FLOOD FORECASTING AND FLOOD DEFENSE IN PAKISTAN

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Islamabad, Pakistan

4th International Symposium on Flood Defence:
Managing Flood Risk, Reliability and Vulnerability
Toronto, Ontario, Canada, May 6-8, 2008
Major Floods of Indus Basin in Pakistan

<table>
<thead>
<tr>
<th>Year</th>
<th>Monetary Losses (Billion Rs)</th>
<th>Lives Lost (No.)</th>
<th>Villages Affected (No.)</th>
<th>Area Flooded (Million Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>9.06</td>
<td>2,618</td>
<td>16,000</td>
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FLOOD PROBLEM IN PAKISTAN

- Economic damages resulting from annual flooding is a major burden on the country.
- Floods have havoc over the years,
- agricultural
- communication infrastructure,
- Infrastructures (Buildings, Roads, ...etc)

with damages worth Rs 225 billion (US $ 4 billion) recorded for the ten largest floods since country’s Independence in 1947. Almost 8000 lives have been lost during these floods.
FLOODING MECHANISMS

• There are three reasons for flooding

1) Floods in the Indus Basin occur in late summer (July to September) during monsoonal rains.
   - In the upper to mid reaches of the Basin, it is generally the tributaries like Jhelum and Chenab Rivers, which are the cause of flooding rather than the Indus River itself.
   - Since many rivers are also snow-fed, an early monsoon may combine with peak snowmelt runoff to exacerbate flooding.

   - The monsoon low or depression that causes intense rain develops either in Arabian Sea or Bay of Bengal. Major flooding is generally associated with the depression from the Bay of Bengal moving across India in west/north-westerly direction and then turning north at the border with Pakistan.

   - Heavy rains occur due to orographic lifting at the high mountain ranges in the river catchments.

   - Generally, the heavy rainfalls are limited to the Chenab, Jhelum, Ravi and Sutlej.

   - River catchments, however, occasionally, the depression can cross further north into the Indus River catchment.
INSTITUTIONAL ARRANGEMENTS FOR FLOOD MANAGEMENT

• **Flood Forecasting Division.**
  The FFD of the Pakistan Meteorological Department plays a central role in flood forecasting and warning in the country.

• **Provincial Irrigation and Drainage Authority.**
  The Authority plays a prominent role in flood management through planning, design, construction and maintenance of flood protection works.

• **Water and Power Development Authority.**
  The authority is the custodian of Tarbela and Mangla dams and undertakes the day to day reservoir management for irrigation flow releases.

• **Provincial Relief Department.**

• **Pakistan Army.**

• **Emergency Relief Cell.**

• **Civil Defence Organisation.**

• **Federal Flood Commission.**
Meteorological Observing Network of Pakistan
Meteorological Department
LATEST IMPROVEMENT IN METEOROLOGICAL OBSERVING NETWORK OF PAKISTAN

Installed AWS
10 AWS under installation
15 More will be installed in 2008.
Tide Guages installed
Tide Guages proposed
Sub-basins in Upper Indus
PART-I

HYDROLOGY AND WATER RESOURCES OF PAKISTAN
INDUS RIVER SYSTEM

5 Major Rivers

4 Large Reservoirs

23 Barrages/headworks

45 Canal Commands
WATER RESOURCES OF INDUS BASIN
Glaciers of Upper Indus Basins

Total: 5,218
Area: 5,218

Source: WRRI, NARC (2005) “Inventory of glaciers”
FLOOD FORECASTING & WARNING SYSTEM
Case Study: Nala Lai

Source: Pakistan Meteorological Department
The built-up area will increase in the future, while agriculture, bare land and forest area decrease as the population growth.
Lai Nullah Basin Area

Geographical Condition

(1) The Margalla range stands behind Islamabad city area and forms the north boundary of the Lai Nullah basin.

(2) The foot of the range expands over the built-up area of Islamabad city with a gradual slope from North to South.

(3) The alluvium plain is developed from Islamabad to the upper part of the Rawalpindi area above Chaklala Bridge.

(4) The valley area forms a definite steep valley with several cascades.
Lai Nullah Basin Area

River Features

Upstream from Kattarian Bridge

- Major three tributaries
  - Bedarawali Kas
  - Tenawali Kas
  - Saidpur Kas

Rather spacious cross-section with less meandering alignment

Channel bed-slope: more than 1/500

The upper stretches of the tributaries have never caused any serious flood overflow.

The lower stretches of the tributaries is under influence of backwater of Lai Nullah.

Extensive flood inundation occurred in Block I-8 and 9 of Islamabad in 2001.

