ISLAMIC REPUBLIC OF PAKISTAN
FEDERAL FLOOD COMMISSION (FFC)
Provincial Irrigation Department(PID), Punjab and Sindh

THE PROJECT FOR CAPACITY DEVELOPMENT OF EFFECTIVE RIVER DIKES MANAGEMENT RESPONSE TO 2022 FLOOD

REPORT ON : COMPARATIVE ANALYSIS OF DESIGN MANUALS OF BUNDS IN PUNJAB & SINDH PROVINCES OF PAKISTAN AND JAPAN

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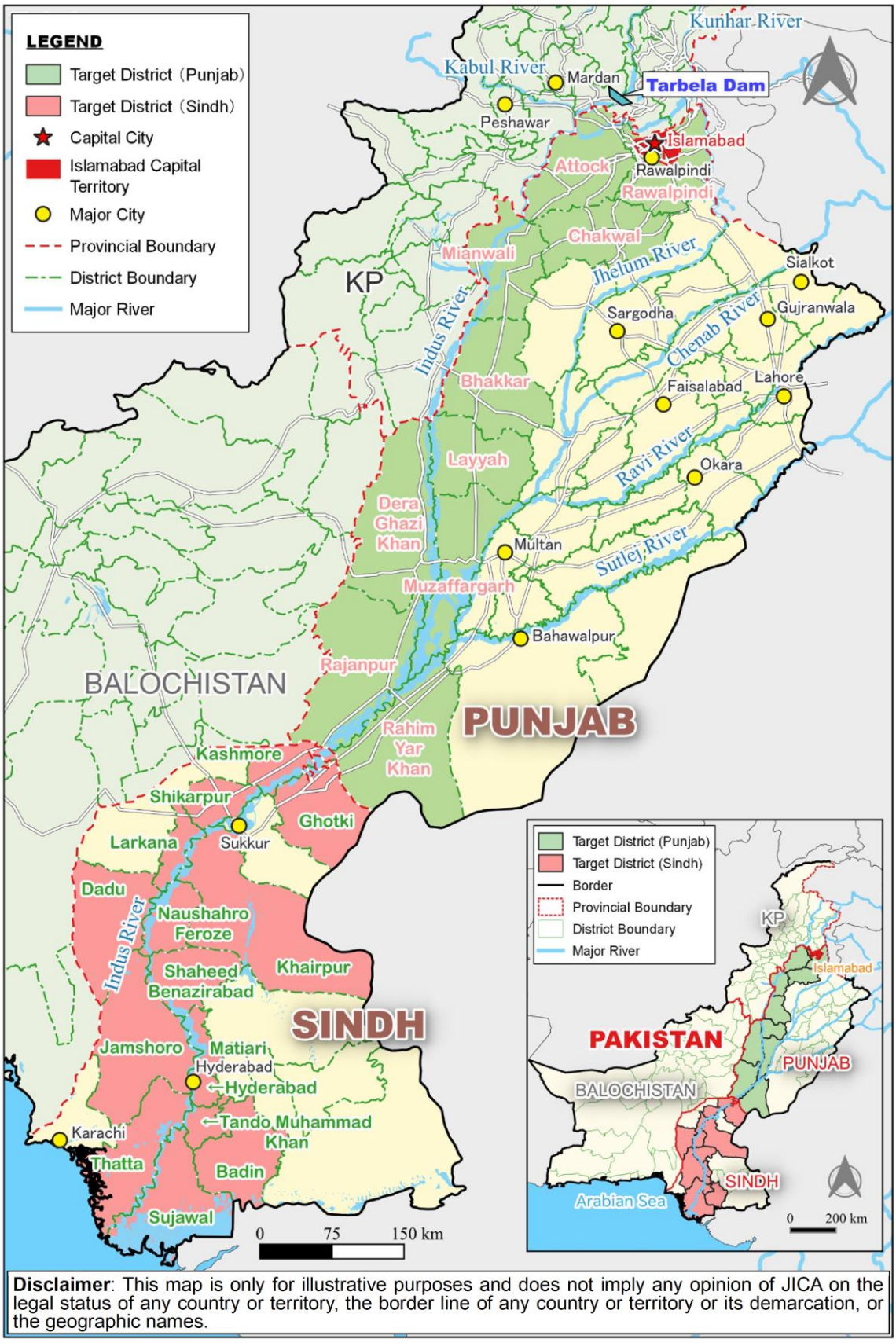
JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.



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PROJECT LOCATION MAP

THE PROJECT FOR CAPACITY DEVELOPMENT OF EFFECTIVE RIVER DIKES MANAGEMENT RESPONSE TO 2022 FLOOD

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ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AIT	Asian Institute of Technology
AMP	Asset Management Plan
ASR	Alkali Silica Reaction
ASTM	American Society for Testing and Materials
CAPEX	Capital Expenditure
CE	Chief Engineer
DEM	Digital Elevation Model
DSS	Decision Support System
EM	Engineer Manual
FFC	Federal Flood Commission
FOS	Factor of Safety
FRAU	Flood Risk Assessment Unit
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HFL	High Flood Level
HGL	Hydraulic Grade Line
HSSEU	Hydraulic Structures Safety Evaluation Unit
HWL	High Water Level
JICA	Japan International Cooperation Agency
LiDAR	Light Detection and Ranging
MCE	Maximum Considered Earthquake
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MMS	Mobile Mapping System
NDMA	National Disaster Management Authority
NDT	Non-Destructive Testing
NESPAK	National Engineering Services Pakistan
NFPP	National Flood Protection Plan
OBE	Operating Basis Earthquake
OPEX	Operational Expenditure
PDCA	Plan-Do-Check-Act
PDNA	Post Disaster Needs Assessment
PID	Provincial Irrigation Department
PMD	Pakistan Meteorological Department
PMF	Probable Maximum Flood
QTY	Quantity
RC	Reinforced Concrete
4RF	Resilient Recovery, Rehabilitation, and Reconstruction Framework
RL	Reduced Level
SCADA	Supervisory Control and Data Acquisition
SE	Superintending Engineer
SIDA	Sindh Irrigation and Drainage Authority

SPT	Standard Penetration Test
SRP	Sindh Resilience Project
UAV	Unmanned Aerial vehicle
UNDP	United Nations Development Programme
USACE	United Stats Army Corps of Engineers
USBR	United States Bureau of Reclamation
WAPDA	Water and Power Development Authority
WB	World Bank
WCAP	Water Sector Capacity Building and Advisory Services Project
XEN	Executive Engineer

CHAPTER 1 INTRODUCTION

1.1 Outline of the Project

(1) Status and Issues of the Flood Protection Sector in Pakistan and the Purpose of Project

The Islamic Republic of Pakistan (hereinafter referred to as "Pakistan".) is a country prone to natural disasters such as floods, landslide disasters, and earthquakes. Among them, the Indus River and its major four tributaries cause a high potential of floods due to heavy rainfall in the upstream during the monsoon season, which may negatively affect Pakistani society through significant economic losses without maintains and improvements of river facility.

In particular, a large-scale flood occurred in Pakistan in 2022, resulting in more than 1,700 deaths and estimated recovery and reconstruction needs of 16.3 billion (Post Disaster Needs Assessment: PDNA, October 2022). In addition, the large-scale flood occurred in 2010, flooding approximately 20% of Pakistan's territory and causing extensive damage of approximately $10 billion, including more than 20 million victims, approximately 1.6 million collapsed houses, and damaged infrastructure such as roads and irrigation facilities (Federal Flood Commission, 2010). In the 2010 flood, Government of Pakistan analyzed that several breaches of the main Indus River bund caused extensive damage. It should be noted that this breach also includes intentional breaches aimed at protecting agricultural infrastructure such as barrage.

Since the time of British rule, bund on the main Indus River has been maintained, and maintaining bund function properly in the future is one way to avoid increasing flood risk. Based on the current situation of severe and frequent flooding, Government of Pakistan has decided to upgrade and reinforce river structure as a priority response in National Flood Protection Plan (National Flood Protection Plan-IV. Hereinafter referred to as "NFPP-IV".), which is planned for 10 years between fiscal 2018/19 and 2027/28, led by Federal Flood Commission (Federal Flood Commission. hereinafter referred to as "FFC".). In addition, the post-disaster needs assessment survey (hereinafter referred to as "PDNA2022".) conducted by Government of Pakistan after the flood in 2022 and the reconstruction assistance plan (Pakistan Floods 2022: Resilient Recovery, Rehabilitation, and Reconstruction Framework (4RF), UNDP) announced in January 2023 have positioned these projects as highly necessary to ensure the rehabilitation of bunds as well as other river and irrigation structures.

Under these circumstances, the technical cooperation "The Project for Capacity Development of Effective River Dikes Management in Response to 2022 Flood" (hereinafter referred to as “the Project".) will grasp the current situation of bunds along the Indus River Basin in terms of the construction/rehabilitation progress and quality; and formulate an action plan for its management and carry out preliminary feasibility study (hereinafter called pre-F/S) for selected priority projects in the action plan, taking into account the effects of climate change.

(2) Output of the Project

The Outcomes of the project are shown in **Table 1.1.1**. This Report is mainly relating with “Activity 2-1: Implementation of a comparative analysis of technical manuals on bund by Pakistani provinces.”

Table 1.1.1 Project Outcomes and Activities

Project Outcome	Activity for Outcome
1. The reproducibility of the 2022 flood considering climate change impact is assessed.	1-1: Analysis of the Reproducibility of the 2022 Flood in Consideration of Climate Change (already implemented by JICA)
2. A mechanism to perform inspection and diagnosis of existing river dikes is established.	**2-1: Implementation of a comparative analysis of technical manuals on bund by Pakistani provinces** 2-2: Implementation of an inventory survey of the present status of the main Indus River bund 2-3: Study on the maintenance and management method of the main Indus River bund suitable for Government of Pakistan system 2-4: Implementation of maintenance demonstrations in vulnerable areas of the Indus River Main River bund
3. The dike operation management plan including short to midterm action plan for the Indus River downstream of Tarbela dam is formulated.	3-1: Analysis of existing plans and projects related to the Indus River Main River bund 3-2: Preparation of supplementary materials to existing Pakistani technical manuals on bund management 3-3: Arrangement and formulation of short- and medium-term action plans for the bund management
4. The prioritized projects based on the dike operation management plan are identified.	4-1: Extraction and arrangement of priority activities in the short to medium term action plan formulated in Output 3. 4-2: Identification of priority projects to be implemented as soon as possible.
5. The necessary pre-feasibility studies among the prioritized projects are performed.	5-1: Implementation of pre-F/S of priority projects identified in Output 4. 5-2: Implementation of capacity-building seminars on bund development and management

Source: JICA Project Team

1.2 Objectives of This Report

The objectives of this report are as follows.

- ✓ Comparing the technical manuals of each province, lacking items or contents in either one manual will be picked up and necessity for the addition will be analyzed to enhance the ability and capacity on the bund management in both Sindh and Punjab Province.
- ✓ Extracting the issues on the existing manual considering the gap between the regulation the manuals and actual practice.
- ✓ In addition to comparative analysis between each province, analysis of contents contributing to improve the technical manuals in each province by referring to technical standards in Japan and, if necessary, third countries.
- ✓ Items that are not commonly described in each manual are picked up by importance and the necessity of additional contents to the manual of the deficient side is checked.
- ✓ Based on the analysis result, measures to improve the existing technical manual will be recommended. Also, the contents to be included in the supplementary materials for the existing manuals which will be prepared in "Activity 3-2: Preparation of supplementary materials to existing Pakistani technical manuals on bund management" will be analyzed.

1.3 Collected Document

Technical manuals on bunds in Pakistan shown in Table 1.3.1 are collected. Those will be the compared and analyzed in this report. Also, the Japanese technical standards on bunds shown in Source: JICA Project Team summarized.

Table 1.3.2 are collected.

Table 1.3.1 Standards Related to Bund in Pakistan

Name of a Standard	Publisher	Year of Publication	Remarks
Manual of Irrigation Practice	Punjab Provincial Irrigation Department	2017	Including River Structure Other Than a Bund, Including Irrigation Facilities
Bund Manual (4th edition)	Sindh Provincial Irrigation Department	2008	Mainly About a Bund
National Flood Protection Plan (NFPP)-IV	Federal Flood Commission (FFC)	2018	Including River Structure Other Than Bund budget Not Approved

Source: JICA Project Team summarized.

Table 1.3.2 Major Standards Related to Bund in Japan

Name of a Standard	Publisher	Year of Publication	Outline
River Law	Government of Japan	Revision in 2022	It covers the management and conservation of rivers, regulations on utilization, roles of river administrators, improvement and flood control measures, conservation of the river environment, management of water rights, regulations on river utilization, and supervision and penalties.
Enforcement Order for River Law	Government of Japan	Revision in 2022	Government ordinance (administrative order) that specifies the detailed operational methods and provisions for the implementation of the River Law. It complements the River Law by providing necessary procedures, criteria, and specific regulations for practical implementation.
Cabinet Order Concerning Structural Standards for River Administration Facilities, etc.	Government of Japan	Revision in 2013	It covers basic design standards, provisions for maintenance and management, regulations for the installation of river structures, seismic resilience requirements, and the responsibilities of administrators. The river structure includes dams, dikes, sluiceways&floodgates, weirs, brides, pumping stations and inverted siphons.
Technical Criteria for River Works: Practical Guide for Designing [I]	Ministry of Land, Infrastructure, Transport and Tourism, Japan	Revision in 2019	It includes criteria for planning, survey&investigation, design, and operation&maintenance of river structures. These criteria cover design details of river structure such as dikes, revetments, spurs, weirs, sluiceways, floodgates, tunnel river, pumping station, inverted siphons.
Technical Criteria for River Works: Practical Guide for O&M(For River)	Ministry of Land, Infrastructure, Transport and Tourism, Japan	Revision in 2011	Same as the above. These criteria cover operation&maintenance details such planning for river management, objectives of river management, grasping river conditions, environmental improvement for river inspection/investigation, measures for river channel management, measures for facility management, measures for river area management, measures for river environmental management and measures for flood fighting.
Standard for Extra Embankment	Ministry of Land, Infrastructure, Transport and Tourism, Japan	1969	This standard specifies the standard height of extra embankment considering the settlement and compression depending on the type of earth material.
Performance Based Seismic Design Criteria for River Structures	Ministry of Land, Infrastructure, Transport and Tourism, Japan	2001	This specifies the methods, items, setting of external force and required function of river structure facilities after the earthquake. It considers Level 1 and Level 2 seismic conditions.

Name of a Standard	Publisher	Year of Publication	Outline
Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels	Ministry of Land, Infrastructure, Transport and Tourism, Japan	Revision in 2023	A regulation that establishes provisions for the inspection and evaluation procedures of embankments, as well as other river management facilities and channels. It covers the purpose and scope of inspection, procedures and frequency, methods and techniques, evaluation and reporting of inspection results.
Guideline for Structural Analysis of River Embankment	Japan Institute of Country-ology and Engineering	Revision in 2012	This guideline consists of inspection&investigation, safety analysis and reinforcement of the river dike especially against seepage, erosion and earthquake. In addition, inspection and reinforcement of the dike adjacent to the structure installed in the dike.
River Earthwork Manual	Japan Institute of Country-ology and Engineering	Revision in 2009	This is a supplement to the "Technical Criteria for River Works:", focusing on the design theory of embankments and complementing the section on river engineering. The manual covers topics, including surveys, design, construction, project management, and planning from start to completion of river engineering projects.

Source: JICA Project Team summarized.

CHAPTER 2 CURRENT O&M OF THE BUNDS ALONG INDUS RIVER

2.1 Current Practice in Sindh-PID

Maintenance of bunds in Sindh is carried out before, during and after the flood period. The flood period in Sindh is defined as from May 1st to October 15th[1].

2.1.1 Basic Practice for O&M

(1) Patrol and Inspection

1) Pre-Flood Inspection

Basically, the pre-flood inspection is conducted to ensure that the bunds can withstand the water level during floods. The shape, quality and continuity of bunds are inspected to confirm the bunds are safe for High Flood Level (H.F.L).

Table 2.1.1 Outline of Pre-Flood Inspection

Items	Contents
Implementation Period	March to April
Implementation Agency	Local offices of PID
Implementer and Methods	Engineers of local offices carry out the inspection on foot or by vehicles.
Contents of Inspection	The main contents of inspection are as follow: 1. Heights of bunds: the comparison with the mile gauges and/or heights of bunds for upstream and downstream are carried out by 200m (= 1fur) intervals. 2. Deformation of bunds: the erosion, depressions and deformities etc. are checked. The drawings at the time of construction are also checked if they are available. 3. Leakage and seepage conditions of bunds: the leakage and seepage conditions of bunds are checked. 4. Tree conditions on bunds: Weakening of bunds due to tree roots during winds and rains and hollowing out due to decay are checked. 5. Animal habitat status of bunds: The holes and hollowing out by rats and moles are checked. 6. Vegetation conditions on the slope of bunds: Clumping plants with a short stature provide excellent protection against slope erosion. 7. Tree conditions on the bottom of bunds: The trees on the bottom of bunds both river side and land side affect the conditions of bunds. 8. Conditions of slope protection works (seawalls): The damage of the stone-clad revetment and stone loss etc. are checked.
Countermeasure	The repair and reinforcement work are carried out based on the inspection results.

Source: JICA Protect Team based on the manual

2) During-Flood Inspection

In the events of floods, the status of the bunds is continuously inspected and monitored.

Table 2.1.2 Outline of During-Flood Inspection

Items	Contents
Implementation Period	In the case of the water level is rising or is likely to rise near H.F.L.
Implementation Agency	Local offices of PID and Sindh-PID
Implementer and Methods	1. Initial response: the patrol is carried out by the engineers of local offices. 2. In the case of water level is rising near H.F.L: the executive engineer goes to the site and determines the urgency of the situation.
Contents of Inspection	The main contents of inspection are as follow: 1. Erosion, leakage and seepage conditions: Continuous inspection and monitoring are conducted for the area likely to occur the bund breaches. 2. Deformation of bunds: if any abnormalities are founded, the local offices receive the information and conduct countermeasures.

[1] It is called Abkalani in Sindhi.

Items	Contents
Countermeasure	1. In the case of the deformation progresses: the materials and equipment are prepared immediately, and emergency countermeasure works are carried out. 2. After the flood: the damage condition is inspected as shown in the next section.

Source: JICA Protect Team based on the manual

3) Post-Flood Inspection

After the flood, the damage condition is inspected.

Table 2.1.3 Outline of Post-Flood Inspection

Items	Contents
Implementation Period	Immediately after the flood.
Implementation Agency	Local offices of PID and Sindh-PID
Implementer and Methods	Post-flood inspection is jointly carried out by local offices of PID and Sindh-PID
Contents of Inspection	The main contents of inspection are as follow: 1. Erosion, leakage and seepage conditions: Detailed inspection is conducted f for the area which the bund breaches occurred or likely to occur. 2. Deformation of bunds: the erosion, depressions and deformities etc. are checked.
Countermeasure	1. Consideration of repair and reinforcement: the menu is decided based on the damage condition. 2. Implementation of construction: the implementation of construction is prioritized according to the importance and promptly carried out after the meeting of engineers has been held.

Source: JICA Protect Team based on the manual

(2) Inspection/Investigation Conducted by PID

The results of the inspection are to be prepared and submitted as described in the manual "Chapter XIII periodical Reports and Returns". Currently, the status of the preparation and storage of the reports are not confirmed.

2.1.2 Owned Equipment for Inspection/Investigation

In accordance with Sindh-PID, they have the conventional survey equipment such as total stations and level machines. However, equipment with an advanced technology for inspection/investigation of the bunds such as a drone with LiDAR, a single beam sonar or a ground penetrating radar is not owned by Sindh-PID.

As of March in 2024, they don't have any plan to procure or introduce such equipment. In fact, this equipment has been introduced and started to be utilized in Punjab-PID. Hence, expansion of the utilization also in Sindh-PID by sharing the knowledge and lesson learned from thee experience in Punjab-PID is preferable.

2.1.3 Other Activity Relating with Bund Management

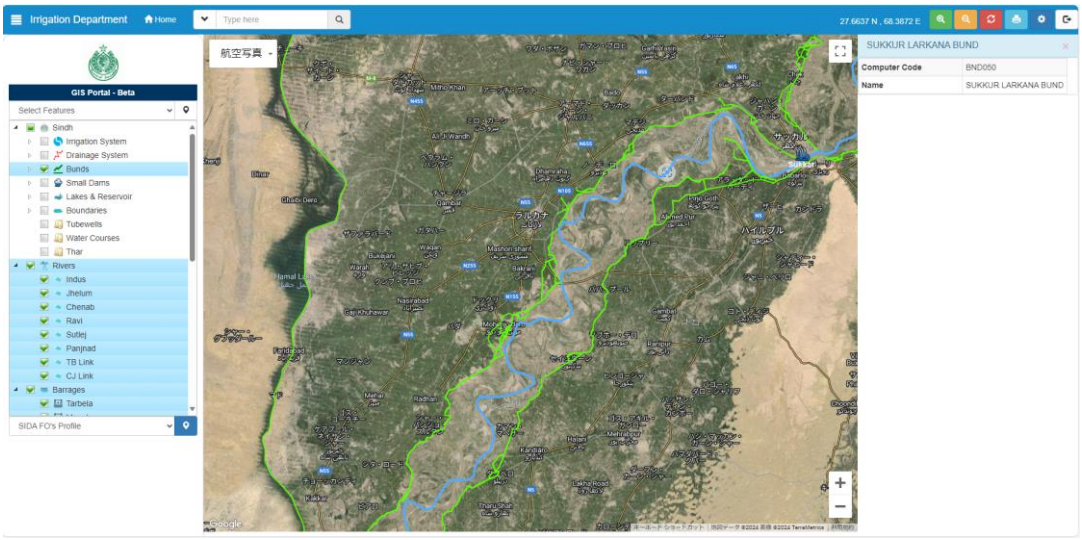
(1) GIS Database operated by SIDA

Sindh Irrigation and Drainage Authority(SIDA), a related organization of Sindh-PID, has a GIS Cell that conducts various analysis and evaluations using GIS. The GIS Cell is responsible for the operation and management of the "Irrigation GIS Portal[2]" that is publicly available on the Sindh-PID website. This system was originally developed with the main purpose of serving as a database for irrigation facilities, but it also includes information on bunds and rivers. Currently, only the alignments and names are registered for the bunds (refer to **Figure 2.1.1**).

Additionally, although not publicly available on the web, the GIS Cell also performs analysis on Flood Inundation Probability Mapping and Indus Morphology (refer to Figure 2.1.2). The main focus of SIDA is irrigation facilities, these flood-related analyses and considerations are seen as the next step. Furthermore, as part of future prospects, they are considering incorporating databases for both irrigation and agriculture, aiming to build a system that allows centralized management of data. As of March in 2024, the GIS Cell currently operates with only three GIS experts and operators, and both

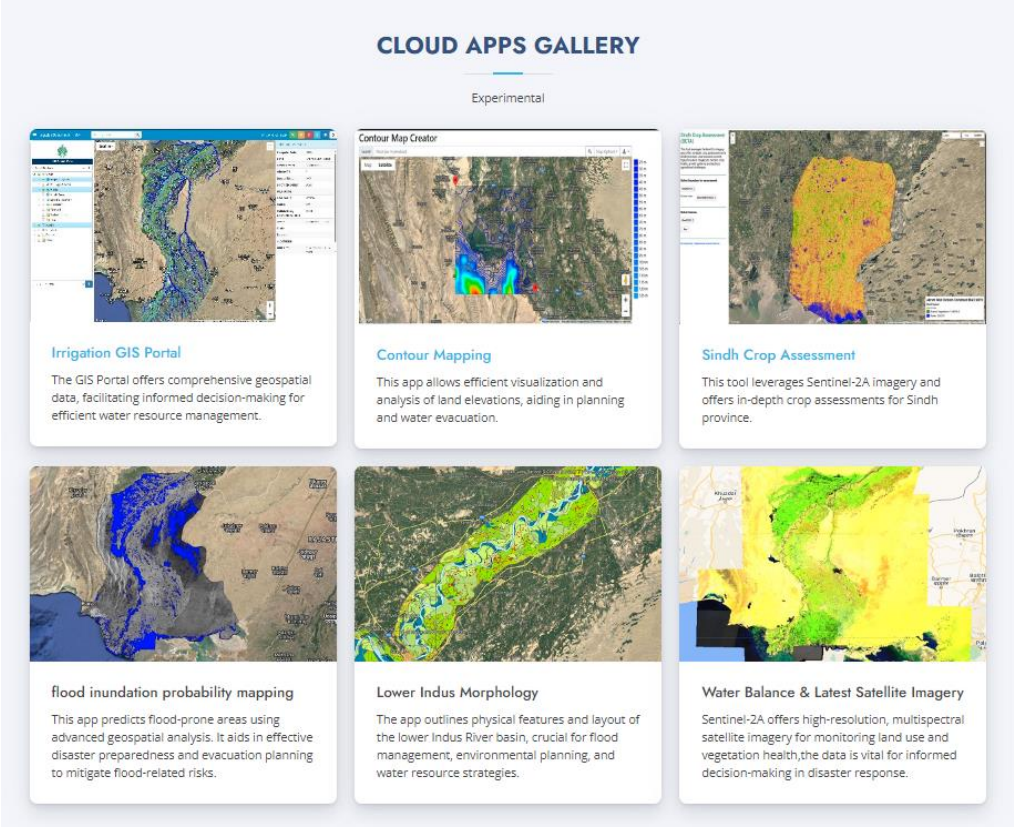
[2] https://irrigation.sindh.gov.pk/pub_gismaps.aspx

personnel and equipment is limited.



Source: Irrigation GIS Portal(https://irrigation.sindh.gov.pk/pub_gismaps.aspx)

Figure 2.1.1 Information Released on Irrigation GIS Portal



Source: Irrigation GIS Portal(https://irrigation.sindh.gov.pk/pub_gismaps.aspx)

Figure 2.1.2 Cloud Application on Irrigation GIS Portal(Only 3 in the Upper Line Are Opened)

(2) Decision Support System(DSS)

As part of Sindh Resilience Project (SRP) supported by the World Bank (WB), there is the Decision Support System (DSS) to assists Sindh-PID's decision-making in flood events. This DSS was developed by the Asian Institute of Technology (AIT) in August 2021 and the function shown in

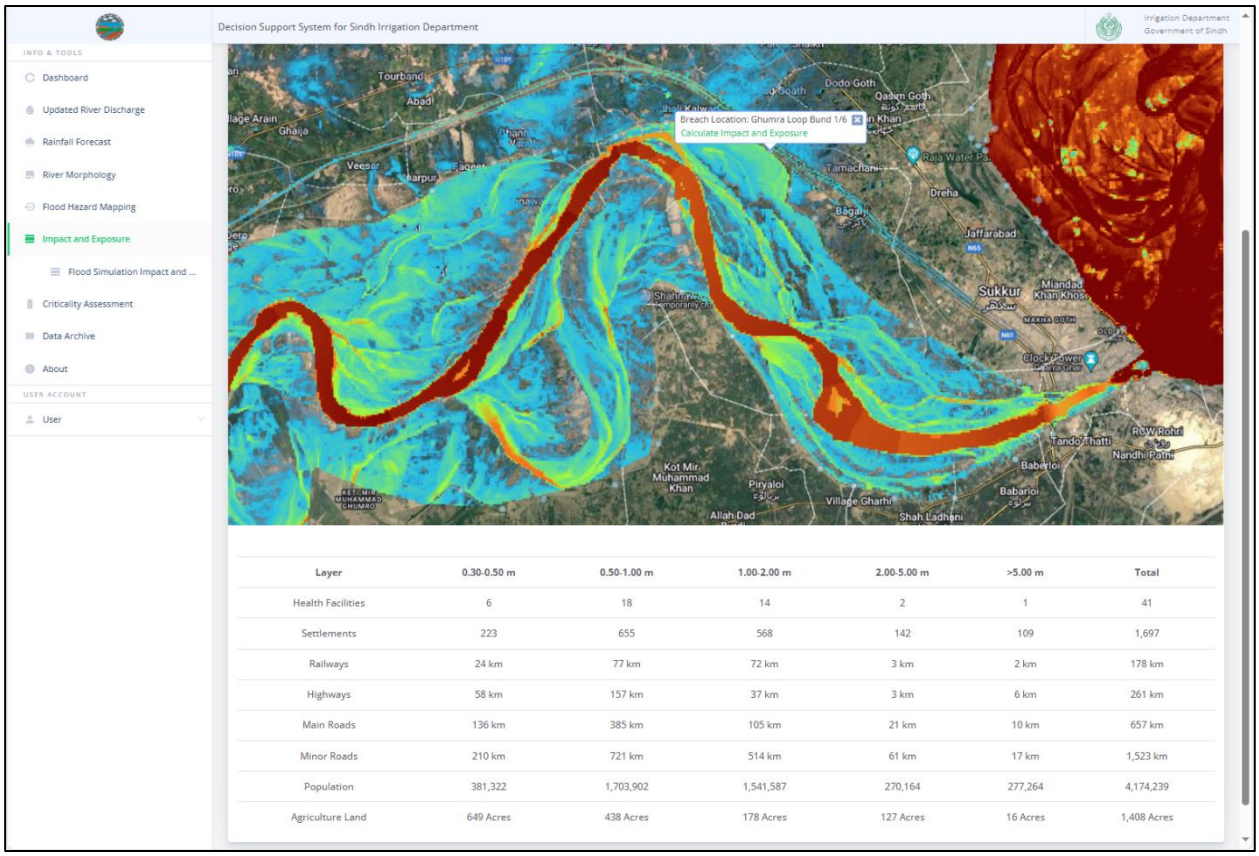
Table 2.1.4 is available on the internet.

Figure 2.1.3 and Figure 2.1.4 show the screenshots of the DSS. As it is shown in Figure 2.1.4, the distances along the bunds are also presented and it is easy and for the users to identify the locations along the bunds.

Table 2.1.4 List of the Functions of Decision Support System (DSS) of Sindh-PID

No	Info & Tools	Functions
1	Dashboard	✓ Showing the latest satellite image(MODIS Terra, MODIS Aqua) ✓ Showing the inflow and out flow of 5 barrages last 2 weeks
2	Updated River Discharge Data	✓ Showing the current flood situation based on the 6 stages, current inflow and outflow at the barrages along Indus River
3	Rainfall Forecast	✓ Showing global rainfall forecast in 1 hour interval from the a day to the day after 5 days ✓ Showing the accumulated global rainfall forecast based on 4 scenarios
4	River Morphology	✓ Showing River Morphology ✓ Showing Cross-sections
5	Flood Hazard Mapping	✓ Showing the predicted inundation map depending on 5 cases of the return periods at 14 breach points
6	Impact and Exposure	✓ With a breach at a certain point, showing the predicted inundation map with the assumed damages depending on the inundation depth
7	Criticality Assessment	✓ With a breach at a certain point, showing the predicted inundation map with the total assumed damages ✓ The total damages are converted to scores for the comparison with other breach points
8	Data Archive	✓ Showing the inflow and out flow at the 5 barrages from 2021 to the present

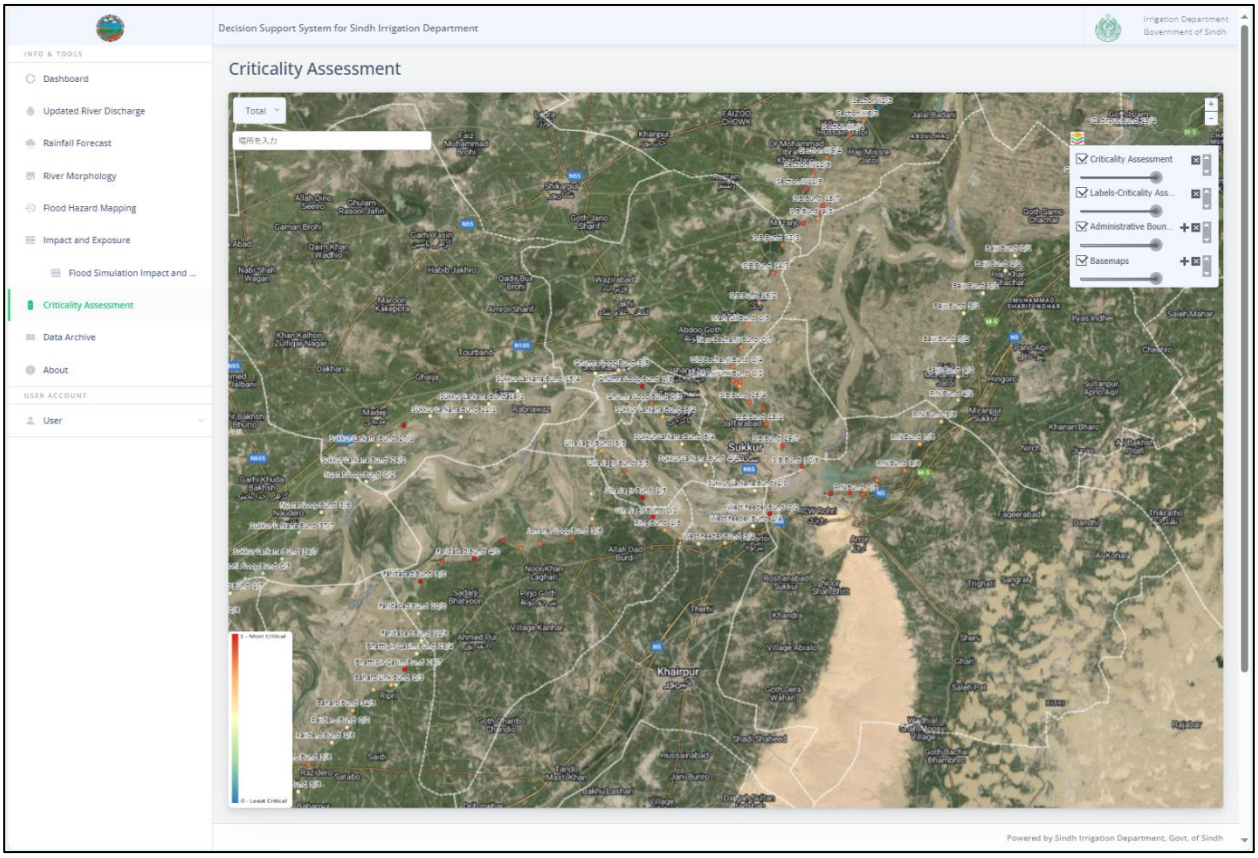
Source: JICA Project Team summarized from the website of DSS.



Layer	0.30-0.50 m	0.50-1.00 m	1.00-2.00 m	2.00-5.00 m	>5.00 m	Total
Health Facilities	6	18	14	2	1	41
Settlements	223	655	568	142	109	1,697
Railways	24 km	77 km	72 km	3 km	2 km	178 km
Highways	58 km	157 km	37 km	3 km	6 km	261 km
Main Roads	136 km	385 km	105 km	21 km	10 km	657 km
Minor Roads	210 km	721 km	514 km	61 km	17 km	1,523 km
Population	381,322	1,703,902	1,541,587	270,164	277,264	4,174,239
Agriculture Land	649 Acres	438 Acres	178 Acres	127 Acres	16 Acres	1,408 Acres

Source ：Decision Support System for Sindh Irrigation Department(https://srpsid-dss.gos.pk/Home/index)

Figure 2.1.3 Screenshot of Impact and Exposure in DSS



Source：Decision Support System for Sindh Irrigation Department(https://srpsid-dss.gos.pk/Home/index)

Figure 2.1.4 Screenshot of DSS Showing Distance along the Bunds

2.1.4 Current Practice during Bund Construction

(1) Current Status of Implementation

The manual stipulates the measures against seepage and erosion, quality of bunds, construction specifications, etc. However, the following points should be kept in mind during actual construction.

- It is difficult to obtain materials that maintain the quality according to the specifications.
- Construction accuracy may not be maintained because the quality of the material is not good.

In addition, the following points should be kept in mind regarding record management.

- Inadequate management and lack of organization of records such as inspection results.
- The report submission cannot be confirmed.
- The storage situation is not standardized.

Currently, the improvement of the countermeasures based on vulnerabilities and deterioration diagnosis is difficult because the history based on the accumulation of the record or the creation of ledgers is not confirmed.

(2) Relating Documents

Following relating documents should be submitted when the bund maintenance inspection is carried out or river construction is conducted. PC-1 as a plan document and PC-2 as an analysis document should be submitted at the planning and design stage. Additionally, PC-3 as a quality control and construction management report should be submitted once the construction begins. After the

construction is completed, PC-4 as a completion report should be submitted.

2.1.5 Summary

There are following challenges for the maintenance and management of the bunds in Sindh Province.

- Creation of a unified inspection sheet (can be operated with a mobile phone)
- The location of the inspection history is displayed on the map (can be operated with a mobile phone)
- Preparation and storage of relating documents based on the manuals.
- Establishment of a search and information storage system that allows related parties to easily obtain data.
- Sharing of local information in the event of a flood.

2.2 Current Practice in Punjab-PID

2.2.1 Basic Practice for O&M

The maintenance of the bunds in Punjab is described as a part of the irrigation manual. Basically, it is written with a focus on irrigation facilities. The maintenance and management of irrigation projects is carried out by formulating an annual work plan. The procedure and schedule for formulating the annual work plan are shown in Table 2.2.1. Repair and reinforcement of bunds are also expected to be the same. The executive engineer (XEN) prepares a work plan and submits it to the Circle Office. And it is finally submitted to Punjab-PID in July through the Zonal Office.

Table 2.2.1 The Procedure and Schedule for Formulating the Annual Work Plan

Date	Schedule
May 1st	Commencement of work plans preparation by executive engineers (XENs).
May 31st	Submission to the Circle Office.
June 22nd	Approval Divisional work plans by SEs. Submission of collated Circle work plans to Zonal Office.
July 7th	Approval of Circle work plans by CEs. Submission of collated Zonal work plans to PID.

Source: Manual of Irrigation Practice Vol.2 chapter10, Punjab

In addition, the schedule for the preparation of the Flood Fighting Plan, including the inspection of the bunds, is as follows.

Table 2.2.2 The Schedule for the Preparation of the Flood Fighting Plan

Date	Schedule
March 1st	Submission of Draft Plan
March 31st	Review of Chief Engineer Drainage and Flood
April 30th	Finalization and Distribution of Plan

Source: Manual of Irrigation Practice Vol.2 chapter2-17.1, Punjab

The schedule for the preparation of Inspection of Flood Protection Works, such as embankment reinforcement, is as follows.

Table 2.2.3 The Schedule for the Preparation of Inspection of Flood Protection Works

Date	Schedule
March 15th	Prepared by Executive Engineer
March 30th	Prepared by Superintending Engineer
April 15th	Prepared by Department and Army Team

Source: Manual of Irrigation Practice Vol.2 chapter2-17.2, Punjab

(1) Patrol and Inspection

1) Pre-Flood Inspection

The inspection of the bunds is conducted to ensure the safety before the flood season.

Table 2.2.4 Outline of Pre-Flood Inspection

Items	Contents
Implementation Period	March to April
Implementation Agency	Irrigation Watershed Office (Zonal Office)
Implementer and Methods	Engineers of zonal offices carry out the inspection on foot or by vehicles.
Contents of Inspection	The sample inspection sheets are shown in **Table 2.2.5**. The main contents of inspection are as follow: 1. Basic Shapes of bunds: the confirmation of the width, slope and height is conducted and the comparison with the mile gauges and/or heights of bunds for upstream and downstream are carried out. 2. Deformation of bunds: the erosion, depressions and deformities etc. are checked. The drawings at the time of construction are also checked if they are available. 3. Leakage and seepage conditions of bunds and land side: the leakage and seepage conditions of bunds and land side are checked. 4. Tree conditions on bunds: Weakening of bunds due to tree roots during winds and rains and hollowing out due to decay are checked. 5. Animal habitat status of bunds: The holes and hollowing out by rats and moles are checked. 6. Tree conditions on the bottom of bunds: The trees on the bottom of bunds both river side and land side affect the conditions of bunds. 7. Conditions of slope protection works (seawalls): The damage of the stone-clad revetment and stone loss etc. are checked.
Countermeasure	The repair and reinforcement work are carried out based on the inspection results.

Source: JICA Protect Team based on the manual

Table 2.2.5 Sample Inspection Sheets (1)

ANNEX-H
Sheet 1 of 3

SAMPLE CHECKLIST FOR BUND SITE INSPECTION

Name of the facility – (say) XYZ Bund

Incharge Division, Circle, Zones: (say) X-Division, Y-Circle & Z-Zone

Date of Inspection .....

Design data (i) Top width; (ii) Top RL; (iii) Side slope; (iv) HFL; (v) Free board etc.

Analysis Carried out .....

Comments on Analysis .....

Observations & Findings

Review on Design with respect to latest standards	
Phreatic line development	
Physical conditions (visual)	
Top width (compared with design)	
Top RL (compared with design)	
Side slopes (compared with design)	
HFL (compared with design)	
Free Board (compared with design)	
Patrol road and section maintenance	
Unauthorized traffic	
Slumping or settlement	
Body materials suitability determined through available data or investigations and grain size	

Source: Manual of Irrigation Practice Vol.1 chapter5, Annex-H, Punjab

Table 2.2.5 Sample Inspection Sheets(2)

analysis at various depths and locations.
Any visible/apparent runnels, caused by old tree roots
Rodent, holes, burrows and dens
Evidence of solutioning
Evidence of piping
Evidence of heavy seepage, springs and boils on the land side
Erosion by flow
Is the bund prone to wave action
Erosion by wave action
Evidence of greater permeability of foundation materials (say in creek crossings)
Rain cuts and ravines
General land subsidence
Damages to stone or other protections
Evidence of compressible or expansive (plastic) soils in foundation.
Evidence of Misuse
Accidents
Vandalism
Sabotage
Flood watching arrangements
Flood fighting arrangements
Gauges observation system

Source: Manual of Irrigation Practice Vol.1 chapter5, Annex-H, Punjab

Table 2.2.5 Sample Inspection Sheets(3)

Flood warning and information system	
Investigation carried out	
Analysis of observations and investigations	

Conclusions and Remarks .....

Recommendations .....

Signatures

Name & Designation	Incharge of the Bund inspected	Member Hydraulics	Member tech	Geo-	Team Leader

Date:

Source: Manual of Irrigation Practice Vol.1 chapter5, Annex-H, Punjab

2) During-Flood Inspection

In the events of floods, the status of the bunds is continuously inspected and monitored according to the interview to Punjab-PID. (There is no description of the correspondence to the floods in the manuals)

Table 2.2.6 Outline of During-Flood Inspection

Items	Contents
Implementation Period	In the case of the water level is rising or is likely to rise near H.F.L.
Implementation Agency	Irrigation Watershed Office (Zonal Office) and Punjab-PID
Implementer and Methods	1. Initial response: the patrol is carried out by the engineers of zonal offices. 2. In the case of water level is rising near H.F.L: the chief engineer determines the urgency of the situation.
Contents of Inspection	The main contents of inspection are as follow: 1. Erosion, leakage and seepage conditions: Continuous inspection and monitoring are conducted for the area likely to occur the bund breaches. 2. Deformation of bunds: if any abnormalities are founded, the zonal offices receive the information and conduct countermeasures.
Countermeasure	Emergency response: in the case of the deformation progresses, the materials and equipment are prepared immediately, and emergency countermeasure works are carried out.

Source: JICA Protect Team based on the manual

3) Post-Flood Inspection

After the flood, the damage condition is inspected.

Table 2.2.7 Outline of Post-Flood Inspection

Items	Contents
Implementation Period	Immediately after the flood.
Implementation Agency	Irrigation Watershed Office (Zonal Office) and Punjab-PID
Implementer and Methods	Post-flood inspection is jointly carried out by local offices of PID and Sindh-PID
Contents of Inspection	The main contents of inspection are as follow: 1. Erosion, leakage and seepage conditions: Detailed inspection is conducted f for the area which the bund breaches occurred or likely to occur. 2. Deformation of bunds: the erosion, depressions and deformities etc. are checked.
Countermeasure	Emergency response. 1. Consideration of repair and reinforcement: the menu is decided based on the damage condition. 2. Implementation of construction: the implementation of construction is prioritized according to the importance and promptly carried out after the meeting of engineers has been held. Preparation for the next flood season. 3. Preparation of flood damage report after the flood. 4. Identifying and prioritizing significant losses. 5. Preparation of proposal and estimation. 6. Implementation of priority construction before the next flood season.

Source: JICA Protect Team based on the manual

(2) Inspection/Investigation conducted by HSSEU

Following trial investigations are conducted by HSSEU. These investigations can be included as a practical use in the future by further analysis and enhancing their equipment and software. Equipment owned by HSSEU is shown in Table 2.2.8.

- Gathering the topography data of the riverbed by a single beam suspended on a drone.
- Analysis of the strata by using ground-penetrating radar.
- Topographic analysis by using drone images.

Table 2.2.8 Equipment owned by HSSEU

Equipment	Quantity	Note
GPR (NOGGIN 500)	1	Underground Radar
OJI M300 Drones for Survey & Mapping with LiDAR's and Eco Sounders	1	
LiDAR's and Eco Sounders	4	
Hydrographic Survey Boat	1	

Source: JICA Protect Team based on the interview to HSSEU

2.2.2 Owned Equipment for Inspection/Investigation

(1) List of the Equipment

The Hydraulic Structures Safety Evaluation Unit (HSSEU) of Punjab-PID has various equipment such as drones, single-beam depth sounders, and ground penetrating radar (GPR) for conducting actual embankment surveys. **Table 2.2.9** provides a list of the major survey equipment owned by HSSEU.

According to **Table 2.2.9**, HSSEU has equipment that allows relatively rough geophysical investigation and bathymetry survey of riverbeds. This equipment is also useful for observing riverbed scouring relating with riverbank erosion, infiltration and groundwater levels related to seepage in the bund body. Additionally, according to HSSEU engineer, it is possible to generate a 3D model from the survey results obtained by the single-beam depth sounder. However, it is also noted that the performance of the PC being used is insufficient, and a high-spec PC is needed for efficient processing and performing more advanced point cloud processing and model creation.

Table 2.2.9 Equipment for the Inspection/Investigation Owned by HSSEU

No	Name of Equipment	QTY	Remarks
1	GPR (NOGGIN 500)	4	Portable Ground Penetrating Radar（Photo 2.2.1）
2	DJI Mavic Pro 2	2	Drone for Photos and Movies（Photo 2.2.2）
3	DJI M300 Drones for Survey & Mapping with LiDAR's and Eco Sounders	3	Drone and Survey Equipment with LiDAR and Single beam（Photo 2.2.3）
4	Hydrographic Survey Boat	1	Radio Control Boat for Surveying the Riverbed（Photo 2.2.4）
5	Total Station	2	For Ground Survey
6	Auto Level	4	For Ground Survey
7	Handheld GPS	3	
8	Laser Distance Measurement Equipment	1	
9	Sieve Analysis Equipment	1	For Laboratory Test
10	Soil Consistency Equipment	1	
11	Standard & Modified Proctor Test Equipment	1	
12	Sand Replacement Method Equipment	2	

Source: HSSEU, Punjab-PID

Photo 2.2.1 Portable Ground Penetrating Radar

Photo 2.2.2 Drone for Photos and Movies

Photo 2.2.3 Drone and Survey Equipment with LiDAR and Single beam

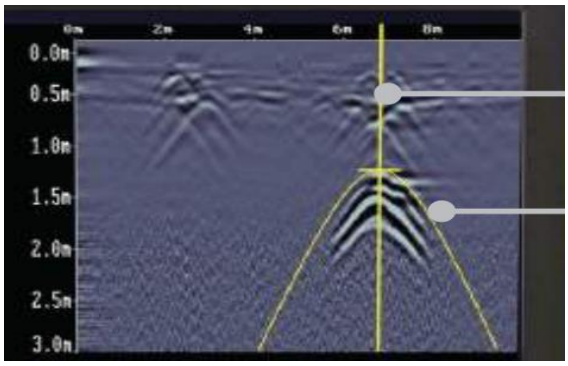
Photo 2.2.4 Radio Control Boat for Surveying the Riverbed

(2) Portable Ground Penetrating Radar

The ground penetrating radar is equipment which can detect areas with different physical properties which seem to be cavities and the boundaries where the soil conditions drastically change. Photo 2.2.5 shows a work with this equipment and Figure 2.2.1 shows a sample of the output.

