir should not have been allowed to rise voluntarily to 1228.

iii) On the other hand, in this case actual flood of about 1,100,000 lacs cusecs was experienced. According to the prescribed procedure, such magnitude flood should be routed within the nominal surcharge of six ft. (upto 1208) by using all the available outlet facilities without triggering operation of Emergency Spillway. The same was done precisely which also enabled reduction of reservoir outflow to 933,000 cusecs against peak discharge of 1,090,000 cusecs.

iv) Provision in the dam foundations for withstanding the eventuality of 1228 elevation cannot be linked with flood mitigation. That is why this provision can only come into play for PMF conditions. Otherwise, there could be a real danger of overtopping the dam, if after having already encroached upon

some part of this storage (say upto elevation 1210) we were faced with PMF conditions.

6. Complacency Regarding Occurrence of Two Peak Flood

Major Jhelum river floods above 700,000 cusecs were experienced in 1929 and 1959 and their comparative plots Fig. 14 showed that these were single peak type. Through projection of this trend PMF (Table-8) was also developed by the designer as a single peak event.

On the other hand less than 700,000 cusecs post-Mangla monsoon floods of 1973 (Fig. 5), 1976 (Fig. 7) and 1988 (Fig. 9) exhibited two peak phenomena.

The above information was only indicative and by no means precluded the possibility of occurrence of two-peak flood. Therefore, there is no reason to believe that after successful routing of the first peak, WAPDA had become complacent regarding occurrence of second peak in quick succession.

7. Improper Management of Second Flood Peak by WAPDA

It is simply speculative that after successful handling of the first peak of 987,000 cusecs within outflow of 645,000 cusecs WAPDA site management got relaxed and could not manage the second peak.

In fact, as soon as the inflows started increasing after the first peak, increase in outflow was started leading to full opening of the gates of the Main Spillway. In the process second unprecedented peak of 1,090,000 cusecs was managed with an outflow of 9,33,000 cusecs. This is sufficient confirmation of the fact that within the technical constraints, the second peak was also managed effectively by WAPDA.

8. Better Operation of Mangla Based on Hindsight Information

In hindsight, a number of operational scenarios can be worked out. But the main question still remains as to what would be the utility of such information for the site opera-

tors at the time of next such event? Based on the peculiar restraints of Mangla namely, over half of the catchment in India, very short lag time in runoff generation and its inflow into reservoir and present state of art limitation for accurate quantitative forecast (±20 % for inflow volume and ±10 % for peak discharge), it is doubtful whether reservoir could be ever factually operated for flood mitigation above elevation 1208.

In view of this position, WAPDA is of the considered view that no useful purpose could be served by this hypothetical exercise.

9. Complaint of Jhelum Residents/Army Authorities Regarding Non-supply of Timely Flood Warning.

Under the Standing Flood Management Procedures, concurred by the Federal Flood Commission, WAPDA's responsibility is to provide hourly information in the case of flood above the medium flood stage to FFWC Lahore and the concerned Irrigation Officers. This was done promptly and warnings were issued through wireless to FFWC with copies to concerned officers of Irrigation Department as listed in Table-9.

In addition, on their own initiative, the project authorities furnished flood warnings to Deputy Commissioner Jhelum land Mirpur by using the available means of telephone/wireless (also refer to Table-9).

Special warning message was also conveyed to Army on the morning of September 9, through Station Commander Mangla Cantt.

It is, therefore, evident that there was no lapse on the part of WAPDA to convey the flood information to the concerned quarters. In fact, the project authorities went out of the way to specially inform DC's Jhelum/Mirpur about the flood. If this information could not be passed on in time to the population of Jhelum city, the lapse lay somewhere else than WAPDA.

10. Lack of Coordination Between WAPDA and Other Concerned Agencies.

Coordination between various concerned agencies of Federal Flood Commission, PMD, WAPDA, Army and Civil Authorities (both Federal/Provincial) is achieved through the

Flood Forecasting and Warning Centre (FFWC) established at Lahore (organizational setup in Fig.15).

Flood Forecasting Unit of FFWC is under PMD and prepares computer based quantitative forecasts on river flows based on QPM from its radars and own/WAPDA rain gauge network and river gauge data of WAPDA/Irrigation Departments. This information is then passed on to the Flood Warning Unit under the control of Flood Relief Commissioner Punjab. After its conversion into proper flood warning, the information is immediately communicated to all the concerned Federal/Provincial agencies. It may not be out of place to mention here that as per in vogue flood management procedure, no other agency except FFWC can issue such flood warnings.