Source: Pakistan Meteorological Department
Lai Nullah Basin Area

River Features

Middle Stream between Kattarian Bri. to Chaklala Bri.

Lai Nullah passes through the Rawalpindi Area.

The area is on the flat alluvium plain with several meandering portions

Channel bed-slope : 1/1,250

The stretch has frequently caused the flood overflow.

Channel flow capacity increased less than 300m$^3$/s to more than 600m$^3$/s by ADB project.

Source: Pakistan Meteorological Department
Middle Stream from Chaklala Bri. to Waterfall

Lai Nullah passes through the Cantonment Area.

There was a heavily meandering section before. (This section was improved by ADB project)

Channel bed-slope : 1/1,250

The stretch has frequently caused the flood overflow.

Source: Pakistan Meteorological Department
Lai Nullah Basin Area

River Features

Downstream from Waterfall to Confluence with Soan River

Lai Nullah passes less populated Area.

The Lai Nullah meets the first waterfall about 3,800m upstream from G.T. Road Bridge.

Channel bed-slope : 1/70

The section has the rather large channel width and depth.

The flood damage along this stretch could be nil.

Source: Pakistan Meteorological Department
Subtropical Triple Season Moderate Climate Zone
Hot summer (40°C) and Cold winter (near 0°C)
Rainy Season (July to September)
Annual Rainfall is 1,000mm (rainy season is 600mm).
Thunderstorm activity is higher in the monsoon season.
Lai Nullah Basin Area

Rain Gauge Station

Existing
Saidpur
PMD (Islamabad)
RAMC
Chaklala

New
Golra
Bokra
Rainfall Observational Network

Legend:
- Red circle: Rainfall Station (New)
- Red circle with dot: Rainfall Station (Existing)
- Thiessen Polygon
- Lai Nullah River Basin Boundary
### Lai Nullah Basin Area

#### Past Flood

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<th>Date</th>
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<tr>
<td>1982</td>
<td>August 10</td>
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<td>N/a</td>
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</table>

#### 19 years at least in 59 year

Once in every 3 years

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### Recorded flood mark at Gawal Mandi Bridge by TMA

<table>
<thead>
<tr>
<th>Year</th>
<th>Maximum Water Level (ft)</th>
<th>Maximum Water Level (m)</th>
<th>Discharge (m³/s)</th>
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<td>25</td>
<td>494.02</td>
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<tr>
<td>1977</td>
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<td>495.54</td>
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<tr>
<td>1978</td>
<td>25</td>
<td>494.02</td>
<td>450</td>
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<td>29</td>
<td>495.24</td>
<td>650</td>
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<td>1982</td>
<td>32</td>
<td>496.15</td>
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<td>2001</td>
<td>41</td>
<td>498.90</td>
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<td>2002</td>
<td>22</td>
<td>493.10</td>
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Source: Pakistan Meteorological Department
The largest flood

Rainfall at Islamabad Station was recorded at 620mm in 10hrs from 6:00 to 16:00 (PST) on 23 July 2001.

The rainfall was caused by freak combination:

(a) intense heating on the surface
(b) presence of mid latitude westerly trough
(c) moisture feeding through monsoon flow.

Inundation depth was 4m or over
Inundation duration was 6hours or more

The flood was too fast to allow them to evacuate. (Interview Survey)
The Main Cause of the Inundation of 2001 flood

Illegal Residents in river zone
Responsible and Implementing Agencies of the Project

(1) Agency Responsible for the Project
- FFC is the agency, overall responsible for the Project.

(2) Implementing Agency for the Project
- PMD is the implementing agency for issuance of flood related information.
- TMA of Rawalpindi is the implementing agency for issuance of flood warning through blow of siren.
Scope of the Project

Pakistan Meteorological Department (PMD)
Rainfall/Water Level Observation
Flood Forecasting