Source: Brochure of Supplier

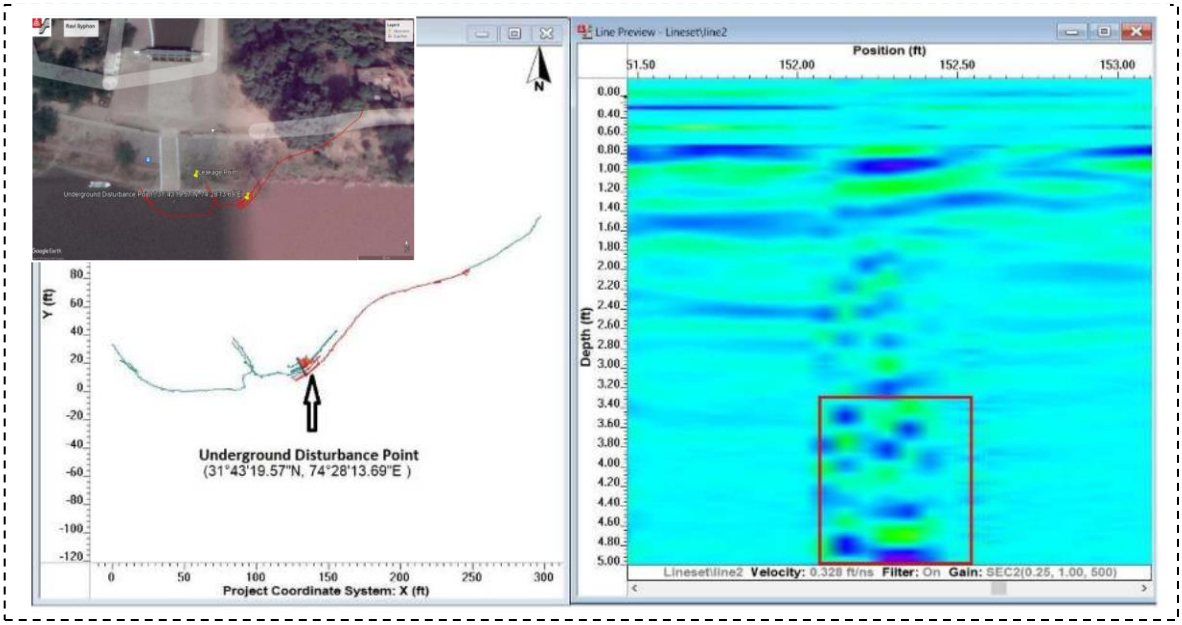
Photo 2.2.5 Work at Site with Portable Ground Penetrating Radar



Source: Brochure of Supplier

Figure 2.2.1 Sample of Output by Ground Penetrating Radar

With this equipment, disturbance in the ground due to water path generated by seepage seems to be detected. However, it is difficult to detect the boundary of soil type such as clay or sand. In Punjab-PID, HSSEU conducted the geophysical investigation with this equipment at Ravi Syphon. In accordance with their result, the disturbance of the foundation ground around the point where leakage occurs was observed (See Figure 2.2.2).



Source: Identification of Subsurface Flow Path by Ground Penetrating Radar(GPR), HSSEU, D&F Zone, Punjab-PID

Figure 2.2.2 GPR Line Scan Showing Disturbance

This equipment is effective to detect a hole and disturbance of the soil located the shallow depth in the foundation ground or bund body.

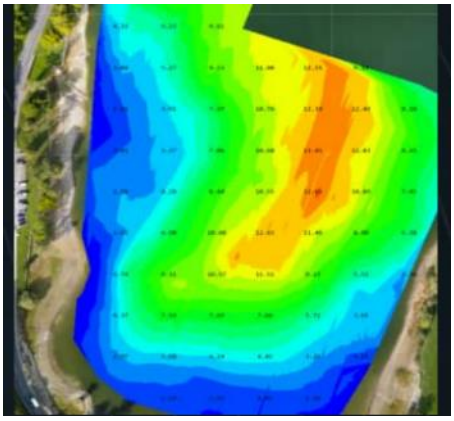
(3) Drone and Survey Equipment with LiDAR and Single Beam

With changing the attachment on a drone, this set of the equipment can survey the ground and riverbed elevation. For the ground elevation LiDAR is used, and Eco-sounder is for the bathymetry of the riverbed.

Photo 2.2.6 shows a work with the single beam sonar and Figure 2.2.5 shows a sample of bathymetry maps as the output. Also, HSSEU conducted drone survey with LiDAR and prepared the point clouds and 3D contour map as shown in Figure 2.2.4 and Figure 2.2.5.

Source: Supplier

Photo 2.2.6 Work at Site with Single Beam Sonar

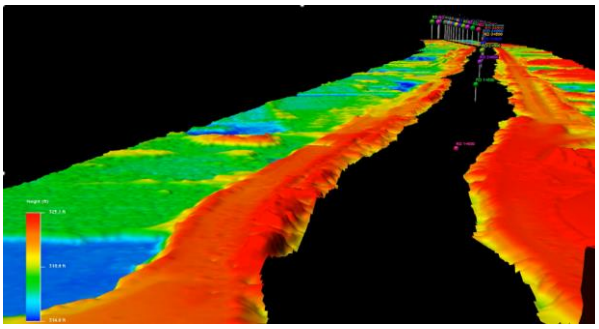


Source: Supplier

Figure 2.2.3 Sample of Output by Single Beam Sonar

Source: HSSEU

Figure 2.2.4 Point Clouds obtained by a Drone with LiDAR



Source: HSSEU

Figure 2.2.5 3D Contour Map generated from the Point Cloud

This set of the equipment is effective to monitor the scouring of the riverbed and the erosion of the riverbanks in front of the bunds. Also, the top elevation of the existing bund can be checked easily. Because it can be carried and operated easily, and the time for the site work is comparatively short. It is convenient to monitor the situation along the long distance of Indus River bunds periodically.

2.2.3 Other Activity Relating with Bund Management

(1) GIS Database Prepared by FRAU

The Flood Risk Assessment Unit(FRAU) is one of the project management unit in Punjab-PID. They are analyzing flood inundation area using numerical analysis result and satellite images. For their analysis, several GIS data have been acclimated and prepared. Currently, the data listed below which are relating with the bund management are owned by them.

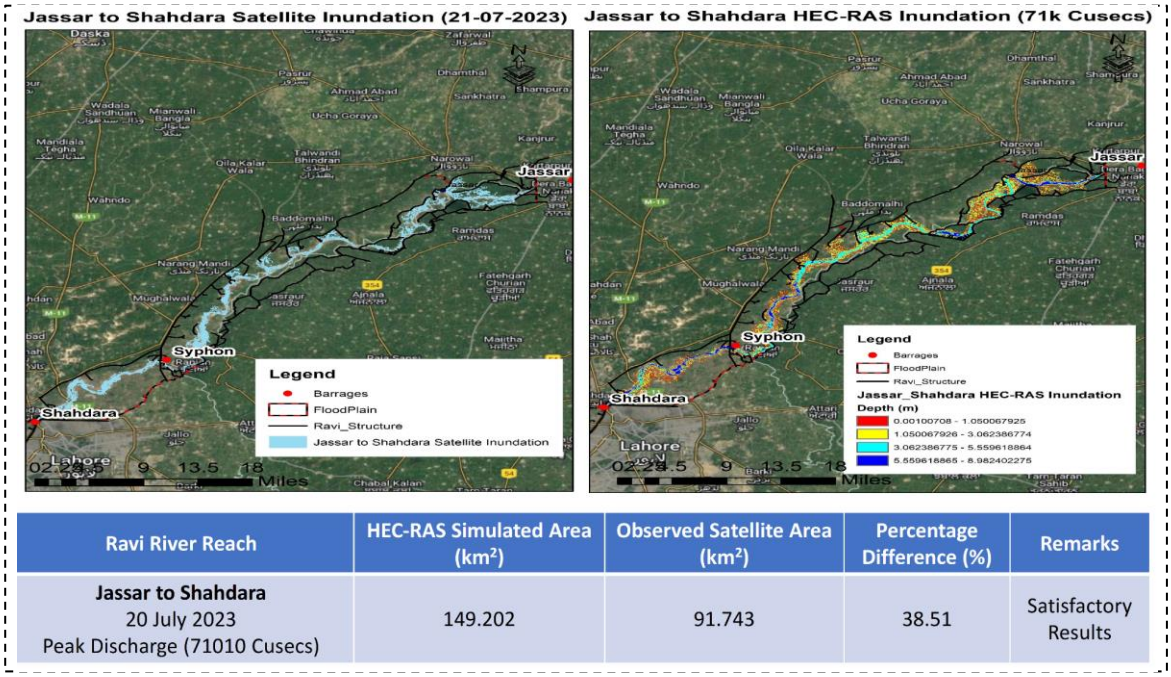
Table 2.2.10 GIS Data Owned by FRAU

No	Description of Data	Remarks
1	Alignment of the Bunds, Spurs and Studs Along Indus River with the bund names	Whole Punjab and Sindh Province
2	Actual Inundation Area during Major Flood after 2010 analyzed from satellite images	
3	Flood Inundation Map by Several Discharge Cases	Flood extent mainly to check the affected villages within the area between bunds in each side.

Source: JICA Protect Team summarized based on the information form FRAU.

(2) Flood Inundation Analysis by FRAU

FRAU has a team which in charge of hydrological modeling and hydraulic modeling. They are conducting flood inundation analysis and making model for the prediction of flood. Their analysis is currently focusing on the river area. For the further improvement to analyze the inundation in the land side, the following information needs to be incorporated into their model.



Ravi River Reach	HEC-RAS Simulated Area (km^2)	Observed Satellite Area (km^2)	Percentage Difference (%)	Remarks
Jassar to Shahdara 20 July 2023 Peak Discharge (71010 Cusecs)	149.202	91.743	38.51	Satisfactory Results

Source: HYDRODYNAMIC MODELING 2023, FRAU

Figure 2.2.6 Sample of the Inundation Analysis Results

1) Top Elevation of the Existing Bunds

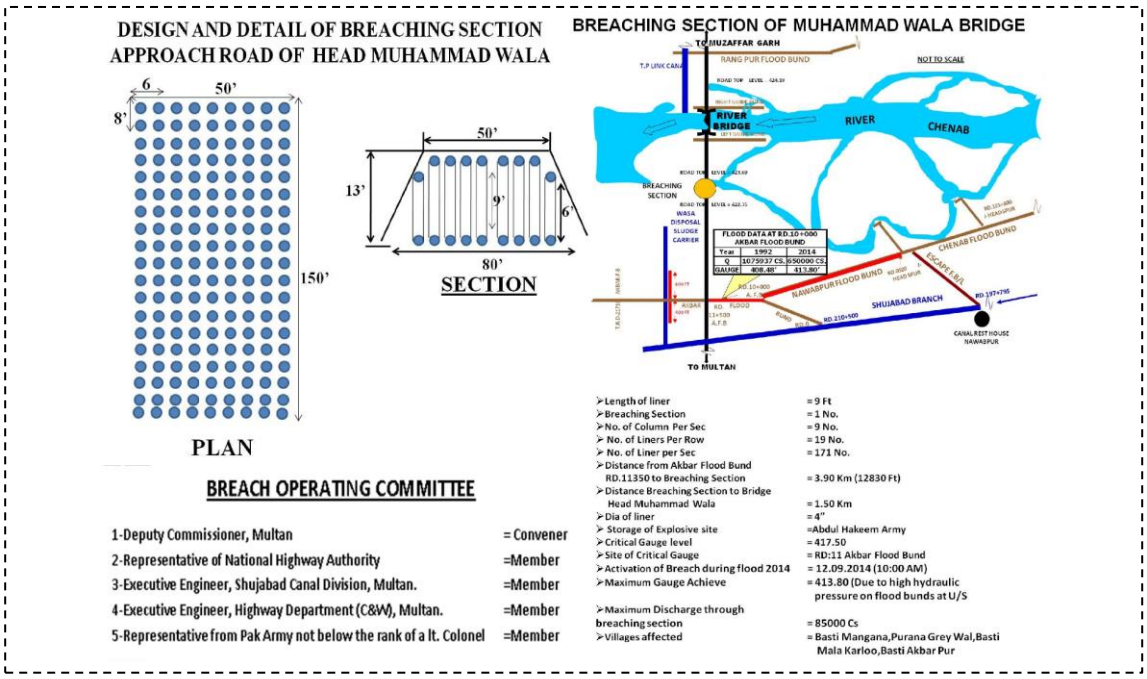
In the current model, the bund height is assumed about 4m from the ground elevation and the ground elevation is based on the digital elevation model(DEM) obtained from the open source. Vulnerability against overflow from the river is depending on the relation between HFL and the bund height considering the HFL with required freeboard. Hence, in order to check the vulnerable points against the overflow, reflecting the top elevation of the existing bunds is necessary.

In order to obtain the top elevation of the existing bund, the collaboration with HSSEU is recommended. HSSEU has the equipment and capacity to take the top elevation of the bund with drone survey and FRAU has the alignment off the existing bund with coordinates.

2) Assumption on the Bund Breach Points with Conditions

In Punjab Province, there are designated breach points and expected breach points for the emergency. In case of the designated breach point, the point and condition has been clearly determined. Figure 2.2.7 shows the sample of the summary information on the designated breach section. On the other hand, expected man-made breach points has only rough location and does not have the specific condition for the man-made breach. In addition, there are vulnerable points for natural breach due to the poor quality of the bund, the river course or the assets behand the bund.

In order to analyze the flood inundation area in the land side, this information is recommended to be considered.

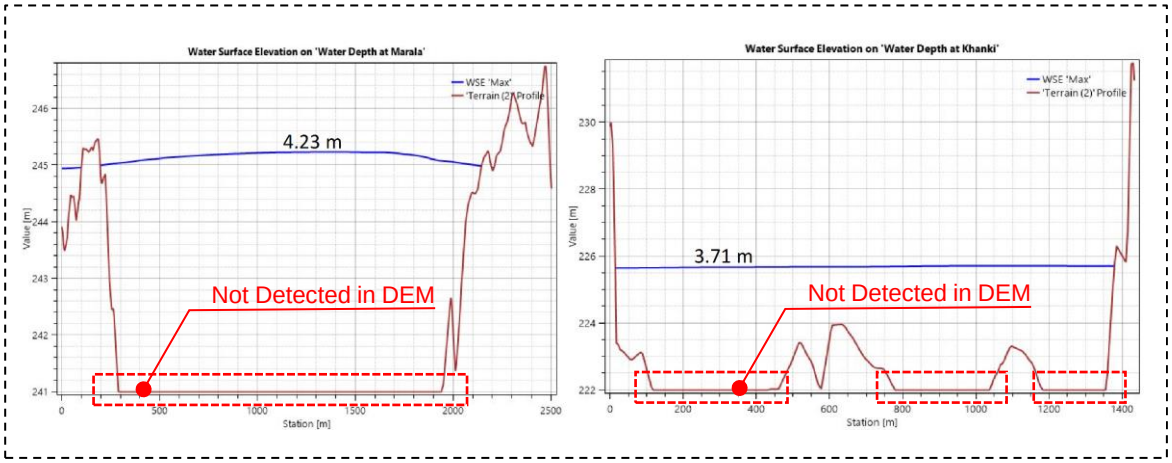


Source: PRE-FLOOD BRIEF ON FLOOD PROTECTION FLOOD BUNDS & BREACHING SECTIONS, Punjab-PID

Figure 2.2.7 Sample of the Summary of Designated Breach Point

3) Riverbed Elevation

In their current analysis, the ground is assumed based on DEM data only, Hence, the riverbed is not properly described(See Figure 2.2.8). Considering the flow area during floods, the influence of it may be not significant. However, when the river width is narrow, it will give an adverse effect on the hydraulic analysis. Therefore, it is recommended that riverbed be surveyed and be reflected on their model.



Source: JICA Project Team added on HYDRODYNAMIC MODELING 2023, FRAU.

Figure 2.2.8 Sample of the Sections in the Chenab Model

2.2.4 Current Practice during Bund Construction

(1) Current Status of Implementation

As the same in Sindh Province, the manual has been revised as the flood conditions change. The manual stipulates the measures against seepage and erosion, quality of bunds, construction specifications, etc. However, the following points should be kept in mind during actual construction.

- It is difficult to obtain materials that maintain the quality according to the specifications.

- Construction accuracy may not be maintained because the quality of the material is not good.

In addition, the following points should be kept in mind regarding record management.

- The records of test results are stored on personal PCs and not shared.
- Insufficient confirmation of the submission of the report.
- The storage situation is not standardized.

Currently, the improvement of the countermeasures based on vulnerabilities and deterioration diagnosis is difficult because the history based on the accumulation of the record or the creation of ledgers is not confirmed.

(2) Relating Documents

As the same in Sindh Province, following relating documents should be submitted when the bund maintenance inspection is carried out or river construction is conducted. PC-1 as a plan document and PC-2 as an analysis document should be submitted at the planning and design stage. Additionally, PC-3 as a quality control and construction management report should be submitted once the construction begins. After the construction is completed, PC-4 as a completion report should be submitted.

2.2.5 Summary

There are following challenges for the maintenance and management of the bunds in Punjab Province.

- Creation of a unified inspection sheet (can be operated with a mobile phone)
- The location of the inspection history is displayed on the map (can be operated with a mobile phone)
- Sharing and storage of relating documents.
- Easy way of search and information acquisition for the related persons.
- Sharing of local information in the event of a flood.

CHAPTER 3 COMPARISON ANALYSIS OF DESIGN MANUAL OF BUND

3.1 General Information on the Collected Design Manuals

3.1.1 Sindh Province

The first edition of the Bund Manual was published in 1936 to improve the capacity of staff and to guide them. Subsequently, the revised editions were published in 1954 and 1978. In the edition of 1978, the changes were made to the design standards and specifications of the bunds to accommodate high water levels. Currently, the edition of 2008 is the latest version, which refers to scientific, efficient and modernized flood management plans in the United States and other countries. The edition of 2008 was approved at the meeting of the Indus River Commission. Table of contents is shown in **Table 3.1.1**. The structure of the bunds is mainly described in Chapter 5, and the maintenance is mainly described in Chapter 9 and 10.

Table 3.1.1 Table of Contents of the Bund Manual in Sindh Province

Chapter	Title
Chapter I	Glossary of terms used in connection with River Bunds in Sindh.
Chapter II	Constitution and Functions of the Indus River Commission.
Chapter III	Classification of expenditure on Bund Works and powers of Officers Subordinate to Government to accord Administrative.
Chapter IV	Proposal for new Bunds, Loops and Bund Sluices.
Chapter V	Design of new Bunds and Loop Bunds.
Chapter VI	Construction of new Bunds or Loops.
Chapter VII	Design and construction of Sand Cores and Diaphragm Walls.
Chapter VIII	Design and construction of Bund Sluices.
Chapter IX	Article Pre-Abkalani Maintenance.
Chapter X	Ordinary Maintenance during Abkalani.
Chapter XI	Emergent Measures or Causes of Failures of Bunds and Methods used to Combat Them.
Chapter XII	Breaches in River Bunds and how to Close them.
Chapter XIII	Periodical Reports and Returns.
Chapter XIV	Flood Management Practices on Mississippi River USA.
Chapter XV	Design of Stone Spurs or Stone Apron and Stone Pitching on Front Bunds as Protection against erosion.

Source: The Bund Manual in Sindh Province

3.1.2 Punjab Province

The bund manuals in Punjab Province are divided into 2 manuals: "Manual of Irrigation Practice volume 1" and "Manual of Irrigation Practice volume 2". The first edition was published in 1943 for the guidance of irrigation engineers at the Punjab Public Works Department. Subsequently, the first edition was reprinted in 1963 but not revised. The Punjab-PID consulted with the World Bank in 2015, and the revised edition was published in 2017. The edition of 2017 was approved at a meeting of the Indus River Commission. Table of contents is shown in **Table 3.1.2**. The structure of the bunds is mainly described in Chapter 5.16 & 5.20 of volume 1 and Chapter 2 of volume 2, and the maintenance is mainly described in Chapter 9 and 10 of volume 2.

Table 3.1.2(1) Table of Contents of the Manual of Irrigation Practice in Punjab Province

Title of Chapter	Author
Chapter 1: Definitions	Syed Mahmood-ul-Hassan
Chapter 2: History of Irrigation Development in Punjab	Mian Asrar-ul-Haq
Chapter 3: Punjab's Irrigation Infrastructure	Muhammad Ehsan
Chapter 4: Administrative Setup of Punjab Irrigation Department	Mian Asrar-ul-Haq
Chapter 5: Barrages	Syed Mansoob AH Zaidi
Chapter 6: Design of Unlined Canals	Dr. Bagh Ali Shahid
Chapter 7: Design of Lined Canals	Dr. Bagh Ali Shahid
Chapter 8: Maintenance of Canals	Syed Mahmood-ul-Hassan
Chapter 9: Outlets	Ghulam Hussain Qadri
Chapter 10: Computerized Monitoring System for Canal Operation	Habib Ullah Bodla

Source: The Manual of Irrigation Practice in Punjab Province

Table 3.1.2(2) Table of Contents of the Manual of Irrigation Practice in Punjab Province

Title of Chapter	Author
Chapter 1: Small Dams	Engr. Malik Ahmad Khan
Chapter 2: River Training & Flood Management	Syed Mansoob AH Zaidi, Ch. Muhammad Azam
Chapter 3: Hill Torrents Management	Sajjad Hussain Nasim
Chapter 4: Groundwater – Optimal Use & Management	Muhammad Shamshad Gohar
Chapter 5: Drainage & Salinity Control	Ahmad Khan Bhatti
Chapter 6: Mechanical, Electrical Works & SCADA	Qazi Anwar AH,, Shafiq AH, Sohaib Raziq Khan Khitran
Chapter 7: Hydraulic Modelling	Muhammad Aslam Raseed Muhammad Uzair
Chapter 8: Asset Management Plan	Muhammad Ehsan
Chapter 9: Preparation of Annual O&M Budget	Muhammad Ehsan
Chapter 10: Preparing Annual M&R Work Plans and their Implementation	Muhammad Ehsan
Chapter 11: Project Management	Muhammad Ehsan

Source: The Manual of Irrigation Practice in Punjab Province

3.1.3 NFPP-IV

The Federal Flood Commission (FFC) developed the National Flood Protection Plan (NFPP) I, II, and III in 1978, 1988, and 1998 to deal with the floods. Subsequently, the review of NFPP started in June 2013 considering the extensive flood damage caused by the 2010 flood. The draft report for tasks A, B and C were submitted in January 2015 and the draft report for task D was submitted in February 2015. A detailed discussion with WCAP, FFC, PID, PMD, WAPDA, NDMA and other stakeholders was conducted and agreed on the contents of NFPP-IV shown in the following series of reports:

- Task A: Development of National Flood Protection Plan-IV (NFPP-IV) and PC-1
- Task B: Development of Inventory of Flood Works, Benefit Monitoring and Evaluation of Flood Protection Works
- Task C: Floodplain Mapping and Zoning
- Task D: Automation of Flood Situation Monitoring and Reporting

In this series of documents for Task A, design criteria were also included in “Annex 3 Design Criteria(hereinafter so called The Design Criteria of NFPP-IV)”.

In this annex, a review of existing design criteria and reports for flood protection structures in Pakistan and proposes new criteria and recommendations for designing and evaluating new and existing structures are induced.

In the design criteria, there are descriptions that the design and construction of flood bunds, bunds, spurs, studs, and flood retaining walls, which are used to reduce flood damages and human sufferings along major rivers and hill torrents. Also, the criteria mention the need for updating the existing criteria and procedures to ensure better performance of flood protection works, especially after the extreme flood events of 2010 and 2014. The criteria also emphasize the use of computer aided engineering software and physical model studies for hydraulic gradient, stability, and scour analysis.

About the bunds, the design criteria are proposing the deign based on hydrological, geotechnical, and structural considerations and specifies the methods and parameters for estimating freeboard, top width, side slopes, base width, hydraulic gradient, wetting channels, sand cores, clay cover, and slope protection.

Table 3.1.3 shows the table of contents of the Design Criteria of NFPP-IV.

Table 3.1.3 Table of Contents of the Design Criteria of NFPP-IV

Section/ Sub-Section	Title
1.	General
2.	Scope
3.	Review of Existing Design Criteria and Reports
3.1	National Flood Protection Plan 1978 (NFPP-I)
3.2	National Flood Protection Plan 1988 (NFPP-II)
3.3	Bund Manual, Sindh (2008)
3.4	Manual of Irrigation Practice, Punjab
3.5	Flood Protection Sector Project - I (1989)
3.6	Flood Protection Sector Project - II (2001)
4.	Need for New Design Criteria
5.	Design Criteria for Flood Bunds/Embankments and River Training Works
5.1	Hydrological Design Criteria
5.2	Flood Bunds and Embankments
5.3	Spurs/Groynes
5.4	Scour Protection
5.5	Stone Pitching
5.6	Geotechnical Explorations and Design
5.7	Model Studies
5.8	Construction Material
5.9	Construction Practices and Procedures
6.	Flood Retaining Walls
6.1	General
6.2	Factors for Selecting Flood Retaining Wall or Embankment
6.3	General Failure Modes of Flood Retaining Walls
6.4	Freeboard Estimation and Wall Top Level
6.5	Geotechnical Design Criteria
6.6	Structural Design Criteria
6.7	Construction Methodology
6.8	Evaluation of Existing Flood Retaining Structures
7.	Evaluation of Existing Flood Protection and River Training Structures
7.1	Hydraulic Evaluation Criteria
7.2	Geotechnical Evaluation
7.3	Field Inspections
7.4	Field Observation and Monitoring

Source: The Design Criteria of NFPP-IV

3.1.4 Standards and Criteria in Japan

The Bund Manuals in Sindh and Punjab Province were reviewed based on the comparison with standards, laws and regulations in Japan. The main standards, laws and regulations in Japan were shown in Table 3.1.4.

Table 3.1.4 Main Standards, Laws and Regulations in Japan

Name of Technical Standards/laws	Publisher	Publication Year	Summary
River Act	Japanese Government	Revised in 2022	This act is the legal framework governing the management and protection of rivers in the country. It covers aspects such as flood control, water quality management, revetment, and water resource utilization.
River Act Enforcement Order	Japanese Government	Revised in 2022	This order is a legal framework that regulates the implementation of the River Act, which governs the management and protection of rivers in the country. The Ordinance outlines steps to ensure compliance with the provisions of the Rivers Act, including regulations regarding river management, flood control, water quality management and environmental protection.

Name of Technical Standards/laws	Publisher	Publication Year	Summary
River Management Facilities Structure Ordinance	Japanese Government	Revised in 2013	This ordinance outlines regulations and guidelines for the construction, maintenance, and operation of structures related to river management. This includes dams, bunds, and other facilities designed to control floods, regulate water flow, and protect against erosion. The ordinance aims to ensure the effectiveness and safety of these structures while minimizing environmental impacts and promoting sustainable river management practices.
River Erosion Control Technical Standards Design Edition I	Ministry of Land, Infrastructure, Transport and Tourism	Revised in 2019	This standard provides guidelines and specifications for designing erosion control measures along rivers. This includes standards for various erosion control structures such as sea walls, bunds, and river revetments.
River Erosion Control Technical Standards Maintenance for River Edition	Ministry of Land, Infrastructure, Transport and Tourism	Revised in 2011	This standard establishes guidelines for maintaining and managing erosion control measures in rivers. This includes aspects such as regular inspections, maintenance procedures, and management protocols to ensure the continued effectiveness and safety of erosion control structures.
Bund Excess Standard	Ministry of Land, Infrastructure, Transport and Tourism (formerly Ministry of Construction)	1969 Notification	This standard specifies the standard height of extra bund considering the settlement and compression depending on the type of earth material.
Seismic Performance Verification Guidelines for River Structures	Ministry of Land, Infrastructure, Transport and Tourism	Revised in 2020	This guideline specifies the methods, items, setting of external force and required function of river structure facilities after the earthquake. It considers Level 1 and Level 2 seismic conditions.
Seismic Performance Verification Guidelines and Explanations for River Structures II Bund Edition	Ministry of Land, Infrastructure, Transport and Tourism	Revised in 2016	This guideline explains seismic performance verification guidelines for bunds and river structures.
Inspection and Evaluation Guidelines for River Management Facilities and River Channels	Ministry of Land, Infrastructure, Transport and Tourism	Revised in 2023	This guideline establishes provisions for the inspection and evaluation procedures of bunds, as well as other river management facilities and channels. It covers the purpose and scope of inspection, procedures and frequency, methods and techniques, evaluation and reporting of inspection results.
Guidance for Considering the Structure of River Bunds	National Land Technology Research Center	Revised in 2012	This guidance consists of inspection & investigation, safety analysis and reinforcement of the river bunds especially against seepage, erosion and earthquake. In addition, inspection and reinforcement of the bunds adjacent to the structure installed in the bunds.
River Earthwork Manual	National Land Technology Research Center	Revised in 2009	This manual is a supplement to the "Technical Criteria for River Works: Practical Guide ", focusing on the design theory of bunds and complementing the section on river engineering. The manual covers topics, including surveys, design, construction, project management, and planning from start to completion of river engineering projects.

Source: JICA Project Team

3.2 Extraction of Item to be Analyzed

3.2.1 Major Issue on Current Bund Management

Prior to the analysis in this report, there are some major issues which have been already recognized. Based on these major issues, the relating items in the technical manuals of bunds to be analyzed are selected as shown in Table 3.2.1.

Table 3.2.1 Major Issues and Relating Items to Be Analyzed

Major Issue	Item to be Analyzed
✓ There are a lot of damage caused by seepage flow and erosion.	➢ Methods of Patrol and Inspection ➢ Methods of Safety Verification Analysis ➢ Countermeasures and the design methods of them
✓ Due to the long stretch and lack of labors and budget, it is necessary to improve the efficiency of maintenance and management activities.	➢ Maintenance & Management plan and its Concept ➢ Organization of Data on Rivers and Bunds ➢ Accessibility to the Site
✓ It is necessary to take into account the conditions of river channels, etc. for the planning and designing the countermeasures against erosion.	➢ Design Methods of Revetments and Spurs ➢ Survey & Inspection for Setting the Design Condition
✓ Improvement of quality control (improvement of insufficient quality, construction defects)	➢ Regulation on Construction Supervision
✓ Promotion of Information Sharing on Inspection Reports and Records on Bunds	➢ Methods of Sharing and Storing the Reports and Record

Source: JICA Project Team

3.2.2 Extraction of Item

Considering the current major issues and items listed in Table 3.2.1, the items are specifically broken down to the followings. These are analyzed and be compared in this report.

- ✓ Definition of a Bund
- ✓ Standard Shape of a Bund
- ✓ Quality Control
- ✓ Service Road/ Maintenance Road
- ✓ Safety Evaluation
- ✓ Improvement of a Bund
- ✓ Revetment
- ✓ Spur(Stone Groyne)
- ✓ Construction Works
- ✓ Management Plan
- ✓ Monitoring of River Conditions
- ✓ Inspection and Ledger
- ✓ River Ledger
- ✓ Bund Breach

3.3 Analysis on the Manual in Sindh

3.3.1 Analysis on the Manual(Bund Manual)

Bund Manual includes information on the basic shape, design, construction, surveys and repairs during a single year, and response to breaches of the bunds. Overall, it mainly provides an overview of the basic principles and matters to be considered. However, there is little specific information on design criteria, design methods, and construction management standards. The followings are summary of the contents for each item.

(1) Definition of a Bund

The definition a bund is described as follows in the manual.

- ✓ *An earthen embankment parallel to the riverbanks*
- ✓ *To protect the country from inundation by the river spill, during floods*

Source: JICA Project Team quoted from the Bund Manual in Sindh

Based on this definition, it seems that the soil material is basically used as a bund material and the river wall made of concrete is not taken as a bund.

(2) Standard Shape of a Bund

About the basic shape of a bund, freeboard, crest width and side slope etc. are specified in detail. **Table 3.3.1** summarizes the basic shape of a bund specified in Bund Manual.

Table 3.3.1 Summary of Basic Shape of a Bund Specified in Bund Manual

Item	Type	Description	Verification/ Remarks
Crest Width	Main Bund	20 ft(=6.1m)	
	Trench Bund	10 ft (=3.05m)	
Side Slope (River Side)	Bund(8 feet and less)	3:1	
	Medium Bund (Upto and including 12 feet.)	3:1(8ft to 12ft in Height) to 4:1(12ft to 13ft in Height)	
	High Bund (Exceeding 12 feet)	3:1(12ft to 13ft in Height) to 4:1(Over 13ft in Height)	
Side Slope (Land Side)	Bund	3:1 without Berm	
	Medium Bund	3:1 without Berm	
	High Bund	2:1(Top to Back Berm), 6:1(Berm to Ground)	
Berm	River Side	-	
	Land Side	5 ft(=1.53m)	8 to 9 ft below from the top depending on the front slope
Freeboard	Main Bund	4 ft(=1.22m)	To allowing for a fair factor of safety for sudden unforeseen rise of water level such as wave, shortening of rive course.
	Trench Bund	2 ft(=0.61m)	
Extra Embankment	Normal	12 1/2 % of Deign Height	In order to allow settlement and compaction
	With Scrapers/Foot Roller	6 1/4 % of Deign Height	

Source: JICA Project Team summarized from Bund Manual.

(3) Quality Control

1) Material

In the manual, the desirable material is described as below.

- ✓ *The bund is built, as a rule, of earth obtainable along the line of the bund or from the borrowpits on the river side immediately in front of the bund.*
- ✓ *Sand mixed with a fair proportion (30 to 40%) of clay is desirable.(The sand in the clay will prevent shrinkage and cracks without destroying the watertightness an toughness of the clay.)*

Source: JICA Project Team quoted from the Bund Manual in Sindh

In accordance with the manual, the importance of the fine particle contents is recognized. On the other hand, it is stated that the embankment material needs to be obtained from the river side immediately in front of the bund.

However, it must be difficult to obtain such a desirable material along Indus River in Sindh Province. In most of the cases, the material which can obtained along Indus River is fine sand. Also, in the manual, available materials based on the past cases are introduced (See **Table 3.3.2**).

Table 3.3.2 Summary of Basic Shape of a Bund Specified in Bund Manual

Item	Description	Verification/ Remarks
Sand with 6 inches thickness clay cover	85% of Sand, 10% of Silt, and 5% of Clay.	Without Clay Cover, due to the flat saturation, large Section is Required.
Sand Mixed with Clay	50-70% of Sand, 30-50 of clay	Optimum admixture
Loam with 6 Inches Thickness Clay Cover	30-50% of Sand, 30-50% of silt, and Less than 20% of Clay.	Little stability when saturated.
Clay with Sand Core	5% of Sand, 40% of Silt, and 55% of Clay.	Bunds should not be constructed of such soils unless absolutely unavoidable

Source: JICA Project Team summarized from Bund Manual.

2) Construction Method

In the manual, the basic procedure for bund embankment is stated. The main contents are extracted as below.

- ✓ *All earth laid in the embankment shall be free from all roots, grass, sticks or other foreign matter.*
- ✓ *The earth shall be deposited and spread in horizontal layers, 6 inches thick, for the full width of the bank.*
- ✓ *All clods, and lumps of earth shall be broken up in the borrow pits to a diameter of not more than 2 inches.*
- ✓ *To facilitate rolling, the bank shall be carried up in uniform layers of not more than 6 inches in thickness*
- ✓ *No fresh layer shall be put on until the previous one has been thoroughly consolidated to the satisfaction of the Executive Engineer or subordinate.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

The manual is describing the importance of embankment with uniformed material without contamination of foreign mattes. When the material is containing organic matters such as roots, grass etc, settlement due to the decomposition is concerned. Furthermore, the low uniformity of the material may bring the concentration of the comparatively weak point and not preferable. Hence, this recognition is important for the bund embankment which is continuous longitudinal structure.

Considering that the thickness of one layer is specified as 6 inches(=about 15.2cm) and the acceptance by Executive Engineer is necessary to proceed to the next layer, the requirement is strict enough.

On the other hand, equipment to be used for the embankment work is not mentioned clearly in this manual, and the description for it is necessary.

3) Degree of Compaction

Due to no description of the degree of compaction(Required value, what to do in case it cannot be satisfied), it is necessary to be added.

(4) Service Road/ Maintenance Road

About the service road/maintenance road, it is not clearly mentioned However, the following instruction is stated.

- ✓ *Public traffic is not permissible on bunds and, therefore, cross fencing is necessary at road crossing and longitudinal and cross fencings near villages.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

According to the abovementioned contents, the road on the top of the bunds is exclusively used for

the PIDs or concerned public agencies.

In fact, it is used by private motorcycles at a lot of locations and there are a lot of sites without cross fencing at road crossing. However, ordinary private vehicles are seldom traveling or parking on the top of the bunds. Hence, no major issue has occurred in practice.

Considering the current conditions of the top of the bunds in which the JICA Project Teams visited, it is recommended to add a description about pavement on the top of bunds to improve access for the sooth access by the maintenance vielles.

Also, It seems necessary to add the standard pavement composition (minimum sample assuming maintenance vehicle traffic) as samples.

(5) Safety Evaluation

1) Slope Stability(Slip Circle)

In the manual, concrete methods and factor of safety on the slope stability analysis are not described and the following is mentioned.

✓ *The cross-section is fixed from experience, on consideration of stability under all conditions.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

There is no mention that the bund shape is determined based on stability analysis using numerical analyzes such as slip circle and seepage flow analysis, but only that the bund shape is determined based on experience, taking into account the effects of seepage, etc.

Seepage flow analysis is thought to be effective in examining vulnerability, because it is expected that the bund body material varies.

2) Erosion

In the manual, the distance where the erosion ordinates which are deemed essential and the distance apart that should be kept between the two consecutive ordinates are introduced as shown in **Table 3.3.3**.

Table 3.3.3 Essential Erosion Ordinates and Distance between Two Consecutive Ordinates

	Where distance between Bund and pucca edge is	Distance between two consecutive ordinates
Above Sukkur	2 to 3 miles 1 to 2 miles Less than a mile	1 mile apart Half a mile part One furlong apart
Below Sukkur	2 to 3 miles 1 to 2 miles Less than a mile	No ordinates Half a mile apart One furlong apart

Source: Bund Manual, Chapter IV, Page 3 of 15

According to **Table 3.3.3**, the development of the bank erosion is being monitored by checking the distance from the riverbank to the bund.

Furthermore, the manual is instructing to send the proposal for a loop bund when the edge of the pucca bank is less than 3,000 ft.

3) Seepage Flow

About the seepage analysis, any concrete methods and conditions are not mentioned in the manual. In addition, no contents on permeability inspection are not included. Hence, it is necessary to be added.

4) Seismic Condition

This the manual, there is not mention on consideration of seismic condition. Along Indus River, the surface soil seems fine sand to silt at most of the site. Hence, the stability against liquefaction is recommended to be considered. On the other hand, damage due to the liquefaction is not often reported and countermeasures against erosion and seepage flow seems to be considered rather important than the influence by earthquake so far. Since the assets in the landside are expected to increase, demand for the consideration of seismic condition must be higher in the future. For this consideration, setting the target external force and required function after the target earthquake is needed as the first step.

(6) Improvement of a Bund

1) Slope Stability (Slip Circle)

As treatments for a slip circle following measures are introduced. These methods are to increase the safety by reducing the water level in the bund body.

a. Expansion of the Rear Section to cover the saturation line.
b. Mangli[1] or a ring bund around the slip
c. Installation of drainage material at the land side toe

Source: JICA Project Team quoted from the Bund Manual in Sindh

These methods are to increase the safety by reducing the water level in the bund body. Aside from these methods, there is the another methods which can be adopted in Sindh Province such as a wall with steel sheet piles to stop the slip circle.

2) Erosion

As improvement methods, the followings are introduced in the manual as major ones.

Table 3.3.4 Major Countermeasures against Erosion Introduced in Bund Manual in Sindh

No.	Item	Remarks
1	Stone Spurs and Stone Aprons	・ Calculation of expected deepest scouring based on the historical highest discharge. ・ Calculation of length and thickness of stone apron by it.
2	Revetment	・ As a feasible options in Sindh, it is introduced without concrete design method.
3	Cemented Stabilized Soil Revetment	Same as above
4	Tree Groynes	Same as above
5	Bandelling	Same as above

Source: JICA project Team extracted from Bund Manual, Chapter XV, Page 1 of 4 and Appendix V, Page 2 of 12

Stone spurs and stone aprons are introduced as the most popular countermeasure and the design method is also described in detail. On the other hand, information on revetment such as design methods and requirements on each type is not clearly mentioned in the manual.

3) Seepage Flow

The following improvement methods for seepage control shown in **Table 3.3.5** are introduced in the manual as major ones.

[1] (Sindi) A ring bund of lighter section, of earth or brushwood or earth and brushwood, generally given around the site of a breach or a leak.

Table 3.3.5 Major Improve Methods for Seepage Control Introduced in Bund Manual in Sindh

No.	New or Existing Bund	Item	Remarks
1	New	Proper Choice of Earth Fill	
2	New and Existing	Apply the Standard Section in Sindh	Bund Manual mentions "Experience has shown that with the standard sections adopted in Sindh the base width is wide enough to prevent piping."
3	New and Existing	Installation of drainage material at the land side toe	This is not introduced as a countermeasure for seepage control. However, this is effective.
3	Existing	Expansion of the Rear Section to cover the saturation line	Not clearly mentioned on seepage control for the existing bund.

Source: JICA project Team extracted from Bund Manual, Chapter V, Page 7 of 18, Chapter VI, Page 7 of 10 and Chapter IX, Page 6 of 17

In accordance with the manual, as far as a bund follows the bund material and standard section stated in Bund Manual, piping may be little concerned. Basically, any other countermeasures for seepage control aside from the expansion of the cross-sectional shape are not introduced. There are other countermeasures which can be adopted in Sindh such as covering with impervious sheet, seepage cut-off wall with sheet piles.

This may increase the initial cost, but due to the improvement in the durability and strength, the numbers of rehabilitations will be reduced, and the scale of damage will also be reduced. Eventually, the total cost will be expected to reduced.

(7) Revetment

1) Material and Structure

In the manual revetment is defined as "a pitching protection of stone, or brick or sand bags containing a certain proportion of cement or similar materials." The following types of revetments are introduced in the manual, but there is no mention on the specification and design method for each type.

a. Stone Masonry Pitching
b. Burnt Brick Masonry Pitching
c. Brushwood Pitching Including Alternate Layers of Earth
d. Muharis, Single or Double
e. Lai Groynes (single)
f. Lai Mats Including Fixing
g. Date Mats Including Fixing
h. Cemented Stabilized Soil Revetment

Source: JICA Project Team quoted from the Bund Manual in Sindh

2) Safety Verification

Since there is no mention of the specification and design method for each type, the contents about safety verification of the revetments are not included in the manual. Therefore, it must be difficult for the engineer at practical level to design revetments only based on this manual. Hence, adding such contents is recommended so that practitioners can make design.

3) Structural Design

(a) Slope

The side slope of the bunds when revetments are installed is specified as 3:1 to 2:1.

(b) Foundation

There is no mention of foundation of the revetments. A Type of revetment which needs foundation is not considered in the manual.

Since there is no description regarding the design of foundations that takes into account seepage

control and scouring, it is recommended that this be added.

(c) Foot Protection

Stone aprons on front bund is introduced in the manual. This is a foot protection work. About this stone apron work, the manual describes a calculation of expected deepest scouring based on the historical highest discharge and a calculation of length and thickness of stone apron by it.

Since there are few descriptions of foot protection other than stone aprons, it is recommended to add more contents considering the other types.

(8) Spur(Stone Groyne)

1) Site Condition

According to the manual, a location where a spur is installed is described as follows.

a. A location where loop bund is needed, but no available land.
b. (a location which needs a loop bund) Where the edge of the pucca bank is less than 3,000 ft. proposals for loop bund should be sent in at once.

Source: JICA Project Team quoted from the Bund Manual in Sindh

2) Basic Shape

Cross sectional shape is not mentioned in the manual.

3) Material

Since a stone groyne is called a spur, the used material is stone.

4) Design Method

The concrete design method is not stated in the manual. Therefore, it must be difficult for the engineer at practical level to design revetments only based on this manual. Additional description are required so that practitioners can make design.

(9) Construction Works

1) Permission

About the permission of the construction work, the following condition is mentioned in the manual.

✓ *The contractor shall not enter upon or commence any portion of the work, except with the written authority and instruction of the Executive Engineer or his subordinate in charge of the work.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

In addition, all proposals for works in connection with river bunds must be submitted to Indus River Commission as shown in below.

✓ *Executive Engineers will submit the proposal to the Divisions concerned to the Secretary, Indus River Commission, through the Superintending Engineer of the Circle, for the administrative approval of the Indus River Commission*

Source: JICA Project Team quoted from the Bund Manual in Sindh

2) Procedure

Based on the manual, procedure of bund construction is summarized as follows.

1. Site Preparation: Cut and remove trees, shrubs, grass, and other vegetation, remove roots, plow and consolidate the site.

2. *Lining Out and Profiles: Mark the base of the embankment and the limits of the borrow pits, construct the side slopes.*
3. *Borrow Pits: All earth for the embankment shall be obtained only from the borrow pits set out by the Executive Engineer.*
4. *Key Trench and Sand Core: If a key trench is provided under the embankment, the excavated trench must be measured, removed, and backfilled. If the bank is designed with a sand core, the sand filling must be laid side by side with the earth layers of the embankment up to the height specified in the plan and estimate.*
5. *Construction of Embankment: The embankment shall be constructed in accordance with the plan and estimate, but the height shall be greater than designed to allow for settlement. The earth shall be deposited and spread in horizontal layers, 6 inches thick, for the full width of the bank.*
6. *Consolidation: Each layer shall be thoroughly consolidated either by ramming, rolling, or by weighted bullock carts as directed by the Executive Engineer.*
7. *Measurements: Measurements of earthwork will be taken as far as possible in the borrow pits.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

Without permission of the Executive Engineer, following items cannot be carried out.

- ✓ Fire the Jungle
- ✓ Put on the New Layer
- ✓ Work after Sunset to Sunrise

3) Site Inspection for Work Accomplishment (Shape inspection)

It is not clearly mentioned. However, permission by the Executive Engineer is needed to proceed to the next layer of embankment.

4) Quality Inspection

Not mentioned.

5) Acceptability Criteria

Not mentioned.

6) Recommendation

Due to the little description of quality control (inspection items and methods, inspection timing, quality control standards), it is recommended to add the content. The durability and strength of an embankment varies depending on its structure, materials, and construction. Standards for constructing embankments with a certain level of strength are necessary.

(10) Management Plan

"Pre-abrakani Maintenance" and ordinary maintenance is stated, and there is no mention on middle and long term management plan.

The maintenance stated in the manual seems to focus on a single year activity.

(11) Monitoring of River Conditions

1) Patrol/Physical Inspection

About the patrol during high flood, the followings are mentioned in the manual.

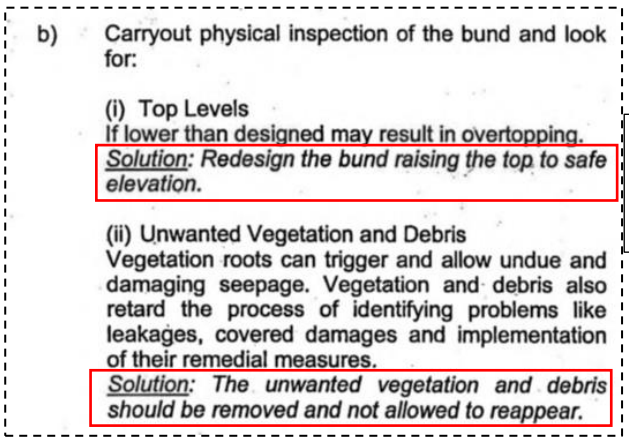
- ✓ *As soon as water comes against a bund, patrolling by beldars should commence. Beldars works in pairs with six hours shift*
- ✓ *The temporary headquarters of the Overseer, Sub-Divisional Officer and Executive Engineer should be in the centre of the active bund line in their charge.*
- ✓ *One daroga for 8-20 miles of active bund line, depending on local conditions, is generally to be provided on the annual establishment.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

Furthermore, about the physical inspection of the bund after a flood, following items are recommended to be checked in another guideline named "SAFETY EVALUATION OF FLOOD BUND"(Not in the Bund Manual of Sindh)."

i. Top Levels
ii. Unwanted Vegetation and Debris
iii. Encroachments
iv. Slope/Section Stability
v. Settlement
vi. Land Subsidence
vii. Damaged Armour
viii. Flood Wall Damage
ix. Runnel

In "SAFETY EVALUATION OF FLOOD BUND," situation and idea for a solution are described for each item. The solutions introduced in this guideline are not targeting the response within a single year but the fundamental measures such as realignment or redesign of a bund. On the other hand, there is no mention of the concrete planning or design consideration about the listed solutions. The extraction of the page in the guideline is shown in below.



b) Carryout physical inspection of the bund and look for:

(i) Top Levels
If lower than designed may result in overtopping.
Solution: Redesign the bund raising the top to safe elevation.

(ii) Unwanted Vegetation and Debris
Vegetation roots can trigger and allow undue and damaging seepage. Vegetation and debris also retard the process of identifying problems like leakages, covered damages and implementation of their remedial measures.
Solution: The unwanted vegetation and debris should be removed and not allowed to reappear.

Ideas for the fundamental solution are indicated. But, no concrete considerations for the planning and design are mentioned.

Source: SAFETY EVALUATION OF FLOOD BUND, 11. SAFETY INSPECTION AND EVALUATION, p11

Figure 3.3.1 Inspection Item and Solution Indicated in "Safety Evaluation of Flood Bund"

It is recommended to add a description of specific planning and designing methods.

