TERMS OF REFERENCE (TOR)
PREPARATION OF AN INVENTORYING INDUS EMBANKMENTS AND BREACHING SECTIONS, TO DOCUMENT THEIR CURRENT CONDITIONS AND FOR INFORMED DISASTER RISK & HAZARD MAPPING

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1. The Challenge

The Sindh Irrigation Department (SID), Government of Sindh intends to undertake a number of activities for institutional strengthening of the department under the 'Sindh Resilience Project' soft component funded by The World Bank.

The envisioned study under soft component is for those hydraulic infrastructures which require evaluation for safety of such structures. The Flood embankments controlled by Sindh Irrigation Department SID have been built in traditional ways and have been protecting surrounding communities, infrastructures and low-lying areas around riverine belts. In Sindh the Indus River has hundreds of kilometers of flood embankments to protect against flooding. Nevertheless, they are not the only sustainable options and receive unfrequented floods, which receive low, medium, high, super and exceptional floods off and on in varied years. The accidental overtopping or breaching of embankments causes a huge damage in terms of economic and human suffering.

This project aims to allow for informed decision making on operational flood management and embankment maintenance strategies. and further the understanding and control of breaching.

The history of floods and inundations in the Sindh Irrigation Department (SID) reveals that improvements could be made by the following steps:

- Availability of an inventory of the status and conditions of the existing embankments
- Analysis tools for options for better inundation and flood risk management by controlled breaching.

- Controlled breaching can be seen as a means to lower the pressure on existing embankments and lower the chance of occurrence of accidental, uncontrollable breaches with uncontrollable damage and impacts.
- Availability of an inventory of embankment sections in terms of their importance, their significance and the associated potential impact in case of failure of each of the embankment sections.

The project would envision an evaluation for the existing conditions of the embankments, to suggest strategies and options for controlled breaching and safety of hydraulic structures for SID.

The project should result in an extension of existing database integrated into DSS already in operation at the Sindh Irrigation Department (SID) and should enhance the existing DSS capabilities of flood warnings and management, based on analysis of embankment situation and condition.

2. The Objective

Develop and implement a database of the situation and condition of the main embankment sections in the Sindh Irrigation Department (SID). Extend existing hazard and impact modeling methods and tools. Develop tools to use the database for strategy development of controlled breaching as an option for flood and inundation risk management.

3. Scope of Work

3.1. Task 1: Survey and Database of Flood Protection Structures and Embankments

Undertake in-depth consultations with SID staff/officials and other the relevant stakeholders, one-to-one meetings and to systematically identify peculiar reasons for deteriorating conditions of river embankments on Indus River by SID. The performance evaluations of existing flood structures for improvement and safety. Review selected constructed, ongoing and planned river embankments and river training works, along a total of 1200miles (~1900km) of embankments on the Indus River in the Sindh province. The review must include, but not be limited to, the most recent edition of the Sindh Bund Manual and related documentation.

The overall objectives of this task are:

1. Carry out comprehensive exercise for the identification of vulnerable and high-risk zones of river embankments and flood protection structures with reference to structural stability of flood bund slopes and proximity to morphological hotspots and adverse flow conditions that may threaten the integrity of flood protection structures. Based on reports review and interviews, document all major historical embankment damages due to flooding in the inventory. The documentation has to provide as many details as possible including date of flood, precise location or overtopping or breaching, causes of failures, undertaken measures, etc.
2. Monitoring survey of all flood embankments/flood infrastructure systems structures to evaluate and document their present condition
3. Provide a methodology to survey 1600 miles including all the critical embankment sections and ensuring representation and reliability of the embankment systems. Survey / counter check L-sections and X-sections of flood embankments / flood infrastructure systems for assuring its accuracy. Technical scrutiny of the proposals and longitudinal sections etc.
4. Propose shear /erosion control structural plans and propose practical and sustainable structural support measures such as vegetated / live brushwood/ Geo-textile soft gabion retaining walls.
5. Recommend tree species for undertaking such structural mitigation measures.
6. Embankment Soil sampling and subsequent sediment size analysis at selected locations along the embankments.
7. Incorporate all survey, analysis and other spatial information in the existing DSS platform.
8. Based on the survey, and subsequent technical analysis, propose policy implications which can be incorporated in existing regulation and policy documents, such as the Sindh Bund Manual.