It can be appreciated for this, that overall coordination is not the purview of WAPDA. However, WAPDA played more than its part as required under the prescribed procedures.

11. Further Improvements Based on 1992 Experience.

Any experience like 1992 super flood always provides a good opportunity to review the performance of existing facilities and procedures. Based on this, further improvements can be brought about in the area of flood forecasting, warning and management.

In the moments of such national calamities the international development agencies always come forward for help. Consequently, both World and Asian Development Banks have already offered financial and technical assistance to Pakistan for not only restoration of infra-structural flood damages but improvement in its management.

The over all activity is now being handled by the Federal Flood Commission (FFC) under an umbrella programme. For strengthening flood forecasting facility a memorandum of understanding (MOU) has been reached between Asian Development Bank and Government of Pakistan in March, 1993. The scope of technical assistance under the MOU takes into account the components to be implemented for improving flood forecasting and warning capability.

Accordingly, the following major activities are envisaged:-

i) Improved facilities for data collection/analysis and hydrological studies to provide a comprehensive basis for rainfall run-off modeling and river flow routing.

ii) Preparation of a system of real-time flood forecasting and management to provide maximum possible lead time.

iii) Development of proposals for improvement of interagency coordination.

FFC is now in the process of recruiting consultants for completing this assignment within a period of about three years. As regards Mangla, it has been emphasized that unless reliability of quantified 12-24 hour forecasts is improved to within $\pm$20% for inflow volume and $\pm$10% for peak, any significant improvement over the existing situation may not be achievable. However, to derive maximum benefit from this project, WAPDA will maintain very close liaison with FFC Consultants and help in evolution of whatever improved procedures are feasible within state-of-art and other locational and design constrains of Mangla.

VIII CONCLUSIONS

Due to its basic function of conserving surplus water for subsequent supplemental irrigation, the inflow pattern of Jhelum warrants that filling of Mangla storage should not be delayed beyond end August. This filling is accomplished seasonally based on a pre-determined reservoir operational criteria.

During the filing operation below maximum conservation level of 1202, significant flood control is feasible. However, after this stage, flood control is only incidental as no space has been reserved in Mangla for this purpose

Consistent with above limitations Mangla did provide significant flood mitigation during floods of 1973, 1976, 1978 and 1988 all of which occurred at reservoir elevation below 1202. In case of 1975, when the flood occurred towards end August with reservoir level close to 1202, some mitigation was also effected through minor encroachment of the surcharge storage within top of the erodible bund at entrance of Emergency Spillway.

1992 flood was caused by the extremely unusual meteorologic event of the combined effect (with 24 hours) of monsoon depression (Over Rajasthan) and westerly (Over Afghanistan) which resulted in intense rain in Mangla catchment within a very short period. Unfortunately this event occurred on September 9, 1992 when the reservoir had already attained the maximum conservation level (on August 29) and entered the normal low season operation.

September 1992 flood developed into a super event with some unique features. Previously all major floods (including 1929 record) had occurred till end of August. In this case, the event took place in September. Historically, high floods in excess of 700,000 cusecs had single peak with generally sharp fall, this was double peaked. The first peak of 987,000 cusecs (second largest on record) was formed within a short period of 11 hours. Within the same period the second peak of 1,090,000 cusecs (against previous record of 1,040,000 cusecs in 1929) followed. In quantitative terms this flood was 2.70 MAF as against 2.24 MAF record flood of 1929.

At this stage Mangla had virtually no flood regulating capability, basically due to design limitation. In addition, the reliability of inflow forecasts was also doubtful. These limitations notwithstanding WAPDA managed the first peak within an outflow of 645,000 cusecs (substantial reduction of 342,000 cusecs). The second record peak of 1,090,000 cusecs (a very unusual hydrologic event) was also handled within an outflow of 933.000 cusecs with a significant reduction of 157,000 cusecs.

While routing the flood the related warning information as per prescribed procedure was continuously provided by WAPDA to the Flood Forecasting and Warning Centre (FFWC) at Lahore and the concerned downstream functionaries of Punjab Irrigation Department. In addition, on the initiative of the project authorities timely warnings were provided to the immediate downstream districts of Mirpur and Jhelum and the concerned Army authorities.