2) Inspection with Equipment/investigation/exploration

Not mentioned.

Since the described inspections are basically only by visual inspection, it is recommended to describe the inspection with equipment such as surveying and underground exploration.

3) River Profile / Inspection Report / Damage Record

There is not mention of the river profile, inspection reports and damage records. There are contents

on vulnerable sites along Indus River. However, those are not organized as a river profile.

4) Analysis and Evaluation

Not mentioned.

(12) Inspection and Ledger

1) Bund

In the manual, forms of ledgers and reports listed in **Table 3.3.6** are introduced.

Table 3.3.6 Forms of Ledgers and Repots Introduced in Bund Manual in Sindh

No.	Item	Interval	Description
1	Erosion Statement	Weekly	The form to report the weekly development of erosion of the riverbank from Subdivision Engineer to Executive Engineer, Superintending Engineer, Secretary and Indus River Commission.
2	Abkalani Report(Bund)	Weekly	As soon as there is water against a bund line, the Sub-Divisional Officer will submit every week The Executive Engineer will consolidate such reports and submit one report to the Superintending Engineer and the Chief Engineer concerned.
3	Reports on the State of Bund Sluices and Regulators.	Yearly	A yearly report which contains the state of bund sluices and regulators specially. This is showing the defects noticed and the steps taken to remedy them. The report should include a certificate signed by the Sub Divisional Officer that he has inspected all the structures in the bund in his charge The Executive Engineer will check at least 50 percent of the sluices and regulators in his charge.
4	Statement of High Flood Levels on Bund Mile Gauges and Free Board Available During the Abkalani	Yearly	This is to compare the H.F.Ls. obtained each year with the previous maximum and to verify if the freeboard is sufficient or not. Once the water level subsides, this report will sent from the Executive Engineer to the Secretary, Indus River Commission, copy to the Superintending Engineer.
5	Position in Line of Defense(Bund Register)	Yearly	Bund Register is to present at a glance the various details of the bund line at every mile. It forms a comprehensive record for reference purposes. It will be posted up-to-date every year after the abkalani. By the 15th October, the Sub-Divisional Officer must complete his compilation of the data and submit his copy of the register to the Executive Engineer concerned.
6	Register Showing Incidence of Leaks	When an Incident Occurs.	A register, showing the position of leaks the immediate action taken at the time of discovering it for plugging or closing the leak and the action subsequently taken for opening out and refilling the entire course of the leak in the full width of the embankment.
7	Report of Leveling on Bunds	Yearly	A yearly report is required on the levelling and check levelling done on the formation levels and slopes of all river bunds (including trench bunds) and the actual position in regard to available freeboard. Existing bunds are also required to be levelled annually by the overseers, and a minimum check of 10 percent is required to be exercised by the Sub-Divisional Officer.

Source: JICA project Team extracted from Bund Manual, Chapter XIII, Page 1 of 4 to 4 of 4.

All the inspection ledger/reports are effective for the bund management. On the other hand, there is no mention of the organization of these documents. Hence, currently it is difficult to immediately grasp the contents of each document from the engineer in the main office of each PID. It seems that who will do what, when, and how has not yet been determined. It is necessary to create records early. to organize and to store them so that they can be easily searched.

Although inspection ledgers related to bunds are prepared, there are no regulations for the storage of the ledgers, and the documents are scattered in various divisions and offices.

2) River Channel

Any ledger or form is not described and introduced. However, the following instruction is indicated in the manual.

> ✓ *The Executive Engineers in charge of bund lines should inspect the river course in their charge immediately after the abkalani.*
>
> ✓ *Inspections should also be made, during the abkalani, if there are reports of an adverse change in course.*
>
> ✓ *A full report, together with any proposals considered necessary, should be forwarded to the Superintending Engineer, if an unfavorable river course or river set is indicated.*

Source: JICA Project Team quoted from the Bund Manual in Sindh

According to the manual, an inspection shall be conducted at least once a year. And, in case an unfavorable river course or river set is indicated, it must be informed with a full report. On the other hand, concrete methodology for the inspection is not introduced. It is recommended to state the methodology to monitor the change of river course such as comparison of satellite images or periodical cross section survey which shows the riverbank and riverbed at the time.

3) Storage

There is no mention of the method to store the ledger sheet and report. However, according to an interview with Sindh PID, The PID is responsible for keeping and maintaining all data for flood bunds such as Vulnerable Points at each mile.

It is necessary to specify the regulation about the storage. Specific examples of forms, report preparation, flow for the storage, and sample cases of management departments are needed to be introduced.

(13) River Ledger

1) Contents

Table 3.3.7 shows the items in each ledger introduced in **Table 3.3.6**. About Reports on the State of Bund Sluices and Regulators. and Report of Leveling on Bunds, no form for ledger is introduced.

Table 3.3.7 Items in Each Ledger Introduced in Bund Manual in Sindh

No.	Item	Item
1	Erosion Statement	・ Date of First Measurement. ・ Amount of Erosion ・ Distance Remining Uncroded ・ Minimum Beight of free board during the week
2	ABKALANI REPORT(BUND)	・ Breach ・ Leak ・ Erosion ・ Works in Progress ・ Health of Establishment
3	Reports on the State of Bund Sluices and Regulators.	No form for a ledger
4	Statement of High Flood Levels on Bund Mile Gauges and Free Board Available During the Abkalani	・ Ground Level ・ High Flood Level ・ Corresponding Discharge at Sukkur. ・ RL of Top of Bund ・ Freeboard on Actually Recorded Level and Extra-polated Level

No.	Item	Item	
5	Position in Line of Defense (Bund Register)	・ Water Level ・ H.F.L ・ Max. Depth ・ Min. Freeboard ・ Date on which Water Taouch the Bund ・ Corresponding Gauge Reading at the barrage ・ RL, and widthof Top of Bund and Slope ・ Ground Level ・ General Condition of Bund ・ Nature of Soil	・ Diaphragm of Sand Trench in the Bund ・ Leak ・ Breach ・ Extent of Erosion ・ Trace of Seepage ・ Trace of Wave Wash ・ Issue in Sluice ・ Expenditure on Repair Last Eason ・ Special Patrol Required During Next Season.
6	Register Showing Incidence of Leaks	・ Location ・ Observation Time ・ Probable Cause ・ Plugging/Closing Time	・ Method Adopted ・ Date of Opening Leak in Full Width ・ Date of Refilling
7	Report of Leveling on Bunds	No form for a ledger	

Source: JICA project Team extracted from Bund Manual, Chapter XIII, Page 1 of 4 to 4 of 4.

According to **Table 3.3.7**, most of the items are the one which are obtained from physical inspection (by eyes) and past record. As the items obtained only from them, there is no excess or deficiency. On the other hand, nothing is described about inspections and investigations with equipment and there is no such item in the ledger sheets.

2) Storage

There is no mention of the method to store the ledger sheet and report. However, it is important and the very first step for the efficient management of the existing bunds. Also, in order to study the improvement of the bunds, the accumulated past record is one of the most important types of information.

(14) Bund Breach

1) Cause of Breach

As the causes of a bund breach, the following 4 are introduced in the manual.

a. Erosion of the Bund by the River Itself
b. Failure of Masonry Works, Such as Sluices and Regulators
c. An Uncontrolled Leak Developing into a Breach
d. Overtopping or Severe Scour of the Bund

Source: JICA Project Team quoted from the Bund Manual in Sindh

These are the influence due to the erosion or seepage flow and by natural. As a cause of breaches, artificial bund breach is not listed in the manual.

According to the results of interview survey in Sindh-PID, there is no designated breach point or officially announced breach point.

2) Artificial Breach

There is no mention of the artificial breach.

3) Immediate Action

About the immediate action, contents of the manual are summarized as follows.

a.	*If a breach occurs or is threatened, the daroga[2] or overseer should immediately send a telegram to the Sub-Divisional Officer and the Executive Engineer, and later send in a report. And then, The Executive Engineer should also immediately inform the Superintending Engineer (and in very serious cases also the Chief Engineer directly), the Collector, other Executive Engineers and the Divisional Forest Officer. Later, the Executive Engineer should make a detailed report to the Superintending Engineer.*
a.	*The report should include 1)the name of the bund, 2)front or back, 3)mileage, 4)time of occurrence, 5)time the report reached the daroga or overseer, 6)time the overseer and daroga reached the spot, 7)causes of the breach, 8)width of the breach at the time of the report, 9)depth of water at the site of the breach, 10)nature of the soil, 11)strength of labor and materials at the site, 12)comments of the Sub-Divisional Officer on the preceding entries, and 13)remarks and orders of the Executive Engineer.*
b.	*If additional labor is required, the Mukhtiarkar and leading zamin-dars should be written to immediately and asked to supply labor immediately.*
c.	*The detailed report indicates the measures taken and the steps proposed to be taken for protecting the ends, closing the breach, and diverting the water where it would do the least damage.*
d.	*The probable route should be reported, after making local enquiry and verifying it on a contour map and topo sheet and flood flow diverted along the valley line or where they would do the least damage.*
e.	*Immediate intimation of any breach should be given to the Railway, Highway, Gas Transmission authorities by the Sub-Divisional Officer, and the Executive Engineer, if any of them likely to be affected.*
f.	*When a breach occurs, the first step to be taken is to prevent the breach from widening.*

Source: JICA Project Team summarized from the Bund Manual in Sindh

In the manual, a communication immediate after a breach and the following reporting is clearly instructed. However, as a method of communication, a telegram is introduced and update considering the latest technology is recommended. About the report, the items are introduced precisely, but introducing the form to be filled is recommended. So that, the accumulation and extraction of the information becomes easier. Also, considering the digitalization which will come in near future, using the fixed format is preferable.

Furthermore, since it is not clearly mentioned who and how to analyze the flood route and who and how to divert flood flow, it is recommended to be clearly stated.

4) Closure of Breach

In the manual, one method of closing with a ring bund is explained in detail The described procedure is summarized as follows.

1.	*Detailed measurements are taken underwater to determine the placement of the ring bund.*
2.	*The location of the juckwork is carefully chosen, with the main considerations being shallow water depth and soil that is resistant to erosion.*
3.	*Once the placement of the 'muhari[3]' has been determined, a time schedule is created to close the breach at the most favorable river condition possible.*

[2] A works-foreman on regular establishment, engaged throughout the year on the maintenance of works, in immediate charge of labor, either regular or casual.

[3] (Sindhi) A brush wood fence, or timber frame-work single or double. Sometimes, at dangerous or deep portions, the muhari may be filled by sand bags instead of brushwood.

4. *The necessary materials and labor are carefully estimated and arranged.*
5. *The final closure gap must be determined at the beginning. The closure gap is chosen with care and foresight after detailed inspection.*
6. *Once the final closure has been determined, the flow through the breach can be adjusted by 'chhabbing' the 'juckwork muharis' as needed.*
7. *Once the position where the manguli should be placed has been determined, stakes are driven into the ground at intervals of about 10-20 feet to determine the exact position. The fence ('muhari') is composed of a double groin 4 feet wide, with the main vertical parts ('munas[4]') of each row placed at intervals of 4 feet.*
8. *In 'ghara[5]' (i.e., where the 'muhari' crosses a deep watercourse), if the flow is too fast and 'lai[6]' packing cannot prevent proper soil filling, it may be necessary to fill one or both sides of the double 'muhari' with sandbags instead of brushwood.*
9. *Following the framework, lining is done with mats, and then the two compartments on either side of the space left for earthwork are packed with brushwood. In deep 'ghara' sections, soil must be placed carefully, not thrown.*
10. *When the edges are joined, further props and supports, as well as support from gunny bags, are provided to prevent the framework from collapsing due to excessive soil pressure.*
11. *If there is the slightest suspicion that the soil may be dug out, the entire length (50 to 100 feet) of the selected gap should be paved with one or two layers of gunny bags so that the soil is not dug out.*
12. *If, after the gap is closed, serious leakage occurs in the manguli and a gap develops, the following method of tracking has been successful. If it is impossible to track the upstream face of the leak, a small ring bund of 8-10 feet in diameter is constructed around the downstream end of the leak, protected by gunny bags in juckwork.*

Source: JICA Project Team summarized from the Bund Manual in Sindh

The best method for the closure is depending on the actual condition of each site. However, introducing the past cases will be good reference for the engineers who are going to work on the closure. In the manual, a closing of 1942 breach in Sukkur Begari Bund is also presented. Since the time has passed and technology has been developing, additional latest cases are also recommended to introduced for the future reference. Furthermore, in order to introduce as the sample case, it is important to accumulate the records of the actual closure work with the specific forms or reports.

3.3.2 Gap between the Manual and Actual Practice

There are some gaps between the regulation of the manual and the actual practice at sites particularly about the items such as construction work and inspection. The major gaps are summarized in the following subsections.

(1) Construction Work

- ✓ Each local office of PID implements, supervises, the construction work and conducts completion inspections. It is not clear which division is in charge of controlling the river construction works in the PID head office. Hence, it seems that the details of the work (progress and components) have not been grasped. Also, information is not shared properly because the responsibility system is not clear. Improvement to improve such situation is necessary.
- ✓ Depending on the scale of construction, there is a difference in the document preparation.

[4] (Sindhi) The main vertical post in a "muhari" framework
[5] (Sindhi) A breach in a river embankment.
[6] (Sindhi) The Tamarisk bush or tree.

- ✓ The regulation stated in the manual might not be sufficiently reflected in the technical specifications of the construction work.
- ✓ The description in the manual is a recommendation for quality and construction management, and on-site judgment may take precedence. (There might be cases where the material is used even when it does not satisfy the required value)
- ✓ Matters not described in the manual (degrees of compaction, etc.) are specified in the technical specification of each construction work.
- ✓ Even in case of the construction supervision by PID staffs, etc., the test results and construction status records were not confirmed (In the Manual, there is a description of submission of reports, etc.).
  Inspection documents related to construction management are not stored properly, or they are stored but are not known where they are. Hence, improvement is necessary.
- ✓ There are cases where only the final as-built inspection report is completed. (There is no verification record of the quality of bunds during construction.)
- ✓ In particular, it is assumed that construction managements by contractors in the repair and reinforcement works tend to be simplified and may not conform to the manual, unlike the case of newly installed bund construction work.
- ✓ Since the records of constructions are not accumulated, and improvement is recommended. It may be necessary to create reference samples for collection and organization of documents.
- ✓ Since the relating documents of the construction project such as technical specification, the reports on the quality inspections, the shape inspections have not been obtained, it is not verified if the implementations of the construction works are in accordance with bund reinforcement specified in the manual or not.

(2) Inspection and O&M

- ✓ Regular inspections from April to May and damage inspections after floods are conducted. However, the records regarding the priority order of implementation have not been confirmed. Because no record of the discussion during the meetings among the engineers in PID have been confirmed.

3.4 Analysis on the Manual in Punjab(Manual of Irrigation Practice)

3.4.1 Analysis on the Manual

(1) Definition of a Bund

The definition a bund is described as follows in the manual.

> **An earthen man-made embankment*
> **To provide protection from inundation and act as a barrier between flood water and protected area.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

Based on this definition, it seems that the soil material is basically used as a bund material and the river wall made of concrete is not taken as a bund.

(2) Standard Shape of a Bund

About the basic shape of a bund, freeboard, crest width and side slope etc. are specified in detail. **Table 3.3.1** summarizes the basic shape of a bund specified in Bund Manual.

The shape of the bund is introduced in both Vol. 1 and 2. Each manual describes different bund typologies, and the shape is specified for each type. Here is a summary of the classifications presented in vol 2. It is necessary to unify the presentation of types of embankments in Vol.1 and 2, or add

explanations for each type.

Table 3.4.1 Summary of Basic Shape of a Bund Specified in Manual of Irrigation Practice

Item	Type	Description	Verification/ Remarks
Crest Width	Marginal Bunds	Minimum: 25 ft (=7.6m) Desirable: 30 ft (=9.1m)	
	Bunds Protecting Strategic locations Bunds along open reaches of the rivers	Same as the Marginal Bunds Minimum: 20 ft (=6.1m) Desirable: 25 ft (=7.6m)	
Side Slope (River Side)	Marginal Bunds(earthen)	Minimum: 3:1, Desirable: 4:1	
	Marginal Bunds(protected)	Minimum: 2:1, Desirable: 3:1	
	Bunds Protecting Strategic locations(earthen)	Minimum: 3:1, Desirable: 4:1	
	Bunds Protecting Strategic locations(protected)	Minimum: 2:1, Desirable: 3:1	
	Bunds along open reaches of the rivers(earthen)	Minimum: 3:1, Desirable: 3:1	
	Bunds along open reaches of the rivers(protected)	Minimum: 2:1, Desirable: 2:1	
Side Slope (Land Side)	Marginal Bunds	Minimum: 2:1, Desirable: 3:1	
	Bunds Protecting Strategic locations	Minimum: 2:1, Desirable: 3:1	
	Bunds along open reaches of the rivers	Minimum: -, Desirable: 2:1	
Berm	River Side	-	
	Land Side Slope Width	6:1 Set so that sufficient cover is provided above hydraulic grade line[7]	Introduced as a countermeasure for seepage control
Freeboard	Marginal Bunds	Minimum: 6 ft (=1.8m) Desirable: 7.0 ft (=2.1m) or as determined by analytical analysis whichever is greater	To allowing for a fair factor of safety for sudden unforeseen rise of water level such as wave, shortening of rive course.
	Bunds Protecting Strategic locations Bunds along open reaches of the rivers	Same as the Marginal Bunds Minimum: 6 ft (=1.8m) Desirable: 6 ft (=1.8m) or as determined by analytical analysis whichever is greater	
Extra Embankment	Not mentioned	-	

Note: The minimum value is the parameter prescribed by FFC about 40 years ago and don't have been revised ever since. In light of this, the Punjab Province has proposed the desirable value.

Source: JICA Project Team summarized from Manual of Irrigation Practice.

(3) Quality Control

Quality control is not mentioned in the manual.

(4) Service Road/ Maintenance Road

Service road and maintenance road are not mentioned in the manual.

Considering the current conditions of the top of the bunds in which the JICA Project Teams visited, it is recommended to add a description about pavement on the top of bunds to improve access for the sooth access by the maintenance vielles.

Also, it seems necessary to add the standard pavement composition (minimum sample assuming maintenance vehicle traffic) as samples.

[7] The hydraulic gradient line should be lie at least 2ft below natural surface level at the toe of the bound and covered with soil at least 4 ft thick.

(5) Safety Evaluation

1) Slope Stability (Slip Circle)

In the manual, concrete methods and factor of safety on the slope stability analysis are described and the following is mentioned.

- ✓ *Slope stability analysis is carried out according to Method of Slices, using Simplified Bishop Method with relevant computer software.*
- ✓ **The needed information is as followings;*
  1. *Geometry of embankment:*
  2. *Soil properties; Bulk density, Saturated density. Cohesion "c", Angle of internal friction, Unconfined shear strength , Permeability "k"*
  3. *Design flood level and low water level of the river*
  4. *Phreatic line and pore water pressure*
  5. *Surcharge on the embankment*
  6. *Earthquake loads*
- ✓ *The calculations are carried out according to the typical cross-section of the embankment for two different geometrical parameters:*
  1. *The river-bed stone apron is intact.*
  2. *The scour of the riverbed is modelled with assumed fully launched stone apron.*
- ✓ *Loading conditions are "Gravity", "Seepage (or Pore water pressure), and "Earthquake".*
- ✓ *Location of the phreatic line (or hydraulic gradient) in the embankment is determined for the relevant seepage condition at the design flood level, by using Casagrande's solution.*
- ✓ *Pore water pressure is determined from "pore pressure ratio" and "depth of soil from the top surface".*
- ✓ *The potential failure surfaces is analyzed for the following four critical conditions; i) End of construction, ii) Design flood level with steady seepage, iii) Flood draw-down, and iv) Assuming fully launched stone apron.*
- ✓ *The minimum safety factor is shown in* Table 3.4.2.

Table 3.4.2 The minimum safety factor mentioned in the manual

Condition	Minimum safety factor	
	Without earthquake	With earthquake
During and end of construction	1.4	1.2
Rapid river draw-down	1.3	1.1
River low flow level	1.2	1.0
Design flood	1.5	1.2

Source: Manual of Irrigation Practice VOL.1, Chapter 5, Page 5-66

2) Erosion

In the manual, the methods to evaluate the safety is not described. However, the estimate methods for scour depth are mentioned and the following is mentioned.

- ✓ *It is recommended to calculate the depth of local scour, constriction scour, bend scour, and confluence scour by several available methods and then use engineering judgment to select the preferred results.*
- ✓ *The recommended local scour depth methods for various river gradient are listed in* Table 3.4.3.

Table 3.4.3 Recommended Local Scour Depth Methods

River gradient	Material	Recommended method
Very mild	Sand and silt	-Lacey method (1930) -Inglis method (1940) - Lacey's equation (Expanded by USBR, 1984) -Blench equation (USBR,1969) -Molesworth and Yenidunia equation
Mild (incised)	Gravel, sand and silt	-Lacey method (1930) -Inglis method (1940) - Lacey's equation (Expanded by USBR, 1984) - Blench equation (USBR,1969) - Neill equation (USBR,1973) -Molesworth and Yenidunia equation
Steep	Gravel and coarse sand	- Blench equation (USBR 1969) -Molesworth and Yenidunia equation - Farraday and Charlton equation - Brown formula
Very steep	Gravel and boulders	- Brown formula

Source: Manual of Irrigation Practice VOL.1, Chapter 5, Page 5-84

3) Seepage Flow

For seepage in the bund body, the concrete method for evaluating the safety is described in the manual. However, for seepage in the foundation, only the survey items are listed. The following is mentioned in the manual.

For seepage in the bund body

- ✓ *Hydraulic Gradient is assumed straight line for practical purpose.*
- ✓ *The hydraulic gradients vary for each soil type, but it is assumed as 6:1 normally.*
- ✓ *Hydraulic Gradient should lie at least 2 ft below the natural surface level at the toe of the bund.*
- ✓ *A minimum cover of 4 ft is provided above hydraulic grade line if it exits on the landside in made up soils.*

For seepage in the foundation

- ✓ *The foundation soil determines the rate of under seepage, formation of boils on the landside natural surface, the settlement of the embankment and stability of side slopes.*
- ✓ *Detailed subsurface investigations will be needed for proper foundation evaluation.*
- ✓ *The investigation will essentially provide the following information: Material type and zoning, Permeability of riverbed material, In-situ density, Hardness of cobles and boulders, and Bearing pressure capacity.*

Since there is no mention of the concrete method for evaluating the safety for foundation stability against piping due to the seepage flow, it is difficult for the field engineer to evaluate it.

It is necessary to add a description of a consideration of piping by seepage flow.

4) Seismic Condition

In the manual, seismic condition is introduced as the loading condition for slope stability analysis and the method for determining the load is also described. The following is mentioned.

- ✓ *Acceleration due to earthquake is selected on the basis of 50% reduction for horizontal and vertical component.*
- ✓ *These earthquake forces act at the center of gravity of the slice.*
- ✓ *The acceleration due to Open Basis Earthquake values is adopted on the basis of specific related earthquake zone criterion.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

(6) Improvement of a Bund

1) Slope Stability (Slip Circle)

Countermeasures for slope stability are not mentioned in the manual and are necessary to be added. However, the drainage material listed as the countermeasure for seepage flow in Chapter **3.4.1 (6) 3)** improve the safety of slope stability by reducing the water level in the bund body.

2) Erosion

As improve methods, the following countermeasures are introduced in the manual as major ones.

Table 3.4.4 Major Countermeasures against Erosion Introduced in Bund Manual in Sindh

No.	Item	Remarks
1	Stone Apron	The concreate design methods based on scour depth, flow velocity, and wave-height are introduced.
2	Slope Protection	・ Various protection types are described. ・ For only stone pitching, the concreate design methods based on scour depth, flow velocity, and wave-height are introduced.
3	Spur	・ Basic Shape is described. ・ For determining the length and angle, the physical model studies are recommended. *Refer to Chapter **3.4.1 (8)**
4	Stubs	・ Basic shape is mentioned. ・ The concreate method for determining the length is not mentioned.
5	Gabion	・ Geometry and stability are checked by the design criteria of Barrage.

Source: JICA project Team extracted from the Manual, Chapter 5.4.5, 5.4.8, 5.5.6 to 5.5.8, and ANNEXURE-A in Vol.1 and Chapter 2.5.3, 2 6.2 in MaVol.2

Spurs, stone pitching, and stone apron are introduced as the most popular countermeasures and the design method is also described in detail. On the other hand, information on other slope protection such as design methods and requirements on each type is not clearly mentioned in the manual.

3) Seepage Flow

The following improvement methods for seepage control shown in **Table 3.3.5** are introduced in the manual as major ones.

Table 3.4.5 Major Improve Methods for Seepage Control Introduced in Manual of Irrigation Practice in Punjab

No.	Purpose (Foundation or Bund)	Item	Remarks
1	Foundation	Cut off trench	It is introduced without concrete design method.
2	Foundation	River side impervious blankets	Same as the above
3	Foundation	Pervious toe trenches	Same as the above
4	Foundation	Pressure relief wells	Same as the above
5	Both	Land side seepage berms	・ The concrete method to determine shape is described (Refer to Chapter **3.4.1 (2)**)

No.	Purpose (Foundation or Bund)	Item	Remarks
6	Bund	Drainage Material	・ 3type, Landside Toe, Horizontal, and Inclined, are described. ・ Only the materials for landside toe is mentioned.

Source: JICA project Team extracted from Manual, Chapter 2 6.2.4 in Vol.2, Chapter 2 6.1.1 to 6.1.11 in Vol.2, and Chapter 5.4.9.8 in Vol.1.

There are other countermeasures which can be adopted in Punjab such as covering with impervious sheet, seepage cut-off wall with sheet piles. The descriptions of measures No. 1~5 in the above table in the Manual of Irrigation Practice in Punjab seem to be excerpts from the U.S. manual[8]. Because some parts are excerpted, concreate design methods are missing. Additionally, the descriptions of the measures are scattered in various chapters in the manual, and there are some inconsistencies between chapter titles and content.

Although manual in the U.S. is referred for the countermeasure against seepage flow, there is no description of the specific design method, and it needs to be added.

4) Other Comment

Since the descriptions of each countermeasure are scattered in various sections in the manual, and there is an inconsistency with the title of the chapter, it makes difficult to refer to the necessary contents. Hence, Improvements are recommended.

(7) Revetment

1) Material and Structure

In the manual there is no definition of revetment and few descriptions of revetment, however the following types are introduced as slope protection.

Table 3.4.6 Major Slope Protection Types in Manual in Punjab

No.	Permanent or Temporary	Type	Remarks
1	Temporary	Khaji Mats	・ No concreate design methods
2	Temporary	Fascine Covering	Same as the above
3	Temporary	Pilch Rolls,	Same as the above
4	Temporary	Longitudinal Stakes and Bushing Protection	Same as the above
5	Temporary	Pilch Pitching	Same as the above
6	Permanent	Brick Pitching	Same as the above
7	Permanent	Dumped Stone Rip-Rap	・ The methods for degerming the stone size and the thickness based on the wave height and Reservoir Fetch are described. ・ It is supposed to be used around a barrage.
8	Permanent	Stone Pitching	・ The methods for degerming the stone size and the thickness based on scour depth, flow velocity, and wave-height are introduced.
9	Permanent	Soil Cement Cover	・ No concreate design methods
10	Permanent	Cement Concrete Paving	Same as the above
11	Permanent	Asphaltic Concrete	Same as the above
12	Permanent	Porous Concrete Slab	Same as the above
13	Permanent	Gabions	Same as the above

[8] Engineering and Design and Construction of Levees

No.	Permanent or Temporary	Type	Remarks
14	Permanent	Geotextile Filter	・ The required strength and the method determining the mesh size based on the soil size and the space and length of pin are introduced.

Note: The reference to the stability verification is stated in the manual, but the location of this reference is unclear.
Source: JICA project Team extracted from Manual, Chapter 2 6.2.6 and 6.2.7 in Vol.2, Chapter 5 5.4.5, Chapter 5 5.5.7 in Vol.1.

2) Safety Verification

Since there is no mention on the specification and design method for all type except for stone pitching, the contents about safety verification of the revetments are not included in the manual. Therefore, it must be difficult for the engineer at practical level to design revetments only based on this manual. Hence, adding the contents is recommended so that practitioners can make design.

3) Structural Design

(a) Slope

The side slope of the bunds when revetments are installed is specified as 3:1 to 2:1.

(b) Foundation

There is no mention of foundation of the revetments. A Type of revetment which needs foundation is not considered in the manual.

Since there is no description regarding the design of foundations that takes into account seepage control and scouring, it is recommended that this be added.

(c) Foot Protection

Stone aprons and gabions on front bund are introduced in the manual. These are a foot protection work. About the stone apron work, the manual describes a calculation of length and thickness of stone apron. They are determined by the expected deepest scouring based on the flood discharge and river characteristics.

(8) Spur

1) Site Condition

According to the manual, a spur is installed where the followings are required.

- ✓ *Creating slack flow with an objective of silting up the area in the vicinity.*
- ✓ *Protecting the river bank by keeping the flow away from it.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

2) Basic Shape

In the manual, a typical cross-section and types of spurs are described, and the following is mentioned.

- ✓ *Typical cross-section:*
  - ➢ *Crest width = 30 ft*
  - ➢ *Side slopes - Shank = 3H:1 V*
  - ➢ *Side slopes - Head = 2H:1V*
- ✓ *There are 10 types of spurs: 1. Bar spur 2. Mole-head spur 3. Hockey spur 4. Inverted hockey spur 5. T-head spur 6. Sloping spur 7. T cum hockey spur 8. T cum hockey-sloping spur 9.*

J-head Spur 10. Guide-head spur.

Source : JICA Project Team quoted from the Manual of Irrigation Practice

3) Material

Since a stone groyne is called a spur, the used material is stone. In the manual, only material of the crest protection is referred to as compacted gravel and sand with 6 inch thick.

4) Design Method

In the manual, only recommended space is described, but the concreate method is not introduced. The following is mentioned.

- ✓ *Recommended Space:*
  - ➢ *Straight reach; Less than (5) to six (6) times the length of spur*
  - ➢ *Convex bends; 2.5 to 3.0 times the length of spur*
  - ➢ *Concave bends; equal to the length of spur*
- ✓ *The position, length, angle, and shape of spurs at any site should be determined by physical model studies.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

(9) Construction Works

Construction works is not mentioned in the manual, it is recommended to add descriptions of them.

The durability and strength of an embankment varies depending on its structure, materials, and construction. Standards for constructing embankments with a certain level of strength are necessary.

(10) Management Plan

In the manual, the introduction of Asset Management Plan (AMP) into all facilities controlled by the Irrigation Department is described in order to increase longevity and sustained utility of the infrastructure and an enhance level of service provision. The following steps involved in preparing AMP are mentioned.

Steps involved in preparing AMP

i. *Defining systems and functions.*
ii. *Assessing system performance - achieved levels of service, how these fit with present and future requirements and what infrastructure adjustments are needed,*
iii. *Studying Operations and Management (O&M) - a parallel review of the organization and its procedures for O&M.*
iv. *Conducting an Asset Survey - their extent, value, and the liabilities they represent*
v. *Building the Cost Model- analysis of historical Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) as a basis for future projections*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

This AMP assumes the long-term plan which includes long term investment covering a 20-year planning and short-term program of expenditure for 5-10 years. However, the maintenance for flood embankments and Spurs seems to focus on a single year activity due to the following PID policy listed in the manual.

PID Policy

- ✓ *Flood protection embankments and spurs are inspected before the advent of flood season every year for assessing their reliability to withstand flood onslaught.*
- ✓ *Their deficiencies are removed prior to flood season.*
- ✓ *As such in ideal conditions there should not exist any deferred maintenance requiring rehabilitation of this type of the infrastructure.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

Moreover, the manual indicates that the bund is strengthened periodically as described below. However, there is no mention of the relationship of this bund enhancement to AMP and PID policy.

- ✓ *Normally in the Punjab, banks require to be strengthened periodically after about five years.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

Based on the abovementioned statements, it is necessary to introduce the concept of the bund management with a multi-year plan.

(11) Monitoring of River Conditions

1) Patrol/Physical Inspection

In Vol.1 of the manual, the inspection of river training work is introduced, and the concrete method listed in Table 3.4.7 are stated. From the composition of survey team members, it seems that this inspection is intended to be conducted by HSSEU.

Table 3.4.7 Summary of Inspection in Punjab

Item	Contents		
Timing	Before and after flood		
Responsibility Person	Sub-engineers and sub-divisional officers see that the actual section is not very much below the standard laid down in the type cross section.		
Survey Team Member	A three-person inspection team should be comprised, a leader, hydraulic engineer, geotech engineer.		
Inspection Item	i. Top Levels ii. Unwanted Vegetation and Debris iii. Encroachments	iv. Slope/Section Stability v. Settlement vi. Land Subsidence	vii. Damaged Armour viii. Flood Wall Damage ix. Runnels Caused by:

Source: JICA project Team extracted from Manual, Chapter 5 5.16.4 , Chapter 5 5.16.7, and Chapter 8, 8.2

On the other hand, in Vol.2 of the manual, the followings are introduced as flood preparedness and the concrete methods for them are not described.

- ✓ *Routine Inspections*
- ✓ *Flood Preparedness Inspection Report before Flood*
- ✓ *Flood inspections during the Flood*
- ✓ *Flood Damage Report after the Floods*
- ✓ *Identification and Prioritization of critical damages*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

From the timing and inspection items, the inspection of river training work in vol.1 is considered to be related to “Flood Preparedness Inspection Report before Flood” and “Flood Damage Report after the Floods” in vol.2, while “Routine Inspections” and” Flood Inspections during the Flood” seems to be patrol. It is desirable for the manual to state the relationship between the inspection of river training work and flood preparedness in order to make it easy to understand.

2) Inspection with equipment/investigation/exploration

Although it is not intended for monitoring, following geophysical investigation is introduced for planning the bund in the manual.

> ✓ *Geophysical investigations: Electrical resistivity/ Cavities, weak soil strata and buried objects through Ground penetrating radar*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

3) River Profile / Inspection Report / Damage Record

There is not mention of the river profile. However, the inspection report which include damage record is described as follows in the manual.

> ✓ *The reports normally comprise an introduction, location of the training works, analysis for design parameters, physical inspection results.*
> ✓ *The committee will formulate its inspection/evaluation report and submit it to the owner/requesting authority within 15 days of the inspection.*
> ✓

Source : JICA Project Team quoted from the Manual of Irrigation Practice

4) Analysis and Evaluation

About the Analysis and Evaluation, the following is mentioned in the manual.

> ✓ *Review the design according to the state-of-the-art design methods/procedures, point out any deficiencies to be corrected and suggest suitable action to withstand the accepted Probable Maximum Flood.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

(12) Inspection and Ledger

1) Bund

One check list which include all inspection items is introduced in the manual, and the main check items in the list are as follows.

- Name of the facility
- Incharge Division, Circle, Zones
- Review on Design with respect to latest standards
- Phreatic line development Top Width
- Physical conditions (visual)
- Top width (compared with design)
- Top RL
- Side slope
- HFL
- Free board
- Any visible/apparent runnels, caused by old tree roots
- Rodent, holes, burrows and dens
- Evidence of solutioning
- Evidence of piping
- Evidence of heavy seepage, springs and boils on the land side
- Erosion by flow
- Is the bund prone to wave action
- Erosion by wave action
- Evidence of greater permeability of foundation
- Evidence of Misuse
- Accidents
- Vandalism
- Sabotage
- Flood watching arrangements
- Flood fighting arrangements
- Gauges observation system
- Flood warning and information system
- Investigation carried out
- Analysis of observations and investigations

- Patrol road and section maintenance
- Unauthorized traffic
- Slumping or settlement
- Body materials suitability determined through analysis at various depths and locations.
- materials (say in creek crossings)
- Rain cuts and ravines
- General land subsidence
- Damages to stone or other protections
- Evidence of compressible or expansive (plastic) soils in foundation.

It is unclear what should be filled in some items such as "Erosion by flow" and "Rain cuts and ravines". It is recommended that the ledger whose inspection items are clear should be included in the manual.

Since there is little explanation of the necessary information for each item, the input information may varies depending on the individual knowledge and experience, It is recommended to improve the ledger.

2) River Channel

Any ledger or form is not described and introduced. However, the following instruction is indicated in the manual.

Table 3.4.8 Investigation Item for River in Punjab

No.	Item	Interval	Description
1	Topo Survey	Yearly	・ Survey area is extending to 15000 x afflux[9] feet he upstream and 25000 ft on the downstream of the barrage. ・ This survey shows the areal placement of river channels, their variations, erosions and shoals and changes in the meanders of the river channels.
2	Bathymetric Survey	Yearly	・ This survey comprises the cross section and contours.

Source: JICA project Team extracted from Manual, Chapter 5 5.16.9 in Vol.1.

The area and objectives of bathymetric survey is not mentioned clearly, but this survey seems to be carried out near the barrage to assess the condition of it.

3) Storage

About the storage, the following table is mentioned in the manual. However, it is unclear whether the check list for bund safety inspection is stored or not because the manual does not indicate the document to be stored and the responsible person is the staff in the barrage.

> ✓ *The sub-divisional officer in charge of the barrage has the responsibility of checking and initiating all the data record regularly at prescribed intervals.*

Source ： JICA Project Team quoted from the Manual of Irrigation Practice

There is no clear provision for the storage of inspection ledgers, and it is stated that the sub-divisional officer in charge of the barrage is responsible for keeping all documents. However, it is preferable to improve it because it has little relevance to the bunds.

[9] Afflux is an increase in water level that can occur upstream of a structure, such as a Dam, Barrage, a bridge or culvert, that creates an obstruction in the flow.

(13) River Ledger

1) Contents

Legers showing the outline of the river or bund is not stated in the manual.

2) Storage

This item is also not described in the manual.

(14) Breach

1) Cause of Breach

As the causes of a bund breach, the following 4 are introduced in the manual.

a. Erosion of the Bund by the River Itself;
b. Failure of Masonry Works, Such As Sluices and Regulators;
c. An Uncontrolled Leak Developing Into a Breach
d. Overtopping or Severe Scour of the Bund

Source : JICA Project Team quoted from the Manual of Irrigation Practice

These are the influence due to the erosion or seepage flow and by natural. The artificial cause is also described in the manual and is explained in next chapter.

Moreover, the main cause of beach is stated in the manual as the following.

✓ *The most frequent cause of a breach is the development of a leak.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

2) Artificial Breach

The conditions and methodology for activation of breaching section are listed in the manual.

About the conditions
a. The location is approved by a committee.
b. The pre-requisite site conditions are followings.
   - The rate of inflow to the structure is most likely to be more than the discharging capacity of the structures.
   - The critical / emergency gauge at a fixed location on left marginal bund or elsewhere has exceeded the limiting value and the river discharge still rising.

About the methodology
- ✓ *The breaching section can be activated through,*
  - *Mechanical means*
  - *Blowing up the body of the bund through use of explosives*
- ✓ *Mechanical means is desirable because it is more reliable. The success rate of blowing up is less than 50%.*

Source : JICA Project Team quoted from the Manual of Irrigation Practice

In addition, the manual mentions refer to the critical gauges values. But it is listed “elsewhere in the manual” where the value has been tabulated. It is desirable to clearly describe the location of the value.

3) Immediate Action

About the immediate action, contents of the manual are summarized as follows.

a. If a breach occurs or is threatened, the sectional overseer should immediately communicate to the Sub-Divisional Officer and the Executive Engineer, and later send in a report. And then, The Executive Engineer should also immediately inform the Superintending Engineer (and in very serious cases also the Chief Engineer directly), the Collector, other Executive Engineers and the Divisional Forest Officer. Later, the Executive Engineer should make a detailed report to the Superintending Engineer.

b. The report should include 1) Name of bund, 2) Location 3) Time of occurrence, 4) Time at which report reached the overseer, 5) Time at which overseer reached the spot, 6) Causes of breach, 7) Width of breach at the time of report, 8) Depth of water at site of breach, 9) Nature of soil, 10) Strength of labour and materials at site, 11) Comments of Sub-Divisional Officer on preceding entries, 12) Remarks and orders of Executive Engineer.

c. The detailed report indicates the measures taken and the steps proposed to be taken for protecting the ends, closing the breach, and diverting the water where it would do the least damage.

d. The probable route should be reported, after making local enquiry and verifying it on a contour map and topo sheet and flood flow diverted along the valley line or where they would do the least damage.

e. Immediate intimation of any breach should be given to the Railway, Highway, Gas Transmission authorities by the Sub-Divisional Officer, and the Executive Engineer, if any of them likely to be affected.

f. When a breach occurs, the first step to be taken is to prevent the breach from widening.

Source : JICA Project Team quoted from the Manual of Irrigation Practice

As well as the Bund Manual in Sindh, the description should be updated to communication methods based on the latest technology.

About the report, the items are introduced precisely, but introducing the form to be filled is recommended. So that, the accumulation and extraction of the information becomes easier. Also, considering the digitalization which will come in near future, using the fixed format is preferable.

Furthermore, since it is not clearly mentioned who and how to analyze the flood route and who and how to divert flood flow, it is recommended to be clearly stated.

4) Closure of Breach

The contents in the Manual of Irrigation Practice in Punjab are the same as the Bund Manual in Sindh.

As well as the Bund manual in Sindh, since the time has passed and technology has been developing, additional latest cases are also recommended to introduced for the future reference. Furthermore, in order to introduce as the sample case, it is important to accumulate the records of the actual closure work with the specific forms or reports.

3.4.2 Gap between the Manual and Actual Practice

There are some gaps between the regulation of the manual and the actual practice at sites particularly about the items such as construction work and inspection. The major gaps are summarized in the following subsections.

(1) Construction Work

- ✓ Each zonal office of PID implements, supervises, the construction work and conducts completion inspections. It is not clear which division is in charge of controlling the river construction works in the PID head office. Hence, it seems that the details of the work (progress and components) have not been grasped.
  Also, information is not shared properly because the responsibility system is not clear.

Improvement is necessary.

- ✓ In case of large scale construction work, a consultant(NESPK(National Engineering Service Pakistan Limited.) is conducting the construction supervision. They have prepared a report including the quality control, construction inspection, shape inspection and completion inspection.
  there is no description of information sharing between NESPAK and PID, which is outsourced for construction supervision, and understanding of construction details, lists, etc. within PID and the improvement is recommended.
- ✓ Depending on the scale of construction, there is a difference in the document preparation.
- ✓ Basically, the regulation stated in the manual might be sufficiently reflected in the technical specifications of the construction work. However, some items seem difficult to be complied in the actual construction works.
- ✓ The description in the manual is a recommendation for quality and construction management, and on-site judgment may take precedence. (There might be cases where the material is used even when it does not satisfy the required value)
- ✓ In particular, it is assumed that construction managements by contractors in the repair and reinforcement works tend to be simplified and may not conform to the manual, unlike the case of newly installed bund construction work.
- ✓ Since the records of constructions are not accumulated, and improvement is recommended. It may be necessary to create reference samples for collection and organization of documents.
- ✓ Since the relating documents of the construction project such as technical specification, the reports on the quality inspections, the shape inspections have not been obtained, it is not verified if the implementations of the construction works are in accordance with bund reinforcement specified in the manual or not.

(2) Inspection and O&M

- ✓ Regular inspections from April to May and damage inspections after floods are conducted. However, the records regarding the priority order of implementation have not been confirmed. Because no record of the discussion during the meetings among the engineers in PID have been confirmed.

3.5 [Reference]Analysis on the Design Criteria of NFPP-IV

3.5.1 Analysis on the Manual

The flood protection bunds have been generally constructed either to protect head works and other irrigation structures or to safeguard certain towns and cities. The construction had been done mostly by manual labor and not resorting to any compaction as is being practiced in the modern times. The old bunds are therefore comparatively much weaker in strength in relation to the recent construction done with the machinery.

(1) Standard Shape of a Bund

Table 3.5.1 summarizes the standard shape of the bund and important considerations mentioned in Final Report of Development of National Flood Protection Plan-IV (NFPP-IV) and Related Studies to Enhance Capacity Building of Federal Flood Commission-FFC, ANNEX-3 Design Criteria for Flood Protection Bunds, Spurs, Studs and Flood Retaining Walls(hereinafter so called the Design Criteria of NFPP-IV).

Table 3.5.1 Summary of Basic Shape of a Bund Specified in Bund Manual

Item	Type	Description	Verification/ Remarks
Crest Width	Bund	25 ft	Wide enough to carry inspection of bunds.

Item	Type	Description	Verification/ Remarks
Side Slope	Bund		
(River Side)	-do-	3:1	
(Land Side)	-do-	2:1 without Berm	The slope provided must be such that there is at least 2.0 ft earth cover over the phreatic line.
Berm	River Side	-	
	Land Side	If the phreatic line does not have 2.0 ft earth cover, then back berm shall be provided.	
Freeboard	Bund	6 ft	To allowing for a fair factor of safety for sudden unforeseen rise of water level such as wave, shortening of rive course.
Hydraulic Gradient	Bund	6:1	
Sand Cores	Bund	To reduce impact of clay cracks and swelling. To close any animal burrow.	
Clay Cover on Sandy Bunds	Bund	6- to 12-inch-thick clay cover to protect the bunds from rain and wind.	

Source: JICA Project Team summarized from the Design Criteria of NFPP-IV.

(2) Construction Quality Control

1) Construction Materials

The construction materials for the embankment construction is not clearly defined in NFPP-IV and a general guideline is defined that the sources must be selected appropriately to meet the site and design requirements since these have a major impact on durability, performance and quality of the structures. The suitable material shall be explored through a systematic investigation and reconnaissance of the surrounding area shall be made for identification of potential sources for different natural materials available for construction. Various potential borrow areas and quarry sites shall also be considered and investigated.

Geological field investigations must be carried out to ascertain the appropriateness of the construction material source so that obtained material complies with the design requirements and site conditions. A reconnaissance survey must be carried out at identified and potential material sites so that the specific geology at that site can be understood. After the reconnaissance survey, detailed investigations and testing, a material source report shall be prepared for the identified construction material sources and quarries and must include the following:

- ✓ *Assessment for quantity of material available in the potential material source.*
- ✓ *Assessment of largest size cobble or boulder observed during the investigation along with any glacial irregularities and variations.*
- ✓ *Qualitative evaluation of all material sources for sand and aggregates will be carried out in accordance with the site requirements and specific potential of each source, which shall include:*
  - ➢ *assessment of mineralogical characteristics of the rock mass*
  - ➢ *assessment of physical engineering characteristics*
  - ➢ *evaluation of results to establish appropriateness of sources to be used for construction material acquisition.*
- ✓ *Identification for the presence of deleterious minerals with respect to alkali-silica and alkali-carbonate reactions and establishment of their percentages.*

- ✓ *Accessibility and haulage*
- ✓ *Suitability of construction materials with reference to physical strength and petrographic properties*
- ✓ *Study for the availability of other manufactured materials such as cement, steel, bricks and admixtures, to be used in bulk quantities, for construction of flood retaining structures.*
- ✓ *Petrographic analysis to ensure the potential of ASR (Alkali Silica Reaction) in the selected fine and coarse aggregate samples collected during investigations along with other properties of rock, soil and aggregate.*

Source : JICA Project Team quoted from the Design Criteria of NFPP-IV

2) Construction Method

Construction activities should be planned in such a manner that the project is completed in shortest possible time. As a general guideline, the following shall be ensured:

- ✓ *The borrow area should be approved by the Engineer-in-charge after satisfying standards before starting transportation of fill materials.*
- ✓ *Extensive testing should be performed on materials to check its suitability for intended purpose.*
- ✓ *Plant roots, vegetation, plastic bags or other deleterious materials that may interfere with the quality of work may be sorted out carefully and discarded from the site.*
- ✓ *A no. of passes of roller of 8-10 tonne capacity are then applied.*
- ✓ *Compaction tests are performed to ensure the compaction of the fill. At least one test per layer per 500 ft length or as specified will be required. However, the degree of compaction is not mentioned.*
- ✓ *Extra fill material from the slope of structure is removed and the slope of the structure is trimmed to design so that it can be p*repared for other activity.

Source : JICA Project Team quoted from the Design Criteria of NFPP-IV

Some general guidelines for the construction of stonework (Stud, Spur, Stone Pitching and Launching of Apron) and gabion are also mentioned.

(3) Safety Evaluation

1) Embankment Seepage Analysis

NFPP-IV suggests that the embankment and other structures seepage can be effectively analyzed for steady state conditions using computer software Seep/W-GeoStudio. **Table 3.5.2** summarizes the safety parameters for the seepage conditions of bund and seepage berm.

Table 3.5.2 Safety Parameters Under Seepage Conditions

Item	Factor	Criteria
Bund	Exit Gradient	Less than 0.5
	Factor of Safety	1.6
Seepage Berm (less than 100m wide)	Exit Gradient	Less than 0.8
	Factor of Safety	1.0

Source: JICA Project Team summarized from the Design Criteria of NFPP-IV.