Subtask 1.1: Develop Protocol for Survey and Evaluation of Current Structural Conditions, and Preparation of Survey Plan

This task should yield a clear and univocal protocol for the survey team of what the focus of the survey and the investigation should be. The protocol should include the obvious parameters such as base width, top width and height of the embankment, visual inspection of condition of the embankments, but should also add parameters for bank erosion, signs of piping and underflow etcetera. A similar protocol should be devised for the hydraulic structures. The

protocol should outline the exact formats of the results of the survey but should also address issues such as photos taken from the section and sketch maps of local situations. The developed protocol will be finalized in consultation with SID officers.

Subtask 1.2: Develop Database Structure and Status Report Structure for Database of Flood Protection Structures and Embankments

1. Develop an online database for the embankment status and situation data (based on results of subtask 1.1).
2. Develop quality checks and completeness checks of information in the database.
3. Develop requirements for reporting and develop report structure.
4. Link database to GIS maps and reporting structure.

Subtask 1.3: Surveys & Investigations for River Embankments: Safety Evaluation of Current Structural Conditions

The consultant will be required to carry out following activities, furnish necessary reports:

a) River Embankments Sections

Both left and right bank of the Indus main channel in the SID are aligned with embankments (total of more than 2x1600 km) in different regions such as Guddu, Sukkur, Kotri and SIDA. These embankments are divided into sections, based on the methodology and system used by SID. The survey team is responsible to make an assessment of the situation and condition of each of these sections, based on the protocol as defined in subtask 1.1.

b) Other Flood Management Structures

Other structures that might be significant for water management (think of road network, embankments of infrastructure etc.).

Subtask 1.4: Implement Data from Survey and Investigations into Database and Develop Policy Implications

Input collected information of task 1.3 into the digital database as developed in task 1.2. Link database to GIS mapping and to the existing DSS.

Based on the survey, and subsequent technical analysis, propose policy implications which can be incorporated in existing regulation and policy documents, such as the Sindh Bund Manual.

3.2. Task 2: Extending Existing Hazard and Risk Mapping for Mapping Impacts of Potential Breaches

The current version of the DSS deployed at the Irrigation department has the ability to simulate the flood including breaching at selected sections of the embankments to model residual flood risk.

Extend existing methods for hazard and risk mapping (the current version of the DSS) and develop a methodology for classification of risks in terms of inundation extent and depth; and impacts on infrastructure, agriculture and livelihoods. This extended hazard mapping methodology and tools serves three goals:

1. Allow for a structured analysis of impact of breaching
2. To provide a tool for impact analysis of controlled breaching
3. To prioritize the criticality, significance and importance of individual embankment sections

Subtask 2.1: Develop Methodology for Automated Hazard Mapping and Risk Mapping

- Develop criteria to be analyzed for impact mapping.
- Develop spatial tools and methods for impact mapping.
- Inventory of necessary input data, data collection and data preparation (input GIS maps).

Subtask 2.2: Implementation in GIS and System Integration

Link developed methods with GIS. allow for:

- end-user controlled impact analysis based on user-defined flood extents
- Automated impacted analysis based on user-defined or batch-mode processing of controlled breaching options
- Automated impacted analysis based on batch-mode processing of embankment section failure analysis

Subtask 2.3: Apply Developed Methods to Historical Breaches and Analyze Results

Apply developed methods to historical breaches and analyze results (Tori bund breach, Sagyoon Matiari breach, Kuka Wari breach, Kot Almo breach, PB breach).

3.3. Task 3: Accidental and Controlled Breaching and Scenario Development

The embankments along the Indus main channel are subject to accidental and spontaneous branching. This spontaneous breaching could result in disastrous inundations of the agricultural land and the villages and various other economic land uses protected by the embankments. History has shown some vulnerable locations for breaching, but a changing morphology in the riverbed will yield new vulnerable locations.

Breaching may also be a controlled way of safeguarding the system similar to the practice in the upper riparian districts: controlled breaching can be a method to take the stress away from vulnerable / critical structures.