In the aftermath of the huge flood damages, caused due to combining of Chenab and Jhelum floods, a lot of criticism was heaped on WAPDA by the press, public and even some Governmental agencies. This related to mismanagement of flood through Mangla and lack of coordination with other concerned agencies to provide timely flood warning. The facts have negated this as well as established that this criticism was either based on lack of information or a deliberate disinformation campaign mounted by the vested interests.

Experiences such as 1992 floods always provide opportunity for augmenting/fine-tuning of flood forecasting, warning and management procedures. Such an exercise is now getting under way in FFC as part of World/Asian Development Bank assistance. WAPDA will keep a close liaison with this activity and render all relevant assistance/inputs to particularly improve Mangla flood management procedures. It is, however, WAPDA's considered view that any significant improvement consistent with design, locational and state-of-art limitations, would have to focus on the improvement of 12-24 flood forecast reliability in quantifying the peaks (within $\pm$10%) and inflow volumes (within $\pm$20%).

TABLE-1

MANGLA DAM PROJECT

SALIENT FEATURES

1.	Location	River Jhelum at Mangla
2.	Initial Storage Capacity:	
	a. Gross	5.88 MAF
	b. Live	5.35 MAF
3.	Maximum Conservation Level	1202 feet
4.	Dead Storage Level	1040 feet
5.	Crest Level of Dam	1234 feet
6.	Main Spillway:	
	a. Maximum Discharge Capacity at Elevation 1202	870,000 Cusecs
	b. Discharge Capacity at Reservoir Pool Elevation 1228 (To Route PMF)	1,100,000 Cusecs
	c. Crest Level	1086 feet
7.	Emergency Spillway:	
	a. Crest Level	1202 feet
	b. Erodible Bund Level At Entrance	1208 feet
	c. Discharge Capacity At Elevation 1228	230,000 Cusecs
8.	Area of Reservoir Lake	100 sq. miles
9.	Power :	
	a. Ultimate Potential	1000 MW
	b. Present Installed Capacity	800 MW (8 Units of 100 MW each)

TABLE - 2 **RAINFALL IN MANGLA CATCHMENT**

DATE	DOMEL		KALLAR		PALANDRI		KOTLI		MANGLA	
6-9-1992	--	--		0.06"	1500-1600	0.03"	1500-1600		--	
7-9-1992	0.02"	0300-0500	0.10"	0800-1000	0.10"	0930-1000	0.05"	0730-0830	0.04"	0745-0800
			0.30"	0900-1000	0.60"	1000-1100	0.06"	0900-1000		
			0.20"	1000-1100	0.20"	1100-1200	0.05"	1000-1100		
					0.03"	1200-1300				
Total :	0.02"		0.60"		0.93"		0.16"		0.04"	
8-9-1992	0.16"	1300-1800			0.15"	1200-1500	0.10"	1700-1800	0.36"	0800-1200
	0.15"	1800-2100			0.19"	1600-1800	0.12"	1900-2100		
	1.60"	2200-2359			0.50"	1800-2100	0.65"	2300-2359		
Total :	1.91"		--		0.84"		0.87"		0.36"	
9-9-1992	1.65"	0001-0700	5.52"	0200-0800	0.70"	0001-0200	0.10"	0001-0200	0.25"	1700-1800
	0.50"	0700-0800	0.05"	0800-0900	0.80"	0200-0600	0.20"	0200-0300	2.35"	1800-2359
	0.35"	0800-0900	0.28"	0900-1000	0.45"	0600-0700	5.60"	0300-0600		
	0.52"	0900-1000	0.35"	1100-1200	0.40"	0700-0900	0.15"	0600-0700		
	0.40"	1000-1100	0.50"	1200-1300	1.10"	0900-1000	0.10"	0700-0800		
	0.50"	1100-1200	0.82"	1300-1400	1.25"	1100-1200	0.07"	0900-1000		
	0.52"	1200-1300	0.22"	1500-1600	0.45"	1200-1300	0.07"	1400-1500		
	1.15"	1300-1400	0.62"	1700-1800	0.85"	1300-1400	0.50"	1500-1600		
	0.40"	1400-1500	0.25"	1800-1900	0.08"	1400-1500	0.04"	1600-1700		
	0.06"	1500-1600	0.35"	1900-2000	0.39"	1500-1600	0.30"	1900-2000		
	1.18"	1600-1800	0.25"	2000-2100	0.13"	1600-1700	0.20"	2000-2100		
	0.15"	1800-1900	0.09"	2100-2200	0.60"	1900-2000	0.30"	2100-2200		
	1.01"	1900-2000	0.05"	2200-2300	0.35"	2000-2100	0.15"	2200-2300		
	0.30"	2000-2100	0.03"	2300-2359	0.20"	2100-2200	0.05"	2300-2359		
	0.36"	2100-2200			0.10"	2200-2300				
	0.25"	2200-2300			0.05"	2300-2359				
	0.15"	2300-2359								
Total:	9.45"		9.38"		7.90"		7.83"		2.60"	
10-9-1992	0.10"	0000-0100	0.02"	0000-0100	0.02"	0000-0100	1.95"	0300-0600	0.54"	0000-0600
							0.09"	2300-2359	2.35"	0600-0800
									2.04"	2300-2350
Total:	0.10"		0.02"		0.02"		2.04"		4.93"	