In calculating the factor of safety for under seepage, the following equations are applied.

$$FOS = \frac{I_c}{I_e}$$

$$I_c = \frac{(\gamma_s - \gamma_w)}{\gamma_w}$$

Where,

FOS = Factor of Safety
I_c = Critical hydraulic gradient
I_e = Calculated exit gradient
γ_s = Saturated unit weight of blanket layer
γ_w = Unit weight of water

If relief wells are constructed for seepage control, the above criteria must be achieved midway between relief wells.

2) Embankment Slope Stability Analysis

The stability of slopes for embankments, studs and spurs etc. are analyzed using computer software SLOPE/W-GeoStudio which is based on limit equilibrium methods. The conventional limit equilibrium methods investigate the equilibrium of the soil mass tending to slide down under the influence of gravity in terms of moment and force equilibrium factor of safety equations. Different limit equilibrium methods available in for analysis of slope stability in the software. The most common limit equilibrium techniques are methods of slices where soil mass is divided into vertical slices.

Several loading conditions are applied considering the scenarios such as (a) End of construction stage, (b) Steady state seepage condition, which shall be further analyzed as (i) Normal Pool Condition (ii) Flood Surcharge Condition, and (iii) Partial Pool Condition (c) Drawdown pore water pressure condition , which shall be further analyzed (i) Rapid drawdown from normal pool , and (ii) Rapid drawdown from maximum pool (d) Earthquake (Pseudostatic Analysis)

The recommended factor of safety for the embankment stability analyses varies with the loading conditions. Long term loading conditions i.e. steady seepage, require higher factor of safety while short term loading conditions i.e. rapid drawdown, requires lower factor of safety.

A recommendation of minimum factors of safety of 1.5 for an upstream slope under rapid drawdown conditions and 1.1 for an upstream slope under rapid drawdown conditions with earthquake loading. The USACE recommends minimum factor of safety of 1.4 to 1.5 for upstream face where rapid drawdown is a routine operating condition and goes on to recommend that if the consequences of an upstream failure are great, such as blockage of the outlet works resulting in a potential catastrophic failure, higher factors of safety should be considered. Factor of safety for stability analysis of flood embankments are given in the **Table 3.5.3** below.

Table 3.5.3 Factor of Safety for Flood Embankment Stability Analysis under Different Loading Conditions

Agency	Loading Condition	Stress Parameter	FOS
USACE (United States Army Corps of Engineers)	During Construction and End of Construction	Total and Effective	1.3
	Long term (Steady seepage, max. storage pool, spillway crest or top of gates)	Effective	1.5
	Max. Surcharge Pool	Effective	1.4
	Sudden Drawdown for Max. Surcharge Pool	Total and Effective	1.1
	Sudden Drawdown for Max. Storage Pool	Total and Effective	1.3
	Sudden Drawdown when Routine Operating Condition (Pumped Storage Facility)	Total and Effective	1.4-1.5

Source: The Design Criteria of NFPP-IV

The factor of safety for the earthquake analysis is not mentioned clearly in the design criteria of NFPP-IV.

3) Seismic Evaluation

Probabilistic Seismic Hazard Analysis for all important and critical flood protection and river training structures are carried out, and peak horizontal ground acceleration 'g' is determined for onward use in structural designs of these structures. The evaluations include through study of regional geological and tectonic information collected from the available literature and maps and collection of historical and instrumental earthquake records. It is recommended that the project structures should be designed after deciding the seismic zone as per the Seismic Provisions (2007) of Building Code of Pakistan after giving due consideration to the foundation material at site.

4) Scour Protection

For flood protection bunds, scour can be calculated using empirical methods such as USBR methods and Browns Formula. Available engineering software must also be used for the calculation of scour depths at riverbed and banks.

5) Stone Pitching

Stone pitching is to be provided where there are chances of severe wave wash damage. A layer of filter material comprising of six inches of sand and gravel is to be provided below the stone pitching to prevent the washing away of fine particles from embankment.

The Hydraulic Design Charts sheet 712-1, by US Army Engineer Waterways Experiment Station, provides a relation for the stability of stone considering flow velocity and stone size. Stone diameter can be determined using the equation by Isbash.

6) Liquefaction Analysis

Liquefaction analysis is carried out to investigate the liquefaction-induced deformation of embankments. The parameters are developed based on SPT-N values and the analysis is carried out depending upon the substrata and peak ground acceleration 'g' factor. The peak ground acceleration is to be selected from Building Code of Pakistan (2007), Seismic Provisions, updated after 2005 earthquake. The liquefaction potential of a facility can be screened using the Seed and Idriss Method.

(4) Improvement/Evaluation of the Existing Bund

The evaluation of existing embankments and bunds will require verification of available freeboard, top width, side slopes, scour and erosion problems, slope protection works etc. to be in accordance with the latest design criteria and standards. It is required that the existing flood protection bunds and embankments may be evaluated and assessed if they are in a position to sustain extreme events like 2010 flood.

(5) Flood Retaining Walls

The selection of flood retaining wall or embankment as a flood protection structure depends on various factors including site conditions. Main factors for choosing between flood wall and embankment are summarized in the **Table 3.5.4** below:

Table 3.5.4 Factors to Choose between Flood Wall and Embankment

Factor	Flood Retaining Wall	Embankment
Space	Ideal when space available for constructing a flood retaining structure is limited.	Requires a lot of space and a wide foot print.
Environment	Ideal for urban conditions where the designed structure is to blend in with local infrastructure.	Ideal for rural locations but an be provided at urban places if space permits.
Foundations	Weak and permeable foundations can complicate the structural design and stability.	A weak and permeable foundation threatens the stability of the embankment.
Seepage	It requires a cutoff for safety against seepage action.	A pushta or back berm is provided to prolong flow path for safety against seepage which increases the foot print (base width) of the designed embankment.
Inspection	Inspection of critical elements should be done before and after floods.	It requires regular inspection.
Maintenance	It requires less maintenance.	It requires careful maintenance including control of unwanted vegetation control, burrow holes and repair of any damages to embankment of protection works.
Cost	The cost depends upon construction materials, construction methods and foundation condition and treatment.	Cost depends mainly upon fill material. If local material is allowed for fill by the Engineer, costs are significantly reduced.

Source: The Design Criteria of NFPP-IV

1) Freeboard and Wall Top Level

Freeboard must be provided above the highest flood elevation to avoid overtopping. The height and run-up of generated waves must be considered in design. The formulas and criteria given in above section for calculation of wave height and wave run-up for embankments can also be used to fix freeboard for flood retaining walls. In case the flood wall is overtopped due to any unforeseen event or extreme flood scenario, the structure design must be such that no collapse or failure occurs. Generally, the flood retaining walls made up of concrete have the ability to sustain flood overtopping.

2) Foundation Design and Bearing Capacity

For safe and economical design, foundations should meet the following design criteria described in **Table 3.5.5** below.

Table 3.5.5 Factor of Safety for Flood Retaining Walls

Sr. No.	Parameter	Factor of Safety
1	Shear failure	3.0
2	settlement	25 mm: Individual foundation 50 mm: Mat foundation Agular distortion between the edge and center of foundation < 1/500

Source: JICA Project Team summarized from the Design Criteria of NFPP-IV.

Bearing capacity of subsoil for shallow and deep foundations is evaluated in accordance with the guidelines given in USACE manuals EM1110-1-1905 and EM1110-1-1902. The ultimate bearing capacity calculated by these methods is divided by a factor of safety of 3.0 to obtain allowable bearing capacity to be used in design.

3) Stability Concerns and Factor of safety

The primary concern for the design of flood retaining wall structures is described in the **Table 3.5.6** below:

Table 3.5.6 Factor of Safety for Flood Retaining Walls

Sr. No.	Stability Parameter	Factor of Safety	Verification/Remarks
1	Against Overturning	2.0	The soil reaction within the middle third of the base and that the soil bearing pressure does not exceed the allowable pressure 150 kN/m^2.

Sr. No.	Stability Parameter	Factor of Safety	Verification/Remarks
2	Against Sliding	1.5	
3	Stress Failure	(i) <2.0 N/mm^2 (f'$_c$= 20 N/mm^2) (ii) 1.5 (tensile stress)	(i) the tension and bending stresses within the mass concrete. (ii) Allowable tensile strength is quoted as 3.0 N/mm^2. The f'$_c$ is to be limited to the characteristic strength.

Source: JICA Project Team summarized from the Design Criteria of NFPP-IV.

The concrete flood retaining walls should be designed using the design procedure given by Nilson and Darwin in Design of Concrete Structures. The safety factors (FOS) applied to the flood retaining walls to meet above design concerns are given below:

4) Structural Design Criteria

Code and Standards

The Codes and Standards used for structural design are provided in the **Table 3.5.7** below.

Table 3.5.7 Codes and Standards for Structural Design

Sr.#	Code and Standard	
1.	BCP (2007)	Building Code of Pakistan Seismic Provisions - 2007
2.	EM 1110-2-2502	Engineering and Design of Retaining and Flood Walls by US Army Corps
3.	PCPHB (1967)	Pakistan Code of Practice for Highway Bridges
4.	ACI 318-11	Building Code Requirements for Reinforced Concrete American Concrete Institute
5.	ACI 301-95	Specifications for Structural Concrete American Concrete Institute
6.	ASTM A615	Specifications for Deformed and Plain Billet Steel Bars for Concrete Reinforcement
7.	ASCE 7-10	Minimum Design Loads for Buildings and other Structures
8.	ASTM C150	Specifications for Portland Cement
9.	ASTM C33	Specifications for Concrete Aggregate
10.	UBC 1997	Uniform Building Code of USA
11.	FEMA P-259 (2012)	Engineering Principles and Practices for Retrofitting Flood Prone Residential Structures
12.	FEMA 274	NEHRP Commentary on the guidelines for the seismic rehabilitation of buildings
13.	ACI 562-13	Code requirement for evaluation repair and rehabilitation concrete buildings and commentary

Source: The Design Criteria of NFPP-IV

Materials

For the concrete, the minimum compressive cylinder strength at 28 days shall be equal to 28 MPa (4,000 psi) and 10.5 MPa (1500 psi) for RC wall and plain/blinding concrete, respectively. The reinforcement steel to be used in reinforced concrete works shall conform to ASTM A615 Grade 60 with minimum yield strength of 414 MPa (60,000 psi) or AASHTO M-31 Grade 60.

5) Evaluation of Existing Flood Retaining Structures

- ✓ *Evaluation of existing structures shall be ascertained by detailed analytical evaluation as per the Design Criteria supplemented by load testing wherever considered necessary. The structural evaluation for existing flood retaining structures will include following activities:*
- ✓ *The collection of design data and documentation must be done for the structures available with the Client. The missing but essential data must be identified and listed down. A checklist should be prepared to ensure that the subsequent site visits and field testing covers all missing parameters and details required to design an effective retrofitting solution.*
- ✓ *The Condition Survey must be carried out by visual inspection of existing structures to observe any signs of structural deterioration.*

- ✓ *Mapping and photography of all the deteriorated areas must be done.*
- ✓ *Preparation and supervision of testing programme must be done to identify the areas and components of flood retaining structures for Non-Destructive Testing (NDT) along with extraction of cores to evaluate present material strength.*
- ✓ *Preparation of Geotechnical Investigation requirements, supervision of field work and laboratory tests for determination of soil design parameters.*
- ✓ *Evaluation and review of all available data, design criteria, documents, investigation reports, surveys, test results to familiarize with the structural system and to establish various options for retrofitting.*
- ✓ *Design verification of structures for all anticipated static and dynamic loadings as per design criteria considered in the existing design.*
- ✓ *Selection of most prudent retrofitting option based on the above said evaluations and preparation of Assessment Report.*
- ✓ *Development of Repair/Retrofit Designs.*

Source：JICA Project Team quoted from the Design Criteria of NFPP-IV

(6) Spur (Stone Groyne)

The spurs/groynes consist of a shank and a nose, or head. The shank is a bund of adequate section which connects the spur head or nose to the highest point above the HFL at a riverbank. The upstream face and nose of the spur are armored with stone pitching and apron. The spur head or nose can have different angles and slopes to cater for local requirements. The spurs are provided with stone pitching launching apron to prevent scouring under water and avoid consequent failure of these structures. Spurs are mainly provided for following purposes:

- ✓ *For river training along desired course to reduce concentration of flow at the point of attack preventing scour.*
- ✓ *For protection of riverbank under erosion attack or vulnerable to erosion in future by keeping the flow away from it.*
- ✓ *For correcting/synchronizing the approach of incoming flows towards a barrage or any other structure*
- ✓ *For creating slack flow with the object of silting up in the area in vicinity of the riverbank and spur.*

Source：JICA Project Team quoted from the Design Criteria of NFPP-IV

The spurs must be designed either for a discharge equal to that of the structure which is in close proximity to the spur or equal to 100-year return period flood, or the highest recorded flood event, whichever is of a greater magnitude.

Spurs may be aligned either normal to flow direction or at angle pointing towards upstream or downstream of the flow. The training of rivers is done either by attracting, deflecting or repelling of flow. Based on alignment, spurs can be classified as attracting spurs, repelling spurs and deflecting spurs.

Spurs/groynes are designed with special shapes each with respect to their purpose for river training. Each of these special spur types must be tested at physical model to ensure satisfactory performance for river training. Some special types of spurs discussed in NFPP-IV are hockey spur, inverted hockey spur, T-head spur, sloping spur, J-head spur, bar spur, mole-head spur, guide head spur. **Table 3.5.8** shows different parameters for spur design.

Table 3.5.8 Parameters of Spur Design

Sr. No.	Item	Criteria
1	Layout	(i) Length in no case should be less than required to keep the scour hole formed at the nose of the spur. (ii) length should be more than 2.5 d_s, where 'd_s' is maximum depth of scour below bed, and angle of repose of sand is assumed to be 2.5H:1V. (iii) In case of a single channel, the effective length of spur must not increase 1/5th of width of flow. (iv) In wide, shallow, and braided rivers the extension of spurs in deep channels is not to exceed 1/5th of the channel width.
2	Number	Number of spurs depends upon the location to be protected, river curvature, discharge intensities, sediment characteristics and control conditions.
3	Spacing	(i) Greater spacing is required for convex banks while a smaller spacing for concave banks. (ii) 2-2.5 times the effective length spacing is provided for convex banks whereas spacing equal to length of spur is provided for concave banks. (iii) To ensure effective spacing of spurs for complex cases, model studies must be carried out.
4	Slope Stability	The slope stability of spurs is analyzed using the computer software SLOPE/W-GeoStudio in the same manner as performed for the flood embankments.

Source: JICA Project Team summarized from the Design Criteria of NFPP-IV.

(7) Construction Methodology for Stonework (Stud, Spur, Stone Pitching and Launching of Apron)

- The natural surface should be excavated to the required level as per the drawings for formation of the base of the structure. The surface of formation should be free from any deleterious material and unwanted foreign objects. Loose pockets if any, should be excavated and filled with suitable granular or backfill material.
- The excavated surface should be compacted by using the roller of 8 to 10 tonne capacity. The design requirements with respect to bearing capacity should be achieved and verified before proceeding further. Density of compacted formation should be as per specifications.
- The excavated surface prepared should be leveled without ruts and undulations.
- Stone of specified weight (size) and quality should be offloaded at site.
- The apron should be excavated to the desired level and size. This activity should be performed as quickly as possible because in many cases, the soil may be wet that may collapse inward.
- Stone should be dumped in apron, but great care should be taken to avoid loose pockets that should be filled with smaller size of stones. Care should be exercised that no earth materials enter the apron.
- The top layer of stone apron should be hand packed.
- Earth filling should be started in layers. Each layer should be moistened up to optimum moisture content and should be compacted up to specified standard. Care should be exercised to remove any deleterious materials like plastic bags, vegetation etc.
- The filter materials of specified gradation and quality should be spread over already prepared slope in specified thickness.
- Stone profiles should be placed at an interval not greater than 100 ft. upto required height so that the overall thickness of stone pitching between profiles of specified thickness can be maintained. Any loose hole should be avoided in pitching and should be filled with smaller size stone.
- In case of studs, stones will be dumped above apron level in specified shape. Care should be taken to avoid loose pocket which should be filled with smaller size stone

(8) Monitoring of River Conditions

Flood bunds require a constant observation before start of monsoon season by local people and concerned authorities to ensure that these are free of cracks, burrow holes, piping, sand boiling, creep

flow, leakage through cracks, poor drainage of seepage water etc. Any such observations made must immediately be reported to the stationed officer so that repairs and rehabilitation can be carried out.

Post monsoon and past flood inspections should be carried out to ascertain the health of structure and repaired works. Regular patrolling of guide, marginal and flood protection bunds should be done during floods to monitor the behavior of structure and to take necessary protection measures.

The inspection of flood bunds and embankments must be carried out in complete detail to gather maximum information for their existing condition. The observations made must be comprehensively recorded in the field report to provide the reader with maximum information and site awareness for the inspected flood bunds. The site inspection shall include the following:

1) Crest of Bund

   Major observations to be made over embankment crests are surface cracking, vegetative growth, animal burrow holes or cave-ins, rutting of embankment top, settlement, deterioration of top surface, human interaction, and seepage. Human activity such as pedestrian movement and light traffic at the embankment top must be observed and recorded in field observations.

2) At Riverside Slope

   The inspection of riverside slopes must be made for observations regarding vegetative growth, burrow holes or cave-ins, surface cracking, formation of rainwater gullies, seepage, sediment or debris accumulation if any, scour and erosion, slope protection works and removed stones at riverside slope.

   The inspections made during high flood season must also include visual observations for any generated waves and the wave action on riverside slopes. High water levels during floods can be visually observed and shall be recorded in field report. The post flood inspection must incorporate visual inspections for flood water marks present at the embankment slope. If measurement is made between water mark and embankment top, it provides a site assessment for freeboard encroachment if any.

3) At Landside Slope

   The inspection of landside slopes must include observations for vegetation, animal burrows, surface cracking, rainwater gully formation, settlement, sliding and erosion.

4) Overall Bund Inspection Items

   Some of the most common features that a field inspection team must be vigilant in observing during field inspection are vegetation, burrow holes, surface cracks, rainwater gullies, seepage, settlement, weathering and deterioration, sliding, scour and erosion, damage to protection works, stone removal.

5) Physical Measurements and Geometric Conditions Observations

   The inspection team shall take the physical measurements and observe the geometric conditions of the flood bunds and observe the top width, riverside and landside slope lengths, embankment height, top and bed levels, back berm top level (if provided), back berm width (if provided) and draw the sketch of inspected flood bund section on the field inspection sheet. A sample of the check list, field observation sheet and site inspection report are provided in NFPP-IV at table 7.3 and 7.4 respectively.

6) Human Interaction and Activity

   The inspection of bunds will vary from one site to another. Human interaction and activity are always present on bunds mostly at crest in form pedestrian or any light traffic. At landside of flood bunds, the activity is mostly considerable as residences are made and land is used for cultivation by locals. Apart from the afore-mentioned, other observations and field findings during inspection must be included in the field report. Photographs must be taken during field inspection and included in field report for all inspected sections. A set of guidelines for the identification of problems in flood

protection structures and erosion protection works along with their cause and concern are provided in **Table 3.5.9** below:

Table 3.5.9 Guidelines for Identifying Problems in Flood Protection Structures

Sr.#	Problem	Observation	Cause	Concern
1.	Overtopping or Loss of Freeboard	- High water surface profile is within the freeboard allowance - Evidence of slumps, sinkholes, slides	- Aggradations of the channel bed - Channel blockages; logs, etc. - Settlement of structure	- Reduced freeboard creating a potential for overtopping
2.	Settlement	- Uneven surface of the crest or slopes - Depressions with gently sloping bowl-like sides	- Internal erosion of the embankment material - Prolonged erosion from wind or water - Poor construction practices, poorly compacted fill, organic material line fill - Foundation consolidation	- Creates areas of structural weakness - Loss of freeboard from settling can create the potential for overtopping
3.	Sinkholes	- Hole in the structure surface - Depression with steep bucket-like sides	- Animal burrows - Internal erosion from seepage piping - Foundation problems such as rotting stumps or other wood debris	- Weakens the structure fill by decreasing the length of the seepage path - Provides an entrance point for surface water - Can pose a danger to vehicular and pedestrian traffic - May signal collapse and/or instability
4.	Seepage/Piping (Wet Areas)	- Turbid (dirty) or cloudy seepage water - Water or wet areas near the toe or on structure slope - Localized or lush vegetation on structure slopes or adjacent to the structure - Increase in seepage flow rates different from past patterns	- Excessive flow of water through the structure fill or through the foundation material - Surface water entering through cracks, sinkholes, animal burrows, along the outside surface of conduit	- May cause slope instability which can lead to failure - Turbid (dirty) seepage water is an indication that piping may be occurring and may result in a piping failure of the foundation and ultimately the embankment
5.	Boils	- Water upwelling on landside of structure, near toe or further away - Upwelling may form cone-shaped 'volcanoes'	- A weak layer of sand or gravel in the foundation material is being charged by hydraulic pressure produced during high water conditions - A concentrated seepage path or pipe has developed through the foundation	- May be an early sign of piping
6.	Desiccation/ Drying Crack	- Random, honeycomb pattern	- Embankment material expands and	- Provides an entrance point for surface water

Source: The Design Criteria of NFPP-IV

Sr.#	Problem	Observation	Cause	Concern
		of cracks along the embankment	contracts with alternating wet and dry weather - Embankment fill with high fines content and/or inadequate compaction	which can saturate the crest material - May affect durability of the crest in wet weather
7.	Transverse Cracking	- Cracks extend across the crest perpendicular to the protection work length	- Uneven movement between two adjacent segments of the embankment - Instability of the embankment or foundation material - Differential settlement	- Provides an entry point for surface water - Creates an area of structural weakness which could result in further movements or failure - May create a seepage path and/or a potential piping failure
8.	Longitudinal Cracking	- Cracks extend roughly parallel to the length of structure	- Uneven settlement within the foundation or embankment - Initial stage of a slope failure or embankment slide	- Possible instability - Can lead to future movements or failure (breach) - Provides an entry point for surface water which can promote movement - Often reduces the effective crest width
9.	Slope Instability (earthen)	- Displaced material on structure slope - Bulges along the embankment slope or toe - Area above the bulge shows cracking or scarps - Excessive moisture or softness upon probing the bulge - Arc-shaped crack (beginning of a slide) - Evidence of settlement - Slides (shallow or deep-seated)	- Tree logs and wave erosion creating vertical slopes - Steep slopes left unsupported by erosion - Embankment fill becomes saturated during high water followed by rapid drop in water levels - Slope too steep for type of embankment material to allow freed raining	- Direct threat to the integrity of the structure - possible breaching - Provides an entry point for surface water which can promote movement - Often reduces the effective crest width
10.	Stone Work (Spur, Stud, Stone Pitching and Launching of Apron)	- damaged apron - damaged stone pitching at toe near apron - settlement of stone pitching at slope	- Excessive scour - Wave action - Poor earthwork or stone work	- Stone apron and stone pitching may collapse - Excessive seepage and piping
11.	Surface Erosion and Rutting	- Evidence of material loss from structure surface - Wheel tracks, animal tracks - Scarring of structure surface - Pooling of water on crest	- Livestock or human traffic - Surface runoff over erodible material -	- Encourages further erosion - Can decrease cross-sectional width and weaken the embankment

Source: The Design Criteria of NFPP-IV

Sr.#	Problem	Observation	Cause	Concern
12.	Unauthorized Construction or Activities	- Embankment material disturbed or removed - New ponds, holes or foundations dug close to the structure	- Uninformed or illegal construction practices	- Otherwise competent system can be compromised by a single unauthorized action - Can block or hamper access - Often hides defects such as poorly compacted fill around a newly placed or repaired conduit increasing the chance of seepage - Can encourage boils or slumping and reduce top width - Can encourage boils and failure from piping
13.	Uncontrolled Vegetation Growth	- Vegetation obscures ability to detect cracks, seepage or other problems	- Lack of maintenance	- Root systems can provide seepage conduits - Rotting root systems weaken the embankment - May prevent emergency access - Provides a habitat for unwanted burrowing animals - Wind throw or uprooting of trees can create holes and weakness
14.	Animals/ Rodent Activity	- Rodent holes, burrows and tunnels - Animal trails - Fallen trees (beaver activity)	- Burrowing animals including bank beavers	- Can weaken the embankment - cause sinkholes and piping - Potential vehicle access restrictions if unchecked
15.	Toe Scour	- Loss of earthwork or stone work from structure slope - Loss of stone from apron - Eddying at the structure to	- Inadequate apron/material size - Shift in flow impact angle due to formation of log jams, shifting river bed materials or man-made obstacles	- Loss of erosion protection material leaving the embankment materials vulnerable to erosion and possible breaching
16.	Changing River Flow Patterns	- Dramatically altered flow pattern of the river - Areas of impingement on the protection work altered - Channel obstructions in the vicinity	- Landslides - Log jams - Gravel accumulations - Man-made obstructions - Natural meander progression and/or formation of cut-offs	- Additional erosive forces applied against existing bank protection works increasing the chance of its failure - Direct flow against sections of the flood protection system not previously subjected to erosion. If not already armoured, could lead to

Source: The Design Criteria of NFPP-IV

Sr.#	Problem	Observation	Cause	Concern
				rapid loss of embankment fill - Outflanking of existing works at upstream end
17.	Bed Degradation	- River channel scouring adjacent and roughly parallel to the erosion protection - Damaged apron and damaged toe of slope	- Changing river currents and high water levels - Deepening of the riverbed in the reach near the structure - Insufficient design or construction of toe protection	- The erosion protection material is vulnerable to undermining and collapse exposing the earthen portion of bank
18.	Outflanking	- River erosion upstream of hard point or key trench	- Erosion protection not extending far enough upstream - Erosion protection not extended to a hard point at the upstream end - Weak upstream key (poor design) - Sudden change in river flow pattern	- Rapid loss of erosion protection material leaving the embankment fill vulnerable to erosion - Exposure of unprotected fill to erosive forces
19.	Overbank Erosion	- Reduced riverbank area - Progressive erosion	- Reduced distance from the structure fill to the river channel due to changing river currents - Natural meander progression - Lack of erosion protection on set-back area	- Threat to embankment stability - Undermining of embankment
20.	Degrading (Weathering)	- Disintegration of stonework - Cracks, spalling, crumbling of stone material - Hollow sound on rock hammer testing	- Chemical or mechanical deterioration of the erosion protection material often accelerated by wave action.	- Widespread weakening of erosion protection material leaving the embankment fill more susceptible to erosion -
21.	Uncontrolled Vegetative Growth	- Vegetation obscuring inspection - Large vegetation and trees on fill - Tree uprooting on riprap - Tree blow down across structure	- Lack of regular vegetation management - Poor maintenance procedures	- Can obscure serious problems which may exist - Tall trees with large root systems can displace large amounts of erosion protection material when forced over by wind, or high water

Source: The Design Criteria of NFPP-IV

7) Field Equipment Requirements

Equipment requirements vary depending on the type of inspection to be carried out and the expected condition at site. Equipment requirements for inspections are provided in the following **Table 3.5.10**:

Table 3.5.10 Equipment Requirements for Field Inspection

Sr.#	Type	Purpose
1.	Inclinometer	Measuring the degree of slope
2.	Measuring tapes	Measuring dimensions of features or abnormalities
3.	Chain	Measuring longer distances
4.	Rock Hammer	Sounding concrete or rock to check quality and checking for pipe corrosion
5.	Shovel	Minor clearing, taking soil samples
6.	Torch Light (flashlights)	For clear observations at dark areas
7.	Probe (steel rod)	Probing wet, soft areas, sinkholes, and voids

Sr.#	Type	Purpose
8.	Bucket and timer	Measuring seepage and other flow rates
9.	Sounding lines or tapes	Measuring water depths
10.	Camera	Taking photographic records
11.	Water sample containers	Obtaining water samples
12.	Sample bags	Obtaining soil or rock samples
13.	Level, rod and tripod	Obtaining accurate elevations and heights
14.	Clipboard and record keeping material	Recording inspection observations
15.	G.P.S. Device	Measuring position of the object

Source: The Design Criteria of NFPP-IV

(9) Inspections

Table 3.5.11 shows different types of inspections being carried out throughout the year.

Table 3.5.11 Field Inspections for Flood Protection Structures

Sr. No.	Inspection	Description
1	Regular Inspection	These are routine inspections to identify the problems early and must be carried out weekly.
2	Annual Inspection	At least once a year prior to high flow season, the entire flood protection system should be inspected in detail.
3	Low Water Inspection	Should be undertaken each year when the river water levels reach their lowest annual levels.
4	Special Inspection	Maybe needed to monitor and react to particular situations such as storms, reports of vandalism, or construction activity on or near the structure.
5	High Water Patrol Inspection	Should be carried out during high water events to monitor the performance of the flood control works due to increased hydraulic pressure (seepage, boils, etc.), increased erosion potential, and chance of reduced freeboard.
6	Post-Flood Inspections	A complete high-water profile along the structure should be obtained after significant flow events to assess the structure crest level and the amount of freeboard.
7	Post-Earthquake Inspections	This type of inspection should be integrated with local emergency plans.
8	Flood Retaining wall Inspection	Prior to floods season, routine inspections must be carried out to observe signs for initiation of problems. During flood season, monitoring will be required to observe the satisfactory performance of these structures. A post flood inspection must be carried out to identify areas for maintenance and repair.

Source: JICA Project Team summarized from the Design Criteria of NFPP-IV.

(10) Bund Breach

1) Natural Breach

When the flood embankment is breached naturally due to some damage such as erosion, rodent holes, poor maintenance of wetting channel or failure of subsurface of embankment. This is unplanned breach.

2) Artificial Breach

Artificial breaches are provided to cater a situation where flood endangers the safety of hydraulic structures and bridges such as barrages, headworks, bridges. This is a planned breach and are provided to cater a situation where flood endangers the safety of hydraulic structures and bridges such as barrages, headworks, bridges. Taunsa Barrage is an exception and does not have breach section due to canals on both sides.

(11) Limitations of NFPP-IV Design Criteria

Following limitations of NFPP-IV Design criteria are observed.

- The degree of compaction for the bunds are not mentioned. At least, a minimum compaction level should be defined.
- The gradation and type of the material is not defined. At least the gradation envelops shall be defined for different typical cases.
- For the slope stability of the bunds, berm should be provided. Based on the height, slope of the bund, type of construction material and degree of compaction, the berm provision should be discussed, and a general guideline shall be developed.
- As there is no discussion on the degree of compaction and the gradation of the material, the hydraulic gradient as 1V:6H shall be reconfirmed / redefined using the design procedure or from the software.
- Some discussion and criteria for the sour depth should be mentioned.
- For testing of the construction material, it is mentioned that test pits / bore holes shall be carried out but any criteria for to pass the material or standard is not mentioned.
- Operating Basis Earthquake (OBE), Maximum Considered Earthquake (MCE) seismic criteria for slope stability are not mentioned.

3.6 Comparison Analysis on the Manual

3.6.1 Comparison of the Manuals between Sindh and Punjab

(1) Definition of a Bund

The Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab have almost the same definition. Both define a bund as an earthen embankment to protect the land from inundation during flood.

(2) Standard Shape of a Bund

Sindh and Punjab have different dike typologies (Main Bund and Trench Bund in Sindh, Marginal Bunds, Bunds Protecting Strategic Locations, and Bunds Along Open Reaches of the Rivers in Punjab[10]). Both provinces also specify different basic shapes for each type of bund. Additionally, in the Manual of Irrigation Practice in Punjab, minimum and desirable values are shown for each item. The minimum value is the parameter currently prescribed by FFC and don't have been changed for 40 years. In light of this, the desirable value is the recommended parameters based on empirical thoughts by the province of Punjab. Therefore, it is difficult to make a pure comparison between Sindh and Punjab, but each item is organized as follows. Although extra embankment is not mentioned in Punjab, it has a value on the safe side compared to Sindh. The reason for this seems to be that the Bund Manual in Sindh was published in 2008, while the Manual of Irrigation Practice in Punjab was updated in 2017, after the 2010 flood. The Bund Manual in Sindh needs to be updated in light of the 2010 flood.

[10] Punjab also has other categories Marginal Bunds, Flood Bunds, Retired Bunds, and C.

1) Crest Width

Crest width is listed in Both Sindh and Punjab, but the descriptions differ. The crest width in Sindh is 10 to20 ft and that in Punjab is 25 ft (minimum)/ 25 to 30 ft (desirable). Punjab specified a wider width.

2) Side Slope (River Side)

Side slope (river side) is listed in Both Sindh and Punjab, but the descriptions differ. Sindh specifies different slopes depending on height of a bund for each type and the slope is 3:1 to 4:1. Punjab specifies slopes without considering the height of a bund and the slope is 3:1(minimum)/ 3:1 to 4:1(desirable).

3) Side Slope (Landslide Side)

In Sindh, the slope without berm is 3:1, the slope of the berm is 6:1, and the upper part of berm is 2:1. In Punjab, the slope without berm 2:1(minimum)/ 2:1 to 3:1(desirable), the slope of the berm is the same as in Sindh, and the top of the berm is not specified.

4) Berm

Berm is listed in Both Sindh and Punjab, but the descriptions differ. The width is 5ft in Sindh and is set to cover the hydraulic gradient line in Punjab[11].

5) Freeboard

The freeboard in Sindh is 2 to4 ft and that in Punjab is 6 ft (minimum)/ 7 ft or as determined by analysis whichever is greater (Desirable). About this, the latest Bund Manual in Sindh was issued in 2008 and it is before the 2010 flood. When the HFL in the 2010 flood is considered in the future revision, the freeboard specified in the Bund Manual in Sindh is expected to be increased.

6) Extra Embankment

This item is only described in the Bund Manual in Sindh. It is recommended for the Manual of Irrigation Practice in Punjab to describe this item based on the description of the manual in Sindh.

(3) Quality Control

Quality control is described only in the Bund Manual in Sindh. It is recommended for the Manual of Irrigation Practice in Punjab to include this item based on the description of the manual in Sindh.

Furthermore, it is necessary for the manual in Punjab to add the specifications of the embankment material.

(4) Service Road/ Maintenance Road

This item is not mentioned in the manual in Sindh and in Punjab. It is recommended for both manuals to describe this item based on manuals in other countries in order at least to secure the better access for the O&M.

(5) Safety Evaluation

Although the method for evaluating the safety on erosion is not described, the Manual of Irrigation Practice in Punjab has the detail description about other items compared to the Bund Manual in Sindh. The comparison about each item are as follows:

1) Slope Stability

The concrete method to evaluate the safety for slope stability is described only in the manual in

[11] The hydraulic gradient line should be lie at least 2ft below natural surface level at the toe of the bound and covered with soil at least 4 ft thick.

Punjab. It is recommended for the manual in Sindh to include this item based on the description of the manual in Sindh.

2) Erosion

The method for evaluating safety against erosion is only described in the manual in Sindh. In addition, about the scour depth calculation, the Bund Manual in Sindh introduced in the methods based on the highest discharge, on the other hand the Manual of Irrigation Practice in Punjab described the detail methods based on the river characteristics such as riverbed materials and river gradient. Therefore, it is recommended for the Bund Manual in Sindh to describe the concreate methods of scour depth calculation based on the Manual of Irrigation Practice in Punjab[12], furthermore the Punjab is recommended to include the method for safety evaluation like the manual in Sindh.

3) Seepage Control

There is no description of seepage control in the manual in Sindh, while the Manual of Irrigation Practice in Punjab describe the seepage through the bund body and the foundation stability. About the seepage through the bund body, the manual introduces the concreate method for the safety evaluation. However, about the foundation stability, only survey items such as permeability and density are introduced, and no specific safety evaluation methods are presented. Therefore, the Bund Manual in Sindh is recommended to add the seepage through the bund body like the Manual of Irrigation Practice in Punjab, and both manuals need to describe the foundation stability with reference to the other countries' manuals.

4) Seismic Condition

This concreate method to consider seismic condition is only described in the Manual of Irrigation Practice in Punjab. The Bund Manual in Sindh is recommended to describe this item based on the description of the manual in Punjab.

(6) Improvement of a Bund

Table 3.6.1 shows major bund improvement methods introduced in each manual. About the countermeasure against slope failure and erosion, similar types of methods are introduced in both standards.

Table 3.6.1 Major Bund Improvement Methods introduced in Each Manual

Item	Bund Manual (Sindh)	Manual of Irrigation Practice (Panjab)
Slope Failure	・ Expansion of the Rear Section to Cover the Saturation Line ・ Mangli or a Ring bund ・ Installation of Drainage Material	・ No countermeasures[13]
Erosion	・ Stone Spurs and Stone Aprons(for Foot Protection) ・ Revetment ・ Cemented Stabilized Soil Revetment ・ Tree Groynes ・ Bandelling	・ Stone Spurs and Stone Aprons(for Foot Protection) ・ Revetment[14]; Stone Pitching, Soil Cement Cover, Cement Concrete Paving, and so on. ・ Geotextile Filter ・ Gabion ・ Stubs
Seepage Flow	・ Proper Choice of Earth Fill ・ Apply the Standard Section ・ Installation of Drainage Material at the Land Side Toe	<For a Bund Body> ・ Installation of Drainage Material; Pervious Toe Drain, Horizontal Drainage Layers, and Inclined Drainage Layers

[12] The Sindh manual also introduces the method of sour depth calculation. However, this is determined by the based on the historical highest discharge.

[13] The Punjab manual introduced a installation of drainage material which improve safety on slope stability by reducing the water level in the bund body as the countermeasure for seepage flow.

[14] In the Punjab manual, revetment is introduced by the term slope protection.

Item	Bund Manual (Sindh)	Manual of Irrigation Practice (Panjab)
	・ Expansion of the Rear Section to Cover the Saturation Line	・ Land Side Seepage Berms* <For Foundation Ground> ・ Cut-off Trench ・ River Side Impervious Blankets ・ Pervious Toe Trenches ・ Pressure Relief Wells ・ Land Side Seepage Berms ・ Reworking of the Foundation Soil ・ Grouting of the Armored River Bed to the Required Extent ・ Inverted Filter or Geo-textile Layer at the Foundation of Revetment / Gabion Hydraulic Structure ・ Where Required, Provision of a Suitable Cut-off

Note) Land Side Seepage Berms is almost the same as Expansion of the Rear Section to Cover the Saturation Line*
Source: JICA Project Team extracted from the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab

About slope stability, the Manual of Irrigation Practice in Punjab has no clear description on the improvement methods and is strongly recommended additionally introduce the improvement method as well as the Bund Manual in Sindh.

About erosion, the Tree Groynes and Bandelling are only introduced in the Bund Manual in Sindh and Stone Pitching, Geotextile Filter, Gabion, and Studs are only listed in the Manual of Irrigation Practice in Punjab. These measures need to be added to the Bund Manual in Sindh also to cover a wide range of improvement methods. As for the design methods of the improvements, Stone Spurs and Stone Aprons are introduced in both manuals, Stone Pitching is listed only in the Manual of Irrigation Practice in Punjab, and the other are not mentioned in either. Thus, both manuals are needed to add the design methods with reference to other countries' manuals.

About seepage flow, the countermeasures in the Bund Manual in Sindh are only for a bund body, and there are no countermeasures for a foundation. In Punjab, countermeasures both for a bund body and a foundation are described. Countermeasures for a bund body are generally the same in both the Bund Manual in Sindh and Punjab manual. As for the design methods of the improvement, the width of bunds is mainly introduced, and other types are not described in both provincial manuals. Adding the improvement method for seepage cut-off is necessary.

Based on the above, the Bund Manual in Sindh is recommended to additionally include countermeasures relating to a foundation based on the Manual of Irrigation Practice in Punjab, and both provincial manuals have to additionally describe design methods with reference to guidelines from other countries.

(7) Revetment

The Bund Manual in Sindh and Punjab manual list stone apron and various material which shown in **Table 3.6.2**. In the Bund Manual in Sindh, gabions are not included as a type of revetment.

Table 3.6.2 Types of Revetments and Materials in the Sindh and Punjab Manual

Material	Bund Manual in Sindh Slope : 3:1 to 2:1	Manual in Punjab Slope : 3:1 to 2:1
Stone	・ Stone Masonry Pitching	・ Dumped Stone Rip-Rap ・ Hand placed Rip-Rap
Wood	・ Brushwood Pitching Including Alternate Layers of Earth ・ Muharis, Single or Double ・ Lai Groynes (single)	・ Weave in the form of mat made from Pilchi, Sarkanda or brush* ・ Pilchi Rolls* ・ Pilchi Pitching* ・ Longitudinal Stakes and Bushing Protection*
Gabion	-	・ Gabions

Material	Bund Manual in Sindh Slope : 3:1 to 2:1	Manual in Punjab Slope : 3:1 to 2:1
Mat, Sheet	・ Lai Mats Including Fixing ・ Date Mats Including Fixing	・ Khaji Mats* ・ Geotextile Filter
Cement, Concrete	・ Cemented Stabilized Soil Revetment	・ Soil Cement Cover ・ Cement Concrete Paving ・ Asphaltic Concrete ・ Porous Concrete Slab
Other	・ Burnt Brick Masonry Pitching	・ Brick Ptiching

Note) The "" mark means the type introduced as Temporary (Limited Duration) Measures*

Source: JICA Project Team extracted from the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab

Among the revetment type listed in the manuals, the Bund Manual in Sindh states the concrete design method only for the stone apron, while the Manual of Irrigation Practice in Punjab describes the standard cross section of gabions and the concrete design method for stone apron and stone pitching. Although the stone apron is listed in both manuals, the design methods are different between them as shown in Table 3.6.3. The Bund Manual in Sindh have larger design value for the same scour depth, although the calculation methodology for the scour depth differs. In addition, the description of the design method of stone apron in the Bund Manual in Sindh is easy to understand because it has the example and describes only one equation compared to the Manual of Irrigation Practice in Punjab which does not have the example and listed old formulas that are not used now.

Table 3.6.3 The Design Method of Stone Apron in the Sindh and Punjab Manual

Material	Bund Manual in Sindh	Manual in Punjab
Quantity Stone(Qs)	$Q_s = 3 \times \sqrt{D^2 + 9D^2}$* Where, D is Scour Depth	$Q_s = 8.5D$ Where, D is Scour Depth
Length in which stone is laid (L)	$L = 2.5\ D$	$L = 1.5\ D$
Thickness of stone apron (T)	$T = 3.5$	$T = 1.3 \sim 4.4$**

Note) In the Bund Manual in Sindh, the formula of Qs states $Q_s = 3 \times \sqrt{D^2 + 3D^2}$, but it is does not match the calculation case. Thus, JICA project Team considered $Q_s = 3 \times \sqrt{D^2 + 3D^2}$ to be correct from the calculation case.*

*** T is determined by Scour Fall Size and Stone Material , and the table showing thickness value is listed in the Manual of Irrigation Practice in Punjab.*

Source: JICA Project Team extracted from the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab

Therefore, it is recommended for the Bund Manual in Sindh to include gabions, their basic design, and the design method for stone pitching referring to the Manual of Irrigation Practice in Punjab, it is desirable for the Manual of Irrigation Practice in Punjab update the presentation of the design method of stone apron with reference to the Bund Manual in Sindh, and both provincial manuals are recommended to add concrete design methods for other types except for stone apron with reference to guidelines from other countries.

(8) Spur (Stone Groyne)

About the site condition in which the spur is needed, the Bund Manual in Sindh describes where there is a high risk of erosion but not available land for loop bund on the land side. On the other hand, the Manual of Irrigation Practice in Punjab doesn't mention about such allowance in the land side.

The basic shape and design method are described only in the Manual of Irrigation Practice in Punjab. The Manual of Irrigation Practice in Punjab shows the typical cross section, various types of spurs, and recommended space between them, although it mentions that the length and angle are determined by the physical model studies. Therefore, the Bund Manual in Sindh is recommended to add the contents on the basic shape and design method with reference to the Manual of Irrigation Practice in Punjab.

(9) Construction Works

This item is described only in the Bund Manual in Sindh. The Manual of Irrigation Practice in Punjab is recommended to incorporate this item with reference to the Bund Manual in Sindh.

(10) Management Plan

In the Bund Manual in Sindh, "Pre-abrakani Maintenance" and ordinary maintenance is stated, but there is no mention on middle and long-term management plan. Also, the maintenance stated in the manual looks focusing on a single year activity.

In the Manual of Irrigation Practice in Punjab, the asset management plan is introduced, and it assumes the long-term plan. However, it is difficult to develop the long-term plan based on only this manual because there is no description of when to repair.

Furthermore, in both manuals, the contents of the inspection seem at the level of first aid measures and repair of damaged areas, and do not have comprehensive perspective.

Therefore, in order to develop long-term management plan, it is recommended for both manuals to additionally describe the concrete methods for management plan with reference to other countries guidelines.

(11) Monitoring of River Conditions

Table 3.6.4 shows the summary of monitoring contents in the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab.

Table 3.6.4 Summary of the Monitoring Content in the Manual in Sindh and Punjab

Item	Bund Manual (Sindh)	Manual of Irrigation Practice (Punjab)
Patrol	・ Timing	・ Timing
Physical Inspection	・ Timing ・ Inspection Item	・ Timing ・ Inspection Item ・ Survey Team Member ・ Responsibility Person
Inspection with equipment / investigation / exploration	・ No description	・ No description[15]
Inspection Report / Damage Record	・ No description	・ Contents and Schedule
Analysis / Evaluation	・ No description	・ Review According to the Latest Design Methods ・ Suggest Action to Withstand the Accepted Probable Maximum Flood

Source: JICA Project Team extracted from the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab

About Patrol, both manuals describe the patrol timing. Both manuals need to introduce the patrol items with reference to guidelines in other countries.

About physical inspection, the Bund Manual in Sindh describes the survey timing and survey items, while the Manual of Irrigation Practice in Punjab describes these as well as the responsible person and survey team composition. The Bund Manual in Sindh is recommended to add the missing items with reference to the Manual of Irrigation Practice in Punjab.

About inspection with equipment / investigation / exploration, there is no description in both manuals. It is desirable for both manuals to additionally introduce this item with reference to guidelines in other countries.

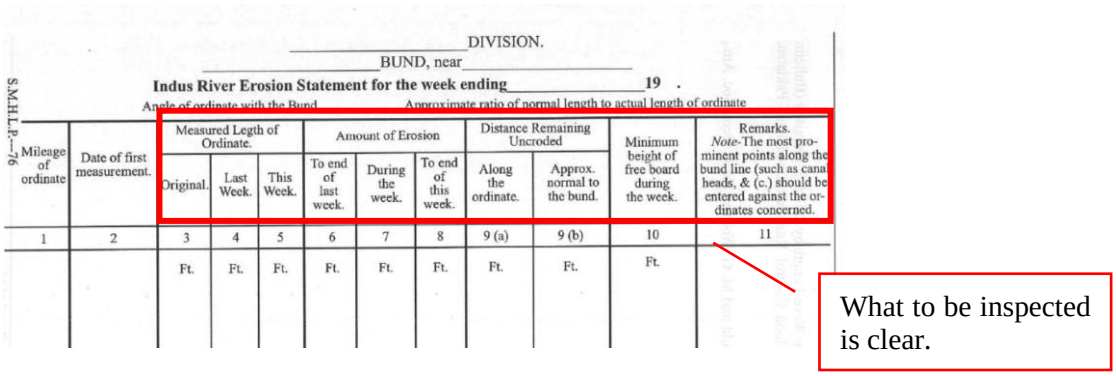
About Inspection Report / Damage Record and Analysis / Evaluation, there is a concrete description only in the Manual of Irrigation Practice in Punjab. It is recommended for the Bund Manual in Sindh to include them.

[15] Although it is not intended for monitoring, Geophysical investigations with ground penetrating radar is introduced as investigation items for planning the bund.

(12) Inspection and Ledger

1) Bund

The Bund Manual in Sindh has prepared a ledger for each item, such as erosion and seepage, and what to inspect in each item is clear. Punjab, on the other hand, has only one checklist that includes only outline with all items, and it is unclear what should be inspected in some items. In order to make the contents of each item clear, the Manual of Irrigation Practice in Punjab is recommended to add ledgers other than the outline of the bunds. Also, since it is unclear what should be input for each item, it is also recommended to improve the ledgers of the bunds.