- Controlled versus accidental/spontaneous breaching
- Define controlled breaching as a strategy to prevent potentially disastrous accidental breaches
- Define preferred locations for controlled branching, based on the analysis of impact of controlled breaching.

Subtask 3.1: Analysis of Potential Hotspots for Spontaneous Breaching

1. Determine scope of the task (inception phase). The exact scope of the task should be specified. Outline the extent of the study area and methodology along with client consultation. Exact specification of proposed methods for hotspot identification. Prepare contribution to the inception report.
2. Preliminary study on existing hotspots and their vulnerability.
3. Preliminary study on recent morphological changes. A detailed study of morphological changes in the Indus main channel and floodplain will provide valuable insight in morpho dynamics and its impact on the vulnerability for breaching at various locations will be assessed.
4. Detailed specification of processes to be included in a webGIS based system for decision support of SID river managers. At this stage all methods and tools to be

included in the system should be fully specified, detailed design of processes and tools will be developed at this stage.

5. Implementation of the processes decided upon in previous subtask

Subtask 3.2: Explore the Strategy of Controlled Breaching, Identify Promising Locations for Controlled Breaching

Floods of exceptionally high magnitude can lead to uncontrolled or accidental embankment breaches along high-risk areas. A deliberate structural breach during floods can have very destructive consequences but can be necessitated to protect critical / high risk zones during exceptionally floods. Better planning and preparation for such decision making, as a result of this project, can lead to flood hazard and risk mapping and lead to more effective flood response & evacuations.

1. Determine scope of the task (inception phase)
2. Preliminary assessment on controlled breaching
3. Analysis of potentially feasible locations for controlled breaching
4. Specification of processes to be included in the DSS
5. Implementation of the processes decided upon in previous subtask

Subtask 3.3: Implement Concepts, Methodology and Tools for Controlled Breaching Scenario Development for Decision Support of Flood Managers

The methodology and tools for controlled breaching scenario should be developed into actionable decision support of SID flood managers. Metrics for evaluation of the scenarios should be presented based on socio-economic impact assessment, flood attenuation (volumetric analysis), drainage and other key metrics.

3.4. Task 4: Prioritized List of the Critical Sections of the Embankments and Survey of Reservoir Structures

The concepts for developing this prioritized list of critical sections starts with the notion that the impact of breaching one particular section is definitely not the same as breaching another section. Breaching of one critical section may result in a huge area being inundated, with a huge impact, while breaching a non-critical section will result in only minor impact. The task here is to develop a prioritized list of sections. High on this list are the sections which have the higher impact in case of failure. Low on this list are the sections with only minor impact.

This prioritized list of critical sections can be useful for various analyses:

- If looking for potential locations for controlled breaching, we should be looking for the sections that are low on this list, as breaching them would have the smaller impact.
- If developing maintenance strategies for embankments one should be looking for the sections high on the list, because in case of failure the impact would be huge.
- Etc.

The task can be further described as:

- Develop a methodology and database for a prioritized list of the critical sections of the embankments and a prioritization of importance of sections, based on inundation extent and potentially exposed assets (based on hazard mapping)
- Develop an ordered list of significance or essentiality of the sections, based on the potential damage and inundation extent in case of failure.

Subtask 4.1: Develop a Methodology for Batch Processing of Consequences of Embankment Section Failures and Integrate Results in GIS and Spatial Database

2D hydrodynamic modeling should be used to model embankment breaches at different locations. The residual risk assessment methodology should use depth, inundation (and flood volumetric analysis) output, along with supplementary spatial and socio-economic information of the area to create hazard and (residual) risk maps. These can be used to develop a list of prioritized critical embankment sections.

The output of Section 4.1 is prioritized embankment sections along with residual risk information as a result of embankment breach. To make these results useful for flood managers and decision makers, it should be catalogued and integrated in SID's spatial database system.