TMA-Rawalpindi
Flood Warning for Evacuation

Monitor Station
- Federal Flood Commission
- Water and Sanitation Agency

Integrated Operation of Warning Post

Announcement
Siren

City Residents

Citizens' Organization

Prompt and Safe Evacuation
to protect lives and properties

Source: Pakistan Meteorological Department
<table>
<thead>
<tr>
<th>Organization in charge</th>
<th>Function</th>
<th>Station</th>
</tr>
</thead>
</table>
| PMD                   | • Flood forecasting data collection  
|                        | • Data processing  
|                        | • Dissemination of flood information to related agencies | TMA Rawalpindi  
|                        |                       | Flood evacuation warning by motor siren and loudspeaker |
| PMD                   |                       | TMA Rawalpindi:  
|                        | - Warning Control & Supervision  
|                        | - Flood Information Monitoring | CDG/TMA  
| WASA                  | Flood information monitoring  
|                       | (Data transmission subsystem) | WASA  
| FFC                   | Flood information monitoring  
|                       | (Data transmission subsystem) | FFC  
| RAMC                  | • Repeater function for telemetry  
|                       | • Repeater function for wireless LAN | PMD  
| RAMC                  | Flood information monitoring  
|                       | (Data transmission subsystem) | RAMC  
| PMD                   | Automatic rainfall data observation  
|                       | (Telemetry subsystem) | PMD  
| PMD                   | Automatic water level data observation  
|                       | (Telemetry subsystem) | PMD  
| Ramco                 | Flood information monitoring  
|                       | (Data transmission subsystem) | Ramco  
| Ramco                 | Control and supervision of warning system | Ramco  
| Ramco                 | Flood information monitoring  
|                       | (Data transmission subsystem) | Ramco  
| Ramco                 | Flood evacuation warning by motor siren and loudspeaker | Ramco  

**1. Master Control Center**
- PMD, Islamabad
- **Function**
  - Flood forecasting data collection
  - Data processing
  - Dissemination of flood information to related agencies
- **Organization in charge**: PMD

**2. Rainfall Gauging Station**
- 2.1 PMD, Islamabad, Saidpur, Gorla, Gorla,Bokla,RAMC, Chaklala
- **Function**: Automatic rainfall data observation (Telemetry subsystem)
- **Organization in charge**: PMD

**3. Water Level Gauging Station**
- 3.1 Kattarian Bridge
- **Function**: Automatic water level data observation (Telemetry subsystem)
- **Organization in charge**: PMD
- 3.2 Gawal Mandi Bridge

**4. Repeater Station**
- 4.1 RAMC Telemetry Repeater
- **Function**: Repeater function for telemetry
- **Organization in charge**: PMD
- 4.2 RAMC Wireless LAN Repeater
- **Function**: Repeater function for wireless LAN

**5. Monitoring Station**
- 5.1 FFC
- **Function**: Flood information monitoring (Data transmission subsystem)
- **Organization in charge**: FFC
- 5.2 WASA
- **Function**: Flood information monitoring (Data transmission subsystem)
- **Organization in charge**: WASA

**6. Flood warning control centre**
- TMA Rawalpindi:
  - Warning Control & Supervision
  - Flood Information Monitoring
- **Function**: Control and supervision of warning system
- **Organization in charge**: CDG/TMA

**7. Flood Warning Post**
- 7.1 WP-I: TMA Rawalpindi
- **Function**: Flood evacuation warning by motor siren and loudspeaker
- **Organization in charge**: TMA
Perspective Map

Source: Pakistan Meteorological Department
Output of the Project

After the Project

PMD

TMA

Real time Rainfall/Water Level Observation

Flood prediction time: 1 to 2 hours before flood

Integrated warning for evacuation

Good enough time to evacuate: 1 to 2 hours by flood prediction

To reach a specified water level for warning

To start warning for evacuation

To start river overflow

Judgement: 10 minutes

Minimal warning activity

Required evacuation time: 1 to 2 hours

To shorter required evacuation time by adequate evacuation plan

Risk time zone causes loss of life

Source: Pakistan Meteorological Department
Forecasting a Flood

Using Mike 11
“When does it rain?” is important information for FFWS and evacuation.
- Morning?
- Daytime?
- Night time?

Rainfall Characteristics

Distribution in Time

29 July 1996 Flood
27 August 1997 Flood
23 July 2001 Flood

Maximum Record in Pakistan

Mid-night
Early-morning
Objectives of the simulation analyses

- To clarify the flood inundation mechanism in the Lai Nullah Basin
- To determine the basic hydrological parameters for designing countermeasures, such as design discharge and design water level
- To examine effects of conceivable countermeasures.

Flow of Flood Simulation

Runoff Calculation from Sub-basins
(SCS Unit-hydrograph method)
(MIKE11)

Flood Routing
(Dynamic one-dimensional model)
(MIKE11)

Flood Mapping
(MIKE11 GIS)

Source: Pakistan Meteorological Department
Runoff Characteristics

Peak Rainfall: 13:00
Peak Water Level:
- Kattarian Br.: 15:00
- Gawal Mandi Br.: 18:00
Peak Discharge:
- Kattarian Br.: 14:30
- Gawal Mandi Br.: 16:00

The flood came in a flash!!!

The peak difference between rainfall and discharge is only 2 hours.