_____DIVISION.
_____BUND, near _____
Indus River Erosion Statement for the week ending_____19 .
Angle of ordinate with the Bund Approximate ratio of normal length to actual length of ordinate

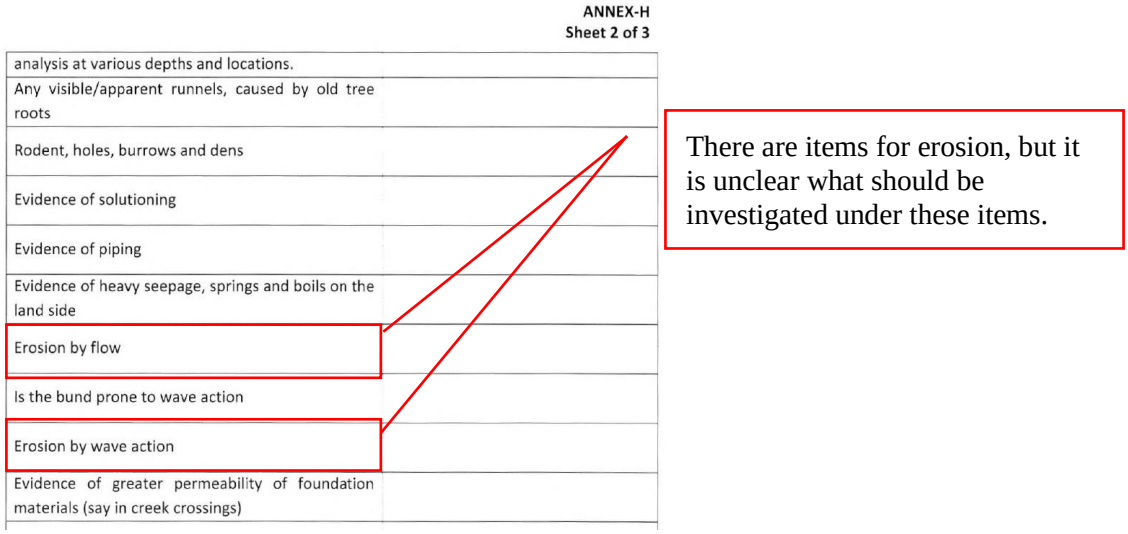
S.M.H.L.P.—76

Mileage of ordinate	Date of first measurement.	Measured Legth of Ordinate.			Amount of Erosion			Distance Remaining Uncroded		Minimum beight of free board during the week.	Remarks. *Note*-The most pro-minent points along the bund line (such as cana heads, & (c.) should be entered against the or-dinates concerned.
		Original.	Last Week.	This Week.	To end of last week.	During the week.	To end of this week.	Along the ordinate.	Approx. normal to the bund.		
1	2	3	4	5	6	7	8	9 (a)	9 (b)	10	11
		Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	

What to be inspected is clear.

Source: JICA Project Team added on the Manual of Irrigation Practice in Punjab

Figure 3.6.1 Excerpt of the Ledger in the Bund Manual in Sindh



ANNEX-H
Sheet 2 of 3

analysis at various depths and locations.
Any visible/apparent runnels, caused by old tree roots
Rodent, holes, burrows and dens
Evidence of solutioning
Evidence of piping
Evidence of heavy seepage, springs and boils on the land side
Erosion by flow
Is the bund prone to wave action
Erosion by wave action
Evidence of greater permeability of foundation materials (say in creek crossings)

There are items for erosion, but it is unclear what should be investigated under these items.

Source: JICA Project Team added on the Manual of Irrigation Practice in Punjab

Figure 3.6.2 Excerpt of the Ledger in the Manual of Irrigation Practice in Punjab

2) River Channel

Following survey and inspection items are listed in the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab respectively, although any ledger or form is not described and introduced in both manuals.

- Sindh: River Course.
- Punjab: River Course, Erosion, and Bathymetry Survey[16]

[16] The survey area is not mentioned but it seems to be around a barrage like River Course and Erosion.

Furthermore, concrete methodology for surveying and inspecting these items is not introduced in both manuals. Also, the inspection of river course and erosion in Punjab is limited to around the barrage. From the above, it is recommended for the Bund Manual in Sindh to add the inspection and survey items of erosion and bathymetry and both manuals need to describe concrete methodology for inspecting with reference to other countries guideline. Also, the Panjab manual is recommended to expand the area of river course inspection and erosion to the entire stretch of the rivers, as they are basic information for maintaining the bund.

3) Storage

There is no description of storage in the Bund Manual in Sindh. The Panjab manual states that the sub-divisional officer in charge of the barrage has the responsibility of checking and initiating all the data record regularly at prescribed intervals. However, it is unclear whether the check list for bund safety inspection is stored or not because the manual does not indicate the document to be stored and the responsible person is the staff in the barrage.

From the above, the Bund Manual in Sindh needs to state the methodology for storage with reference to the Manual of Irrigation Practice in Punjab, and both manuals have to clearly describe the type of reports to be stored.

(13) River Ledger

1) River Ledger

Although a river leger is not included in both Sindh and Punjab manuals, the Bund Manual in Sindh introduces the list showing the outline of a bund which is helpful for many people to roughly understand the characteristics of the bund. The Manual of Irrigation Practice in Punjab is recommended to include them with reference to the Bund Manual in Sindh.

2) Storage

This item is not described in both manuals. It is desirable for both manuals to additionally mention it.

(14) Breach

1) Cause of Breach

The same cause of breach is listed on both Sindh and Punjab manuals. Also, the Manual of Irrigation Practice in Punjab states the main cause of breach in addition to introduction of the cause.

2) Artificial Breach

This item is only listed in the Manual of Irrigation Practice in Punjab. The reason for that seems that there is no designated breach point or officially announced breach point in the province of Sindh.

3) Immediate Action

The contes are almost same in both manuals. The only difference between the two is whether or not mileage is listed as the report item.

4) Close of breach

The contents are completely same in both manuals.

(15) Summary

The analysis results are summarized in Table 3.6.5 indicated in the following pages.

Table 3.6.5 Comparison of the Manuals between Sindh and Punjab

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Definition of a Bund	Definition		1	Chapter I, Glossary of terms used in connection with River Bunds in Sindh, Page 3 of 15	・ An earthen embankment parallel to the river banks ・ To protect the country from inundation by the river spill, during floods	VOL.2 : Chapter 2 3, p185	・ An earthen man-made embankment ・ To provide protection from inundation and act as a barrier between flood water and protected area.	・ Both manuals define a bund as an earthen embankment to protect the land from inundation during flood.
Standard Shape of a Bund	Crest Width		2	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Main Bund: 20 ft(=6.1m) ・ Trendh Bund: 10 ft (=3.05m)	VOL.2 Chapter 2 4.3.1.3, p187 to 189	・ Marginal Bunds: 25 ft(=7.6m) (Minimum)/30 ft(=9.1m) (Desirable) ・ Bunds Protecting Strategic locations: 25 ft(=7.6m) (Minimum)/30 ft(=9.1m) (Desirable) ・ Bunds along open reaches of the rivers: 20 ft(=6.1m) (Minimum)/25 ft(=7.6m) (Desirable) *The minimum value is the parameter currently prescribed by FFC and don't have been changed for 40 years. The desirable value is the recommended parameters based on empirical thoughts by the province of Punjab.	・ Punjab specified a wider width.
	Side Slope	River side	3	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Bund: 3:1 ・ Medium Bund: 3:1(8ft to 12ft in Height) to 4:1(12ft to 13ft in Height) ・ High Bund: 3:1(12ft to 13ft in Height) to 4:1(Over 13ft in Height)	VOL.2 Chapter 2 4.3.1.3, p187 to 189	Earthen ・ Marginal Bunds: 3:1(Minimum)/4:1(Desirable) ・ Bunds Protecting Strategic locations: 3:1(Minimum)/4:1(Desirable) ・ Bunds along open reaches of the rivers: 3:1(Minimum)/3:1(Desirable) Protected ・ Marginal Bunds: 2:1(Minimum)/3:1(Desirable) ・ Bunds Protecting Strategic locations: 2:1(Minimum)/3:1(Desirable) ・ Bunds along open reaches of the rivers: 2:1(Minimum)/2:1(Desirable)	・ Sindh specifies different slopes depending on height of a bund for each type. ・ The range of slope in the earthen type is 3:1 to 4:1 in both.
		Land side	4	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Bund,: 3:1 without Berm ・ Medium Bund: 3:1 without Berm ・ High Bund: 2:1(Top to Back Berm), 6:1(Berm to Ground)	VOL.2 Chapter 2 4.3.1.3, p187 to 189 VOL.2 Chapter 2 6.2.4, p205 to 20	・ Marginal Bunds: 2:1(Minimum)/3:1(Desirable) ・ Bunds Protecting Strategic locations: 2:1(Minimum)/3:1(Desirable) ・ Bunds along open reaches of the rivers: -/2:1(Desirable) ・ Berm: 6:1	・ The slope of berm is same in both. ・ The slop without berm is 3:1 in Sindh and 2:1 to 3:1 in Punjab.
	Berm		5	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	High Bund ・ River Side: Not Specified ・ Land Side: 5 ft(=1.53m) *8 to 9 ft below from the top depending on the front slope	VOL.1 Chapter 5, 5.4.9.8, p5-69, VOL.2 Chapter 2 6.2.4, p205 to 206	・ Back berm (Pushta) (on landside) is provided to keep the hydraulic gradient within the cross-section. ・ The hydraulic gradient line should be lie at least 2ft below natural surface level at the toe of the bound and covered with soil at least 4 ft thick.	・ The width is 5ft in Sindh and is set to cover the hydraulic gradient line in Punjab.
	Freeboard		6	Chapter V, Page 5 of 18 33. Freeboard Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Main Bund: 4 ft(=1.22m) ・ Trendh Bund: 2 ft(=0.61m) *To allowing for a fair factor of safety for sudden unforeseen rise of water level such as wave, shortening of rive course.	VOL.2 Chapter 2 4.3.1.3, p187 to 189 and Chapter 2, 6.2.1, p198 to 200 VOL.1 Chapter 5, 5.4.9.2, p5-60,	・ Marginal Bunds: 6 ft(=1.8m)(Minimum)/ 7.0 ft (=2.1m)or as determined by analytical analysis whichever is greater(Desirable) ・ Bunds Protecting Strategic locations: 6 ft(=1.8m)(Minimum)/ 7.0 ft (=2.1m)or as determined by analytical analysis whichever is greater(Desirable) ・ Bunds along open reaches of the rivers: 6 ft(=1.8m)(Minimum)/ 6.0 ft (=2.1m)or as determined by analysis(Desirable) ・ In the case of analysis, Free board = Wave Run-up + Wind Set + River Set + 1.0 ft *The concreate calculation method of Wave Run-Up, Wind Set-up, and River Set is mentioned.	・ Punjab specified a higher freeboard. ・ The reason for this seems to be that the Bund Manual in Sindh was published in 2008, while the Manual of Irrigation Practice in Punjab was updated in 2017, after the 2010 flood.
	Extra Embank-ment	Levelling of Top of Bunds after Construct-ion.	7	Chapter VI, Page 3 of 14 53. Method of good construction	・ Normal: 12 1/2 % of Deign Height ・ With Scrapers/Foot Roller: 6 1/4 % of Deign Height *In order to allow settlement and compaction	-	No description	・ It is recommended for the Manual of Irrigation Practice in Punjab to describe this item based on the description of the manual in Sindh.
Quality Control	Material	Desirable Material	8	Chapter VI, Page 1 of 14 51. Requisites of suitable soils for bund building	・ The bund is built, as a rule-, of earth obtainable along the line of the bund or from the borrowpits on the river side immediately in front of the bund. ・ Sand mixed with a fair proportion (30 to 40%) of clay is desireble. *The sand in the clay will prevent shrinkage and cracks without destroying the watertightness an toughness of the clay.	-	No description	・ It is recommended for the Manual of Irrigation Practice in Punjab to include this item based on the description of the manual in Sindh.

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
		Available Material	9	Chapter VI, Page 1 of 14 52. Relative Merits of different soils for Bund Building.	· Sand(With 6 inches thickness clay cover): 85% of sand, 10% of silt, and 5% of clay. *Without clay cover, due to the flat saturation, large section is required. · Sand Mixed with Clay: 50-70% of sand, 30-50 of clay *Optimum admixture · Loam(With 6 inches thickness clay cover): 30-50% of sand, 30-50% of silt, and Less than 20% of clay. *Little stability ehwn saturated. · Clay(With Sand Core): 5% of sand, 40% of silt, and 55% of clay. *Bunds, should not be constructed of such soils unless absolutely unavoidable,	-	No description	Same as the above
	Construct-ion Method		10	Chapter VI, Page 10 of 14 60. Specifications for Earth work for River Embankment.	· All earth laid in the embankment shall be free from all roots, grass, sticks or other foreign matter. · The earth shall be deposited and spread in horizontal layers, 6 inches thick, for the full width of the bank. · All clods, and lumps of earth shall be broken up in the borrow pits to a diameter of not more than 2 inches. · To facilitate rolling, the bank shall be carried up in uniform layers of not more than 6 inches in thickness · No fresh layer shall be put on until the previous one has been thoroughly consolidated to the satisfaction of the Executive Engineer or subordinate.	-	No description	Same as the above
	Degree of Compact-ion		11	-	No description	-	No description	· Both manuals are recommended to describe this item based on o manuals in other countries.
Service Road/ Mainte-nace Road			12	Chapter V, Page 18 of 18 50. Fencing.	· Not clearly mentioned. · However, public traffic is not permissible on bunds and fencing is needed.	-	No description	· Both manuals are recommended to describe this item based on o manuals in other countries.
Safety Evaluation	General		13	-	No description	-	No description	-

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Sub Item</th><th rowspan="2">Sub-sub Item</th><th rowspan="2">No.</th><th colspan="2">Sindh</th><th colspan="2">Punjab</th><th rowspan="2">Comments</th></tr>
<tr><th>Technical Codes</th><th>Value/ Contents</th><th>Technical Codes</th><th>Value/ Contents</th></tr>
<tr><td></td><td>Slope Stability/ Slip Circle</td><td></td><td>14</td><td>Chapter V, Page 8 of 18
37. Stability of Section.</td><td>The cross-section is fixed from experience, on consideration of stability under all conditions.</td><td>VOL.1 Chapter 5, 5.4.9.6, p5-62</td><td>・ Slope stability analysis is carried out according to Method of Slices, using Simplified Bishop Method with relevant computer software.
・ The needed information is as followings.
1. Geometry of embankment:
2. Soil properties: Bulk density, Saturated density. Cohesion “c”, Angle of internal friction, Unconfined shear strength, Permeability “k"
3. Design flood level and low water level of the river
4. Phreatic line and pore water pressure
5.Surcharge on the embankment
6.Earthquake loads
・ The calculations are carried out according to the typical cross-section of the embankment for two different geometrical parameters:
1. The river-bed stone apron is intact.
2. The scour of the riverbed is modelled with assumed fully launched stone apron.
・ Loading conditions are “Gravity”, “Seepage (or Pore water pressure), and “Earthquake”.
・ Location of the phreatic line (or hydraulic gradient) in the embankment is determined for the relevant seepage condition at the design flood level, by using Casagrande's solution.
・ Pore water pressure is determined from “pore pressure ratio” and “depth of soil from the top surface”.
・ The potential failure surfaces is analyzed for the following four critical conditions; i) End of construction, ii) Design flood level with steady seepage, iii) Flood draw-down, and iv) Assuming fully launched stone apron.
・ The minimum safety factor is shown in the following table.
<table><tr><th rowspan="2">Condition</th><th colspan="2">Minimum safety factor</th></tr><tr><th>Without earthquake</th><th>With earthquake</th></tr><tr><td>During and end of construction</td><td>1.4</td><td>1.2</td></tr><tr><td>Rapid river draw-down</td><td>1.3</td><td>1.1</td></tr><tr><td>River low flow level</td><td>1.2</td><td>1.0</td></tr><tr><td>Design flood</td><td>1.5</td><td>1.2</td></tr></table></td><td>・ It is recommended for the manual in Sindh to include this item based on the description of the manual in Sindh.</td></tr>
<tr><td></td><td>Erosion</td><td></td><td>15</td><td>Chapter IV, Page 3 of 15
20. Cutting of Erosion Lines and Spacing of Erosion Ordinates.</td><td>・ The following table gives the distance where the erosion ordinates are deemed essential and the distance apart that should be kept between the two consecutive ordinates
<table><tr><th></th><th>Where distance between Bund and pucca edge is</th><th>Distance between two consecutive ordinates</th></tr><tr><td>Above Sukkur</td><td>2 to 3 miles
1 to 2 miles
Less than a mile</td><td>1 mile apart
Half a mile part
One furlong apart</td></tr><tr><td>Below Sukkur</td><td>2 to 3 miles
1 to 2 miles
Less than a mile</td><td>No ordinates
Half a mile apart
One furlong apart</td></tr></table>Where the edge of the pucca bank is less than 3,000 ft. proposals for loop bund should be sent in at once.</td><td>VOL.2 Chapter 2, 5.3, p190</td><td>・ The methods to evaluate the safety is not described. However, the estimate methods for scour depth are mentioned.
・ It is recommended to calculate the depth of local scour, constriction scour, bend scour, and confluence scour by several available methods and then use engineering judgment to select the preferred results.
・ The recommended local scour depth methods for various river gradient are listed in the following table.
<table><tr><th>River gradient</th><th>Material</th><th>Recommended method</th></tr><tr><td>Very mild</td><td>Sand and silt</td><td>-Lacey method (1930)
-Inglis method (1940)
- Lacey’s equation (Expanded by USBR, 1984)
-Blench equation (USBR,1969)
-Molesworth and Yenidunia equation</td></tr><tr><td>Mild (incised)</td><td>Gravel, sand and silt</td><td>-Lacey method (1930)
-Inglis method (1940)
- Lacey’s equation (Expanded by USBR, 1984)
- Blench equation (USBR,1969)
- Neill equation (USBR,1973)
-Molesworth and Yenidunia equation</td></tr><tr><td>Steep</td><td>Gravel and coarse sand</td><td>- Blench equation (USBR 1969)
-Molesworth and Yenidunia equation
- Farraday and Charlton equation
- Brown formula</td></tr><tr><td>Very steep</td><td>Gravel and boulders</td><td>- Brown formula</td></tr></table></td><td>・ It is recommended for the Bund Manual in Sindh to describe the concreate methods of scour depth calculation based on the Manual of Irrigation Practice in Punjab
・ The Punjab is recommended to include the method for safety evaluation like the manual in Sindh.</td></tr>
<tr><td></td><td>Seepage Control</td><td>Permabili-ty Inspection</td><td>16</td><td>-</td><td>No description</td><td>VOL.2 Chapter 2, 6.2.3, p204</td><td>・ For foundation stability, following information should be investigated through test pits and boreholes; Permeability of riverbed material/ In-situ density/ Hardness of cobles and boulders/ Bearing pressure capacity.</td><td>・ It is recommended for the Bund Manual in Sindh to describe this item based on the Manual of Irrigation Practice in Punjab.</td></tr>
<tr><td></td><td></td><td>Seepage Analysis</td><td>17</td><td>-</td><td>No description</td><td>VOL.2 Chapter 2, 6.2.4, p205 to 208</td><td>・ Hydraulic Gradient is assumed straight line for practical purpose. Typical values of hydraulic gradients vary for each soil type. But normally it is assumed as 6:1.
・ Hydraulic Gradient should lie at least 2ft below at the toe of the bund.
・ A minimum cover of 4 ft is provided above hydraulic grade line if it exits on the landside in made up soils.
* Hydraulic Grade Line (HGL) = Phreatic Line
** Hydraulic Grade Line (HGL) = Phreatic Line</td><td>・ The Bund Manual in Sindh is recommended to add the seepage through the bund body like the Manual of Irrigation Practice in Punjab</td></tr>
</table>

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
			18	-	No description	VOL.1 Chapter 5, 5.4.9.6(f), p5-66	・ Acceleration due to earthquake is selected on the basis of 50% reduction for horizontal and vertical component. For example, after reduction and using Punjab OBE, horz = 0.08g and vertical = 0.04g. ・ These earthquake forces act at the center of gravity of the slice. ・ The acceleration due to Open Basis Earthquake values is adopted on the basis of specific related earthquake zone criterion.	・ The Bund Manual in Sindh is recommended to describe this item based on the description of the manual in Punjab.
Mprove-ment of a BundI	Slope Stability/slip Circle		19	Chapter XI, Page 6 of 17 125. Slips and their treatment	・ Expansion of the Rear Section to cover the saturation line ・ Mangli or ringl bund around the slip ・ Installation of drainage material at the land side toe	-	No description	
	Erosion		20	Chapter XV, Page 1 of 4 156. Necessity of stone spurs and stone apron	Stone Spurs and Stone Aprons *Calculation of expected deepest scouring based on the historical highest discharge. Calculation of length and thickness of stone apron by it.	VOL.2 Chapter 2, 5.3, p190	・ Robust design and construction ・ Strengthening the weak / inadequately strong reaches ・ Providing erosion protection interventions like stone pitching, mattresses, ・ studs, spurs	・ In order to cover a wide range of countermeasures, countermeasures that are unique to one side should be added to each other. ・ It is recommended for both manuals to add concreate design methods with reference to manuals from other countries so that the design methods can be described for all countermeasures.
				Appendix V Miscellaneous River Works., Page 2 of 12 2. Revetment	・ Revetment ・ Cemented Stabilized Soil Revetment ・ Tree Groynes ・ Bandelling, etc... *As feasible options in Sindh, they are introduced without design method.	VOL.1 Chapter 5,4.5, p5-41 Chapter 5,4.8, p5-57 Chapter 5,5.6, p5-86 Chapter 5, 5.7 p5-93 Chapter 5.5.8, p5-86	・ Gabion: Basic shape is introduced. ・ Studs: Basic shape is mentioned but the design of length is not described. ・ Stone Apron: Concrete design methods for determining the shape and material based on scour depth, flow velocity, and so on are mentioned. ・ Stone Pitching: Concrete design methods for determining the thickness and material based on flow velocity and wave-height are mentioned. ・ Geotextile Filter: When it is difficult to get stones, Geotextile filter can be used instead of it. The requirement condition about materials are mentioned.	
						VOL.2 Chapter 2, 6.2.6 ,p208	Slope Protection (Temporary measures) ・ Khaji Mats, ・ Fascine Covering, ・ Pilchi Rolls, ・ Longitudinal Stakes and Bushing Protection (termed as MUHARI in Sind Province), ・ Pilchi Pitching (Revetment) *What the measures are for is not mentioned. **The concreate design method is not described	
						VOL.2 Chapter 2, 6.2.7 ,p212	Slope Protection (Permanent measures) ・ Brick Pitching ・ Dumped Stone Rip-Rap ・ Hand placed Rip-Rap (Stone Pitching) ・ Soil Cement Cover ・ Cement Concrete Paving ・ Asphaltic Concrete ・ Porous Concrete Slab ・ Protection Digest. *What the measures are for is not mentioned. **The concreate design method is not described	
	Seepage Control (Newly Construct-ed)	Types of Improve-ment Methods	21	Chapter V, Page 7 of 18 35. Piping	・ Proper choice of Earth Fill ・ Apply the Standard section in Sindh	VOL.2 Chapter 2, 5.5, p204	Foundation Stability ・ Reworking of the foundation soil ・ Grouting of the armoured river bed to the required extent ・ Inverted filter or geo-textile layer at the foundation of revetment / gabion hydraulic structure ・ Where required, provision of a suitable cut-off *The concreate design method is not described	・ Countermeasures for a bund body are generally the same in both manuals. ・ The Bund Manual in Sindh is recommended to additionally include countermeasures relating to a foundation based on the Manual of Irrigation Practice in Punjab, . ・ Both provincial manuals have to additionally describe design methods with reference to guidelines from other countries.
						VOL.2 Chapter 2, 6.1.1, p191	Foundation Stability ・ Cut off trench ・ River side impervious blankets ・ Pervious toe trenches ・ Pressure relief wells ・ Land side seepage berms *The concreate design method is not described	
						VOL.2 Chapter 2, 6.1.8 to 6.1.13, p195	Seepage through Body ・ Pervious Toe Drain ・ Horizontal Drainage Layers ・ Inclined Drainage Layers *The difference amoung these 3 countermeasures are where the drainage material is located.	
		Existing Bund	22	Chapter XI, Page 6 of 17 125. Slips and their treatment	Expansion of the Rear Section to cover the saturation line *Not clearly mentioned on seepage control for the existing bund.	VOL.2 Chapter 2 6.2.4, p205 to 206	Seepage through Body ・ Land side Seapage Berm	Same as above
		Earth-quake	23	-	No description	-	No description	-

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Revetment	General		24	Chapter I, Glossary of terms used in connection with River Bunds in Sindh Page 11 of 14	A pitching protection of stone, or brick or sand bags containing a certain proportion of cement or similar materials.	-	No description	-
	Material and Structure		25	Appendix V, Page 2 of 12 2. Revetment	・ Stone masonry pitching ・ Burnt Brick masonry pitching ・ Brushwood pitching including alternate layers of earth ・ Muharis, single or double ・ Lai groynes (single) ・ Lai mats including fixing ・ Date mats including fixing ・ Cemented Stabilized Soil Revetment *Not mentioned on the specification and design methods for each types	VOL.2 Chapter 2, 6.2.6, p208	About Slope Protection (Temporary measures) ・ Khaji Mats, ・ Fascine Covering, ・ Pilchi Rolls, ・ Longitudinal Stakes and Bushing Protection (termed as MUHARI in Sind Province), ・ Pilchi Pitching (Revetment) *Same as those described in the improvement for erosion. **Specification and design methods for each types are not mentioned.	・ The main difference between them is that the only Panjab manual states the introduction and the standard cross section of gabions and the concrete design method for stone pitching. ・ It is desireable for the Bund Manual in Sindh to additionally describe the above items.
						VOL.2 Chapter 2, 6.2.7, p212	Slope Protection (Permanent measures) ・ Brick Pitching ・ Dumped Stone Rip-Rap ・ Hand placed Rip-Rap (Stone Pitching) ・ Soil Cement Cover ・ Cement Concrete Paving ・ Asphaltic Concrete ・ Porous Concrete Slab ・ Protection Digest. *Same as those described in the improvement for erosion. **The specification and design methods for all types except for stone pitching are not mentioned.	
						VOL.2 Chapter 2, 6.2.7, p212	Vegetation *This assume trees in front of the bound at a distance of 10 ft from the toe.	Same as above
						VOL.1 28Chapter 5, 4.5, p5-41	Gabion *Basic shape is introduced.	Same as above
	Safety Verifi-cation		26	-	No description	-	No description	・ Both are recommended to describe in reference to manuals in other countries.
	Structural Design	Slope	27	Chapter V, Page 9 of 18 37. Stability of Section	3:1 to 2:1 *Where stone or brick pitching is resorted to, the slope may be steepened from 3: 1 to 2 : 1	VOL.2 Chapter 2 4.3.1.3, p187 to 189	Marginal Bunds(protected): 2:1(Minimum)/3:1(Desirable) Bunds Protecting Strategic locations(protected): 2:1(Minimum)/3:1(Desirable) Bunds along open reaches of the rivers(protected): 2:1(Minimum)/2:1(Desirable) *Same as those described in the bund shape.	・ The contents in both are almost the same.
		Founda-tion	28	-	No description	-	No description	・ Both are recommended to describe in reference to manuals in other countries.
		Foot Protection	29	Chapter XV, Page 1 of 4 156. Necessity of stone spurs and stone apron	Stone Aprons on Front Bund *Calculation of expected deepest scouring based on the historical highest discharge. Calculation of length and thickness of stone apron by it.	VOL.1 Chapter 5, 5.6, p5-86	Stone Apron *Concrete design methods for determining the shape and material based on scour depth, flow velocity, and so on are mentioned. **Same as those described in the improvement for erosion.	・ The Bund Manual in Sindh have larger design value for the same scour depth, although the calculation methodology for the scour depth differs. ・ Since the Bund Manual in Sindh is easy to understand, it is advisable for the Manual of Irrigation Practice in Punjab to modify the writing style with reference to the Sindh.

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Spur (Stone Groyne)	Site Condition		30	Chapter XV, Page 1 of 4 156. Necessity of stone spurs and stone apron Chapter IV, Page 3 of 15 21. Instructions regarding pegging and measurements of erosion ordinates	The location where loop bund is needed, but no available land. *Where the edge of the pucca bank is less than 3,000 ft. proposals for loop bund should be sent in at once.	VOL.1 Chapter 5, 5.4.7, p5-46, 5.4.7.5, p5-57	The location where the followings are required. ・ Creating slack flow with an objective of silting up the area in the vicinity. ・ Protecting the riverbank by keeping the flow away from it.	・ Land restriction is mentioned only in the Sind manual.
	Basic Shape		31	-	No description	VOL.1 Chapter 5, 5.4.7.4, p5-49	・ Typical cross-section is following. ➢ Crest width = 30 ft ➢ Side slopes - Shank = 3H:1 V ➢ Side slopes - Head = 2H:1V ・ There are 10 types of spurs; 1. Bar spur 2. Mole-head spur 3. Hockey spur 4. Inverted hockey spur 5. T-head spur 6. Sloping spur 7. T cum hockey spur 8. T cum hockey-sloping spur 9. J-head Spur 10. Guide-head spur	・ It is recommended for the Bund Manual in Sindh to state this item based on the Manual of Irrigation Practice in Punjab.
	Material		32	Chapter I, Glossary of terms used in connection with River Bunds in Sindh Page 6 of 14	Stone A stone groyne is called a spur	VOL.1 Chapter 5, 5.4.7.4, p5-49	Compacted gravel and sand with 6 inch thick for the crest protection *The necessity of stone protection for other parts is mentioned but the requirements for those is not mentioned.	・ The contents in both are almost the same.
	Design Method		33	-	No description	VOL.1 Chapter 5, 5.4.7.2 p5-48	The general recommendations for spacing are introduced as followings. ・ The minimum spacing in a straight reach should thus be five (5) to six (6) times the length of spur. ・ Convex bends; 2.5 to 3.0 times the length of spur ・ Concave bends; equal to the length of spur	・ It is recommended for the Bund Manual in Sindh to state this item based on the Manual of Irrigation Practice in Punjab.
						VOL.1 Chapter 5, 5.4.7 p5-46	The position, length, and shape of spurs at any site should be determined by physical model studies.	
						VOL.1 Chapter 5, 5.4.7.5, p5-57	The determination of angle of spur with respect to current axis requires physical model study	
Construct-ion Works	Permission		34	Chapter VI, Page 14 of 14 60. The contractor shall not enter upon or commence any portion of the work Chapter II, Page 4 of 8 4. Execution of Works	・ The contractor shall not enter upon or commence any portion of the work, except with the written authority and instruction of the Executive Engineer or his subordinate in charge of the work. ・ Executive Engineers will submit the proposal to the Divisions concerned to the Secretary, Indus River Commission, through the Superintending Engineer of the Circle, for the administrative approval of the Indus River Commission	-	No description	・ It is recommended for the Manual of Irrigation Practice in Punjab to state this item based on the Manual of Irrigation Practice in Punjab.

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Construct-ion	Procedure	35	Chapter VI, Page 7-8 of 14 60. The contractor shall not enter upon or commence any portion of the work	・ Removal of all trees, shrubs, grass or other growths on the site of the embankment ・ Mark the base of the embankment and the limits of the borrow pits, construct the side slopes. ・ All earth for the embankment shall be obtained only from the borrow pits set out by the Executive Engineer. ・ If a key trench is provided under the embankment, the excavated trench must be measured, removed, and backfilled. ・ The earth shall be deposited and spread in horizontal layers, 6 inches thick, for the full width of the bank ・ each layer shall be thoroughly consolidated either by ramming, rolling, or by weighted bullock carts as directed by the Executive Engineer. ・ Measurements of earthwork will be taken as far as possible in the borrow pits.	-	No description	Same as the above
		Site Inspection for Work Accomp-lishment (Shape inspection)	36	Chapter VI, Page 7-8 of 14 60. The contractor shall not enter upon or commence any portion of the work	Not clearly mentioned. *However, permission by the Executive Engineer is needed to proceed to the next layer of embankment	-	No description	・ Both are recommended to describe in reference to manuals in other countries.
		Quality Inspection	37	-	No description	-	No description	Same as the above
		Acceptabil ity Criteria	38	-	No description	-	No description	Same as the above
Manage-ment Plan	Manage-ment Plan		39	Chapter IX, Page 1-5 of 5, Pre-Abkalani Maintenance Chapter X, Page 1-13 of 13 Ordinary Maintenance during Abkalani	Pre-abrakani maintenance and oridinary maintenance is stated. *There is no statement on middle and long-term management plan. The maintenance within a single year is focused on.	VOL.2 Chapter 8, 1.1 p591	・ Asset management plan (AMP) is introduced. ・ Six stages for preparing an AMP a framework are the followings. I. Devise procedures for preparing the AMP and keeping it up to date. II. Prepare a statement of the Utility's relevant standards and policies. III. Identify various functions of the Utility and prepare a list of systems under each heading. Each system will comprise a number of assets. IV. Collect information on performance and condition of the principal components of each system. (Note that performance information relates to a system whereas condition information relates to individual assets). V. Estimate long term investment covering a 20-year planning period to meet shortfalls of performance and condition and to provide for expansion and improvement. VI. Prepare short term program of expenditure for 5-10 years.	・ Long-term maintenance plan is introduced only in the Punjab manual, but it is difficult to develop the plan based on it. ・ it is recommended for the both manuals to additionally describe the concrete methods for management plan with reference to other countries guidelines.
						VOL.2 Chapter 8, 1.2 p592	Aim of Asset Management is to increase longevity and sustain utility of the infrastructure and an enhanced level of service provision to the water user.	
						VOL.2 Chapter 8, 1.7.2 p601	PID's policy in respect of flood protection embankments and spurs is the followings. ・ They are inspected before the advent of flood season every year for assessing their reliability to withstand flood onslaught. ・ Their deficiencies are removed prior to flood season and flood fighting plan is prepared annually. ・ As such in ideal conditions there should not exist any deferred maintenance requiring rehabilitation of this type of the infrastructure.	
	Manage-ment Cycle		40	-	No description	-	No description	・ Both manuals are recommended to describe with reference to manuals in other countries.
Monitor-ing of River Conditions	General		41	-	No description	-	No description	-

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Patrol/ Physical Inspection		42	Chapter X, Page 3 of 13 107. Organization for patrolling and duties of members of staff	(Patrol During high flood) ・ As soon as water comes against a bund, patrolling by beldars should commence. Beldars works in pairs with six hours shift ・ The temporary headquarters of the Overseer, Sub-Divisional Officer and Executive Engineer should be in the centre of the active bund line in their charge. ・ One daroga for 8-20 miles of active bund line, depending on local conditions, is generally to be provided on the annual establishment.	VOL.2 Chapter 2, 17 p266 to 267	Following activities are listed as part of flood preparedness. ・ Routine Inspections ・ Flood Preparedness Inspection Report before Flood ・ Flood inspections during the flood ・ Flood Damage Report after the Floods ・ Identification and Prioritization of critical damages *Inspection before and after flood are described in detail in other chapter, but there is no description of the concrete method for routine inspection and inspection during flood.	About Patrol ・ The Punjab Manual is recommended to describe the patrol structure with reference to on the Bund Manual in Sindh ・ Both manuals need to introduce the patrol items with reference to guidelines in other countries. About physical inspection ・ The Bund Manual in Sindh is recommended to add the missing items such as responsible person and survey team composition with reference to the Manual in Punjab.
				SAFETY EVALUATION OF FLOOD BUND 11. SAFETY INSPECTION AND EVALUATION, p11	(Physical inspection of the bund after a flood) ・ Top Levels ・ Unwanted Vegetation and Debris ・ Encroachments ・ Slope/Section Stability ・ Settlement ・ Land Subsidence ・ Damaged Armour ・ Flood Wall Damage ・ Runnel *Situation and solution are described.	VOL.1 Chapter 8, 8.2, p8-1 And Chapter 5, 5.16.4, p5-198 And Chapter 5,5.16.8, p5-199	For inspection before and after flood, ・ Person in charge: It is the duty of Sub-engineers and sub-divisional officers to see that the actual section is not very much below the standard laid down in the type of cross section. ・ Survey team member: A three-person inspection team should be comprised, a leader, hydraulic engineer, Geotech engineer. ・ Inspection Item are the followings. i. Top Levels, ii. Unwanted Vegetation and Debris iii. Encroachments iv. Slope/Section Stability v. Settlement vi. Land Subsidence vii. Damaged Armour viii. Flood Wall Damage ix. Runnels Caused by: a. Old tree roots b. Solutioning of Soluble Materials c. Rodent burrows, holes and dens d. Piping action through foundation alluvial materials. e. Damage by river flow. f. Erosion by wave action. g. Ravines caused by heavy rains h. Accidents i. Vandalism j. Sabotage *Inspection before and after flood is called “Safety Inspection” in Chapter 5.	
	Inspection with Equip-ments / Investi-gation / Exploration		43	-	No description	VOL.2 Chapter 2, 4.3.1.2, p87	Not mentioned *Although it is not intended for monitoring, the followings sentence is introduced as investigation items. “Geophysical investigations: Electrical resistivity/ Cavities, weak soil strata and buried objects through Ground penetrating radar.”	・ It is desirable for both manuals to additionally introduce this item with reference to guidelines in other countries.
	River Profile / Inspection Report / Damage Record		44	APPENDIX I. River Conditions and Flood Control Measures in Sindh	No description *There are contents on Indus River and vulnerable sites along it. However, not organised as a river profile.	VOL.1 Chapter 5, 5.16.6, p5-198	・ About safety inspection, the committee will formulate its inspection/evaluation report and submit it to the owner/requesting authority within 15 days of the inspection. ・ This report will normally comprise an introduction, location of the training works, analysis for design parameters, physical inspection results i.e. observation and findings, conclusions, and recommendations.	・ It is recommended for the Bund Manual in Sindh to state this item based on the Manual of Irrigation Practice in Punjab.
	Analysis and Evaluation		45	-	No description	VOL.1 Chapter 5, 5.16.6, p5-198	Review the design according to the state-of-the-art design methods/procedures, point out any deficiencies to be corrected and suggest suitable action to withstand the accepted PMF (Probable Maximum Flood).	Same as the above
Inspection and Ledger	General		46	-	No description	-	No description	-
	Bund		47	CHAPTER XIII Periodical Reports and Returns. APPENDIX VIII 2. I.R.C. Forms	・ Erosion Statement ・ ABKALANI REPORT(BUND) ・ Reports on the State of Bund Sluices and Regulators. ・ Statement of High Flood Levels on Bund Mile Gauges and Free Board Available During the Abkalani ・ Position in Line of Defence ・ Register Showing Incidence of Leaks ・ Report of Leveling on Bunds	VOL.1 Chapter 5, 5.16.4, p5-198, and Annex-H,	・ The checklist is instructed. ・ The items of the Checklist listed in Annex-H are Top Width, Top RL,, Side slope, HFL, Free board, review on deign parameters, phreatic line development, physical condition, patrol road and section maintenance, unauthorized traffic, slumping or settlement, body materials suitability, heavy seepage, rain cuts, general land subsidence, damages to stone or other protections, evidence of compressible or expansile soils in foundation, evidence of misuse, flood watching and fighting arrangements, gauges observation system, flood warning and information system, analysis of observations.	・ The Punjab manual is recommended to add ledgers such as those listed in the Bund Manual in Sindh in order to clarify what needs to be checked.

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	River Channel		48	Chapter IX, Page 4 of 5 98. Inspection of river course and proposals for measures	・ Ledger or form is not described. ・ A full report, together with any proposals considered necessary, should be forwarded to the Superintending Engineer, *if an unfavorable river course or river set is indicated.	VOL.1 Chapter 5, 5.16.9, p5-200	・ Ledger or form is not described. ・ Periodical topo and bathymetric surveys of river channels and khadir (active flood plain) are carried out every year after flood season. ・ Topo survey: extends to about 15000 x afflux feet at upstream and 25000 ft on the downstream of barrage. This survey shows the areal placement of river channels, their variations, erosions andshoals and changes in the meanders of the river channel.	・ it is recommended for the Bund Manual in Sindh to add the inspection and survey items of erosion and bathymetry. ・ Both manuals need to describe concrete methodology for inspecting with reference to other countries guideline. ・ The Panjab manual is recommended to expand the area of river course inspection and erosion to the entire stretch of the rivers, as they are basic information for maintaining the bund.
	Storage		49	-	No description	VOL.1 Chapter 5, 5.21, p5-241	The sub-divisional officer in charge of the barrage has the responsibility of checking and initiating all the data record regularly at prescribed intervals. *Target record of the above sentence is unclear because it is not mentioned. It seems to be that the target records are those related to the barrage because the responsivity person is the officer in the barrage.	・ The Bund Manual in Sindh needs to state the methodology for storage with reference to the Manual of Irrigation Practice in Punjab ・ Both manuals have to clearly describe the type of reports to be stored.
River Ledger	General		50		River Ledger or form is not described		No description	-
	Contents		51	APPENDIX VIII 2. I.R.C. Forms	Erosion Statement ・ Date of first measurement. ・ AmoW1t of Erosion ・ Sistance Remining Uncroded ・ Minimum Beight of free board during the week ABKALANI REPORT(BUND) ・ Breach ・ Leak ・ Erosion ・ Works in Progeress ・ Health of Establishment Statement of High Flood Levels on Bund Mile Gauges and Free Board Available During the Abkalani ・ Ground Level ・ High Flood Level ・ Corresponding Discharge at Sukkur. ・ RL of Top of Bund ・ Freeboard on actually recorded level and extra polated level Position in Line of Defence ・ Water Level ・ H.F.L ・ Max. Depth ・ Min. Freeboard ・ Date on which water taouch the Bund ・ Corresponding Gauge Reading at the barrage ・ RL, and widthof Top of Bund and Slope ・ Ground Level ・ General Condition of Bund ・ Nature of Soil ・ Diaphragm of sand Trench in the Bund ・ Leak ・ Breach ・ Extent of Erosion ・ Trace of Seepage ・ Trace of Wave Wash ・ Issue in Sluice ・ Expenditure on repair last eason ・ Special patrol required during next season. Register Showing Incidence of Leaks ・ Location ・ Obsevation time ・ Probable Cause ・ Plugging/Closing Time ・ Method Adopted ・ Date of opening leak in full width ・ Date of refilling	-	No description	・ The Manual of Irrigation Practice in Punjab is recommended to include the ledger which shows the characteristics of the bund with reference to the Bund Manual in Sindh.
	Storage		52	-	No description	-	No description	・ Both manuals are recommended to describe with reference to manuals in other countries.

Item	Sub Item	Sub-sub Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Bund Breach	Cause of Breach		53	Chapter IIX, Page 1 of 15 131. Causes of breaches	(a) Erosion of the bund by the river itself; (b) Failure of masonry works, such as sluices and regulators; (c) An uncontrolled leak developing into a breach (d) overtopping or severe scour of the bund	Chapter 2 8.1.1, p219	· Erosion of the bund by the river itself; · Failure of masonry works, such as sluices and regulators; · An uncontrolled leak developing into a breach · Overtopping or severe scour of the bund *The most frequent cause of a breach is the development of a leak.	· The same cause of breach is listed on both Sindh and Punjab manuals.
	Artificial Breach		54	-	No description	VOL.2 Chapter 2 7.1, p217(242/754)	About conditions for activation of bleaching section · The location is approved by a committee. · The pre-requisite site conditions are followings. ➢ The rate of inflow to the structure is most likely to be more than the discharging capacity of the structures. ➢ The critical / emergency gauge at a fixed location on left marginal bund or elsewhere has exceeded the limiting value and the river discharge still rising. · The critical gauge level was already set, but it is desirable to change this value because it was set more than 40 years ago. About how to make a breach · There are two ways; Mechanical means and Blowing up the body of the bund through use of explosives. · Mechanical means is desireable because it is more reliable. The success rate of explosive is less than 50%.	· This item is only listed in the Manual of Irrigation Practice in Punjab. The reason for that seems that there is no designated breach point or officially announced breach point in the province of Sindh.
	Immediate Action		55	Chapter IIX, Page 1 of 15 132. Immediate action in the event of a breach	· The sectional overseer should immediately communicate to Sub-Divisional Officer and Executive Engineer, and the items reported to them is clearly listed on the manual. · The probable route will be estimated. And in the case that important infrastructure such as Railway and Gas likely be affected, they will be informed. · The Executive Engineer should also immediately inform the higher staff and then should make report. · To prevent the breach widening, a groin should be constructed.	VOL.2 Chapter 2 7.1, p217(242/754)	· The sectional overseer should immediately communicate to Sub-Divisional Officer and Executive Engineer, and the items reported to them is clearly listed on the manual. · The probable route will be estimated. And in the case that important infrastructure such as Railway and Gas likely be affected, they will be informed. · The Executive Engineer should also immediately inform the higher staff and then should make report. · To prevent the breach widening, a groin should be constructed.	· The contes are almost same in both manuals
	Closure of Breach		56	Chapter XII, Page 4 of 15 137. One method of closing a large river breach	One method of closing with a ring bund is explained in detail.	VOL.2 Chapter 2 8.1.3, p220(245/754) Chapter 2 8.1.7, p222 to 229(247 to 253/754)	· One method of closing with a ring bund is explained in detail.	· The contents are completely same in both manuals

Source: JICA Project Team extracted from the Bund Manual in Sindh and the Manual of Irrigation Practice in Punjab and analyzed

3.6.2 Comparison of the Manual in Sindh and the Japanese Manuals

(1) Definition of a Bund

In both the Bund Manual in Sindh and Japanese standard, a bund is basically an earthen structure which is aiming at protecting the country from inundation by the river spill, during floods.

While as the target water level which shall be protected by a bund, high water level(HWL) based on a probabilistic analysis is used in Japanese standard, Designed H.F.L. is used in Sindh Province. According to the manual, it is set to equal to 2 ft. above the Actual H. F. L.[17] at any point on all the Bund lines in the province in 1972. Since Actual H. F. L. has been updated since 1972, the Designed H.F.L. has been also increased.

Hence, in Sindh Province, once the highest water level due to a flood is updated, the target water level for the bund design will increase.

(2) Standard Shape of a Bund

Top width is defined as 20 ft(=6.1m) in the Bund Manual in Sindh, this is almost the same as the rivers which has 176,573 to 353,146 cusec(=5,000 to 10,000 m^3/s) in discharge in the Japanese standard.

The widths of a berm are 5 ft(=1.53m) in the Bund Manual in Sindh and 9.84ft(=3 m) in the Japanese standard.

Freeboard which stated in the Bund Manual in Sindh is 4 ft(=1.22m), and it is almost the same as the rivers which has 70,629 to 176,573 cusec(=2,000 to 5,000 m^3/s) in discharge in the Japanese standard.

Considering the discharge during floods, duration of high water level and the available earthen material around Indus River, wider or higher value is preferable.

On the other hand, the side slope in the Bund Manual is set to 3:1 to 4:1, which is milder than it in the Japanese standard. It is preferable when considering a high water level with long duration in Indus River.

The extra embankment in the Bund Manual is 6.25% of the design height, which is about 0.3m with 5 m height of an embankment. This is almost the same value as it in the Japanese standard(30-40cm depending on the type of soil).

(3) Quality Control

1) Material

In the Bund Manual in Sindh, about the embankment material, the necessity of fine particle contents is described. On the other hand, it is also stated that the embankment material needs to be obtained from the river side immediately in front of the bund. In the Japanese standard, the necessity of fine particle contents is also mentioned. However, the recommendation stated in each is different a little.

Since a soil with small contents of fine particles has high permeability, the minimum contents of clay stated in the Bund Manual is preferable considering the long duration of a flood in Indus River. On the hand, it is recommended to the Bund Manual in Sindh to state the maximum particle size and allowable range of the particle size distribution.

[17] The actual "H.F.L." has been defined as the highest recorded level at the particular point, since 1914.

Table 3.6.6 Desirable Embankment Material

Bund Manual in Sindh	River Earth Work Manual in Japan
・ Sand mixed with a fair proportion (30 to 40%) of clay is desirable. ・ 50-70% of Sand, 30-50 of clay is optimum.	・ 15% to 50% of fine particles (Not larger than 0.075mm in the size) is desirable. ・ Maximum particle size is not larger than 10 to 15 cm. ・ A soil which has wide distribution in particle size, and not so many contents of silt.

Source: JICA Project Team extracted from Bund Manual in Sindh and River Earth Work Manual in Japan

In the Bund Manual, there is also mention of the location of borrow pit and the embankment material needs to be obtained on the river side immediately in front of the bund. However, due to the actual site conditions along the river, it is difficult to obtain the material which satisfies the abovementioned recommendation. Hence, this rule is better to be revised.

2) Construction Method

Between the Bund Manual in Sindh and the Japanese standard, the thickness of 1 layer of a embankment is different and these are 6 inches(=about 15.2cm) in the Bund Manual and 11.8 inches(=30cm) in the Japanese standard respectively.

About the equipment to be used for earth works, there is no mention to specify the equipment in the Bund Manual in Sindh, On the other hand, Japanese standard is describing the required and recommended equipment to be used for each earth work item. In the Japanese standard, 5 major equipment such as bulldozer, wheel roller, vibrating roller, vibrating compactor and tamping machine is introduced with the applicable types of embankment materials(See Table 3.6.7). It is recommended to include the mention of equipment to be used also in the Bund Manual in Sindh.

Table 3.6.7 General Adaptation of Soil Types and Equipment for Compaction

Equipment / Type of Soil	Normal Bulldozer	Wheel Roller	Vibrating Roller,	vibrating compactor	Tamping Machine	Remarks
Sand Sand with Gravel	○	○	○	△	△	Single-grained sand, incised gravel without fine grains, sand from dunes etc.
Snad Sandy Soil Sandy soil with Gravel	◎	◎	○	△	△	Good particle size mixed soil that contains moderate fine particles, decomposed granite soil, mountain gravel, etc.
Caly Clay with Gravel	○	○	○	×	△	Sensitive Soil with a little fine particle, loam with low moisture content, easy-to-crush mud rock, etc.
Sandy Soil with High Water Content Clayey Soil with High Water Content	○	×	×	×	×	Soil which is difficult to adjust the water content and to secure sufficient trafficability, silty soil, etc.