Subtask 4.2: Surveys & Investigations for Barrages and Reservoirs: Safety Evaluation of Current Structural Conditions

a) Main Hydraulic Structures (Guddu, Sukkur, Kotri barrage)

Three major barrages and a number of smaller structures are under control and operation of Sindh Irrigation Department. As these structures are of major importance to the operation and flood management in the province, these structures should be included in the survey and

catalogued in the database. Note that this inventory should include all structures which are relevant for the water management in the Sindh.

b) Major Reservoirs (Manchar, Chotiari, Keenjhar etc)

These reservoirs are of critical importance to the hydrology and flood management in the province. The current conditions of the structures and their associated embankments needs to be assessed and catalogued in the database.

In addition, evaluate existing gate operation procedures during high inflow conditions, and its impact on downstream because sudden release of huge amount of water from reservoirs or barrages by full gate opening may result in serious flood damages downstream. Propose revised gate opening procedures if needed based on the evaluation.

3.5. Task 5: Integration of Geo-Database into Existing System and Training

Subtask 5.1: Integration of Developed Tools into SID Geodatabase

Oversee, supervise and integrate the implementation of tools developed in task 1.4 into the SID spatial/geo database and decision support systems. Safeguard the integrity of the system. Design user control flow through the system and ensure the overall user-experience with the system.

Subtask 5.2: Training and Local Capacity Development

Enhance the institutional capacity and sectoral knowledge related to various studies and tasks outlined in this project particularly related to Integrated water resource management, hill torrent flood management, and operational flood management.

- User-interaction design and user-requirement dialogue workshops
- Hands-on training of developed tools
- Workshops and stakeholder dialogues
- Training on accessing and maintaining the database and related tools

4. Deliverables

Reports:

- Inception Report
- Report on Survey Plan and Preliminary Assessments
- Interim Report on Survey and Database of Flood Protection Structures and Embankments
- Interim Report on Extending Existing Hazard and Risk Mapping for Mapping Impacts of Potential Breaches
- Interim Report on Accidental and Controlled Breaching and Scenario Development
- Interim Report on Prioritized List of the Critical Sections of the Embankments and Survey of Reservoir Structures.
- Interim Report on Integration of Geo-Database into Existing System and Training
- Final Report, and Integration of Results into Existing SID Database and Systems

Databases & Tools

- Database of Status, Condition and Situation of Embankment Sections and Hydraulic Structures
- Prioritized List of Critical Embankment Sections Based on Analysis of Task 4
- Hazard and Impact Assessment Tools

5. Project Plan

5.1 Time Schedule

The project is expected to start October 2021. With an expected duration of 15 month this project should be finished by January 2023.

5.2 Expertise Required for Consulting Services

5.2.1 Summary Table of Staffing

A summary of the consultant inputs is listed in the table below:

S.No.	Position	Months
A	***Key Staff***	
1.	Team Leader	15

S.No.	Position	Months
2.	Hydrodynamics and River Morphology Expert	12
3.	Hydraulics Design Specialist	12
4.	GIS And Spatial Data Expert	12
5.	Database Expert	12
6.	Contract Engineer / Project Manager	15
7.	Training and Capacity Building Expert	09
	Sub - Total A	**87**
B	***Non- Key Staff***	
1.	Hydraulics Engineer (x2)	24
2.	Structural Engineer (x2)	24
3.	Surveyors (x4)	48
4.	GIS Experts (x3)	36
5.	Geotechnical Engineer (x2)	24
6.	Data Analyst (x2)	24
7.	Field Coordinator	12
	Sub - Total B	**192**
C	***Other Technical & Support Staff***	
1.	Assistants / Computer Operators (x4)	48
3.	Support Staff (x8)	104
	Sub - Total C	**152**
	TOTAL A+B+C	**431**

5.2.2 Key Experts

1. Team Leader

Main qualifications

The Team Leader shall have a master's degree in Civil Engineering, Hydrology or Integrated Water Resources Management with at least 15 years" of experience in irrigation planning,

management and administration of government and foreign funded Projects/ Development Schemes.

2. Hydrodynamics and River Morphology Expert

Main qualifications

The Hydrodynamics and River Morphology Expert shall have a master's degree in Flood Hydraulic / Civil Engineering or equivalent with at least 10 years' experience in Flood modeling, River Morphology and River dynamics. Specific experience with inundation modeling, hydrodynamic modeling of large river systems and embankment breaching would be an advantage.