TABLE - 3
HOURLY DISCHARGE DATA OF MANGLA CATCHMENT STATIONS
(1000 X CUSECS)

DATE	TIME (Hrs.)	STATIONS						
		KOTLI	AZAD PATTAN	KOHALA	MANGLA INFLOW	MUZAFAR ABAD	DOMEL	G. H. ULLAH
6.9.92	0100	8	19	21	26	12	12	
"	0200	8	19	22	26	12	12	
"	0300	8	19	22	26	12	12	
"	0400	8	19	23	26	13	12	
"	0500	8	18	23	26	13	12	
"	0600	8	18	23	26	13	11	
"	0700	7	18	24	26	13	11	
"	0800	7	18	23	26	13	11	6
"	0900	7	17	23	30	12	11	6
"	1000	7	18	23	26	12	11	6
"	1100	7	18	22	27	12	11	6
"	1200	7	19	21	34	12	11	6
"	1300	7	19	21	25	12	11	
"	1400	7	19	21	25	12	11	
"	1500	7	19	21	12	12	11	
"	1600	7	19	20	15	12	11	
"	1700	11	19	20	15	12	11	
"	1800	9	19	20	60	11	11	
"	1900	9	19	21	25	11	11	
"	2000	13	19	20	69	11	11	
"	2100	16	18	20	29	11	11	
"	2200	16	18	20	19	11	12	
"	2300	16	18	20	10	11	12	
"	2400	16	18	20	10	11	12	
Average		9	19	21	27	12	11	

TABLE - 3
HOURLY DISCHARGE DATA OF MANGLA CATCHMENT STATIONS
(1000 X CUSECS)

DATE	TIME (Hrs.)	STATIONS						
		KOTLI	AZAD PATTAN	KOHALA	MANGLA INFLOW	MUZAFAR ABAD	DOMEL	G. H. ULLAH
7.9.92	0100	15	18	20	50	11	12	
"	0200	15	18	21	10	11	12	
"	0300	14	18	21	10	11	12	
"	0400	14	18	21	10	11	12	
"	0500	14	18	22	10	11	12	
"	0600	13	18	22	51	11	12	
"	0700	12	18	22	11	11	11	
"	0800	11	18	21	10	11	11	6
"	0900	11	18	21	52	12	11	6
"	1000	10	18	21	136	12	11	6
"	1100	10	18	21	59	12	11	6
"	1200	10	18	21	18	11	11	6
"	1300	9	18	21	17	11	11	6
"	1400	9	19	21	19	11	11	6
"	1500	9	19	21	25	11	11	6
"	1600	9	18	21	69	11	11	6
"	1700	9	18	20	33	11	11	
"	1800	9	18	20	33	11	11	
"	1900	9	18	20	33	11	11	
"	2000	9	18	20	33	11	11	
"	2100	9	18	21	33	11	11	
"	2200	9	18	21	33	11	12	
"	2300	9	18	21	29	11	12	
"	2400	9	18	20	33	11	12	
Average		11	18	21	34	11	11	

TABLE - 3
HOURLY DISCHARGE DATA OF MANGLA CATCHMENT STATIONS
(1000 X CUSECS)