Source: Pakistan Meteorological Department
Runoff Characteristics

Source: Pakistan Meteorological Department
Simulation Model Set-up

Legend
- Sub-basin
- Rivers
- Bridge

Inflow from Sub-basin

Flood Plain

SB4
SB5
SB6
SB7
SB8
SB9
SB10
SB11
SB12
SB13
SB14
SB15

Influent Nallah
Chaklala
Mandi Br.
Soan R.
A unit-hydrograph method based on the SCS Curve Number was selected to estimate runoff discharge from 15 sub-basins.

The estimated runoff discharges were further used as inflow data to river network for the flood routing.

The main river, Lai Nullah, and four major tributaries, Saidpur Kas, Tenawali Kas, Bedarawali Kas and Johd Kas were considered.

Runoff is estimated by SCS Unit-hydrograph Method.

Source: Pakistan Meteorological Department
The flood routing is made along the river network consisting of the five rivers.

<table>
<thead>
<tr>
<th>River</th>
<th>Stretch</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lai Nullah</td>
<td>Kattarian Br. to Soan River</td>
<td>17.5</td>
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<tr>
<td>Saidpur Kas</td>
<td>Zero Point to Tenawali Kas</td>
<td>5.8</td>
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<td>Tenawali Kas</td>
<td>Jinnah Avenue to Bedarawali Kas</td>
<td>8.7</td>
</tr>
<tr>
<td>Bedarawali Kas</td>
<td>E-9 to Lai Nullah</td>
<td>12.7</td>
</tr>
<tr>
<td>Johd Kas</td>
<td>Golra Village to Bedarawali Kas</td>
<td>7.3</td>
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<table>
<thead>
<tr>
<th>Branch Name</th>
<th>Topo-ID (FFWS Model in 2007)</th>
<th>Manning’s Number</th>
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<td>low water channel = 0.035</td>
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<td>JICA-2002</td>
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<td>E-AI-DWN</td>
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<td>Lai Nullah</td>
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<td></td>
<td></td>
<td>low water channel = 0.035</td>
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</table>

Source: Pakistan Meteorological Department
### 2001 flood hourly rain

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<tr>
<th>Time</th>
<th>1: Saiidpur [m]</th>
<th>2: Islamabad [m]</th>
<th>3: RANIC [m]</th>
<th>4: Chaklala [m]</th>
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Flood Routing
Calculation Result

Reproduced Max. Water Level
Flood Mark of Max. Water Level
(Source: ADB project and TMA)
Present Criteria of Evacuation

Water Level Profile (Issuance of Warning)

Source: Pakistan Meteorological Department
Present Criteria of Evacuation

Water Level Profile (Issuance of Warning)

Source: Pakistan Meteorological Department
Flow Capacity of Lai Nullah River

Flow Capacity Profile of Lai Nullah River

Source: Pakistan Meteorological Department
Table 3.1 Water Level Criteria

<table>
<thead>
<tr>
<th>Criteria Water Level</th>
<th>Kattarian Bridge</th>
<th>Gawal Mandi Bridge</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Level m</td>
<td>Water Depth ft</td>
<td>Water Level m</td>
</tr>
<tr>
<td>Rank-A Water Level</td>
<td>499.6</td>
<td>20.0</td>
<td>492.7</td>
</tr>
<tr>
<td>Rank-C Water Level</td>
<td>496.5</td>
<td>10.0</td>
<td>489.8</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Kattarian Bridge</th>
<th>Gawal Mandi Bridge</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Discharge m³/s</td>
<td>Water Level m</td>
<td>Discharge m³/s</td>
</tr>
<tr>
<td>[1] Design Discharge</td>
<td>2,270</td>
<td>505.6</td>
<td>2,640</td>
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<tr>
<td>[2] Min. Flow Capacity</td>
<td>640</td>
<td>500.0</td>
<td>620</td>
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<tr>
<td>[3] Existing Criterion</td>
<td>559</td>
<td>499.6</td>
<td>839</td>
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<tr>
<td>[4] 50% of [2]</td>
<td>320</td>
<td>498.2</td>
<td>310</td>
</tr>
<tr>
<td>[5] Based on 5-year Model Hyeto</td>
<td>330</td>
<td>498.2</td>
<td>390</td>
</tr>
<tr>
<td>[7] 20% of [2]</td>
<td>128</td>
<td>496.5</td>
<td>124</td>
</tr>
</tbody>
</table>

Ground Level: 1,948 504.7 1,261 495.0
Riverbed Level: - 493.5 - 487.5

*1: Japan Criterion is 3-year but simulation was done with minimum model hyet of 5-year.
*2: Meaning like criterion (b) of Japan Warning Stage
1 foot = 0.3048 m

Rank-A water level corresponds to the Danger Stage
Rank-B corresponds to the Warning Stage
Rank-C corresponds to the Advisory Stage

Source: Pakistan Meteorological Department
Flood Warning Code

1. Pre-Alert
2. Alert
3. Evacuation
4. All Clear
Pre-Alert

50mm / 180min (calculated after every 10 minutes)
Each agency should take position to Flood Watch.
Broadcast heavy rainfall and flood prediction, if the rainfall intensity is bigger than the above figures.