3. Hydraulics Design Specialist

Main qualifications

The Hydraulic Design specialist shall have a master's degree in Hydraulic / Irrigation Engineering with at least 15 years" experience in Irrigation Planning. Specific experience on hydraulic design of Irrigation structure would be an advantage.

4. GIS and Spatial Data Expert

Main qualifications

The GIS and Spatial Data expert shall have a master's degree in spatial hydrology, RS & GIS, geomatics or equivalent with special focus on geodata and hydrometeorological data handling and managing. He/she should be experienced in creating impact maps from simulation modeling results. Experience in ICT and web-based ICT solutions for geo-informatics projects, or spatial data ingestion systems would be an advantage.

5. Database Expert

Main qualifications

The Database expert shall have a master's degree in software development and ICT with at least 10 years" experience in development of Database for water management and/or early warning systems.

6. Training and Capacity Development Expert

Main qualifications

The training and capacity development expert shall have university degree in related discipline with at least 8-10 years of relevant experience in the relevant sector Governance and Participatory DRM, Floods and Droughts, Climate Change Mitigation, IWRM, Groundwater Hydrology / Geohydrology and agricultural practices and the adaptation to water availability issues.

7. Contracts Engineer / Project Manager

Main qualifications

The Contracts Engineer shall be graduate engineer with minimum 15 years" experience of preparing bidding documents, procurement, contract and project management of mega projects particularly projects funded by international banks.

5.2.3 Non-Key Staff

1. Hydraulics Engineer
2. Surveyors
3. GIS Experts
4. Geotechnical Engineer
5. Data Analyst
6. Field Coordinator

5.3 Reporting

S.No.	Name of Deliverables	Timeline (After Commencement of Services)
1.	Inception Report	1 month after project start
2.	Report on Survey Plan and Preliminary Assessments	3 months after project start
3.	Interim Report on Extending Existing Hazard and Risk Mapping for Mapping Impacts of Potential Breaches (based on preliminary survey results)	6 months after project start
4.	Interim Report on Survey and Database of Flood	8 months after project start

	Protection Structures and Embankments	
5.	Interim Report on Accidental and Controlled Breaching and Scenario Development	10 months after project start
6.	Interim Report on Prioritized List of the Critical Sections of the Embankments and Survey of Reservoir Structures	12 months after project start
7.	Interim Report on Integration of Geo-Database into Existing System and Training	13 months after project start
8.	Final Report, and Integration of Results into Existing SID Database and Systems	15 months after project start

6. Schedule of payment

The schedule of payment for consultancy services is as under:

S.No.	Name of Deliverables	Amount in percentage
1.	Inception Report	15%
2.	Report on Survey Plan and Preliminary Assessments	10%
3.	Interim Report on Extending Existing Hazard and Risk Mapping for Mapping Impacts of Potential Breaches (based on preliminary survey results)	15%
4.	Interim Report on Survey and Database of Flood Protection Structures and Embankments	10%
5.	Interim Report on Accidental and Controlled Breaching and Scenario Development	10%
6.	Interim Report on Prioritized List of the Critical Sections of the Embankments and Survey of Reservoir Structures	15%
7.	Interim Report on Integration of Geo-Database into Existing System and Training	10%
8.	Final Report, and Integration of Results into Existing SID Database and Systems	15%

7. Coordination

The consulting firm shall report to the Project Director, Sindh Resilience Project or any other staff designated. The Project Director or the designated staff shall approve all work.

8. Qualification

The interested firm must:

- Be a tax registered consultancy firm incorporated for at least ten (10) years.
- The Consultants/ Firms who have completed minimum of five (05) numbers of similar of assignment of scale and complexity.
- The firm and its staff must have experience of offering similar services and have completed similar projects of this scale and complexity.
- Adequate Logistical Capacity

9. Selection Process

A consulting firm(s) / Joint Venture(s) will be selected in accordance with the procedures set out in the “World Bank Procurement Regulations for IPF Borrowers (July 2016) revised November 2017 & August 2018 (“Procurement Regulations”) following Quality and Cost Based Selection (QCBS) method.