Legend: ◎ *Applicable*
○ *Usable*
△ *Usable but it is used depending on the site condition such as the area limitation*
× *Not Usable*

Source: River Earth Works Manual, Japan, 4.3.4 Embankment, Reference Table 4.15

The required degree of compaction is not specified in the Bund Manual, but it is normally stated in the technical specification of each construction contract and 95% of the maximum laboratory dry density in accordance with ASTM is usually specified. On the other hand, 90% in average is required and the minimum is set to 80%. However, depending on the embankment material used, it may not be possible to ensure an average compaction degree of 90% or more. In such cases, it is necessary to confirm the degree of compaction by trial embankment and set compaction management standards suitable for the soil material used.

Aside from the above mentioned contents, there are mentions of inspection & investigation to verify

the applicability for the embankment material, methodology of quality control, countermeasures for soft ground and environmental aspects. Such contents are also recommended to be included in the Bund Manual in Sindh.

(4) Service Road/ Maintenance Road

According to the Bund Manual in Sindh, public traffic is not permissible on bunds. However, there is no mention of the maintenance road on the top of bunds. Hence, pavements are not specified in the Bund Manual.

In the Japanese standard, the minimum width of the maintenance road is set to 3m considering purposes of patrols, rehabilitation and flood fighting during floods. Also, easy access and use by the residents nearby is considered. Due to these purposes, a paved road is recommended in the Japanese standard.

In case of the existing bund in Sindh, in a lot of location tops of the bunds are not paved and there are many of location where vehicles cannot pass smoothly. In order at least to secure the better access for the O&M, installation of the pavements on the top of the bund for all the stretch is highly recommended.

(5) Safety Evaluation

Table 3.6.8 shows the methods for safety evaluations against slope failure, erosion, seepage flow and seismic force. Except for the erosion, numerical analysis is instructed in the Japanese standard. In case of erosion, while evaluation with the distance from the riverbank to the bund is the similar method between them, features of the river and flow velocity around the target site has to be considered in the Japanese standard and the method is more based on the engineering factor.

Also in case of the Bund Manual in Sindh, it is necessary to conduct studies and evaluations based on numerical analysis or assessment with calculation taking into account river conditions and geological conditions.

Table 3.6.8 Methods for Safety Evaluations

Item	Bund Manual in Sindh	Japanese Standard
Slope Failure	・ Secure the Basic Dimensions of the Bund Specified in the Manual	・ Verify the stability against slip circle by a numerical analysis with a software. ・ Modified Fellenius Method is specified for slip circle analysis.
Erosion	・ Secure the Distance from the Riverbank to the Bund Specified in the Manual	・ Secure the Distance from the Riverbank to the bund, which varies depending on the feature of the river(called a “segment” in Japan) ・ Verify the stability of slope protection material against the design flow velocity.
Seepage Flow	・ No Mention	・ Numerical analysis with a software ・ Verify the stability against slip circle and local hydraulic gradient at the toe of a bund considering the movement of the water level during floods
Earthquake	・ No Mention	・ Numerical analysis with a software ・ Verify if the top elevation of a bund after an earthquake is higher than the specific water level.

Source: JICA Project Team extracted from Bund Manual in Sindh and Guideline for Structural Analysis of River Embankment in Japan

With regard to the impact on earthquakes, it is desirable to predict the expansion of urban areas and the accumulation of assets in the future, and to study for adding the description of stability to earthquakes.

(6) Improvement of a Bund

Table 3.6.9 shows major bund improvement methods introduced in each manual. About the

countermeasure against slope failure and erosion, similar types of methods are introduced in both standards.

Table 3.6.9 Major Bund Improvement Methods introduced in Each Manual

Item	Bund Manual in Sindh	Japanese Standard
Slope Failure	・ Expansion of the Rear Section to Cover the Saturation Line ・ Mangli or a Ring bund ・ Installation of Drainage Material	・ Milder Slope ・ Counterweight Embankment ・ The Measures for Seepage Flow to Reduce the Water Level in the Bund Body ・ Sheet Pile to Stop the Slip Circle
Erosion	・ Stone Spurs and Stone Aprons(for Foot Protection) ・ Revetment ・ Cemented Stabilized Soil Revetment ・ Tree Groynes ・ Bandelling	<Without Revetment> ・ Revetment(for a Bund/low Water Channel) ・ Erosion Control Mat ・ Control the Vegetation on the Bund ・ Realignment ・ Spur <With Revetment> ・ Strengthening the Revetment ・ Extension of Bottom of the Revetment ・ Making a Dry Masonry to a Wet Masonry ・ Foot Protection Work ・ Realignment ・ Spur
Seepage Flow	・ Proper Choice of Earth Fill ・ Apply the Standard Section ・ Installation of Drainage Material at the Land Side Toe ・ Expansion of the Rear Section to Cover the Saturation Line	<For a Bund Body> ・ Expansion of Bund Body ・ Installation of Drain(Gabion) ・ Covering Riverside Slope(Impervious Sheet) ・ Covering All the Surface <For Foundation Ground> ・ Seepage Cut-off in front of a Band ・ Blanket Method ・ Well Method
Earthquake	・ No Mention	・ Counterweight Embankment ・ Vibrating Compaction ・ Static Compaction ・ Deep Mixing Soil Stabilization ・ Cement Grouting ・ Jet Grout ・ Gravel Drain ・ Drain(Gabion) at the Toe of the Bund ・ Steel Sheet Piling ・ Replacement of the Soil

Source: JICA Project Team extracted from Bund Manual in Sindh and Guideline for Structural Analysis of River Embankment in Japan

About erosion, vegetation on the slope is one of the most popular measures for slope protection. However, it is difficult to be used in Sindh due to its climate which has only small amount of rain through a year. Instead of the vegetation with sodding in Japan, other types of slope protection material are recommended to be considered to reduce the damage on the slope and maintenance for it. As of now, dry stone pithing is an option because it is one of the most popular covering materials in Sindh. In the future, application of erosion control mat or a vegetation which can resist such severe climate in Sindh with inexpensive cost is desirable. Furthermore, about the foot protection work, concrete blocks are one of the most major items. Considering the variety of the rock sizes which are currently used for covering material and difficulty to obtain the rock material with large size, application of concrete blocks is a better option to let the foot protection work have the performance uniformly.

About seepage flow, expansion of the cross sectional shape and installation of a drain material are introduced in both standards, on the other hand, there are some countermeasures which have high applicability to the case of Sindh such as impervious sheet and seepage cut-off wall in the Japanese standard. In addition, areas or lengths of each countermeasure is verified with numerical analysis. It

is recommended to the Bund Manual to include the more contents for the countermeasures for seepage flow and numerical analysis to validate the effect of the countermeasures.

About seismic force, some of the major countermeasure against seismic force and liquefaction are indicated in the Japanese standard. In addition, the countermeasure against earthquake needs to be studied considering the effect of the countermeasures installed for seepage and erosion. Currently, there is no mention of the countermeasures against earthquake in Bund Manual in Sindh. However, the demand of the improvement for the safety against earthquakes is expected to increase due to the expansion of urban areas. Hence, as one of the highest priorities next to the countermeasures against erosion and seepage, it is recommended to the Bund Manual to include it.

(7) Revetment

1) Material

The materials used for revetments varies and concretes, rocks, woods and vegetations are introduced in the Japanese standard. Table 3.6.6 shows the types of revetments and materials introduced in each standard. About the material of stones and woods, similar types of revetments are introduced in both standards. However, there are the difference in the material of gabion, concrete, mat and others. In Japan, concrete blocks, gabion and vegetation are widely used. In addition, geotextile mattress is placed under the revetments in a lot of cases to prevent the soil particles from draining out from the bund body. Revetments with gabion and concrete blocks is little affected by an influence due to the variety of the sizes of stones unlike dry stone pitching, the strength and performance of the revetment can be uniformed in a certain stretch. Hence, adding these types of the revetment is recommended as an option.

In addition, there are a lot of cases that the existing revetment have been damaged due to the suck out of the soil particles behind it, it is recommended to include the importance of placing filter cloth under the revetment main body.

Since slope protection with vegetation is inexpensive, it is widely used and can be used in the condition that the flow velocity at less than 2 m/s in Japan. However, it is hard to use the same vegetation in Pakistan due to its dry climate. It is also recommended to develop the inexpensive and suitable covering material with something like a plant or a mat for the improvement of the maintenance.

Table 3.6.10 Types of Revetments and Materials in Each Standard

Material	Bund Manual in Sindh	Japanese Standard	
	Slope : 3:1 to 2:1	Slope : Not milder than 1.5:1	Slope : Milder than 1.5:1
Stone	・ Stone Masonry Pitching	・ Wet Stone Masonry ・ Dry Natural Stone Masonry	・ Wet Stone Masonry ・ Dry Natural Stone Masonry
Wood	・ Brushwood Pitching Including Alternate Layers of Earth ・ Muharis, Single or Double ・ Lai Groynes (single)	・ Wooden Lattice, Block, Picket Fence	・ Wooden Lattice, Block, Fascine Mattress
Gabion	-	・ Gabion(Step Type)	・ Gabion(Mattress, Net Gabion)
Mat, Sheet	・ Lai Mats Including Fixing ・ Date Mats Including Fixing	-	・ Geotextile Mattress ・ Block Mattress
Cement, Concrete	・ Cemented Stabilized Soil Revetment	・ Concrete Block Retaining Wall ・ Reinforced Concrete Retaining Wall	・ Concrete Block (Lining, Connecting)
Other	・ Burnt Brick Masonry Pitching	・ Steel Sheet Pile Wall	・ Vegetation

Source: JICA Project Team extracted from Bund Manual in Sindh and Basic Disaster Recovery Policy to Protect Beautiful Mountains and Rivers in Japan

2) Structural Design

Except for a stone apron(a foot protection), the concrete design methods considering the condition

of the river and site are not mentioned in the Bund Manual in Sindh. On the other hand, stability of each type of revetment shall be verified considering such condition based on the Japanese standards and guidelines. Each method is specified in the standards and guidelines and is used practically in designing.

It is recommended to the Bund Manual to state the detailed design method of each type of revetment, so that the manual will be more practical.

(8) Spur (Stone Groyne)

About the site condition in which spurs are needed, similar situation is considered between the Bund Manual in Sindh and the Japanese standard. However, there is more detained mention of the purpose of spurs with the types such as permeable and impermeable ones in the Japanese standard.

In the Japanese standard, 2 types of spurs are introduced shown in Table 3.6.11. Based on the site inspection in Sindh Province by JICA Project Team, there are a lot of spurs which are made by riprap with almost same height as the adjacent bund. At some locations, there are several spurs installed in parallel with short length. In such situations, the main purpose of the set of spurs are deemed to reduce the flow velocity in front of the bund. Hence, the height of the spurs can be reduced based on the guidance in the Japanese standard.

Table 3.6.11 Types of a Spur and its Purpose

	Type I	Type II
Purpose	Reducing the Flow Velocity	Controlling the Flow Direction
Feature	a. The height of the water system is low. b. A Spur with low permeability considering the water depth or permeable. c. Mainly light structure such as piling work. d. Several to dozens of lines are installed in parallel and act as a whole.	a. The height of the water system is high. b. Semi-permeable or Impermeable. c. Heavy and large structures made of earth, stone, concrete, etc. d. Single or in small numbers in parallel.

Source: JICA Project Team extracted from Technical Criteria for River Works: Practical Guide for Planning [I] in Japan

About the basic shape and design method are not mentioned in detailed in the Bund Manual. On the other hand, the guidance for these items is included in the Japanese standard. In order to make the manual more practical, it is recommended to the Bund Manual to include such a detailed information relating with the practical design method.

(9) Construction Works

1) Permission

In case of Japan, the river administrator is specified by cabinet orders, who is in charge of the management of the certain or whole stretch of rivers. Usually, rivers which have large catchment area are managed by the national government (MLIT) and are called class A rivers. Local governments are managing class B rivers with smaller catchment area and particular stretch of class A rivers.

According to River Law in Japan, somebody who have a permission from the river administrator can implement works or conduct maintenance in a river area[18]. On the other hand, According to Bund Manual in Sindh, implementation of works by the other public or private sector in the river area is not clearly mentioned and there is no mention of the permission for it.

2) Procedure, Quality Inspection and Criteria

In Bund Manual in Sindh, quality inspection and criteria are not stated. About the procedures, there is the mention of the construction procedure of a bund and necessity of approvals by the Executive Engineer at some stages. However, procedure of the preparation of the necessary inspections and

[18] River Law, Article 20

documents depending on the stages, is not summarized in the manual.

In the Japanese standards, such procedure is stated and quality inspection method and criteria for the approval are specified in detail. In case of Pakistan, such instruction is seemed to be included in technical specification in each contract.

(10) Management Plan

In the Bund Manual in Sindh, "Pre-abrakani Maintenance" and ordinary maintenance is stated, and there is no mention on middle and long term management plan. Also, the maintenance stated in the manual looks focusing on a single year activity.

In the Japanese standard, there is a mention of the river management plan which defines the outline of the river, item to be paid attention to for the river management, division of stretch of the river, goal of the river management fitting to the feature of the river and the area, methods and frequency for grasping the status of the river, concrete measures for the river management, collaboration with the local area, action for the improvement and efficiency. And the target duration of the plan is set to about 5 years in case of the large scale rivers. In addition, there is a mention of the PDCA cycle management. According to the "*Technical Criteria for River Works: Practical Guide for O&M(For River), Japan*," the importance of the PDCA cycle management is described as follows.

> *In river management, safety has been adaptively ensured through the repetition of dealing with river abnormalities and their responses, as well as the occurrence of disasters due to flooding and countermeasures, and new developments. Therefore, in managing rivers, it is necessary to establish a PDCA cycle that involves repeated river patrols, inspections to grasp the condition, management measures over a long period, and analyzing & evaluating the knowledge gained through these series of tasks to reflect it in the river management plan or implementation content.*

Source : JICA Project Team quoted from Technical Criteria for River Works: Practical Guide for O&M(For River), Japan

Since the river management is improved and updated by the repetition of the damage by the floods and the countermeasures for it, monitoring, inspection and countermeasures shall be repeated for a long duration(not a short duration such as a single year) and the knowledge from them must be reflected to the management plan.

Instead of inspections and repairs within a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years. Current description is like an emergency annual plan. It is necessary to create a plan that improves the durability and strength of the bunds by repair and reinforcement.

(11) Monitoring of River Conditions

In the Bund Manual in Sindh, patrol during floods is described. And physical inspection after a flood is described in "SAFETY EVALUATION OF FLOOD BUND" with the items. However, in these manuals, there is no mention of inspection with equipment/ investigations/ explorations and river profiles/ inspection record/ damage record and the analysis and evaluation.

On the other hand, In the Japanese standard, in addition to the abovementioned items, the several items such as hydraulic and hydrological observation, topographic survey, inspection after earthquake and inspection for mechanical equipment, and river ledger are described for monitoring of river conditions.

It is necessary to include the description not only to conduct visual inspections, but also to carry out inspections and exploration with equipment as needed and to collect basic data such as hydrological data and topographic surveys.

Especially, hydraulic and hydrological observation, topographic survey is the very fundamental information for the analysis and evaluation. So that, strengthening data sharing from the other authority such as WAPDA and PMD and periodical survey work by PID is recommended.

In addition, it is necessary to verify that the inspection sheet format, storage, and viewing system are functioning. If something is not working properly, it may be necessary to create a system with reference to the Japanese one.

(12) Inspection and Ledger

1) Bund

In the Bund Manual, there are mentions of yearly reports and weekly reports during the rainy season. Deformation of the existing bunds aside from the erosion, leakage and top elevation is not included the items to be recorded in a report or a ledger. In accordance with the Japanese guideline, concrete inspection items on the deformation of the existing bunds are described in detail. Some of the inspection items for a bund are listed in **Table 3.6.12**. The items listed in **Table 3.6.12** are to be checked by physical inspections and are concrete and practical. Hence, it is comparatively easy for the inspector or engineer at the sites to conduct the inspection. Furthermore, these inspection items need to be updated in improved in accordance with the PDCA cycle management.

Focusing on the seepage and erosion, leakage and top elevation is important, but the deformation of the bund body also needs to be checked carefully.

About the frequency of the inspections, twice a year is instructed, which is before or after a rainy season and during a typhoon season.

Table 3.6.12 Inspection Items on Bunds Listed in the Japanese Guideline

Structure	Portion	Inspection Item
Earthen Bund	Slope, Berm	Are there any cracks, holes, protrusions, collapses or deformation of slope, erosion, etc. (or are they more developed than the previous inspection)?
		Are there any abnormalities in the condition of the vegetation and topsoil, such as peeling of the sodding (or are they more developed than the previous inspection)?
		Are there any inverted slopes or locally low areas of the berms that may cause problems with drainage
		Are there any unevenness?
		Are there any areas that seem to be muddy?
		Is there a cavity in the embankment due to the concentration of holes of small animals such as moles?
		Is there a cave-in in the place where the holes of small animals such as moles were concentrated?
		Has there been any tree invasion or spread?
		Is there any scouring or erosion due to the concentration of road surface drainage at the slope and stair connecting part?
	Top of the Bund	Are there any deformations such as cracks, cave-ins, unevenness, or subsidence at the top of the bund and the shoulder of the bund (or are they more developed than the previous inspection)?
		Is there any erosion at the shoulder (or are they more developed than the previous inspection)?
	Land Side Toe of the Bund	Is there any infiltration due to poor drainage near the bund?
		Is there a risk of the fluidization of the embankment soil due to the soil near the toe becoming soft?
		Is there any infiltration due to poor drainage near the bund?
		Are there any water leaks or boiling sand near the toe?
		Is there any deformation of the slope protection (or are they more developed than the previous inspection)?
		Are there clusters of vegetation species that prefer local wetness?
		Is there any clogging of the drain or turbid water?
	Bund Foot Drainage	Is there any leakage or boiling sand from the joint of the drainage channel?
		Is there any blockage in the drainage channel?

Source: Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels

About the ledgers, in case of the Bund Manual, situation and location for the single location will be recorded. In case of the Japanese guideline, each deformation will be evaluated with the levels

presented in a to d[19] and the basis for the a to d is also described in the guideline as show in **Table 3.6.13**. Considering the evaluation for each inspection item and numbers of deformations in a certain stretch, the state of the bund will be comprehensively evaluated. Such evaluation can help to set the prioritization of the bunds to be improved.

Table 3.6.13 Comprehensive Evaluation in the Japanese Guideline

Evaluation		Status	Deformation	Malfunction
A	No Problem	✓ There is no visible deformation, or there is some visible light deformation, but the river is in a healthy condition with no malfunction of river management facilities such as bunds.	NO	NO
B	Needs Monitoring	✓ The function of river management facilities such as bunds is not lost, but development of the deformation has been confirmed, and the progress needs to be monitored (including cases where minor repairs are required).	OBSERBED	NO
C	Needs Preventive Maintenance	✓ Although the functions of river management facilities such as bunds is not lost, the problem is progressive and it is desirable to take measures from a preventive maintenance perspective. ✓ A situation in which it is necessary to reevaluate the state of decrease in the function of river management facilities such as bunds through detailed inspections (including surveys).	OBSERBED	NO
D	Needs Taking Measures	✓ The functioning of river management facilities such as buns is affected and measures such as repair or renewal are required. ✓ Detailed inspection (including investigation) has evaluated that there is a problem with functionality, and countermeasures are required.	OBSERBED	OBSERBED

Source: Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels

2) River Channel

In the Bund Manual, in case an unfavorable river course or river set is indicated, it must be informed with a full report. On the other hand, concrete methodology for the inspection is not introduced.

In the Japanese guideline, some of the inspection items for a river channel are listed in Table 3.6.14. The items listed in Table 3.6.14 are to be checked by topographic survey results and satellite images etc. and are concrete and practical.

In the Bund Manual, it is recommended to include such information for the improvement of the evaluation. Monitoring is important for vulnerability prediction.

Table 3.6.14 Inspection Items on River Channels Listed in the Japanese Guideline

Type	Inspection Items
Flow Capacity	✓ Is there any sediment accumulation such as riverbed rise that obstructs the flow of the river? ✓ Is there any shrinkage in the river width due to redeposition in the section where low water channel expansion has been carried out? ✓ Are there groups of trees that may obstruct the flow? ✓ Are there any obstructions to river flow due to driftwood, etc.?
Riverbed Decline	✓ Is there any deformation (subsidence, etc.) of the structure as a sign of riverbed decline or local scouring?
Riverbank Erosion	✓ ・Are there any collapses or erosion occurring on the natural riverbank? Does the riverbank normal line cross the bund protection line/low channel riverbank management line and approach the bund side? ✓ Are there any drifting currents (water impact/scouring) caused by groups of trees?
Estuary Closing	✓ Are there any signs of estuary closing or increase in estuary sand bar height?

Source: Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels

[19] a: No Problem, b: Needs Monitoring, c Needs Preventive Maintenance, d:Needs Taking Measures

3) Storage

In the Bund Manual in Sindh, there is no mention about how to store the inspection ledgers and reports. According to the interview to Sindh-PID, the basic office is Executive Engineer Office to store and keep the all record, then it consolidated at Zonal level and all Field CE take care to store the consolidated record.

On the other hand, the method and responsibility of storing the inspection ledgers are specified in Japanese standard as follows:

For river channels and facilities other than major flood control river management facilities (excluding dams) as defined in Article 7-2, Paragraph 1 of the Ordinance for Enforcement of the River Law, inspection results shall be recorded, and the inspection results shall be retained for a period until the next inspection or longer.

Source : JICA Project Team quoted from Technical Criteria for River Works: Practical Guide for O&M(For River), Japan

In Japan, the method of the storage is specified in the Ordinance for Enforcement of the River Law as well as the standard and the storage and accumulation of the record is recognized really important.

In case of the Sindh-PID, it is recommended to specify the method and responsivities for storing the inspection ledgers and report like the case of Japan.

(13) River Ledger

In the Bund Manua in Sindh, there is no mention of river ledger like the Japanese ones. Among the reports and forms introduced in the manual, "Position in Line of Defense(Bund Register)" seems to be containing the most similar information as the river ledgers in Japan, but it is only for the particular portion along the bunds and not including the general profile of the river or a stretch of the bunds.

In accordance with the Japanese law, the river ledgers must be prepared including the following items.

<For a Ledger>	*<For a Figure>*
✓ *Name of River System*	✓ *Boundaries of River Area*
✓ *River Name*	✓ *Information of the Power of River Manager on the land within the river area*
✓ *Length of the River*	✓ *Major River Management Facilities*
✓ *River Area*	✓ *Major permitted structures*
✓ *General Profile of Major River Management Facilities*	

Source : JICA Project Team quoted from Enforcement Order for River Law, Japan

Furthermore, the Japanese law is specifying the storage of the ledgers as follows.

The river ledger shall be stored at the offices of the relevant regional development bureaus (including the offices of the Hokkaido Development Bureau, same as in Article 39-3, Paragraph 1, Item 1) for first-class rivers, and at the offices of the relevant prefectures for second-class rivers, as prescribed by the Ministry of Land, Infrastructure, Transport and Tourism.

Source : JICA Project Team quoted from Enforcement Order for River Law, Japan

This means that the accumulation of records is recognized important.

In Sindh-PID, a river ledger is not prepared. This may be because Indus River is only the major river in Sindh Province. In addition, the information of major river facilities including the bunds is stored but is very scattered. So that, it is difficult to reach the required information without the support of the staffs or engineers in the local offices.

Such situation is not preferable, and the important information is dependent on the individual knowledges. However, as of now, little people seem to be recognizing that such situation is an issue. In Pakistan, bund management and maintenance must be more efficient and be more advanced due to the consideration of its length and limited resources such as manpower and budget. And it is not preferable to take time for gathering information which is dependent on the individuals. In addition,

in order to maintain the technical skill not less than a certain level, sharing the information and knowledge is necessary.

It is recommended to prepare the river ledgers for the purpose of accumulating data aimed at improving the efficiency of bund management.

(14) Summary

The analysis results are summarized in **Table 3.6.15** indicated in the following pages.

Table 3.6.15 Comparison of the Manual in Sindh and Japan

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Definition of a Bund	Definition		1	Chapter I, Glossary of terms used in connection with River Bunds in Sindh, Page 3 of 15	・ An earthen embankment parallel to the river banks ・ To protect the country from inundation by the river spill, during floods	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 17～Article 19	・ Earthen embankment designed and constructed to prevent water from flowing out of the river. ・ It is safe against water levels below the target water level.	In Sindh Province, once the highest water level due to a flood is updated, the target water level for the bund design will increase.
Standard Shape of a Bund	Crest Width		2	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Main Bund: 20 ft(=6.1m) ・ Trendh Bund: 10 ft (=3.05m)	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 21	Depending on the design discharge as shown in the following table Discharge / Width Under 17,657 cusec (=500 m3) / 9.8 ft (= 3 m) 17,657 to 70,629 cusec (=500 to 2,000 m3) / 13.1 ft (= 4 m) 70,629 to 176,573 cusec (=2,000 to 5,000 m3) / 16.4 ft (= 5 m) 176,573 to 353,146 cusec (=5,000 to 10,000 m3) / 19.7 ft (= 6 m) Over 353,146 cusec (=10,000 m3) / 23.0 ft (= 7 m)	Considering the discharge during floods, duration of high water level and the available earthen material around Indus River, higher value is preferable.
	Side Slope	River side	3	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Bund: 3:1 ・ Medium Bund: 3:1(8ft to 12ft in Height) to 4:1(12ft to 13ft in Height) ・ High Bund: 3:1(12ft to 13ft in Height) to 4:1(Over 13ft in Height)	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 22	・ Gentler than 2:1 except for the bund with a heigh of 2.0 ft (=0.6 m)	Value in Sindh Province is milder than it in Japan. It is preferable when considering a high water level with long duration in Indus River.
		Land side	4	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Bund,: 3:1 without Berm ・ Medium Bund: 3:1 without Berm ・ High Bund: 2:1(Top to Back Berm), 6:1(Berm to Ground)	Same as the above.	・ Same as the above. ・ *The gradients on the land side and the river side are not determined separately.	Same as above
	Berm		5	Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	High Bund ・ River Side: Not Specified ・ Land Side: 5 ft(=1.53m) *8 to 9 ft below from the top depending on the front slope	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 22	・ Larger than 3 m	Considering the discharge during floods, duration of high water level and the available earthen material around Indus River, higher value is preferable.
	Freeboard		6	Chapter V, Page 5 of 18 33. Freeboard Chapter V, Page 13 of 18 41. Standard sections or type designs of bund	・ Main Bund: 4 ft(=1.22m) ・ Trendh Bund: 2 ft(=0.61m) *To allowing for a fair factor of safety for sudden unforeseen rise of water level such as wave, shortening of rive course.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 20	Depending on the design discharge as shown in the following table Discharge / Freeboard Under 7,062 cusec (=200 m3) / 2.0 ft (= 0.6 m) 7,062 to 17,657 cusec (=200 to 500 m3) / 2.6 ft (= 0.8 m) 17,657 to 70,629 cusec (=500 to 2,000 m3) / 3.3 ft (= 1.0 m) 70,629 to 176,573 cusec (=2,000 to 5,000 m3) / 3.9 ft (= 1.2 m) 176,573 to 353,146 cusec (=5,000 to 10,000 m3) / 4.9 ft (= 1.5 m) Over 353,146 cusec (=10,000 m3) / 6.6 ft (= 2.0 m)	Same as Above
	Extra Embank-ment	Levelling of Top of Bunds after Construct-ion.	7	Chapter VI, Page 3 of 14 53. Method of good construction	・ Normal: 12 1/2 % of Deign Height ・ With Scrapers/Foot Roller: 6 1/4 % of Deign Height *In order to allow settlement and compaction	Standard for Extra Embankment	Depends on the soil type and bund height as shown in the following table Embankment Height / Foundation Materials: Normal Soil / Sand / Gravel; Extra Banking Materials: Normal Soil / Sand / Gravel / Normal Soil / Sand / Gravel (cm) / (cm) / (cm) / (cm) ≤ 3 m / 20 / 15 / 15 / 10 3m – 5m / 30 / 25 / 25 / 20 5m – 7m / 40 / 35 / 35 / 30 ≥7 m / 50 / 45 / 45 / 40	This is almost the same value between Sindh Province and Japan.
Quality Control	Material	Desirable Material	8	Chapter VI, Page 1 of 14 51. Requisites of suitable soils for bund building	・ The bund is built, as a rule-, of earth obtainable along the line of the bund or from the borrowpits on the river side immediately in front of the bund. ・ Sand mixed with a fair proportion (30 to 40%) of clay is desireble. *The sand in the clay will prevent shrinkage and cracks without destroying the watertightness an toughness of the clay.	River Earthwork Manual [3.1.3]	・ Fine particle contents is important. ・ 15% to 50% of fine particles (Not larger than 0.075mm in the size) is desirable. ・ Maximum particle size is not larger than 10 to 15 cm. ・ A soil which has wide distribution in particle size, and not so many contents of silt.	Recommend to the Bund Manual in Sindh to state the maximum particle size and allowable range of the particle size distribution. The rule for the source of the embankment material is necessity be revised.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
		Available Material	9	Chapter VI, Page 1 of 14 52. Relative Merits of different soils for Bund Building.	· Sand(With 6 inches thickness clay cover): 85% of sand, 10% of silt, and 5% of clay. *Without clay cover, due to the flat saturation, large section is required. · Sand Mixed with Clay: 50-70% of sand, 30-50 of clay *Optimum admixture · Loam(With 6 inches thickness clay cover): 30-50% of sand, 30-50% of silt, and Less than 20% of clay. *Little stability ehwn saturated. · Clay(With Sand Core): 5% of sand, 40% of silt, and 55% of clay. *Bunds, should not be constructed of such soils unless absolutely unavoidable,		Same as above	
	Construct-ion Method		10	Chapter VI, Page 10 of 14 60. Specifications for Earth work for River Embankment.	· All earth laid in the embankment shall be free from all roots, grass, sticks or other foreign matter. · The earth shall be deposited and spread in horizontal layers, 6 inches thick, for the full width of the bank. · All clods, and lumps of earth shall be broken up in the borrow pits to a diameter of not more than 2 inches. · To facilitate rolling, the bank shall be carried up in uniform layers of not more than 6 inches in thickness · No fresh layer shall be put on until the previous one has been thoroughly consolidated to the satisfaction of the Executive Engineer or subordinate.	River Earthwork Manual [4.2.5], [6.1] to [6.4], [3.4.5], [5,6]	· The thickness of 1 layer of a embankment is 11.8 inches(=30cm). · The required and recommended equipment to be used for each earth work item is listed, and 5 major equipment such as bulldozer, tire roller, vibrating roller, vibrating compactor, and tamping machine is introduced with the applicable types of embankment materials. · Inspection & investigation to verify the applicability for the embankment material, methodology of quality control, countermeasures for soft ground and environmental aspects are also introduced.	It is necessary to add the description of the construction equipment and the feature of materials that can be used. It is necessary to add descriptions about the method of embankment material survey and quality control. It is recommended to add a description about countermeasures for soft ground.
	Degree of Compact-ion		11	-	No description	River Earthwork Manual [3.1.4]	The degree of compaction needs to require following two criteria. However, depending on the embankment material used, it may not be possible to ensure these criteria. In such cases, it is necessary to confirm the degree of compaction by trial embankment and set compaction management standards suitable for the soil material used. -The average value is larger than 90% of the maximum laboratory dry density. -The minimum value is larger than 80% of the maximum laboratory dry density.	It is recommended to add the description of the case in which the required degree of compaction cannot be satisfied. Adding a description about setting a compaction criteria by a trial embankment is recommended.
Service Road/ Mainte-nace Road			12	Chapter V, Page 18 of 18 50. Fencing.	· Not clearly mentioned. · However, public traffic is not permissible on bunds and fencing is needed.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 27	· The minimum width of the maintenance road is set to 3m considering purposes of patrols, rehabilitation and flood fighting during floods. · Easy access and use by the residents nearby is considered. · Due to these purposes, a paved road is recommended in the Japanese standard.	For the smooth passage of maintenance vehicles, it is recommended to add a description about the pavement on the top.
Safety Evaluation	General		13	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]	The following safety conditions are verified by setting an appropriate river level as a verification condition. · Normal Time ➢ Slope stability against slip ➢ Settlement ➢ Erosion caused by rainwater drainage · During Flood ➢ Direct erosion and lateral erosion ➢ Seepage (Slope stability against slip and Piping) · Earthquake ➢ Settlement due to liquefaction · During Storm Surges ➢ Erosion ➢ Wave overtopping	It is necessary to conduct studies and evaluations based on numerical analysis, taking into account river conditions and geological conditions.
	Slope Stability/ Slip Circle		14	Chapter V, Page 8 of 18 37. Stability of Section.	The cross-section is fixed from experience, on consideration of stability under all conditions.	Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]	· Verify the stability against slip circle by a numerical analysis with a software. · Modified Fellenius Method is specified for slip circle analysis.	Same as above

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Erosion		15	Chapter IV, Page 3 of 15 20. Cutting of Erosion Lines and Spacing of Erosion Ordinates.	・ The following table gives the distance where the erosion ordinates are deemed essential and the distance apart that should be kept between the two consecutive ordinates <table><tr><td></td><td>Where distance between Bund and pucca edge is</td><td>Distance between two consecutive ordinates</td></tr><tr><td>Above Sukkur</td><td>2 to 3 miles 1 to 2 miles Less than a mile</td><td>1 mile apart Half a mile part One furlong apart</td></tr><tr><td>Below Sukkur</td><td>2 to 3 miles 1 to 2 miles Less than a mile</td><td>No ordinates Half a mile apart One furlong apart</td></tr></table>Where the edge of the pucca bank is less than 3,000 ft. proposals for loop bund should be sent in at once.	Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]	・ Secure the Distance from the Riverbank to the bund, which varies depending on the feature of the river(called a “segment” in Japan) ・ Verify the stability of slope protection material against the design flow velocity.	Verification of the stability against the target flow velocity is recommended.
	Seepage Control	Permabili-ty inspection	16	-	No description	River Earthwork Manual [2.1.7] Guide of Structural Analysis of River Embankment - 3.2.2 Soil Investigation	・ Unsteady flow calculations considering rainfall and river level changes.	Due to no mention, nothing is compared
		Seepage analysis	17	-	No description	River Earthwork Manual [3.3.1] Guide of Structural Analysis of River Embankment - 4.3.2 Item and criteria for analysis	・ Verify the stability against slip circle and local hydraulic gradient at the toe of a bund considering the movement of the water level during floods ・	Same as above
	Seismic Condition		18	-	No description	Performance Based Seismic Design Criteria for River Structures II. Dike	・ Verify if the top elevation of a bund after an earthquake is higher than the specific water level. ・ Numerical analysis with a software	It is desirable to study for adding the description of stability against earthquakes considering the future condition.
Improve-ment of a Bund	Slope Stability/Slip Circle		19	Chapter XI, Page 6 of 17 125. Slips and their treatment	・ Expansion of the Rear Section to cover the saturation line ・ Mangli or ringl bund around the slip ・ Installation of drainage material at the land side toe	Technical Criteria for River Works: Practical Guide for Designing [I] [2.8.2] Guide of Structural Analysis of River Embankment - 4.4.3 Selection of Improvement Method	・ Milder Slope ・ Counterweight Embankment ・ The Measures for Seepage Flow to Reduce the Water Level in the Bund Body ・ Sheet Pile to Stop the Slip Circle	Similar types of methods are introduced in both standards.
	Erosion		20	Chapter XV, Page 1 of 4 156. Necessity of stone spurs and stone apron	Stone Spurs and Stone Aprons *Calculation of expected deepest scouring based on the historical highest discharge. Calculation of length and thickness of stone apron by it.	Technical Criteria for River Works: Practical Guide for Designing [I] [2.8.3] Guide of Structural Analysis of River Embankment - 5.3.2 Item and criteria for analysis	<Without Revetment> ・ Revetment(for a Bund/low Water Channel) ・ Erosion Control Mat ・ Control the Vegetation on the Bund ・ Realignment ・ Spur <With Revetment> ・ Strengthening the Revetment ・ Extension of Bottom of the Revetment ・ Making a Dry Masonry to a Wet Masonry ・ Foot Protection Work ・ Realignment ・ Spur	As a foot protection work, it is recommended to introduce concrete blocks and net gabion.
				Appendix V Miscellaneous River Works., Page 2 of 12 2. Revetment	・ Revetment ・ Cemented Stabilized Soil Revetment ・ Tree Groynes ・ Bandelling, etc... *As feasible options in Sindh, they are introduced without design method.			
	Seepage Control (Newly Construct-ed)	Types of improve-ment methods	21	Chapter V, Page 7 of 18 35. Piping	・ Proper choice of Earth Fill ・ Apply the Standard section in Sindh	River Earthwork Manual [3.4] Guide of Structural Analysis of River Embankment - 4.4.3 Selection of Improvement Method	<For a Bund Body> ・ Expansion of Bund Body ・ Installation of Drain(Gabion) ・ Covering Riverside Slope(Impervious Sheet) ・ Covering All the Surface <For Foundation Ground> ・ Seepage Cut-off in front of a Band ・ Blanket Method ・ Well Method	It is recommended to include improvement methods that can be applied in Sindh Province, such as seepage cut-off walls and impervious sheets, as seepage control works.

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Sub Item</th><th rowspan="2">Sub-Sub Item</th><th rowspan="2">No.</th><th colspan="2">Sindh</th><th colspan="2">Japan</th><th rowspan="2">Comments</th></tr>
<tr><th>Technical Codes</th><th>Value/ Contents</th><th>Technical Codes</th><th>Value/ Contents</th></tr>
<tr><td></td><td></td><td>Existing bund</td><td>22</td><td>Chapter XI, Page 6 of 17
125. Slips and their treatment</td><td>Expansion of the Rear Section to cover the saturation line
*Not clearly mentioned on seepage control for the existing bund.</td><td></td><td>Same as above</td><td>Same as above</td></tr>
<tr><td></td><td></td><td>Earth-quake</td><td>23</td><td>-</td><td>No description</td><td>Guidelines for Seismic Performance Verification of River Structures Vol.2</td><td>・ Counterweight Embankment
・ Vibrating Compaction
・ Static Compaction
・ Deep Mixing Soil Stabilization
・ Cement Grouting
・ Jet Grout
・ Gravel Drain
・ Drain(Gabion) at the Toe of the Bund
・ Steel Sheet Piling
・ Replacement of the Soil</td><td>It is desirable to add countermeasures against earthquakes.</td></tr>
<tr><td>Revetment</td><td>General</td><td></td><td>24</td><td>Chapter I, Glossary of terms used in connection with River Bunds in Sindh
Page 11 of 14</td><td>A pitching protection of stone, or brick or sand bags containing a certain proportion of cement or similar materials.</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc.
Article 25</td><td>The purpose of revetment is to protect the bunds from the action of flowing water when necessary.
Slope Protection : Work direct contact between the embankment surface and flowing water to prevent scouring.
Foundation Work : Supports the Slope Protection.
Foot Protection Work : Prevents scouring of the riverbed in front of the foundation during floods and stabilizes the foundation work.</td><td>There is no mention of the parts consisting of a revetment.</td></tr>
<tr><td></td><td>Material and Structure</td><td></td><td>25</td><td>Appendix V, Page 2 of 12
2. Revetment</td><td>・ Stone masonry pitching
・ Burnt Brick masonry pitching
・ Brushwood pitching including alternate layers of earth
・ Muharis, single or double
・ Lai groynes (single)
・ Lai mats including fixing
・ Date mats including fixing
・ Cemented Stabilized Soil Revetment
*Not mentioned on the specification and design methods for each types</td><td>Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.2]

Basic Disaster Recovery Policy to Protect Beautiful Mountains and Rivers in Japan[4.3]</td><td>The materials used for revetments vary, including concrete blocks, stones, wood, vegetation, etc. When designing a revetment, it is necessary to carefully consider its durability and strength and ensure that it is a safe structure with functions for protecting bunds.
There is description of types of revetments with the concrete design methods. Mainly the following types are used.
<table>
<tr><th>Material</th><th>Slope : Not milder than 1.5:1</th><th>Slope : Milder than 1.5:1</th></tr>
<tr><td>Stone</td><td>・ Wet Stone Masonry
・ Dry Natural Stone Masonry</td><td>・ Wet Stone Masonry
・ Dry Natural Stone Masonry</td></tr>
<tr><td>Wood</td><td>・ Wooden Lattice, Block, Picket Fence</td><td>・ Wooden Lattice, Block, Fascine Mattress</td></tr>
<tr><td>Gabion</td><td>・ Gabion(Step Type)</td><td>・ Gabion(Mattress, Net Gabion)</td></tr>
<tr><td>Mat, Sheet</td><td>-</td><td>・ Geotextile Mattress
・ Block Mattress</td></tr>
<tr><td>Cement, Concrete</td><td>・ Concrete Block Retaining Wall
・ Reinforced Concrete Retaining Wall</td><td>・ Concrete Block (Lining, Connecting)</td></tr>
<tr><td>Others</td><td>・ Steel Sheet Pile Wall</td><td>・ Vegetation(Not Revetment)</td></tr>
</table></td><td>It is recommended to include Gabion, Concrete Block(connected type, articulated type) and Filter Cloth.

In addition to recommending the development of an inexpensive surface covering material to replace the grass sodding, it is recommended to add a slope protection with stone pitching etc. as an immediate measure.</td></tr>
<tr><td></td><td>Safety Verifi-cation</td><td></td><td>26</td><td>-</td><td>No description</td><td>Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.3]</td><td>The assessment of the safety performance of revetments shall be conducted for the slope protection work, foundation work, and foot protection work. For the assessment, it needs setting the required conditions and acts depending on each installation location, type of work, and structural form of each component according to the table below. Based on this, the assessment items shall be set.
<table>
<tr><th>Condition</th><th>Act</th></tr>
<tr><td>Normal</td><td>Dead Weight, Earth Pressure, Water Pressure</td></tr>
<tr><td>Flood</td><td>Acting Force generated by the Flowing Water which has the water level below HWL, Dead Weight, Earth Pressure, Water Pressure</td></tr>
<tr><td>Seimas</td><td>Dead Weight, Earth Pressure, Water Pressure, Influence of Earthquake</td></tr>
</table></td><td>For each model, it is recommended to add the description of a concrete design method that allows practitioners to perform the design.</td></tr>
<tr><td></td><td>Structural Design</td><td>Slope</td><td>27</td><td>Chapter V, Page 9 of 18
37. Stability of Section</td><td>3:1 to 2:1
*Where stone or brick pitching is resorted to, the slope may be steepened from 3: 1 to 2 : 1</td><td>Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.4 (1)]</td><td>0.5:1 to milder than 2:1
Slope : Not milder than 1.5:1 → Piled up Type
Slope : Milder than 1.5:1 → Lining Type
In case of the stability analysis for the lining type, situations such as sliding, overturning, traction are considered.</td><td>Due to the mild slope of bunds, only lining type revetment is considered in the manual of Sindh.</td></tr>
</table>

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
		Founda-tion	28	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.4 (2)]	The foundation work of revetments is designed as a safe structure that can support the slope protection work, taking into consideration factors such as scouring caused by floods. Additionally, there are four basic approaches to consider when determining the elevation of the foundation work: 1. Setting the expected deepest riverbed as the elevation of the foundation work and, if necessary, installing minimal foot protection work in the front against scouring. 2. Setting the elevation of the foundation work above the expected deepest riverbed and addressing scouring with foot protection work in the front. 3. Setting the elevation of the foundation work above the expected deepest riverbed and addressing scouring with foot protection work in the front, as well as using foundation sheet piles or other embedding methods. 4. In areas with significant water depth such as tidal areas where it is difficult to install the foundation, using self-supporting sheet piles to support the foundation.	It is recommended to add the description of a concrete design method that allows practitioners to perform the design.
		Foot Protection	29	Chapter XV, Page 1 of 4 156. Necessity of stone spurs and stone apron	Stone Aprons on Front Bund *Calculation of expected deepest scouring based on the historical highest discharge. Calculation of length and thickness of stone apron by it.	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.4 (3)]	The purpose of a foot protection work is to design a safe structure for the foundation by considering the fluctuation of the riverbed and other factors related to fluid forces. The following are typical types of foot protection works: 1. Riprap: Using sufficiently heavy stones. 2. Wooden Mattress: Includes fascine mattress, wooden mattress, and improved wooden mattress. 3. Gabion Works: Using steel baskets with filling stones. 4. Piled up Concrete Blocks: Using various types of concrete blocks, including layered and random piled up.	Concrete Blocks can be considered in the Bund Manual. It is recommended to add the description of a concrete design method that allows practitioners to perform the design.
Spur (Stone Groyne)	Site Condition		30	Chapter XV, Page 1 of 4 156. Necessity of stone spurs and stone apron Chapter IV, Page 3 of 15 21. Instructions regarding pegging and measurements of erosion ordinates	The location where loop bund is needed, but no available land. *Where the edge of the pucca bank is less than 3,000 ft. proposals for loop bund should be sent in at once.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 26	· They are designed to regulate the direction of flow during floods and keep low water channel areas away from the bunds, as well as to mitigate the impact on riverbanks or bunds by the water flow. · They are installed to reduce the flow velocity during floods in the rivers with steep gradient and to protect riverbanks and bunds from erosion. · They are also installed for the purpose of maintaining and preserving navigation and river environments. · They can be classified based on their water permeability: permeable structures and impermeable structures.	It is recommended to the Bund Manual to include such a detailed information relating with the practical design method.
	Basic Shape		31	-	No description	-	No description	The manual in Punjab is including the description.
	Material		32	Chapter I, Glossary of terms used in connection with River Bunds in Sindh Page 6 of 14	Stone A stone groyne is called a spur	Technical Criteria for River Works: Practical Guide for Designing [I] [4.5]	Piled up Concrete Blocks, Piled up Natural Stones and Wooden Type	Concrete Blocks can be considered.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Design Method		33	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [4.5]	Considerations for the safety of spurs is similar to those for revetment. However, designing spurs is more challenging with theoretical interpretation beyond it for revetment. To address this, past experiences, records from similar rivers, and the results of trial construction, model experiments, and research surveys for new construction methods are utilized to design spurs with consideration for construction feasibility, cost-effectiveness, maintenance management, and the safety of river users. The following reference values have been provided based on previous cases: 1. Spurs to Reduce Flow Velocity: Length: Less than 10% of the river width. Height: Approximately 0.2 to 0.3 times the HWL. Spacing: Often 2 to 4 times the length and 10 to 30 times the height. 2. Spurs to Regulate the Flow Direction and to Prevent Riverbank Erosion: Height at the connection point of the spur: Approximately the HWL. Spacing: Usually 1/2 to 1/3 of the length of the sandbar formed in the respective section. Direction: Mostly perpendicular to the riverbank or slightly downward.	It is recommended to include such a detailed information relating with the practical design method.
Construct-ion Works	Permission		34	Chapter VI, Page 14 of 14 60. The contractor shall not enter upon or commence any portion of the work Chapter II, Page 4 of 8 4. Execution of Works	・ The contractor shall not enter upon or commence any portion of the work, except with the written authority and instruction of the Executive Engineer or his subordinate in charge of the work. ・ Executive Engineers will submit the proposal to the Divisions concerned to the Secretary, Indus River Commission, through the Superintending Engineer of the Circle, for the administrative approval of the Indus River Commission	River Law Article 16(3)～Article 21	Somebody other than river administrators may implement river works or maintenance of rivers with the approval of the river administrator as prescribed by the cabinet order. However, for those considered to be of a minor nature as determined by the cabinet order, approval from the river administrator is not required.	In Sindh, implementation of works by the other public or private sector in the river area is not clearly mentioned and there is no mention of the permission for it.
	Construct-ion	Procedure	35	Chapter VI, Page 7-8 of 14 60. The contractor shall not enter upon or commence any portion of the work	・ Removal of all trees, shrubs, grass or other growths on the site of the embankment ・ Mark the base of the embankment and the limits of the borrow pits, construct the side slopes. ・ All earth for the embankment shall be obtained only from the borrow pits set out by the Executive Engineer. ・ If a key trench is provided under the embankment, the excavated trench must be measured, removed, and backfilled. ・ The earth shall be deposited and spread in horizontal layers, 6 inches thick, for the full width of the bank ・ each layer shall be thoroughly consolidated either by ramming, rolling, or by weighted bullock carts as directed by the Executive Engineer. ・ Measurements of earthwork will be taken as far as possible in the borrow pits.	River Earthwork Manual [6.1]	The process of construction inspections can vary depending on the type of construction, the inspector, and the conditions at the time of inspection. However, as a general example, the following flowchart illustrates the typical order: Inspection with Documents: 1. Bid Document; 2. Contract Document; 3. Construction Plan; 4. Work Schedule; 5. Documents on Meeting for Construction; 6. Documents on Quality Control; 7. Documents on Shape Control; 8. Site Photos; 9. As-built Drawings and others Inspection at Site: Shape Inspection Check of Quality and Finished Shape with Drawings, Quality Calculations and Measurement Record	In case of Pakistan, such instruction is seemed to be included in technical specification in each contract.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
		Site Inspection for Work Accomp-lishment (Shape inspection)	36	Chapter VI, Page 7-8 of 14 60. The contractor shall not enter upon or commence any portion of the work	Not clearly mentioned. *However, permission by the Executive Engineer is needed to proceed to the next layer of embankment	River Earthwork Manual [6.2]	✓ Embankment Work: Longitudinal Inspection: Stations are often placed every 20 meters to measure the length of embankment work. Benchmark elevation is typically measured at a location per 100 meters. Cross-sectional Inspection: Using a level and scale, measurement is conducted using the stations placed every 20 meters. ✓ Excavation Work: Inspection is conducted by measuring benchmark elevation, distance, and cross-section at representative stations. The areas between representative stations are inspected visually. ✓ Dredging Work: Bathymetry survey is conducted at the dredging site. Measurement points are selected at a location per 20 m2. Even if there is over-dredging beyond the proposed cross-section, that portion is not accepted as part of the work volume. Cross-sectional surveys are conducted to calculate the volume of soil, and this is compared with the acceptance criteria mentioned above. If there is a significant discrepancy between the results of the two methods, a re-measurement is necessary.	Due to no mention in the manual in Punjab, nothing is compared.
		Quality Inspection	37	-	No description	River Earthwork Manual [6.3]	Quality inspections are basically conducted by the client based on the document submitted by the contractor, following the specifications. However, in some cases, the client may also perform quality tests and inspections themselves. ✓ Embankment Martial Quality: If specified in the contract, the client will inspect the records of the material tests. They will also verify if the material is sourced from the designated borrow pit if specified. ✓ Thickness of a Layer: The client primarily verifies if the embankment has been constructed to the specified thickness as specified in the contract or based on the results of trial embankment, often using photographs as evidence. For general soil, the typical thickness of a layer is 35 to 45 cm. ✓ Compaction: If compaction degree inspections are required after the completion of embankment work, the client will confirm the results through the quality control records approved by the supervisor or through the supervisor's confirmation. During constructions, compaction degree tests for quality control can be conducted using methods such as dry density, saturation degree or void ratio, strength characteristics, or based on the type of compaction equipment and number of passes.	Due to no mention in the manual in Punjab, nothing is compared.
		Acceptability Criteria	38	-	No description	River Earthwork Manual [6.4]	The criteria for determining acceptance is specified in the specifications or contract conditions. There are two common methods for determining acceptance: 1. Specification value method: This method typically involves 100% inspection, where all measured values during the inspection must meet the specified values (allowable tolerances) as indicated in the design drawings or specifications. This method is commonly used for inspections of structural dimensions, among other things. 2. Acceptance criteria method: In case of sampling inspections, the size of the lot and the number of samples per lot are determined, and measurements are taken. The results are considered acceptable if they satisfy the following criteria: This method is commonly used for quality inspections and other types of inspections. Upper acceptance criteria value ≥ Average of measured values ≥ Lower acceptance criteria value.	Same as above