DATE	TIME (Hrs.)	STATIONS						
		KOTLI	AZAD PATTAN	KOHALA	MANGLA INFLOW	MUZAFAR ABAD	DOMEL	G. H. ULLAH
8.9.92	0100	9	18	20	28	10	12	
"	0200	9	18	20	33	10	12	
"	0300	9	18	21	33	10	12	
"	0400	9	18	21	33	10	12	
"	0500	9	18	21	33	10	11	
"	0600	9	18	21	33	11	11	
"	0700	8	18	21	22	11	11	
"	0800	8	18	21	29	11	11	6
"	0900	8	19	21	29	12	10	6
"	1000	8	19	21	33	12	10	6
"	1100	8	19	21	23	12	10	6
"	1200	8	19	22	33	12	10	6
"	1300	8	19	22	33	12	11	6
"	1400	8	18	22	33	12	11	6
"	1500	8	18	21	33	12	11	6
"	1600	8	19	21	25	11	11	7
"	1700	8	19	21	33	11	11	
"	1800	8	19	20	33	11	12	
"	1900	8	20	20	73	11	12	
"	2000	8	21	20	113	11	12	
"	2100	8	21	21	73	11	12	
"	2200	8	22	21	33	11	12	
"	2300	8	22	21	33	11	12	
"	2400	3	23	21	33	11	12	
Average:		8	19	21	38	11	11	

TABLE - 3
HOURLY DISCHARGE DATA OF MANGLA CATCHMENT STATIONS
(1000 X CUSECS)

DATE	TIME (Hrs.)	STATIONS						
		KOTLI	AZAD PATTAN	KOHALA	MANGLA INFLOW	MUZAFAR ABAD	DOMEL	G. H. ULLAH
9.9.92	0100	10	23	21	32			
"	0200	11	24	20	74			
"	0300	15	24	20	114			
"	0400	13	51	21	74			
"	0500	69	95	22	115			
"	0600	185	95	25	115	16	16	
"	0700	185	135	32	235			
"	0800	376	154	52	274			
"	0900	314	155	131	315			
"	1000	336	172	141	248			
"	1100	276	175	141	162			
"	1200	233	175	145	262	73	87	38
"	1300	220	Overflow	Overflow	348	89	89	38
"	1400	252	"	"	470	96	97	Overflow
"	1500	252	"	"	621	97	Overflow	"
"	1600	182	"	"	652	97	"	"
"	1700	149	"	"	987	99	97	"
"	1800	128	"	"	685	101	96	"
"	1900	114	"	"	543	102	95	"
"	2000	107	"	"	617	102	96	"
"	2100	101	"	"	555	106	97	"
"	2200	98	"	"	575	105	97	"
"	2300	98	"	"	590	104	Overflow	"
"	2400	95	"	"	658	103	"	"
Average		162.			388.			

TABLE - 3
HOURLY DISCHARGE DATA OF MANGLA CATCHMENT STATIONS
(1000 X CUSECS)

DATE	TIME (Hrs.)	STATIONS						
		KOTLI	AZAD PATTAN	KOHALA	MANGLA INFLOW	MUZAFAR ABAD	DOMEL	G. H. ULLAH
10.9.92	0100	95	Overflow	Overflow	742	102	Overflow	Overflow
"	0200	95	"	"	870	103	"	"
"	0300	95	"	"	965	104	"	"
"	0400	95	"	"	1090	104	"	"
"	0500	95	"	"	1013	104	"	"
"	0600	233	"	"	933	136	"	"
"	0700	210	"	"	769	138	"	"
"	0800	171	"	"	728	117	92	"
"	0900	152	"	"	687	110	87	"
"	1000	140	"	"	645	98	86	"
"	1100	119	"	"	639	103	81	"
"	1200	108	"	"	519	110	78	"
"	1300	95	"	"	569	106	76	"
"	1400	88	"	"	582	103	74	"
"	1500	82	"	"	468	100	72	"
"	1600	79	"	"	465	97	71	"
"	1700	71	"	"	397	97	71	"
"	1800	66	"	"	372	97	70	"
"	1900	62	"	"	414	96	70	"
"	2000	59	"	"	337	91	67	"
"	2100	57	"	"	271	86	65	"
"	2200	55	"	"	251	85	63	"
"	2300	53	"	"	245	85	63	"
"	2400	52	"	"	234	74	62	"
Average		101			592	102	80	