Alert

- **Rainfall**
  50mm / 60min ; 135mm / 180min.
- **Water Level**
  Kattarian Bridge : 496.5m (10 feet from riverbed)
  GawalMandi Bridge : 489.8m (7.5 feet from riverbed)

Broadcast flood warning, if the rainfall intensity and raising water level is higher than the above mentioned figures.
### Flood Warning Code

#### Evacuation

**Kattarian Bridge**

- **Pattern1:** Water Level exceed Alert Level *and* Rainfall exceed Alert Level
- **Pattern2:** Water Level exceed 499.6m (20 feet from riverbed)

**Gawal Mandi Bridge**

- **Pattern1:** Water Level exceed Alert Level *and* Rainfall exceed Alert Level
- **Pattern2:** In case of Kattarian Warning
- **Pattern3:** Water Level exceed 493.6m (20 feet from riverbed)

Broadcast siren and announcement for evacuation in case of “Evacuation”.

All flood watches and flood warnings are cleared, if no flood is expected and the rainfall intensity and declining water level is smaller than the following:

- **Rainfall**
  
  20mm /per 180min.

  and

- **Water Level**
  
  Kattarian Bridge: **496.5m (below alert level)**

  Gawal Mandi Bridge: **489.8m (below alert level)**
Flood Warning Code

The possible time for evacuation (excluding decision making, operation time, etc.)

Old criterion (20 feet from riverbed)

10 minutes

New Flood Warning Code

One and half hour

lengthened
Telemetry and Data Transmission System in PMD
SUPERVISORY & CONTROL SYSTEM IN TMA.

- It controls all the 10 warning posts present in different vicinity of the City along the Nullah Lai

Source: Pakistan Meteorological Department
Remote Controlled Warning Posts (10 Station)

- There are 10 Warning Posts.
- 5 in Up Stream
- 5 in Down Stream
- Each warning Post operated from TMA by Radio Waves.
- Each Post Comprises of 4 Speakers, One emergency light and One Siren
- In Case of Power Failure a battery is installed which provide backup to the warning post for 5 days.

Source: Pakistan Meteorological Department
## Rainfall during June 2007 in Balochistan

<table>
<thead>
<tr>
<th>Climatic Stations</th>
<th>June 1-29, 2007</th>
<th>Monthly Normal</th>
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<tbody>
<tr>
<td>Barkhan</td>
<td>44</td>
<td>43</td>
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<tr>
<td>Dalbandin</td>
<td>103*</td>
<td>0.9</td>
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<tr>
<td>Gwadar</td>
<td>52</td>
<td>**</td>
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<tr>
<td>Jiwani</td>
<td>78*</td>
<td>0.8</td>
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<tr>
<td>Kalat</td>
<td>89*</td>
<td>5.3</td>
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<tr>
<td>Khuzdar</td>
<td>73*</td>
<td>12.6</td>
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<tr>
<td>Lasbela</td>
<td>135*</td>
<td>7.8</td>
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<td>Nokkundi</td>
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<td>4</td>
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<td>Pasni</td>
<td>104*</td>
<td>0.4</td>
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<td>Quetta</td>
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<td>1.5</td>
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<td>Sibi</td>
<td>176*</td>
<td>5.5</td>
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<td>Turbat</td>
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<td>Zoab</td>
<td>67*</td>
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</table>
Flood Damage in Balochistan during June 2007

Figure 1. Floodwater in Jaffarabad

Figure 2. Damage to the railway track in Noshki

Figure 3. Floodwater in Jaffarabad

Figure 4. Floodwater in Dasht, Mastung

Figure 5. Damage to electric supply in Noshki

Figure 6. Damaged bridge in Mach, Bolan

Figure 7. Damage to electric supply in Noshki

Figure 8. Damage to tubewells in Noshki
Flood Damage in Balochistan during June 2007

Figure 9. Damage to agriculture and rural housing, Noshki

Figure 10. Damage to agriculture in Kharan
Thank You