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Manage-ment Plan	Manage-ment Plan		39	Chapter IX, Page 1-5 of 5, Pre-Abkalani Maintenance Chapter X, Page 1-13 of 13 Ordinary Maintenance during Abkalani	Pre-abrakani maintenance and ordinary maintenance is stated. *There is no statement on middle and long-term management plan. The maintenance within a single year is focused on.	Technical Criteria for River Works: Practical Guide for O&M(For River) [2.1]	About the river maintenance management, the basic principle is to establish a PDCA (Plan-Do-Check-Act) cycle. This involves conducting river patrols and inspections to assess the condition, implementing maintenance measures, and analyzing and evaluating the knowledge gained from these activities. The insights obtained are then reflected in the river maintenance management plan and implementation.	It is necessary to create a plan that improves the durability and strength of the bunds by repair and reinforcement.
	Manage-ment Cycle		40	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [2.1]	A PDCA cycle involves repeated river patrols, inspections to grasp the condition, management measures over a long period, and analyzing & evaluating the knowledge gained through these series of tasks to reflect it in the river management plan or implementation content.	Instead of inspections and repairs with in a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years.
Monitor-ing of River Conditions	General		41	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [4]	River patrols for river channels and river management facilities in large scaled rivers are conducted based on the River Patrol Regulations 1, with the aim of carrying out planned, efficient, and effective inspections. For small and medium-scaled rivers, the basic principle is to conduct river patrols effectively, following the example of major rivers..	It is necessary to verify that the inspection sheet format, storage, and viewing system are functioning.
	Patrol/ Physical Inspection		42	Chapter X, Page 3 of 13 107. Organization for patrolling and duties of members of staff	(Patrol During high flood) ・ As soon as water comes against a bund, patrolling by beldars should commence. Beldars works in pairs with six hours shift ・ The temporary headquarters of the Overseer, Sub-Divisional Officer and Executive Engineer should be in the centre of the active bund line in their charge. ・ One daroga for 8-20 miles of active bund line, depending on local conditions, is generally to be provided on the annual establishment.	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.4]	✓ Regular River Patrol: General Patrol: Conducting inspections based on predetermined patrol items. Purpose-specific Patrol: Select the inspection items, objectives, and locations to gain a more detailed understanding of the situation. ✓ River Channel and River Management Facility Patrol: Conduct to visually identify relatively significant changes or abnormalities that can be observed in the river channel or facilities. ✓ Illegal Activity Detection Patrol: Conducted within the river area to check for any illegal occupancy of land or unauthorized installation of structures. ✓ River Use Monitoring Patrol: Conducted to monitor the use of the river and assess its utilization. ✓ Natural Environment Assessment Patrol: Conducted to assess the condition of the natural environment in and around the river. ✓ Patrol During Floods: Conduct during flood events to quickly and comprehensively assess the situation, including the condition of bunds, flood flows, trees within the river channel, river management facilities, and the extent of inundation in the surrounding areas. It also involves monitoring the progress of flood control operations and water drainage.	It is necessary to include the description not only to conduct visual inspections, but also to carry out inspections and exploration with equipment as needed and to collect basic data such as hydrological data and topographic surveys.
				SAFETY EVALUATION OF FLOOD BUND 11. SAFETY INSPECTION AND EVALUATION, p11	(Physical inspection of the bund after a flood) ・ Top Levels ・ Unwanted Vegetation and Debris ・ Encroachments ・ Slope/Section Stability ・ Settlement ・ Land Subsidence ・ Damaged Armour ・ Flood Wall Damage ・ Runnel *Situation and solution are described.			
	Inspection with Equip-ments / Investi-gation / Exploratio n		43	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.5]	Inspection before Rainy Seasons and During Typhoons In these inspections, technologies such as MMS (Mobile Mapping System) are used to assess the condition of long and extensive structures, and radar void exploration is employed for non-destructive investigation of the rear side of revetment. Additionally, for the inspections of river channels and bunds, new technologies such as airborne laser-based river topography monitoring and UAV (Unmanned Aerial Vehicle) terrain surveying are being developed and utilized.	Same as Above

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	River Profile / Inspection Report / Damage Record		44	APPENDIX I. River Conditions and Flood Control Measures in Sindh	No description *There are contents on Indus River and vulnerable sites along it. However, not organized as a river profile.	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.6]	In large scaled rivers, the history of river maintenance management is preserved and documented as a river ledger, serving as a fundamental resource for river management. The river ledger includes implemented measures such as inspections and repairs, as well as records of river construction work projects, disasters, and corresponding countermeasures. To ensure efficient data management, the river ledger is stored in a database, enabling efficient recording and accumulation of information relevant to river management history.	Same as Above
	Analysis and Evaluation		45	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.7]	To enhance the implementation of specific maintenance management for each river based on the river maintenance management plan, it is important to clearly identify the challenges that need to be addressed according to the situation of each river. It is also crucial to analyze these challenges progressively as they are being addressed and implemented.	In the Japanese standard,, the several items such as hydraulic and hydrological observation, topographic survey, inspection after earthquake and inspection for mechanical equipment, and river ledger are described for monitoring of river conditions.
Inspection and Ledger	General		46	-	No description	Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels [I]	The inspections are conducted to ensure the following two functions related to flood control in rivers: 1. Confirming that the river channel maintains the required flow capacity. 2. Ensuring that the river management facilities, such as bunds, maintain the necessary functions. Inspection Targets: I. Embankments: a. Earthen Bunds, Revetments, Steel Sheet Pile Revetments, Foot Protection Works, Spurs. b. High Tide Wall, Special Type Bund, Land Gates. II. River Structures: Facilities equipped with sluice gates, culverts, water gates, weirs, and drainage pump stations. III. Inspection Timing: Prior to Rainy Season, During Typhoon Seasons, and After Flooding Events. IV. Inspection Methods: Inspections are conducted using visual observation and other appropriate methods. V. Evaluation Methods: The inspections focus on visible "deformation" that could impact the functionality of the facilities. Evaluations are conducted for each identified deformation, considering the presence of deformations and malfunctions. A comprehensive evaluation is provided based on these factors. VI. Recording and Utilization: The results of the inspections and evaluations are recorded in a database. The recorded inspection results are utilized for comprehensive evaluations and consideration of countermeasures. In cases where multiple deformations occur, deformations recur, or there is significant development of deformations, factor analysis is conducted to assess the need for fundamental repairs or updates to the structures..	In addition to preparing inspection ledgers for each site, it is recommended to perform a graded evaluation based on the observed deformations to score the degree of soundness, and then use it as an index of priority for repair and improvement.
	Bund		47	CHAPTER XIII Periodical Reports and Returns. APPENDIX VIII 2. I.R.C. Forms	· Erosion Statement · ABKALANI REPORT(BUND) · Reports on the State of Bund Sluices and Regulators. · Statement of High Flood Levels on Bund Mile Gauges and Free Board Available During the Abkalani · Position in Line of Defence · Register Showing Incidence of Leaks · Report of Leveling on Bunds	Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels [II]	Specific inspection items and evaluation criteria are provided for the following types of bunds and related structures. Additionally, inspection items are listed for each specific component of the structures. · Earth Bund (Slope/Berm, Top, Land Side Toe, Bund Foot Drainage) · Revetment · Steel Sheet Pile Revetment (Steel Sheet Pile, Land Side Ground, Coping Concrete) · Foot Protection Work, Spurs · Seawall (Parapet, Protection Works, Drayage, Breakwater/Foot Protection) · River Wall (Main Body, Drainage, Breakwater/Foot Protection, Parapet) · Parapet	It is recommended to inspect and record the deformation of each part of the embankment.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	River Channel		48	Chapter IX, Page 4 of 5 98. Inspection of river course and proposals for measures	・ Ledger or form is not described. ・ A full report, together with any proposals considered necessary, should be forwarded to the Superintending Engineer, *if an unfavorable river course or river set is indicated.	Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels [IV]	Specific inspection items and evaluation criteria are provided for the following items: ・ Flow Capacity ・ Riverbed Lowering ・ Riverbank Erosion ・ River Mouth Closing The evaluation of flow capacity is primarily based on water level calculations, while the evaluation of riverbed lowering, riverbank erosion, and river mouth closing are evaluated based on periodically conducted longitudinal and cross-sectional surveys conducted periodically.	In case of the vulnerable points against erosion, it is necessary to analyze and evaluate the transition of river channels using surveys and satellite images.
	Storage		49	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [5]	For river channels and facilities other than major flood control river management facilities (excluding dams) as defined in Article 7-2, Paragraph 1 of the Ordinance for Enforcement of the River Law, inspection results shall be recorded, and the inspection results shall be retained for a period until the next inspection or longer.	It is recommended to specify the method and responsivities for storing the inspection ledgers and report like the case of Japan.
River Ledger	General		50		River Ledger or form is not described	River Law Article 12	1. The river administrator shall prepare and maintain a ledger for the rivers under their management. 2. The ledger for rivers shall consist of a current river ledger and a water management ledger. 3. The contents of the river ledger and other necessary matters regarding its preparation and storage shall be prescribed by the cabinet order. 4. When requested to view the river ledger, the river administrator shall not refuse unless there is a legitimate reason to do so..	It is recommended to prepare the river ledgers for the purpose of accumulating data aimed at improving the efficiency of bund management.
	Contents		51	APPENDIX VIII 2. I.R.C. Forms	Erosion Statement ・ Date of first measurement. ・ Sistance Remining Uncroded ・ AmoW1t of Erosion ・ Minimum Beight of free board during the week ABKALANI REPORT(BUND) ・ Breach ・ Works in Progeress ・ Leak ・ Health of Establishment ・ Erosion Statement of High Flood Levels on Bund Mile Gauges and Free Board Available During the Abkalani ・ Ground Level ・ RL of Top of Bund ・ High Flood Level ・ Freeboard on actually recorded level and extra polated level ・ Corresponding Discharge at Sukkur. Position in Line of Defence ・ Water Level ・ Diaphragm of sand Trench in the Bund ・ H.F.L ・ Leak ・ Max. Depth ・ Breach ・ Min. Freeboard ・ Extent of Erosion ・ Date on which water taouch the Bund ・ Trace of Seepage ・ Corresponding Gauge Reading at the barrage ・ Trace of Wave Wash ・ Issue in Sluice ・ RL, and widthof Top of Bund and Slope ・ Expenditure on repair last eason ・ Special patrol required during next season. ・ Ground Level ・ General Condition of Bund ・ Nature of Soil	Enforcement Order for River Law Article 4, Article 5	<For a Ledger> ・ Name of River System ・ River Name ・ Length of the River ・ River Area ・ General Profile of Major River Management Facilities <For a Figure> ・ Boundaries of River Area ・ Information of the Power of River Manager on the land within the river area ・ Major River Management Facilities ・ Major permitted structures	Among the reports and forms introduced in the manual, “Position in Line of Defense (Bund Register)” seems to be containing the most similar information as the river ledgers in Japan,

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
					Register Showing Incidence of Leaks ・ Location ・ Observation Time ・ Probable Cause ・ Plugging/Closing Time ・ Method Adopted ・ Date of opening leak in full width ・ Date of refilling			
	Storage		52	-	No description	Enforcement Order for River Law Article 7	The river ledger shall be stored at the offices of the relevant regional development bureaus (including the offices of the Hokkaido Development Bureau, same as in Article 39-3, Paragraph 1, Item 1) for first-class rivers, and at the offices of the relevant prefectures for second-class rivers, as prescribed by the Ministry of Land, Infrastructure, Transport and Tourism.	It is recommended to specify the method and responsivities for storing the inspection ledgers and report like the case of Japan.

Source: JICA Project Team extracted from the Bund Manual in Sindh & concerned Japanese standards and guidelines and analyzed.

3.6.3 Comparison of the Manual in Punjab and the Japanese Manuals

(1) Definition of a Bund

In both the Manual in Punjab and Japanese standard, a bund is basically an earthen structure which is aiming at protecting the country from inundation by the river spill, during floods.

While as the target water level which shall be protected by a bund, high water level (HWL) based on a probabilistic analysis is used in Japanese standard, Designed Flood Level is used in Punjab Province. According to the manual, it is the highest recorded flood level in Pakistan. Although there is no detail description of it, if the way of setting is same as the Bund Manual on Sindh, it is set to equal to 2 ft. above the Actual H. F. L.[20] at any point on all the Bund lines in the province in 1972.

Hence, in Punjab Province, once the highest water level due to a flood is updated, the target water level for the bund design will increase.

(2) Standard Shape of a Bund

Top width is defined as 25 to 30 ft(=7.6 to 9.1 m) in the Manual of Irrigation Practice in Punjab, this is almost the same as the rivers which has over 353,146 cusec(=10,000 m^3/s) in discharge in the Japanese standard.

The width of a berm is no specified and are determined to cover the hydraulic gradient line in the Manual of Irrigation Practice in Punjab and 9.84ft (=3 m) in the Japanese standard.

Freeboard which stated in the Manual in Punjab is 6 to 7ft (=1.8 to 2.1m) or as determined by analysis whichever is greater, and it is almost the same as the rivers which has over 353,146 cusec (=10,000 m^3/s) in discharge in the Japanese standard.

The side slope in the Manual is set to 3:1 to 4:1, which is milder than it in the Japanese standard.

These values are considered to be reasonable compared to the Japanese standard, even when considering the discharge during floods, duration of high water level and the available earthen material around Indus River.

On the other hand, the extra embankment is not described in the Manual of Irrigation Practice in Punjab. In the Japanese standard, the extra embankment height depending on the bund height and type of soil is introduced. It is necessary for the Manual of Irrigation Practice in Punjab to describe this item considering the surface erosion due to rain throughout the bund.

(3) Quality Control

In the Manual of Irrigation Practice in Punjab, there is no description of this item. As mentioned in Chapter **3.6.2 (3) 1)** in this report, the Japanese standard states as follows. It is necessary for the Manual of Irrigation Practice in Punjab to include such contents as quality control, requirement and survey for the embankment material, and also the options for the case when it is difficult to obtain the required embankment material.

Furthermore, it is recommended to add a description about countermeasures for soft ground.

About Material

- ✓ *Fine particle content is important.*
- ✓ *15% to 50% of fine particles (Not larger than 0.075mm in the size) is desirable.*
- ✓ *Maximum particle size is not larger than 10 to 15 cm.*
- ✓ *A soil which has wide distribution in particle size, and not so many contents of silt.*

[20] The actual "H.F.L." has been defined as the highest recorded level at the particular point, since 1914.

About Construction Methods

- ✓ *The thickness of 1 layer of an embankment is 11.8 inches(=30cm).*
- ✓ *The required and recommended equipment to be used for each earth work item is listed, and 5 major equipment such as bulldozer, tire roller, vibrating roller, vibrating compactor and tamping machine is introduced with the applicable types of embankment materials.*
- ✓ *The degree of compaction needs to require following two criteria. However, depending on the embankment material used, it may not be possible to ensure these criteria. In such cases, it is necessary to confirm the degree of compaction by trial embankment and set compaction management standards suitable for the soil material used.*
  - ➢ *The average value is larger than 90% of the maximum laboratory dry density.*
  - ➢ *The minimum value is larger than 80% of the maximum laboratory dry density.*
- ✓ *Inspection & investigation to verify the applicability for the embankment material, methodology of quality control, countermeasures for soft ground and environmental aspects are also introduced.*

Source : JICA Project Team quoted from River Earth Work Manual, Japan

(4) Service Road/ Maintenance Road

In the Manual of Irrigation Practice in Punjab, there is no description of this item. As mentioned in Chapter **3.6.2 (4)** in this report, in the Japanese standard, the minimum width of the maintenance road is set to 3m considering purposes of patrols, rehabilitation and flood fighting during floods. Also, easy access and use by the residents nearby is considered. Due to these purposes, a paved road is recommended in the Japanese standard.

In case of the existing bund in Punjab, in a lot of location tops of the bunds are not paved and there are many of location where vehicles cannot pass smoothly. In order at least to secure the better access for the O&M, installation of the pavements on the top of the bund for all the stretch is highly recommended.

(5) Safety Evaluation

Table 3.6.16 shows the methods for safety evaluations against slope failure, erosion, seepage flow and seismic force. Except for the erosion, numerical analysis is instructed in the Japanese standard.

In case of seepage flow, the verification of stability against slip circle is similar method between them. However, the method for determining the pore water pressure and hydraulic gradient line is different. A numerical analysis is introduced in the Japanese standard, while the simple relational equation is listed in the Manual of Irrigation Practice in Punjab.

It is necessary to conduct studies and evaluations based on numerical analysis, taking into account river conditions and geological conditions in seepage analysis. Seepage flow analysis is thought to be effective in examining vulnerability, because the bund body material are expected to varies.

In case of earthquake, the assumed type of damage differs between the Manual of Irrigation Practice in Punjab and the Japanese standard. The assumed damage is the slip of bund body in Punjab but the subsidence of bund in Japan. It is desirable to add safety evaluation against settlement by earthquakes.

Table 3.6.16 Methods for Safety Evaluations in Punjab and Japan

Item	Manual of Irrigation Practice in Punjab	Japanese Standard
Slope Failure	・ Verify the stability against slip circle by a numerical analysis with a software. ・ Simplified Bishop Method is specified for slip circle analysis.	・ Verify the stability against slip circle by a numerical analysis with a software. ・ Modified Fellenius Method is specified for slip circle analysis.

Item	Manual of Irrigation Practice in Punjab	Japanese Standard
Erosion	・ No Mention[21]	・ Secure the Distance from the Riverbank to the bund, which varies depending on the feature of the river(called a "segment" in Japan) ・ Verify the stability of slope protection material against the design flow velocity.
Seepage Flow	・ Verify the stability against slip circle and location of hydraulic gradient line at the toe of a bund considering Design H.W.L. ・ Numerical analysis with a software only for verification of the stability against slip circle	・ Verify the stability against slip circle and local hydraulic gradient at the toe of a bund considering the movement of the water level during floods ・ Numerical analysis with a software
Earthquake	・ Verify the stability against slip circle in the event of earthquake	・ Verify if the top elevation of a bund after an earthquake is higher than the specific water level. ・ Numerical analysis with a software

Source: JICA Project Team extracted from the Manual of Irrigation Practice in Punjab and Guideline for Structural Analysis of River Embankment in Japan

(6) Improvement of a Bund

Table 3.6.9 shows major bund improvement methods introduced in each manual.

Table 3.6.17 Major Bund Improvement Methods Introduced in the Punjab and Japan Manual

Item	Manual of Irrigation Practice in Punjab	Japanese Standard
Slope Failure	・ No countermeasures[22]	・ Milder Slope ・ Counterweight Embankment ・ The Measures for Seepage Flow to Reduce the Water Level in the Bund Body ・ Sheet Pile to Stop the Slip Circle
Erosion	・ Stone Spurs and Stone Aprons (for Foot Protection) ・ Revetment[23]; Stone Pitching, Soil Cement Cover, Cement Concrete Paving, and so on. ・ Geotextile Filter ・ Gabion ・ Studs	<Without Revetment> ・ Revetment(for a Bund/low Water Channel) ・ Erosion Control Mat ・ Control the Vegetation on the Bund ・ Realignment ・ Spur <With Revetment> ・ Strengthening the Revetment ・ Extension of Bottom of the Revetment ・ Making a Dry Masonry to a Wet Masonry ・ Foot Protection Work ・ Realignment ・ Spur
Seepage Flow	<For a Bund Body> ・ Installation of Drainage Material; Pervious Toe Drain, Horizontal Drainage Layers, and Inclined Drainage Layers ・ Land Side Seepage Berms* <For Foundation Ground> ・ Cut-off Trench ・ River Side Impervious Blankets ・ Pervious Toe Trenches ・ Pressure Relief Wells ・ Land Side Seepage Berms ・ Reworking of the Foundation Soil ・ Grouting of the Armored River Bed to	<For a Bund Body> ・ Expansion of Bund Body ・ Installation of Drain(Gabion) ・ Covering Riverside Slope(Impervious Sheet) ・ Covering All the Surface <For Foundation Ground> ・ Seepage Cut-off in front of a Band ・ Blanket Method ・ Well Method

[21] The concrete method for scour depth is described.

[22] The Punjab manual introduced a installation of drainage material which can improve safety on slope stability by reducing the water level in the bund body as the countermeasure for seepage flow.

[23] In the Punjab manual, revetment is introduced by the term slope protection.

Item	Manual of Irrigation Practice in Punjab	Japanese Standard
	the Required Extent ・ Inverted Filter or Geo-textile Layer at the Foundation of Revetment / Gabion Hydraulic Structure ・ Where Required, Provision of a Suitable Cut-off	
Earthquake	・ No countermeasures[24]	・ Counterweight Embankment ・ Vibrating Compaction ・ Static Compaction ・ Deep Mixing Soil Stabilization ・ Cement Grouting ・ Jet Grout ・ Gravel Drain ・ Drain(Gabion) at the Toe of the Bund ・ Steel Sheet Piling ・ Replacement of the Soil

Source: JICA Project Team extracted from Manual of Irrigation Practice in Punjab and Guideline for Structural Analysis of River Embankment in Japan

About slope stability, the Manual of Irrigation Practice in Punjab has no clear description on the improvement methods and is necessary additionally introduce the improvement method as well as the Japanese standard.

About erosion, vegetation on the slope is one of the most popular measures for slope protection. However, it is difficult to be used in Punjab due to its climate which has only small amount of rain through a year. Instead of the vegetation with sodding in Japan, other types of slope protection material are recommended to be considered to reduce the damage on the slope and maintenance for it. As of now, dry stone pithing is an option because it is one of the most popular covering materials in Pakistan. In the future, application of erosion control mat or a vegetation which can resist such severe climate in Punjab with inexpensive cost is desirable. Furthermore, about the foot protection work, concrete blocks are one of the most major items in Japan. Considering the variety of the rock sizes which are currently used for covering material and difficulty to obtain the rock material with large size in Punjab, application of concrete blocks is a better option to let the foot protection work have the performance uniformly.

About seepage flow, major countermeasures are introduced in both standards, on the other hand, there are some countermeasures which have high applicability to the case of Punjab such as expansion of bund body, impervious sheet, and seepage cut-off wall with steel sheet piles in the Japanese standard. In addition, areas or lengths of each countermeasure is verified with numerical analysis. It is recommended to the Manual of Irrigation Practice in Punjab to include the more contents for the countermeasures for seepage flow and numerical analysis to validate the effect of the countermeasures.

This may increase the initial cost, but due to the improvement in the durability and strength, the number of rehabilitations will be reduced, and the scale of damage will also be reduced.

About seismic force, some of the major countermeasure against seismic force and liquefaction are indicated in the Japanese standard. In addition, the countermeasures against earthquake needs to be studied considering the effect of the countermeasures installed for seepage and erosion. Currently, there is no mention of the countermeasures against earthquake in the Manual of Irrigation Practice in Punjab. However, the demand of the improvement for the safety against earthquakes is expected to increase due to the expansion of urban areas. Hence, as one of the highest priorities next to the countermeasures against erosion and seepage, it is desirable to the manual to include it.

[24] The Punjab manual introduced a installation of drainage material which improve safety on slope stability by reducing the water level in the bund body as the countermeasure for seepage flow.

(7) Revetment

1) Material

The materials used for revetments varies and concretes, rocks, woods and vegetations are introduced in the Japanese standard. Table 3.6.6 shows the types of revetments and materials introduced in each standard. About the material of stones, similar types of revetments are introduced in both standards. On the other hand, However, no type with wood materials for the permanent structure is listed in the manual in Punjab. There is the difference in the material of concrete and others. In Japan, concrete blocks and vegetation are widely used. In addition, geotextile mattress is placed under the revetments in a lot of cases to prevent the soil particles from draining out from the bund body. Revetments with gabion and concrete blocks is little affected by an influence due to the variety of the sizes of stones unlike dry stone pitching, the strength and performance of the revetment can be uniformed in a certain stretch. Hence, adding concrete blocks is recommended as an option.

In addition, there are a lot of cases that the existing revetment have been damaged due to the suck out of the soil particles behind it, it is recommended to include the importance of placing filter cloth under the revetment main body.

Since slope protection with vegetation is inexpensive, it is widely used and can be used in the condition that the flow velocity at less than 2 m/s in Japan. However, it is hard to use the same vegetation in Pakistan due to its dry climate. It is also recommended to develop the inexpensive and suitable covering material with something like a plant or a mat for the improvement of the maintenance.

Table 3.6.18 Types of Revetments and Materials in Each Standard

Material	Manual of Irrigation Practice in Punjab	Japanese Standard	
	Not Specified	Slope : Not milder than 1.5:1	Slope : Milder than 1.5:1
Stone	・ Stone Pitching ・ Damped Stone Riprap	・ Wet Stone Masonry ・ Dry Natural Stone Masonry	・ Wet Stone Masonry ・ Dry Natural Stone Masonry
Wood	-	・ Wooden Lattice, Block, Picket Fence	・ Wooden Lattice, Block, Fascine Mattress
Gabion	・ Gabions	・ Gabion(Step Type)	・ Gabion(Mattress, Net Gabion)
Mat, Sheet	・ Geotextile Filter	-	・ Geotextile Mattress ・ Block Mattress
Cement, Concrete	・ Soil Cement Cover ・ Asphalt Concrete ・ Porous Concrete Slab	・ Concrete Block Retaining Wall ・ Reinforced Concrete Retaining Wall	・ Concrete Block (Lining, Connecting)
Other	・ Brick Pitching	・ Steel Sheet Pile Wall	・ Vegetation

Source: JICA Project Team extracted from Manual of Irrigation Practice in Punjab and Basic Disaster Recovery Policy to Protect Beautiful Mountains and Rivers in Japan

2) Structural Design

Except for a stone apron(a foot protection), the concrete design methods considering the condition of the river and site are not mentioned in the Manual of Irrigation Practice in Punjab. On the other hand, stability of each type of revetment shall be verified considering such condition stated in the Japanese standards and guidelines. Each method is specified in the standards and guidelines and is used practically in designing.

It is recommended to the Manual of Irrigation Practice in Punjab to include the detailed design method of each type of revetment, so that the manual will be more practical.

(8) Spur (Stone Groyne)

About the site condition in which spurs are needed, similar situation is considered between the Manual of Irrigation Practice in Punjab and the Japanese standard except for the objective of silting

up the area by crating slack flow. There is a mention of the purposes of spurs with the types such as permeable and impermeable ones in Japanese standard. In the Japanese standard, 2 types of spurs are introduced shown in Table 3.6.11. The purposes are to reduce the flow velocity and to regulate the flow direction, and silting up the area by creating slack flow is not clearly stated. Since silting up the area is expected in the manual of Irrigation Practice in Punjab, the expected length of spurs seems longer than the spur in Japan.

About the basic shape, only the interval of the adjacent spurs is specified, and design method are not mentioned in detailed in the Manual of Irrigation Practice in Punjab. On the other hand, the guidance for these items is included in the Japanese standard. In order to make the manual more practical, it is recommended to the Manual of Irrigation Practice in Punjab to include such a detailed information relating with the practical design method.

(9) Construction Works

Since there is no mention about this item in the Manual of Irrigation Practice in Punjab, nothing would be compared here.

1) Permission

In case of Japan, the river administrator is specified by cabinet orders, who is in charge of the management of the certain or whole stretch of rivers. Usually, rivers which have large catchment area are managed by the national government (MLIT) and are called class A rivers. Local governments are managing class B rivers with smaller catchment area and particular stretch of class A rivers.

According to River Law in Japan, somebody who have a permission from the river administrator can implement works or conduct maintenance in a river area[25].

2) Procedure, Quality Inspection and Criteria

In the Japanese standards, such procedure is stated and quality inspection method and criteria for the approval are specified in detail. In case of Pakistan, such instruction is seemed to be included in technical specification in each contract.

(10) Management Plan

In case of Punjab-PID, Asset Management Plan (AMP) considering the middle to long term is stated in the manual. However, about the maintenance for bunds and spurs the manual is focusing on single year activities only, and there is no mention on middle (5-10 years) and long (20 years) term management plan. On the other hand, the bunds in Punjab Province are needed to strengthen periodically after about 5 years based on the manual. It is important to incorporate the concept of the asset management plan to the bund management and to maintain or strengthen the function of the bunds looking ahead multiple years. So that, fundamental countermeasures against the currently faced issues can be studied and be implemented.

As it is stated in p3-71, in the Japanese standard, there is a mention of the river management plan. The target duration of the plan is set to about 5 years in case of the large scale rivers. In addition, there is a mention of the PDCA cycle management.

Since the river management is improved and updated by the repetition of the damage by the floods and the countermeasures for it, monitoring, inspection and countermeasures shall be repeated for a long duration(not a short duration such as a single year) and the knowledge from them must be reflected to the management plan.

(11) Monitoring of River Conditions

In the Manual of Irrigation Practice in Punjab, physical inspection before after a flood is described with the responsible person, structure of the survey team and inspection items. As an Inspection with

[25] River Law, Article 20

equipment, investigation and exploration, geophysical investigation with ground penetrating radar(GPR) is introduced.

On the other hand, In the Japanese standard, in addition to the abovementioned items, the several items such as hydraulic and hydrological observation, topographic survey, inspection after earthquake and inspection for mechanical equipment, and river ledger are described for monitoring of river conditions.

It is necessary to include the description not only to conduct visual inspections, but also to carry out inspections and exploration with equipment as needed and to collect basic data such as hydrological data and topographic surveys.

Especially, hydraulic and hydrological observation, topographic survey is the very fundamental information for the analysis and evaluation. So that, strengthening data sharing from the other authority such as WAPDA and PMD and periodical survey work by PID is recommended.

In addition, it is necessary to verify that the inspection sheet format, storage, and viewing system are functioning. If something is not working properly, it may be necessary to create a system with reference to the Japanese one.

(12) Inspection and Ledger

1) Bund

In the Manal for Irrigation Practice, there are mentions of safety inspection of the river training works. About the inspection on the bunds, there is a sample check list in the manual. The list covers several items and there are items not only on the erosion, leakage and top elevation but also on the deformation of the existing bunds is included.

In accordance with the Japanese guideline, concrete inspection items on the deformation of the existing bunds are described in detail by the portions. Some of the inspection items for a bund are listed in **Table 3.6.12**. In case of the sample list in Manual of Irrigation Practice in Punjab, while it covers several times, the items are not organized by the portions. Hence, it is better to improve the sample list form to include the information of the portions. So that, the presentation of the list will be more unified and monitoring the issue becomes easier. In addition, making the name of each item more concrete can reduce the variety of inspection record depending on each inspector.

About the frequency of the inspections, twice a year is instructed, which is before or after a rainy season and during a typhoon season.

As it is stated in p3-53, considering the evaluation for each inspection item and numbers of deformations in a certain stretch, the state of the bund will be comprehensively evaluated. Such evaluation can help to set the prioritization of the bunds to be improved(Refer to **Table 3.6.13**).

2) River Channel

In the Manual of Irrigation Practice, topographic survey and bathymetric survey are introduced as items for the inspection and survey for river channels. However, they seem to be focusing on only the area around the barrages.

As it is sated in p3-1, In the Japanese guideline, some of the inspection items for a river channel are listed in Table 3.6.14. The items listed in Table 3.6.14 are to be checked by topographic survey results and satellite images etc. and are concrete and practical.

In the Manual of Irrigation Practice, it is recommended to include such information not only for the area around the barrages but also for the vulnerable sites for erosions as well as the case of the Bund Manual in Sindh.

3) Storage

In the Manual of Irrigation Practice in Punjab, there is no mention about how to store the inspection ledgers and reports.

On the other hand, the method and responsibility of storing the inspection ledgers are specified in Japanese standard as follows:

> *For river channels and facilities other than major flood control river management facilities (excluding dams) as defined in Article 7-2, Paragraph 1 of the Ordinance for Enforcement of the River Law, inspection results shall be recorded, and the inspection results shall be retained for a period until the next inspection or longer.*

As well as the Bund manual in Sindh, it is recommended to specify the method and responsivities for storing the inspection ledgers and report like the case of Japan.

(13) River Ledger

In the Manual of Irrigation Practice in Sindh, there is no mention of river ledger like the Japanese ones.

In accordance with the Japanese law, the river ledgers must be prepared including the following items.

<For a Ledger>	*<For a Figure>*
✓ *Name of River System*	✓ *Boundaries of River Area*
✓ *River Name*	✓ *Information of the Power of River Manager on the land within the river area*
✓ *Length of the River*	
✓ *River Area*	✓ *Major River Management Facilities*
✓ *General Profile of Major River Management Facilities*	✓ *Major permitted structures*

Source : JICA Project Team quoted from Enforcement Order for River Law, Japan

Furthermore, the Japanese law is specifying the storage of the ledgers as follows.

> *The river ledger shall be stored at the offices of the relevant regional development bureaus (including the offices of the Hokkaido Development Bureau, same as in Article 39-3, Paragraph 1, Item 1) for first-class rivers, and at the offices of the relevant prefectures for second-class rivers, as prescribed by the Ministry of Land, Infrastructure, Transport and Tourism.*

Source : JICA Project Team quoted from Enforcement Order for River Law, Japan

This means that the accumulation of records is recognized really important.

In Punjab-PID, a river ledger is not prepared. This may be because the information of major river facilities including the bunds is stored but is very scattered. So that, it is really difficult to reach the required information without the support of the staffs or engineers in the local offices.

Such situation is not preferable, and the important information is dependent on the individual knowledges. However, as of now, little people seem to be recognizing that such situation is an issue. In Pakistan, bund management and maintenance must be more efficient and be more advanced due to the consideration of its length and limited resources such as manpower and budget. And it is not preferable to take time for gathering information which is dependent on the individuals. In addition, in order to maintain the technical skill not less than a certain level, sharing the information and knowledge is necessary.

It is recommended to prepare the river ledgers for the purpose of accumulating data aimed at improving the efficiency of bund management. Monitoring is important for vulnerability prediction.

(14) Summary

The analysis results are summarized in **Table 3.6.19** indicated in the following pages.

Table 3.6.19 Comparison of the Manual in Punjab and Japan

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Definition of a Bund	Definition		1	VOL.2 : Chapter 2 3, p185	・ An earthen man-made embankment ・ To provide protection from inundation and act as a barrier between flood water and protected area.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 17～Article 19	・ Earthen embankment designed and constructed to prevent water from flowing out of the river. ・ It is safe against water levels below the target water level.	Contents are almost same in both manuals.
Standard Shape of a Bund	Crest Width		2	VOL.2 Chapter 2 4.3.1.3, p187 to 189	・ Marginal Bunds: 25 ft(=7.6m) (Minimum)/30 ft(=9.1m) (Desirable) ・ Bunds Protecting Strategic locations: 25 ft(=7.6m) (Minimum)/30 ft(=9.1m) (Desirable) ・ Bunds along open reaches of the rivers: 20 ft(=6.1m) (Minimum)/25 ft(=7.6m) (Desirable) *The minimum value is the parameter currently prescribed by FFC and don't have been changed for 40 years. The desirable value is the recommended parameters based on empirical thoughts by the province of Punjab.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 21	Depending on the design discharge as shown in the following table Discharge / Width Under 17,657 cusec (=500 m3) / 9.8 ft (= 3 m) 17,657 to 70,629 cusec (=500 to 2,000 m3) / 13.1 ft (= 4 m) 70,629 to 176,573 cusec (=2,000 to 5,000 m3) / 16.4 ft (= 5 m) 176,573 to 353,146 cusec (=5,000 to 10,000 m3) / 19.7 ft (= 6 m) Over 353,146 cusec (=10,000 m3) / 23.0 ft (= 7 m)	The design value in Punjab is almost the same as the rivers which has over 353,146 cusec(=10,000 m3/s) in discharge in the Japanese standard.
	Side Slope	River side	3	VOL.2 Chapter 2 4.3.1.3, p187 to 189	Earthen ・ Marginal Bunds: 3:1(Minimum)/4:1(Desirable) ・ Bunds Protecting Strategic locations: 3:1(Minimum)/4:1(Desirable) ・ Bunds along open reaches of the rivers: 3:1(Minimum)/3:1(Desirable) Protected ・ Marginal Bunds: 2:1(Minimum)/3:1(Desirable) ・ Bunds Protecting Strategic locations: 2:1(Minimum)/3:1(Desirable) ・ Bunds along open reaches of the rivers: 2:1(Minimum)/2:1(Desirable)	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 22	・ Gentler than 2:1 except for the bund with a heigh of 2.0 ft (=0.6 m)	The design value in Punjab is milder than it in the Japanese standard.
		Land side	4	VOL.2 Chapter 2 4.3.1.3, p187 to 189 VOL.2 Chapter 2 6.2.4, p205 to 20	・ Marginal Bunds: 2:1(Minimum)/3:1(Desirable) ・ Bunds Protecting Strategic locations: 2:1(Minimum)/3:1(Desirable) ・ Bunds along open reaches of the rivers: -/2:1(Desirable) ・ Berm: 6:1	Same as the above.	・ Same as the above. *The gradients on the land side and the river side are not determined separately.	
	Berm		5	VOL.1 Chapter 5, 5.4.9.8, p5-69, VOL.2 Chapter 2 6.2.4, p205 to 206	・ Back berm (Pushta) (on landside) is provided to keep the hydraulic gradient within the cross-section. ・ The hydraulic gradient line should be lie at least 2ft below natural surface level at the toe of the bound and covered with soil at least 4 ft thick.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 22	・ Larger than 3 m	The design concept differs in both manuals.
	Freeboard		6	VOL.2 Chapter 2 4.3.1.3, p187 to 189 and Chapter 2, 6.2.1, p198 to 200 VOL.1 Chapter 5, 5.4.9.2, p5-60,	・ Marginal Bunds: 6 ft(=1.8m)(Minimum)/ 7.0 ft (=2.1m)or as determined by analytical analysis whichever is greater(Desirable) ・ Bunds Protecting Strategic locations: 6 ft(=1.8m)(Minimum)/ 7.0 ft (=2.1m)or as determined by analytical analysis whichever is greater(Desirable) ・ Bunds along open reaches of the rivers: 6 ft(=1.8m)(Minimum)/ 6.0 ft (=2.1m)or as determined by analysis(Desirable) ・ In the case of analysis, Free board = Wave Run-up + Wind Set + River Set + 1.0 ft *The concreate calculation method of Wave Run-Up, Wind Set-up, and River Set is mentioned.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 20	Depending on the design discharge as shown in the following table Discharge / Freeboard Under 7,062 cusec (=200 m3) / 2.0 ft (= 0.6 m) 7,062 to 17,657 cusec (=200 to 500 m3) / 2.6 ft (= 0.8 m) 17,657 to 70,629 cusec (=500 to 2,000 m3) / 3.3 ft (= 1.0 m) 70,629 to 176,573 cusec (=2,000 to 5,000 m3) / 3.9 ft (= 1.2 m) 176,573 to 353,146 cusec (=5,000 to 10,000 m3) / 4.9 ft (= 1.5 m) Over 353,146 cusec (=10,000 m3) / 6.6 ft (= 2.0 m)	The design value in Punjab is almost the same as the rivers which has over 353,146 cusec (=10,000 m3/s) in discharge in the Japanese standard.
	Extra Embank-ment	Levelling of Top of Bunds after Construct-ion.	7	-	No description	Standard for Extra Embankment	Depends on the soil type and bund height as shown in the following table Embankment Height / Foundation Materials: Normal Soil / Sand / Gravel; Extra Banking Materials: Normal Soil (cm) / Sand / Gravel (cm) / Normal Soil (cm) / Sand / Gravel (cm) ≤ 3 m / 20 / 15 / 15 / 10 3m – 5m / 30 / 25 / 25 / 20 5m – 7m / 40 / 35 / 35 / 30 ≥7 m / 50 / 45 / 45 / 40	It is recommended for the Punjab manual to describe this item with reference to the Japanese guideline.

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
Quality Control	Material	Desireble Material	8	-	No description	River Earthwork Manual [3.1.3]	・ Fine particle contents is important. ・ 15% to 50% of fine particles (Not larger than 0.075mm in the size) is desirable. ・ Maximum particle size is not larger than 10 to 15 cm. ・ A soil which has wide distribution in particle size, and not so many contents of silt.	It is recommended for the Punjab manual to describe this item with reference to the Japanese guideline.
		Available Material	9	-	No description		Same as above	
	Construct-ion Method		10	-	No description	River Earthwork Manual [4.2.5], [6.1] to [6.4], [3.4.5], [5,6]	・ The thickness of 1 layer of a embankment is 11.8 inches(=30cm). ・ The required and recommended equipment to be used for each earth work item is listed, and 5 major equipment such as bulldozer, tire roller, vibrating roller, vibrating compactor, and tamping machine is introduced with the applicable types of embankment materials. Inspection & investigation to verify the applicability for the embankment material, methodology of quality control, countermeasures for soft ground and environmental aspects are also introduced.	Same as the above.
	Degree of Compact-ion		11	-	No description	River Earthwork Manual [3.1.4]	The degree of compaction needs to require following two criteria. However, depending on the embankment material used, it may not be possible to ensure these criteria. In such cases, it is necessary to confirm the degree of compaction by trial embankment and set compaction management standards suitable for the soil material used. -The average value is larger than 90% of the maximum laboratory dry density. -The minimum value is larger than 80% of the maximum laboratory dry density.	Same as the above.
Service Road/ Mainte-nance Road			12	-	No description	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 27	・ The minimum width of the maintenance road is set to 3m considering purposes of patrols, rehabilitation and flood fighting during floods. ・ Easy access and use by the residents nearby is considered. ・ Due to these purposes, a paved road is recommended in the Japanese standard.	It is recommended for the Punjab manual to describe this item with reference to the Japanese guideline.
Safety Evaluation	General		13	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]	The following safety conditions are verified by setting an appropriate river level as a verification condition. ・ Normal Time ➢ Slope stability against slip ➢ Settlement ➢ Erosion caused by rainwater drainage ・ During Flood ➢ Direct erosion and lateral erosion ➢ Seepage (Slope stability against slip and Piping) ・ Earthquake ➢ Settlement due to liquefaction ・ During Storm Surges ➢ Erosion ➢ Wave overtopping	It is necessary to conduct studies and evaluations based on numerical analysis, taking into account river conditions and geological conditions.