TABLE - 4

HOURLY MANGLA RESERVOIR DATA - SEPTEMBER 6, 1992

DATE	TIME (Hrs.)	RESERVOIR LEVEL FT. SPD	INFLOW (1000xCusecs)	OUTFLOW (1000xCusecs)
6.9.1992	0100	1201.83	26	26
"	0200	1201.83	26	26
"	0300	1201.83	26	26
"	0400	1201.83	26	26
"	0500	1201.83	26	26
"	0600	1201.83	26	26
"	0700	1201.83	26	26
"	0800	1201.83	26	26
"	0900	1201.83	30	30
"	1000	1201.83	26	26
"	1100	1201.83	27	27
"	1200	1201.88	34	28
"	1300	1201.88	25	25
"	1400	1201.88	25	25
"	1500	1201.83	12	25
"	1600	1201.83	15	15
"	1700	1201.83	15	15
"	1800	1201.88	60	25
"	1900	1201.88	25	25
"	2000	1201.93	69	33
"	2100	1201.93	29	29
"	2200	1201.93	19	19
"	2300	1201.93	10	10
"	2400	1201.93	10	10
		Average	27	24

TABLE - 4
HOURLY MANGLA RESERVOIR DATA - SEPTEMBER 7, 1992

DATE	TIME (Hrs.)	RESERVOIR LEVEL FT. SPD	INFLOW (1000xCusecs)	OUTFLOW (1000xCusecs)
7-9-1992	0100	1201.98	50	10
"	0200	1201.98	10	10
"	0300	1201.98	10	10
"	0400	1201.98	10	10
"	0500	1201.98	10	10
"	0600	1202.03	51	11
"	0700	1202.03	11	11
"	0800	1202.03	10	10
"	0900	1202.08	52	14
"	1000	1202.23	136	19
"	1100	1202.28	59	19
"	1200	1202.28	18	18
"	1300	1202.28	17	17
"	1400	1202.28	19	19
	1500	1202.28	25	25
	1600	1202.33	69	33
"	1700	1202.33	33	33
"	1800	1202.33	33	33
"	1900	1202.33	33	33
"	2000	1202.33	33	33
"	2100	1202.33	33	33
"	2200	1202.33	33	33
"	2300	1202.33	29	29
"	2400	1202.33	33	33
		Average	34	21

TABLE - 4

HOURLY MANGLA RESERVOIR DATA - SEPTEMBER 8, 1992

DATE	TIME (Hrs.)	RESERVOIR LEVEL FT. SPD	INFLOW (1000xCusecs)	OUTFLOW (1000xCusecs)
8-9-1992	0100	1202.28	28	33
"	0200	1202.28	33	33
"	0300	1202.28	33	33
"	0400	1202.28	33	33
"	0500	1202.28	33	33
"	0600	1202.28	33	33
"	0700	1202.23	22	29
"	0800	1202.23	29	29
"	0900	1202.23	29	29
"	1000	1202.23	33	33
"	1100	1202.18	23	23
"	1200	1202.18	33	33
"	1300	1202.18	33	33
"	1400	1202.18	33	33
"	1500	1202.18	33	33
"	1600	1202.13	25	33
"	1700	1202.13	33	33
"	1800	1202.13	33	33
"	1900	1202.18	73	33
"	2000	1202.28	113	33
"	2100	1202.33	73	33
"	2200	1202.33	33	33
"	2300	1202.33	33	33
"	2400	1202.33	33	33
		Average	38	32

TABLE - 4
HOURLY MANGLA RESERVOIR DATA - SEPTEMBER 9, 1992

DATE	TIME (Hrs.)	RESERVOIR LEVEL FT. SPD	INFLOW (1000xCusecs)	OUTFLOW (1000xCusecs)
9-9-1992	01.00	1202.33	32	33
"	02.00	1202.38	74	33
"	03.00	1202.48	114	33
"	04.00	1202.53	74	33
"	05.00	1202.63	115	33
"	06.00	1202.73	115	33
"	07.00	1202.98	235	29
"	08.00	1203.28	274	29
"	09.00	1203.63	315	29
"	10.00	1203.83	248	141
"	11.00	1203.83	162	184
"	12.00	1203.93	262	184
"	13.00	1204.13	348	184
"	14.00	1204.48	470	184
"	15.00	1204.98	621	239
"	16.00	1205.48	652	253
"	17.00	1206.33	987	328
"	18.00	1206.73	685	388
"	19.00	1206.83	543	535
"	20.00	1206.93	617	535
"	21.00	1206.93	555	561
"	22.00	1206.93	575	590
"	23.00	1206.93	590	590
"	24.00	1206.98	658	645
		Average:	388	243