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Sub Item</th><th rowspan="2">Sub-sub Item</th><th rowspan="2">No.</th><th colspan="2">Punjab</th><th colspan="2">Japan</th><th rowspan="2">Comments</th></tr>
<tr><th>Technical Codes</th><th>Value/ Contents</th><th>Technical Codes</th><th>Value/ Contents</th></tr>
<tr><td></td><td>Slope Stability/ Slip Circle</td><td></td><td>14</td><td>VOL.1 Chapter 5, 5.4.9.6, p5-62, 257 PDF</td><td>・ Slope stability analysis is carried out according to Method of Slices, using Simplified Bishop Method with relevant computer software.
・ The needed information is as followings.
1. Geometry of embankment:
2. Soil properties: Bulk density, Saturated density. Cohesion “c”, Angle of internal friction, Unconfined shear strength, Permeability “k"
3. Design flood level and low water level of the river
4. Phreatic line and pore water pressure
5.Surcharge on the embankment
6.Earthquake loads
・ The calculations are carried out according to the typical cross-section of the embankment for two different geometrical parameters:
1. The river-bed stone apron is intact.
2. The scour of the riverbed is modelled with assumed fully launched stone apron.
・ Loading conditions are “Gravity”, “Seepage (or Pore water pressure), and “Earthquake”.
・ Location of the phreatic line (or hydraulic gradient) in the embankment is determined for the relevant seepage condition at the design flood level, by using Casagrande's solution.
・ Pore water pressure is determined from “pore pressure ratio” and “depth of soil from the top surface”.
・ The potential failure surfaces is analyzed for the following four critical conditions; i) End of construction, ii) Design flood level with steady seepage, iii) Flood draw-down, and iv) Assuming fully launched stone apron.
・ The minimum safety factor is shown in the following table.
<table><tr><th rowspan="2">Condition</th><th colspan="2">Minimum safety factor</th></tr><tr><th>Without earthquake</th><th>With earthquake</th></tr><tr><td>During and end of construction</td><td>1.4</td><td>1.2</td></tr><tr><td>Rapid river draw-down</td><td>1.3</td><td>1.1</td></tr><tr><td>River low flow level</td><td>1.2</td><td>1.0</td></tr><tr><td>Design flood</td><td>1.5</td><td>1.2</td></tr></table></td><td>Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]</td><td>・ Verify the stability against slip circle by a numerical analysis with a software.
・ Modified Fellenius Method is specified for slip circle analysis.</td><td>Contents are almost the same in both manuals.</td></tr>
<tr><td></td><td>Erosion</td><td></td><td>15</td><td>VOL.2 Chapter 2, 5.3, p190</td><td>・ The methods to evaluate the safety is not described. However, the estimate methods for scour depth are mentioned.
・ It is recommended to calculate the depth of local scour, constriction scour, bend scour, and confluence scour by several available methods and then use engineering judgment to select the preferred results.
・ The recommended local scour depth methods for various river gradient are listed in the following table.
<table><tr><th>River gradient</th><th>Material</th><th>Recommended method</th></tr><tr><td>Very mild</td><td>Sand and silt</td><td>-Lacey method (1930)
-Inglis method (1940)
- Lacey’s equation (Expanded by USBR, 1984)
-Blench equation (USBR,1969)
-Molesworth and Yenidunia equation</td></tr><tr><td>Mild (incised)</td><td>Gravel, sand and silt</td><td>-Lacey method (1930)
-Inglis method (1940)
- Lacey’s equation (Expanded by USBR, 1984)
- Blench equation (USBR,1969)
- Neill equation (USBR,1973)
-Molesworth and Yenidunia equation</td></tr><tr><td>Steep</td><td>Gravel and coarse sand</td><td>- Blench equation (USBR 1969)
-Molesworth and Yenidunia equation
- Farraday and Charlton equation
- Brown formula</td></tr><tr><td>Very steep</td><td>Gravel and boulders</td><td>- Brown formula</td></tr></table></td><td>Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]</td><td>・ Secure the Distance from the Riverbank to the bund, which varies depending on the feature of the river(called a “segment” in Japan)
・ Verify the stability of slope protection material against the design flow velocity.</td><td>Verification of the stability against the target flow velocity is recommended.</td></tr>
<tr><td></td><td>Seepage Control</td><td>Permability inspection</td><td>16</td><td>VOL.2 Chapter 2, 6.2.3, p204</td><td>・ For foundation stability, following information should be investigated through test pits and boreholes; Permeability of riverbed material/ In-situ density/ Hardness of cobles and boulders/ Bearing pressure capacity.</td><td>River Earthwork Manual [2.1.7]

Guide of Structural Analysis of River Embankment - 3.2.2 Soil Investigation</td><td>・ Unsteady flow calculations considering rainfall and river level changes.</td><td>A numerical analysis for seepage analysis is introduced in the Japanese standard, while the simple relational equation is listed in the Manual of Irrigation Practice in Punjab.</td></tr>
</table>

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
		Seepage analysis	17	VOL.2 Chapter 2, 6.2.4, p205 to 208	・ Hydraulic Gradient is assumed straight line for practical purpose. Typical values of hydraulic gradients vary for each soil type. But normally it is assumed as 6:1. ・ Hydraulic Gradient should lie at least 2ft below at the toe of the bund. ・ A minimum cover of 4 ft is provided above hydraulic grade line if it exits on the landside in made up soils. * Hydraulic Grade Line (HGL) = Phreatic Line ** Hydraulic Grade Line (HGL) = Phreatic Line	River Earthwork Manual [3.3.1] Guide of Structural Analysis of River Embankment - 4.3.2 Item and criteria for analysis	・ Verify the stability against slip circle and local hydraulic gradient at the toe of a bund considering the movement of the water level during floods	
	Seismic Condition		18	VOL.1 Chapter 5, 5.4.9.6(f), p5-66, 261 PDF	・ Acceleration due to earthquake is selected on the basis of 50% reduction for horizontal and vertical component. For example, after reduction and using Punjab OBE, horz = 0.08g and vertical = 0.04g. ・ These earthquake forces act at the center of gravity of the slice. ・ The acceleration due to Open Basis Earthquake values is adopted on the basis of specific related earthquake zone criterion.	Performance Based Seismic Design Criteria for River Structures II. Dike	・ Verify if the top elevation of a bund after an earthquake is higher than the specific water level. ・ Numerical analysis with a software	It is desirable to study for adding the description of stability against earthquakes considering the future condition.
Improve-ment of a Bund	Slope Stability/Slip Circle		19	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [2.8.2] Guide of Structural Analysis of River Embankment - 4.4.3 Selection of Improvement Method	・ Milder Slope ・ Counterweight Embankment ・ The Measures for Seepage Flow to Reduce the Water Level in the Bund Body ・ Sheet Pile to Stop the Slip Circle	It is strongly recommended for the Punjab manual to describe this item with reference to the Japanese guideline.
	Erosion		20	VOL.2 Chapter 2, 5.3, p190 (PDF 215)	・ Robust design and construction ・ Strengthening the weak / inadequately strong reaches ・ Providing erosion protection interventions like stone pitching, mattresses, ・ studs, spurs	Technical Criteria for River Works: Practical Guide for Designing [I] [2.8.3] Guide of Structural Analysis of River Embankment - 5.3.2 Item and criteria for analysis	<Without Revetment> ・ Revetment(for a Bund/low Water Channel) ・ Erosion Control Mat ・ Control the Vegetation on the Bund ・ Realignment ・ Spur <With Revetment> ・ Strengthening the Revetment ・ Extension of Bottom of the Revetment ・ Making a Dry Masonry to a Wet Masonry ・ Foot Protection Work ・ Realignment ・ Spur	It is recommended to include counter measures that can be applied in the Punjab Province, such as the expansion of cross-sectional shape, seepage cut-off walls and impervious sheets, as seepage control works.
				VOL.1 Chapter 5,4.5, p5-41 Chapter 5,4.8, p5-57 Chapter 5,5.6, p5-86 Chapter 5, 5.7 p5-93 Chapter 5.5.8, p5-86	・ Gabion: Basic shape is introduced. ・ Studs: Basic shape is mentioned but the design of length is not described. ・ Stone Apron: Concrete design methods for determining the shape and material based on scour depth, flow velocity, and so on are mentioned. ・ Stone Pitching: Concrete design methods for determining the thickness and material based on flow velocity and wave-height are mentioned. ・ Geotextile Filter: When it is difficult to get stones, Geotextile filter can be used instead of it. The requirement condition about materials are mentioned.			
				VOL.2 Chapter 2, 6.2.6 ,p208	Slope Protection (Temporary measures) ・ Khaji Mats, ・ Fascine Covering, ・ Pilchi Rolls, ・ Longitudinal Stakes and Bushing Protection (termed as MUHARI in Sind Province), ・ Pilchi Pitching (Revetment) *What the measures are for is not mentioned. **The concreate design method is not described			
				VOL.2 Chapter 2, 6.2.7 ,p212	Slope Protection (Permanent measures) ・ Brick Pitching ・ Dumped Stone Rip-Rap ・ Hand placed Rip-Rap (Stone Pitching) ・ Soil Cement Cover ・ Cement Concrete Paving ・ Asphaltic Concrete ・ Porous Concrete Slab ・ Protection Digest. *What the measures are for is not mentioned. **The concreate design method is not described			

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Seepage Control (Newly Construct-ed)	Types of Improve-ment Methods	21	VOL.2 Chapter 2, 5.5, p204	Foundation Stability ・ Reworking of the foundation soil ・ Grouting of the armoured river bed to the required extent ・ Inverted filter or geo-textile layer at the foundation of revetment / gabion hydraulic structure ・ Where required, provision of a suitable cut-off *The concreate design method is not described	River Earthwork Manual [3.4] Guide of Structural Analysis of River Embankment - 4.4.3 Selection of Improvement Method	<For a Bund Body> ・ Expansion of Bund Body ・ Installation of Drain(Gabion) ・ Covering Riverside Slope(Impervious Sheet) ・ Covering All the Surface <For Foundation Ground> ・ Seepage Cut-off in front of a Band ・ Blanket Method ・ Well Method	It is recommended to include counter measures that can be applied in the Punjab Province, such as the expansion of cross-sectional shape, seepage cut-off walls and impervious sheets, as seepage control works.
				VOL.2 Chapter 2, 6.1.1, p191	Foundation Stability ・ Cut off trench ・ Pressure relief wells ・ River side impervious blankets ・ Land side seepage berms ・ Pervious toe trenches *The concreate design method is not described			
				VOL.2 Chapter 2, 6.1.8 to 6.1.13, p195	Seepage through Body ・ Pervious Toe Drain ・ Inclined Drainage Layers ・ Horizontal Drainage Layers *The difference amoung these 3 countermeasures are where the drainage material is located.			
		Existing Bund	22	VOL.2 Chapter 2 6.2.4, p205 to 206	Seepage through Body ・ Land side Seapage Berm		Same as above	Same as Above
		Earth-quake	23	-	No description	Guidelines for Seismic Performance Verification of River Structures Vol.2	・ Counterweight Embankment ・ Jet Grout ・ Vibrating Compaction ・ Gravel Drain ・ Static Compaction ・ Drain(Gabion) at the Toe of the Bund ・ Deep Mixing Soil Stabilization ・ Steel Sheet Piling ・ Cement Grouting ・ Replacement of the Soil	It is desirable to add countermeasures against earthquakes.
Revetment	General		24	-	No description	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 25	The purpose of revetment is to protect the bunds from the action of flowing water when necessary. Slope Protection : Work direct contact between the embankment surface and flowing water to prevent scouring. Foundation Work : Supports the Slope Protection. Foot Protection Work : Prevents scouring of the riverbed in front of the foundation during floods and stabilizes the foundation work.	Due to no mention in the manual in Punjab, nothing is compared.
	Material and Structure		25	VOL.2 Chapter 2, 6.2.6, p208	About Slope Protection (Temporary measures) ・ Khaji Mats, ・ Fascine Covering, ・ Pilchi Rolls, ・ Longitudinal Stakes and Bushing Protection (termed as MUHARI in Sind Province), ・ Pilchi Pitching (Revetment) *Same as those described in the improvement for erosion. **Specification and design methods for each types are not mentioned.	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.2] Basic Disaster Recovery Policy to Protect Beautiful Mountains and Rivers in Japan[4.3]	The materials used for revetments vary, including concrete blocks, stones, wood, vegetation, etc. When designing a revetment, it is necessary to carefully consider its durability and strength and ensure that it is a safe structure with functions for protecting bunds. There is description of types of revetments with the concrete design methods. Mainly the following types are used.	It is recommended to include Concrete Block(connected type, articulated type) and Filter Cloth. In addition to recommending the development of an inexpensive surface covering material to replace the grass sodding, it is recommended to add a slope protection with stone pitching etc. as an immediate measure.
				VOL.2 Chapter 2, 6.2.7, p212	Slope Protection (Permanent measures) ・ Brick Pitching ・ Cement Concrete Paving ・ Dumped Stone Rip-rap ・ Asphaltic Concrete ・ Hand placed Rip-rap (Stone Pitching) ・ Porous Concrete Slab ・ Soil Cement Cover ・ Protection Digest. *Same as those described in the improvement for erosion. **The specification and design methods for all types except for stone pitching are not mentioned.			
				VOL.2 Chapter 2, 6.2.7, p212	Vegetation *This assume trees in front of the bound at a distance of 10 ft from the toe.			
				VOL.1 28Chapter 5, 4.5, p5-41	Gabion *Basic shape is introduced.			

Material	Slope : Not milder than 1.5:1	Slope : Milder than 1.5:1
Stone	・ Wet Stone Masonry ・ Dry Natural Stone Masonry	・ Wet Stone Masonry ・ Dry Natural Stone Masonry
Wood	・ Wooden Lattice, Block, Picket Fence	・ Wooden Lattice, Block, Fascine Mattress
Gabion	・ Gabion(Step Type)	・ Gabion(Mattress, Net Gabion)
Mat, Sheet	-	・ Geotextile Mattress ・ Block Mattress
Cement, Concrete	・ Concrete Block Retaining Wall ・ Reinforced Concrete Retaining Wall	・ Concrete Block (Lining, Connecting)
Others	・ Steel Sheet Pile Wall	・ Vegetation(Not Revetment)

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Safety Verifi-cation		26	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.3]	The assessment of the safety performance of revetments shall be conducted for the slope protection work, foundation work, and foot protection work. For the assessment, it needs setting the required conditions and acts depending on each installation location, type of work, and structural form of each component according to the table below. Based on this, the assessment items shall be set. Condition / Act Normal: Dead Weight, Earth Pressure, Water Pressure Flood: Acting Force generated by the Flowing Water which has the water level below HWL, Dead Weight, Earth Pressure, Water Pressure Seimas: Dead Weight, Earth Pressure, Water Pressure, Influence of Earthquake	For each model, it is recommended to add the description of a concrete design method that allows practitioners to perform the design.
	Structural Design	Slope	27	VOL.2 Chapter 2 4.3.1.3, p187 to 189	Marginal Bunds(protected): 2:1(Minimum)/3:1(Desirable) Bunds Protecting Strategic locations(protected): 2:1(Minimum)/3:1(Desirable) Bunds along open reaches of the rivers(protected): 2:1(Minimum)/2:1(Desirable) *Same as those described in the bund shape.	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.4 (1)]	0.5:1 to milder than 2:1 Slope : Not milder than 1.5:1 → Piled up Type Slope : Milder than 1.5:1 → Lining Type In case of the stability analysis for the lining type, situations such as sliding, overturning, traction are considered.	Due to the mild slope of bunds, only lining type revetment is considered in the manual of Punjab.
		Founda-tion	28	-	No description	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.4 (2)]	The foundation work of revetments is designed as a safe structure that can support the slope protection work, taking into consideration factors such as scouring caused by floods. Additionally, there are four basic approaches to consider when determining the elevation of the foundation work: 1. Setting the expected deepest riverbed as the elevation of the foundation work and, if necessary, installing minimal foot protection work in the front against scouring. 2. Setting the elevation of the foundation work above the expected deepest riverbed and addressing scouring with foot protection work in the front. 3. Setting the elevation of the foundation work above the expected deepest riverbed and addressing scouring with foot protection work in the front, as well as using foundation sheet piles or other embedding methods. 4. In areas with significant water depth such as tidal areas where it is difficult to install the foundation, using self-supporting sheet piles to support the foundation.	For each model, it is recommended to add the description of a concrete design method that allows practitioners to perform the design.
		Foot Protection	29	VOL.1 Chapter 5, 5.6, p5-86 (PDF 281)	Stone Apron *Concrete design methods for determining the shape and material based on scour depth, flow velocity, and so on are mentioned. **Same as those described in the improvement for erosion.	Technical Criteria for River Works: Practical Guide for Designing [I] [4.4.4 (3)]	The purpose of a foot protection work is to design a safe structure for the foundation by considering the fluctuation of the riverbed and other factors related to fluid forces. The following are typical types of foot protection works: 1. Riprap: Using sufficiently heavy stones. 2. Wooden Mattress: Includes fascine mattress, wooden mattress, and improved wooden mattress. 3. Gabion Works: Using steel baskets with filling stones. 4. Piled up Concrete Blocks: Using various types of concrete blocks, including layered and random piled up.	Concrete Blocks can be considered. It is recommended to add the description of a concrete design method that allows practitioners to perform the design.
Spur (Stone Groyne)	Site Condition		30	VOL.1 Chapter 5, 5.4.7, p5-46, 241 PDF, 5.4.7.5, p5-57, 252 PDF	The location where the followings are required. · Creating slack flow with an objective of silting up the area in the vicinity. · Protecting the riverbank by keeping the flow away from it.	Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 26	· They are designed to regulate the direction of flow during floods and keep low water channel areas away from the bunds, as well as to mitigate the impact on riverbanks or bunds by the water flow. · They are installed to reduce the flow velocity during floods in the rivers with steep gradient and to protect riverbanks and bunds from erosion. · They are also installed for the purpose of maintaining and preserving navigation and river environments. · They can be classified based on their water permeability: permeable structures and impermeable structures.	It is recommended to add specific design items other than the installation interval.
	Basic Shape		31	VOL.1 Chapter 5, 5.4.7.4, p5-49 (PDF 244)	· Typical cross-section is following. ➢ Crest width = 30 ft ➢ Side slopes - Shank = 3H:1 V ➢ Side slopes - Head = 2H:1V · There are 10 types of spurs; 1. Bar spur 2. Mole-head spur 3. Hockey spur 4. Inverted hockey spur 5. T-head spur 6. Sloping spur 7. T cum hockey spur 8. T cum hockey-sloping spur 9. J-head Spur 10. Guide-head spur	-	No description	Detailed dimensions are specified in the manual of Punjab.
	Material		32	VOL.1 Chapter 5, 5.4.7.4, p5-49	Compacted gravel and sand with 6 inch thick for the crest protection *The necessity of stone protection for other parts is mentioned but the requirements for those is not mentioned.	Technical Criteria for River Works: Practical Guide for Designing [I] [4.5]	Piled up Concrete Blocks, Piled up Natural Stones and Wooden Type	Concrete Blocks can be considered in the manual of Punjab.

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	Design Method		33	VOL.1 Chapter 5, 5.4.7.2 p5-48 (PDF 243)	The general recommendations for spacing are introduced as followings. ・ The minimum spacing in a straight reach should thus be five (5) to six (6) times the length of spur. ・ Convex bends; 2.5 to 3.0 times the length of spur ・ Concave bends; equal to the length of spur	Technical Criteria for River Works: Practical Guide for Designing [I] [4.5]	Considerations for the safety of spurs is similar to those for revetment. However, designing spurs is more challenging with theoretical interpretation beyond it for revetment. To address this, past experiences, records from similar rivers, and the results of trial construction, model experiments, and research surveys for new construction methods are utilized to design spurs with consideration for construction feasibility, cost-effectiveness, maintenance management, and the safety of river users. The following reference values have been provided based on previous cases: 1. Spurs to Reduce Flow Velocity: Length: Less than 10% of the river width. Height: Approximately 0.2 to 0.3 times the HWL. Spacing: Often 2 to 4 times the length and 10 to 30 times the height. 2. Spurs to Regulate the Flow Direction and to Prevent Riverbank Erosion: Height at the connection point of the spur: Approximately the HWL. Spacing: Usually 1/2 to 1/3 of the length of the sandbar formed in the respective section. Direction: Mostly perpendicular to the riverbank or slightly downward.	It is recommended to add specific design items other than the installation interval.
				VOL.1 Chapter 5, 5.4.7 p5-46	The position, length, and shape of spurs at any site should be determined by physical model studies.			
				VOL.1 Chapter 5, 5.4.7.5, p5-57	The determination of angle of spur with respect to current axis requires physical model study			
Construct-ion Works	Permission		34	-	No description	River Law Article 16(3)～Article 21	Somebody other than river administrators may implement river works or maintenance of rivers with the approval of the river administrator as prescribed by the cabinet order. However, for those considered to be of a minor nature as determined by the cabinet order, approval from the river administrator is not required.	Due to no mention in the manual in Punjab, nothing is compared.
	Construct-ion	Procedure	35	-	No description	River Earthwork Manual [6.1]	The process of construction inspections can vary depending on the type of construction, the inspector, and the conditions at the time of inspection. However, as a general example, the following flowchart illustrates the typical order: Inspection with Documents: 1. Bid Document; 2. Contract Document; 3. Construction Plan; 4. Work Schedule; 5. Documents on Meeting for Construction; 6. Documents on Quality Control; 7. Documents on Shape Control; 8. Site Photos; 9. As-built Drawings and others Inspection at Site: Shape Inspection Check of Quality and Finished Shape with Drawings, Quality Calculations and Measurement Record	Same as above
		Site Inspection for Work Accomp-lishment (shape Inspection)	36	-	No description	River Earthwork Manual [6.2]	✓ Embankment Work: Longitudinal Inspection: Stations are often placed every 20 meters to measure the length of embankment work. Benchmark elevation is typically measured at a location per 100 meters. Cross-sectional Inspection: Using a level and scale, measurement is conducted using the stations placed every 20 meters. ✓ Excavation Work: Inspection is conducted by measuring benchmark elevation, distance, and cross-section at representative stations. The areas between representative stations are inspected visually. ✓ Dredging Work: Bathymetry survey is conducted at the dredging site. Measurement points are selected at a location per 20 m2. Even if there is over-dredging beyond the proposed cross-section, that portion is not accepted as part of the work volume. Cross-sectional surveys are conducted to calculate the volume of soil, and this is compared with the acceptance criteria mentioned above. If there is a significant discrepancy between the results of the two methods, a re-measurement is necessary.	Same as above

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
		Quality Inspection	37	-	No description	River Earthwork Manual [6.3]	Quality inspections are basically conducted by the client based on the document submitted by the contractor, following the specifications. However, in some cases, the client may also perform quality tests and inspections themselves. ✓ Embankment Martial Quality: If specified in the contract, the client will inspect the records of the material tests. They will also verify if the material is sourced from the designated borrow pit if specified. ✓ Thickness of a Layer: The client primarily verifies if the embankment has been constructed to the specified thickness as specified in the contract or based on the results of trial embankment, often using photographs as evidence. For general soil, the typical thickness of a layer is 35 to 45 cm. ✓ Compaction: If compaction degree inspections are required after the completion of embankment work, the client will confirm the results through the quality control records approved by the supervisor or through the supervisor's confirmation. During constructions, compaction degree tests for quality control can be conducted using methods such as dry density, saturation degree or void ratio, strength characteristics, or based on the type of compaction equipment and number of passes.	Same as above
		Acceptability Criteria	38	-	No description	River Earthwork Manual [6.4]	The criteria for determining acceptance is specified in the specifications or contract conditions. There are two common methods for determining acceptance: 1. Specification value method: This method typically involves 100% inspection, where all measured values during the inspection must meet the specified values (allowable tolerances) as indicated in the design drawings or specifications. This method is commonly used for inspections of structural dimensions, among other things. 2. Acceptance criteria method: In case of sampling inspections, the size of the lot and the number of samples per lot are determined, and measurements are taken. The results are considered acceptable if they satisfy the following criteria: This method is commonly used for quality inspections and other types of inspections. Upper acceptance criteria value ≥ Average of measured values ≥ Lower acceptance criteria value.	Same as above
Management Plan	Management Plan		39	VOL.2 Chapter 8, 1.1 p591 (PDF 650)	・ Asset management plan (AMP) is introduced. ・ Six stages for preparing an AMP a framework are the followings. VII. Devise procedures for preparing the AMP and keeping it up to date. VIII. Prepare a statement of the Utility's relevant standards and policies. IX. Identify various functions of the Utility and prepare a list of systems under each heading. Each system will comprise a number of assets. X. Collect information on performance and condition of the principal components of each system. (Note that performance information relates to a system whereas condition information relates to individual assets). XI. Estimate long term investment covering a 20-year planning period to meet shortfalls of performance and condition and to provide for expansion and improvement. XII. Prepare short term program of expenditure for 5-10 years.	Technical Criteria for River Works: Practical Guide for O&M(For River) [2.1]	About the river maintenance management, the basic principle is to establish a PDCA (Plan-Do-Check-Act) cycle. This involves conducting river patrols and inspections to assess the condition, implementing maintenance measures, and analyzing and evaluating the knowledge gained from these activities. The insights obtained are then reflected in the river maintenance management plan and implementation.	Current description is like an emergency annual plan. It is necessary to create a plan that improves the durability and strength of the bunds by repair and reinforcement.
				VOL.2 Chapter 8, 1.2 p592	Aim of Asset Management is to increase longevity and sustain utility of the infrastructure and an enhanced level of service provision to the water user.			

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
				VOL.2 Chapter 8, 1.7.2 p601	PID's policy in respect of flood protection embankments and spurs is the followings. · They are inspected before the advent of flood season every year for assessing their reliability to withstand flood onslaught. · Their deficiencies are removed prior to flood season and flood fighting plan is prepared annually. · As such in ideal conditions there should not exist any deferred maintenance requiring rehabilitation of this type of the infrastructure.			
	Manage-ment Cycle		40	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [2.1]	A PDCA cycle involves repeated river patrols, inspections to grasp the condition, management measures over a long period, and analyzing & evaluating the knowledge gained through these series of tasks to reflect it in the river management plan or implementation content.	Instead of inspections and repairs with in a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years.
Monitor-ing of River Conditions	General		41	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [4]	River patrols for river channels and river management facilities in large scaled rivers are conducted based on the River Patrol Regulations 1, with the aim of carrying out planned, efficient, and effective inspections. For small and medium-scaled rivers, the basic principle is to conduct river patrols effectively, following the example of major rivers..	It is necessary to verify that the inspection sheet format, storage, and viewing system are functioning.
	Patrol/ Physical Inspection		42	VOL.2 Chapter 2, 17 p266 to 267	Following activities are listed as part of flood preparedness. · Routine Inspections · Flood Preparedness Inspection Report before Flood · Flood inspections during the flood · Flood Damage Report after the Floods · Identification and Prioritization of critical damages *Inspection before and after flood are described in detail in other chapter, but there is no description of the concrete method for routine inspection and inspection during flood.	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.4]	✓ Regular River Patrol: General Patrol: Conducting inspections based on predetermined patrol items. Purpose-specific Patrol: Select the inspection items, objectives, and locations to gain a more detailed understanding of the situation. ✓ River Channel and River Management Facility Patrol: Conduct to visually identify relatively significant changes or abnormalities that can be observed in the river channel or facilities. ✓ Illegal Activity Detection Patrol: Conducted within the river area to check for any illegal occupancy of land or unauthorized installation of structures. ✓ River Use Monitoring Patrol: Conducted to monitor the use of the river and assess its utilization. ✓ Natural Environment Assessment Patrol: Conducted to assess the condition of the natural environment in and around the river. ✓ Patrol During Floods: Conduct during flood events to quickly and comprehensively assess the situation, including the condition of bunds, flood flows, trees within the river channel, river management facilities, and the extent of inundation in the surrounding areas. It also involves monitoring the progress of flood control operations and water drainage.	It is necessary to include the description not only to conduct visual inspections, but also to carry out inspections and exploration with equipment as needed and to collect basic data such as hydrological data and topographic surveys.
				VOL.1 Chapter 8, 8.2, p8-1, 662 PDF And Chapter 5, 5.16.4, p5-198, 394 PDF And Chapter 5,5.16.8, p5-199, 394 PDF	For inspection before and after flood, · Person in charge: It is the duty of Sub-engineers and sub-divisional officers to see that the actual section is not very much below the standard laid down in the type of cross section. · Survey team member: A three-person inspection team should be comprised, a leader, hydraulic engineer, Geotech engineer. · Inspection Item are the followings. i. Top Levels, ii. Unwanted Vegetation and Debris iii. Encroachments iv. Slope/Section Stability v. Settlement vi. Land Subsidence vii. Damaged Armour viii. Flood Wall Damage ix. Runnels Caused by: a. Old tree roots b. Solutioning of Soluble Materials c. Rodent burrows, holes and dens d. Piping action through foundation alluvial materials. e. Damage by river flow. f. Erosion by wave action. g. Ravines caused by heavy rains h. Accidents i. Vandalism j. Sabotage *Inspection before and after flood is called “Safety Inspection” in Chapter 5.			
	Inspection with Equip-ments / Investi-gation / Exploratio n		43	VOL.2 Chapter 2, 4.3.1.2, p87	Not mentioned *Although it is not intended for monitoring, the followings sentence is introduced as investigation items. “Geophysical investigations: Electrical resistivity/ Cavities, weak soil strata and buried objects through Ground penetrating radar.”	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.5]	Inspection before Rainy Seasons and During Typhoons In these inspections, technologies such as MMS (Mobile Mapping System) are used to assess the condition of long and extensive structures, and radar void exploration is employed for non-destructive investigation of the rear side of revetment. Additionally, for the inspections of river channels and bunds, new technologies such as airborne laser-based river topography monitoring and UAV (Unmanned Aerial Vehicle) terrain surveying are being developed and utilized.	Same as Above

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	River Profile / Inspection Report / Damage Record		44	VOL.1 Chapter 5, 5.16.6, p5-198	・ About safety inspection, the committee will formulate its inspection/evaluation report and submit it to the owner/requesting authority within 15 days of the inspection. ・ This report will normally comprise an introduction, location of the training works, analysis for design parameters, physical inspection results i.e. observation and findings, conclusions, and recommendations.	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.6]	In large scaled rivers, the history of river maintenance management is preserved and documented as a river ledger, serving as a fundamental resource for river management. The river ledger includes implemented measures such as inspections and repairs, as well as records of river construction work projects, disasters, and corresponding countermeasures. To ensure efficient data management, the river ledger is stored in a database, enabling efficient recording and accumulation of information relevant to river management history.	Same as Above
	Analysis and Evaluation		45	VOL.1 Chapter 5, 5.16.6, p5-198, 393 PDF	Review the design according to the state-of-the-art design methods/procedures, point out any deficiencies to be corrected and suggest suitable action to withstand the accepted PMF (Probable Maximum Flood).	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.7]	To enhance the implementation of specific maintenance management for each river based on the river maintenance management plan, it is important to clearly identify the challenges that need to be addressed according to the situation of each river. It is also crucial to analyze these challenges progressively as they are being addressed and implemented.	In the Japanese standard, the several items such as hydraulic and hydrological observation, topographic survey, inspection after earthquake and inspection for mechanical equipment, and river ledger are described for monitoring of river conditions.
Inspection and Ledger	General		46	-	No description	Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels [I]	The inspections are conducted to ensure the following two functions related to flood control in rivers: 1. Confirming that the river channel maintains the required flow capacity. 2. Ensuring that the river management facilities, such as bunds, maintain the necessary functions. Inspection Targets: I. Embankments: a. Earthen Bunds, Revetments, Steel Sheet Pile Revetments, Foot Protection Works, Spurs. b. High Tide Wall, Special Type Bund, Land Gates. II. River Structures: Facilities equipped with sluice gates, culverts, water gates, weirs, and drainage pump stations. III. Inspection Timing: Prior to Rainy Season, During Typhoon Seasons, and After Flooding Events. IV. Inspection Methods: Inspections are conducted using visual observation and other appropriate methods. V. Evaluation Methods: The inspections focus on visible "deformation" that could impact the functionality of the facilities. Evaluations are conducted for each identified deformation, considering the presence of deformations and malfunctions. A comprehensive evaluation is provided based on these factors. VI. Recording and Utilization: The results of the inspections and evaluations are recorded in a database. The recorded inspection results are utilized for comprehensive evaluations and consideration of countermeasures. In cases where multiple deformations occur, deformations recur, or there is significant development of deformations, factor analysis is conducted to assess the need for fundamental repairs or updates to the structures..	In addition to preparing inspection ledgers for each site, it is recommended to perform a graded evaluation based on the observed deformations to score the degree of soundness, and then use it as an index of priority for repair and improvement.
	Bund		47	VOL.1 Chapter 5, 5.16.4, p5-198, and Annex-H,	・ The checklist is instructed. ・ The items of the Checklist listed in Annex-H are Top Width, Top RL,, Side slope, HFL, Free board, review on deign parameters, phreatic line development, physical condition, patrol road and section maintenance, unauthorized traffic, slumping or settlement, body materials suitability, heavy seepage, rain cuts, general land subsidence, damages to stone or other protections, evidence of compressible or expansile soils in foundation, evidence of misuse, flood watching and fighting arrangements, gauges observation system, flood warning and information system, analysis of observations.	Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels [II]	Specific inspection items and evaluation criteria are provided for the following types of bunds and related structures. Additionally, inspection items are listed for each specific component of the structures. ・ Earth Bund (Slope/Berm, Top, Land Side Toe, Bund Foot Drainage) ・ Revetment ・ Steel Sheet Pile Revetment (Steel Sheet Pile, Land Side Ground, Coping Concrete) ・ Foot Protection Work, Spurs ・ Seawall (Parapet, Protection Works, Drayage, Breakwater/Foot Protection) ・ River Wall (Main Body, Drainage, Breakwater/Foot Protection, Parapet) ・ Parapet	It is recommended to inspect and record the deformation of each part of the embankment.

Item	Sub Item	Sub-sub Item	No.	Punjab		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	River Channel		48	VOL.1 Chapter 5, 5.16.9, p5-200	・ Ledger or form is not described. ・ Periodical topo and bathymetric surveys of river channels and khadir (active flood plain) are carried out every year after flood season. ・ Topo survey: extends to about 15000 x afflux feet at upstream and 25000 ft on the downstream of barrage. This survey shows the areal placement of river channels, their variations, erosions andshoals and changes in the meanders of the river channel.	Inspection and Evaluation Guidelines for River Management Facilities such as Dikes and River Channels [IV]	Specific inspection items and evaluation criteria are provided for the following items: ・ Flow Capacity ・ Riverbed Lowering ・ Riverbank Erosion ・ River Mouth Closing ・ The evaluation of flow capacity is primarily based on water level calculations, while the evaluation of riverbed lowering, riverbank erosion, and river mouth closing are evaluated based on periodically conducted longitudinal and cross-sectional surveys conducted periodically.	In the case of vulnerable points against erosion, it is necessary to analyze and evaluate the transition of river channels using surveys and satellite images.
	Storage		49	VOL.1 Chapter 5, 5.21, p5-241, 436 PDF	The sub-divisional officer in charge of the barrage has the responsibility of checking and initiating all the data record regularly at prescribed intervals. *Target record of the above sentence is unclear because it is not mentioned. It seems to be that the target records are those related to the barrage because the responsivity person is the officer in the barrage.	Technical Criteria for River Works: Practical Guide for O&M(For River) [5]	For river channels and facilities other than major flood control river management facilities (excluding dams) as defined in Article 7-2, Paragraph 1 of the Ordinance for Enforcement of the River Law, inspection results shall be recorded, and the inspection results shall be retained for a period until the next inspection or longer.	it is recommended to specify the method and responsivities for storing the inspection ledgers and report like the case of Japan.
River Ledger	General		50		No description	River Law Article 12	1. The river administrator shall prepare and maintain a ledger for the rivers under their management. 2. The ledger for rivers shall consist of a current river ledger and a water management ledger. 3. The contents of the river ledger and other necessary matters regarding its preparation and storage shall be prescribed by the cabinet order. 4. When requested to view the river ledger, the river administrator shall not refuse unless there is a legitimate reason to do so..	It is recommended to prepare the river ledgers for the purpose of accumulating data aimed at improving the efficiency of bund management.
	Contents		51	-	No description	Enforcement Order for River Law Article 4, Article 5	<For a Ledger> ・ Name of River System ・ River Name ・ Length of the River ・ River Area ・ General Profile of Major River Management Facilities <For a Figure> ・ Boundaries of River Area ・ Information of the Power of River Manager on the land within the river area ・ Major River Management Facilities ・ Major permitted structures	Due to no mention in the manual in Punjab, nothing is compared.
	Storage		52	-	No description	Enforcement Order for River Law Article 7	The river ledger shall be stored at the offices of the relevant regional development bureaus (including the offices of the Hokkaido Development Bureau, same as in Article 39-3, Paragraph 1, Item 1) for first-class rivers, and at the offices of the relevant prefectures for second-class rivers, as prescribed by the Ministry of Land, Infrastructure, Transport and Tourism.	It is recommended to specify the method and responsivities for storing the inspection ledgers and report like the case of Japan.

Source: JICA Project Team extracted from the Manual of Irrigation Practice & concerned Japanese standards and guidelines and analyzed.

3.7 Issue on the Manuals in Pakistan

Based on the above-mentioned analysis, major issues on the current manuals are as follows.
Considering these issues, the recommendation to improve the bund management in Pakistan would be studied in the following Chapter.

From the Analysis on the Manual Itself	✓ Description on Safety Evaluation is in sufficient especially for the seepage flow. ✓ Improvement method of bunds is not concretely stated, and it is difficult for the practitioners to conduct the planning and design. ✓ Design method of each type of revetment is not described. ✓ Description about quality control and inspection during construction is insufficient or not stated. ✓ There is no mention of storage of the inspection ledger and report. Hence, such documents are scatteringly kept and not accumulated. ✓ About the record of the construction works, the situation is as same as above. ✓ The inspection of the existing bund and river which is mentioned in the manual is mainly by eyes only.
From the Comparison Between 2 Provinces	✓ Both 2 manuals have some lacking items and description in each other. <Bund Manual in Sindh> ✓ Description of Safety Evaluation is less detailed. ✓ Description of the designing of a spurt is less specific. ✓ Concept of Asset Management Plan is needed. <Manual of Irrigation Practices in Punjab> ✓ There is no description of Quality Control during construction works and requirement of embankment material. ✓ No inspection ledger is introduced other than it for bunds.
From the Comparison with Japanese Standards	✓ Descriptions of embankment material such as the requirement and the case in which the required material is not obtained are insufficient. ✓ Description of the Maintenance Road is not included. ✓ It is necessary to conduct studies and evaluations based on numerical analysis or scientific method, considering river conditions and geological conditions. ✓ With regard to the impact on earthquakes, it is desirable to be incorporated considering the expansion of urban areas and the accumulation of assets in the future. ✓ There are some types of seepage control works and revetment which are used in Japan and can be applicable in Pakistan. ✓ Description of the concrete planning and designing methods for seepage control works and revetement works is lacking. ✓ Instead of inspections and repairs within a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years. ✓ A Method or an indicator to evaluate the priority for the bund improvement is needed. ✓ Data storage and sharing must be strengthened.

CHAPTER 4 RECOMMENDED UPDATE ON THE MANUALS IN PAKISTAN

4.1 Recommendation on the Manuals

Considering the analysis results in Chapter 3, recommendations on the update of the current manual would be proposed. The recommendations are prepared for each items indicated below, which are basically as same as the items used in Chapter 3 for the analysis. These items are extracted considering the major issues which have been already recognized in Pakistan(See Sub-section **3.2.1 Extraction of Item to be Analyzed**).

- ✓ Standard Shape of a Bund
- ✓ Quality Control
- ✓ Service Road/ Maintenance Road
- ✓ Safety Evaluation
- ✓ Improvement of a Bund
- ✓ Revetment
- ✓ Spur(Stone Groyne)
- ✓ Construction Works
- ✓ Management Plan
- ✓ Monitoring of River Conditions
- ✓ Inspection and Ledger
- ✓ River Ledger
- ✓ Bund Breach
- ✓ Gap from the Actual Practice

The recommendations on the update of the current manual in each province which would be proposed by JICA Project Team are shown in the following tables. The recommendations are indicated with rank presented from A to C considering their priorities. The rank of the priority is set in accordance with the following criteria.

A : 1st Priority, Necessary
It is relating with the current issues to be urgently dealt with and is deemed highly effective to improving bund management.

B : 2nd Priority, Recommended.
It is relating with the issues which have not been recognized serious at present or which have been considered partially, but it is highly effective to improving bund management.

C : 3rd Priority, Desirable.
It is relating with the issues which are not recognized fatal at present, but it is desirable to be dealt with considering the future.

Table 4.1.1 shows the proposed recommendations for the update on the manual in Sindh Province (Bund Manual), and **Table 4.1.2** is for the one in Punjab Province (Manual for Irrigation Practice) respectively.

Table 4.1.1 Recommended Update on the Manual in Sind (Bund Manual)

Item	Recommendation by JICA Project Team					
	Based on the Analysis on the Manual	Priority	Based on the Comparison with the Manual in Punjab	Priority	Based on the Comparison with the Japanese standards	Priority
Standard Shape of a Bund			Since it was published in 2008, the basic dimensions are smaller than those of Punjab. Needs to be updated in light of the 2010 flood.	B		
Quality Control	Due to the little description about equipment to be used for embankment, it is necessary to be added.	A			It is desirable to describe the maximum particle size and the range of particle size distribution in the specification of the embankment material.	B
	Due to no description of the degree of compaction (Required value, what to do in case it cannot be satisfied), it is necessary to be added.	A			Since material obtained along river channels is often not applicable to embankment, it is necessary to modify the description about the source of materials so that materials that satisfy the requirements can be used without limiting the source along river channels.	A
					Since material obtained along river channels is often not applicable to embankment, it is necessary to modify the description about the source of materials so that materials that satisfy the requirements can be used without limiting the source along river channels. it seems necessary to describe what to do when there is no suitable embankment material nearby.	A
					It is recommended to add the description of the case in which the required degree of compaction cannot be satisfied. Adding a description about setting a compaction criterion by a trial embankment is recommended to be added.	B
					It is necessary to add descriptions about the method of embankment material survey and quality control.	A
					It is recommended to add a description about countermeasures for soft ground.	B
Service Road/ Maintenance Road	"It is recommend to add a description about pavement on the top of bunds to improve access. It seems necessary to add the standard pavement composition (minimum sample assuming maintenance vehicle traffic).	B			For the smooth passage of maintenance vehicles, it is recommended to add a description about the pavement on the top.	B
Safety Evaluation	"Since the cross-section shape of the embankment have been determined only from past experience considering the infiltration line, it is necessary to add an evaluation by numerical analysis, including the setting of analysis conditions. Seepage flow analysis is thought to be effective in examining vulnerability, because variety in the bund body material are expected."	A	It is necessary to add a disruption about slope stability analysis by slip circle. "It is necessary to add a disruption about slope stability analysis by slip circle. In addition to the seepage flow analysis, it is necessary to verify the structural stability of the embankment material.	A	It is necessary to conduct studies and evaluations based on numerical analysis, considering river conditions and geological conditions.	A
	Due to no specific description of seepage flow analysis (numerical analysis, permeability test), it is recommended to add the contents.	A	It is necessary to add the calculation method of the maximum scouring depth	A	With regard to the impact on earthquakes, it is desirable to predict the expansion of urban areas and the accumulation of assets in the future, and to study for adding the description of stability to earthquakes.	C
	Earthquakes are not described, but it is desirable to include them for future needs.	C	It is necessary to add a description of the specific method of seepage flow analysis.	A		
			It is necessary to add a description about slope stability in consideration of earthquakes.	A		
Improvement of a Bund	It is recommended to enhance the description of countermeasures (steel sheet piles, etc.) against slope stability.	B	Geotextile Filter, Gabion and Studs need to be added as countermeasures against erosion.	A	As a foot protection work, it is recommended to introduce concrete blocks and net gabion.	B
	"It is necessary to enhance the description of seepage control work that can be applied in Sindh Province, such as a impervious sheet. This may increase the initial cost, but due to the improvement in the durability and strength, the number of rehabilitations will be reduced, and the scale of damage will also be reduced."	A	About countermeasures against seepage flow, it is necessary to consider the measures for the foundation grounds.	A	It is recommended to include construction methods that can be applied in Sindh Province, such as seepage cut-off walls and impervious sheets, as seepage control works.	B
	Due to no specific description of the design method and design condition setting of others than Stone Apron, it is recommended to be added.	B			It is desirable to add countermeasures against earthquakes.	C
Revetment	There are mentions of the revetment types, but there is no description of the specific design method. Hence, adding the contents is recommended so that practitioners can make design.	B	Gabion needs to be added.	A	It is recommended to include Gabion, Concrete Block(connected type, articulated type) and Filter Cloth.	B
	Due to no description of the revetment foundation, it is recommended to add it.	B			In addition to recommending the development of an inexpensive surface covering material to replace the grass sodding, it is recommended to add a slope protection with stone pitching etc. as an immediate measure.	B
	Since there are few descriptions of foot protection, and it is only for Stone Apron. it is recommended to add it.	B			For each model, it is recommended to add the description of a concrete design method that allows practitioners to perform the design.	B
Spur(Stone Groyne)	There is a lack of description of the design method, including cross-sectional and planar shapes. Additional descriptions are required so that practitioners can make design.	A	It is necessary to add the description for how to determine the basic shape and the other dimensions.	A		

Item	Recommendation by JICA Project Team					
	Based on the Analysis on the Manual	Priority	Based on the Comparison with the Manual in Punjab	Priority	Based on the Comparison with the Japanese standards	Priority
Construction Works	Due to the little description of quality control (inspection items and methods, inspection timing, quality control standards), it is recommended to add the content. The durability and strength of an embankment varies depending on its structure, materials, and construction. Standards for constructing embankments with a certain level of strength are necessary."	B				
Management Plan			Based on the statement of the concept of the Asset Management Plan and that bunds need to be strengthened periodically, it is necessary to introduce the concept of the bund management with a multi-year outlook.	A	Instead of inspections and repairs with in a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years. Current description is like an emergency annual plan. It is necessary to create a plan that improves the durability and strength of the bunds by repair and reinforcement."	A
Monitoring of River Conditions	In the "SAFTY EVALUATION OF FLOOD BUND", there is a description of visual inspection items and countermeasures on bund deformations. However, it is the concepts only. In order for practitioners to be able to design countermeasure, it is recommended to add a description of specific planning and designing methods.	B	About physical Inspection, it is necessary to add the description of Survey Team Member and Responsibility Person.	A	It is necessary to include the description not only to conduct visual inspections, but also to carry out inspections and exploration with equipment as needed and to collect basic data such as hydrological data and topographic surveys.	A
	Since the described inspections are basically only by visual inspection, it is recommended to describe the inspection with equipment such as surveying and underground exploration.	B	It is necessary to add the description of Inspection Report, Damage Record and Analysis/Evaluation.	A	It is necessary to verify that the inspection sheet format, storage, and viewing system are functioning. If something is not working properly, it may be necessary to create a system with reference to the Japanese one.	B
	Since the ledgers and reports have not been stored properly, it is necessary to specify it in the manual Specific examples of forms, report preparation, flow for the storage, and sample cases of management departments are needed.	A				
Inspection Ledger	Although inspection ledgers related to bunds are prepared, there are no regulations for the storage of the ledgers, and the documents are scattered in various divisions and offices, so it is necessary to specify the regulation about the storage. It seems that who will do what, when, and how has not yet been determined. It seems necessary to create records early. to organize and to store them so that they can be easily searched.	A	Additional descriptions are required for monitoring of river channels by ground and bathymetry surveys.	A	It is recommended to inspect and record the deformation of each part of the embankment.	B
	Since there is no description of specific inspection items or methods for inspecting river channels, it is necessary to add description about the utilization of satellite photo comparison and topographic survey.	A	It is necessary to add a description of how to store the ledgers and reports.	A	In addition to preparing inspection ledgers for each site, it is recommended to perform a graded evaluation based on the observed deformations to score the degree of soundness, and then use it as an index of priority for repair and improvement.	B
					In the case of vulnerable points against erosion, it is necessary to analyze and evaluate the transition of river channels using surveys and satellite images. Monitoring is important for vulnerability prediction.	A
River Ledger					It is recommended to prepare the river ledgers for the purpose of accumulating data aimed at improving the efficiency of bund management.	B
Bund Breach	Description should be updated to communication methods based on the latest technology.	A				
	For the purpose of preventing variation of the information and continuous monitoring, it is recommended to prepare with unified forms and to accumulate information.	B				
	Since it is not clearly mentioned who and how to analyze the flood route and who and how to divert flood flow, it is recommended to be clearly stated.	B				
	It is desirable to include multiple examples of the closure.	C				

Item	Recommendation by JICA Project Team					
	Based on the Analysis on the Manual	Priority	Based on the Comparison with the Manual in Punjab	Priority	Based on the Comparison with the Japanese standards	Priority
Gap between the Manual and the Actual Practice	Since it is not clear which division is in charge of information on river construction, it takes time to grasp the details. Also, information is not shared properly because the responsibility system is not clear. Improvement is necessary.	**A**				
	The description of the manual may not be sufficiently reflected in the specifications of the construction works.	**B**				
	Inspection documents related to construction management are not stored properly, or they are stored but are not known where they are. Hence, improvement is necessary	**A**				
	Compared to construction of new bunds, construction management in repairing and strengthening existing bunds tends to be simplified	**C**				
	Since the records of constructions are not accumulated, improvement is recommended. It may be necessary to create reference samples for collection and organization of documents.	**A**				

Legend: *A* : *1st Priority, Necessary*
It is relating with the current issues to be urgently dealt with and is deemed highly effective to improving bund management.

B : *2nd Priority, Recommended.*
It is relating with the issues which have not been recognized serious at present or which have been considered partially, but it is highly effective to improving bund management.

C : *3rd Priority, Desirable.*
It is relating with the issues which are not recognized fatal at present, but it is desirable to be dealt with considering the future.

Table 4.1.2 Recommended Update on the Manual in Punjab (Manual for Irrigation Practice)

Item	Recommendation by JICA Project Team					
	Based on the Analysis on the Manual	Priority	Based on the Comparison with the Manual in Sindh	Priority	Based on the Comparison with the Japanese standards	Priority
Standard Shape of a Bund	It is necessary to unify the presentation of types of embankments in Vol.1 and 2, or add explanations for each type.	A	It is necessary to add a description of the extra embankment.	A	It is necessary to add a description of the extra embankment.	A
Quality Control			It is necessary to add a description to Quality Control.	A	It is necessary to add a description to Quality Control.	A
			It is necessary to add the specifications of the embankment material.	A	It is recommended to add the specifications of the embankment material in detail as well as Japanese standard.	B
					It is recommended to add the description of the case in which the required degree of compaction cannot be satisfied. Adding a description about setting a compaction criterion by a trial embankment is recommended to be added.	B
					It is necessary to add descriptions about the method of embankment material survey.	A
					It is recommended to add a description about countermeasures for soft ground.	B
Service Road/ Maintenance Road	It is recommend to add a description about pavement on the top of bunds to improve access. It seems necessary to add the standard pavement composition (minimum sample assuming maintenance vehicle traffic).	B			For the smooth passage of maintenance vehicles, it is recommended to add a description about the pavement on the top.	B
Safety Evaluation	It is necessary to add a description of a consideration of piping by seepage flow.	A	It is necessary to add the description of the indicator on safety evaluation for erosion.	A	It is necessary to conduct studies and evaluations based on numerical analysis, taking into account river conditions and geological conditions in seepage analysis. Seepage flow analysis is thought to be effective in examining vulnerability, because variety in the bund body material are expected.	A
					It is recommended to add safety evaluation against settlement by earthquakes.	C
Improvement of a Bund	There is a specific description of the slope stability by slip surface, but the description of the countermeasure is sufficient, so it is necessary to add it	A	It is necessary to add a description of the countermeasures against slip circle.	A	It is necessary to add a description of the countermeasures against slip circle.	A
	Although manual in the U.S. is referred for the countermeasure against seepage flow, there is no description of the specific design method, so it needs to be added.	A			"It is recommended to include counter measures that can be applied in the Punjab Province, such as the expansion of cross-sectional shape, seepage cut-off walls and impervious sheets, as seepage control works. This may increase the initial cost, but due to the improvement in the durability and strength, the number of rehabilitations will be reduced, and the scale of damage will also be reduced."	B
	Since the descriptions of each countermeasure are scattered in various sections in the manual, and there is an inconsistency with the title of the chapter, it makes difficult to refer to the necessary contents. Hence, Improvements are recommended.	B			It is desirable to add countermeasures against earthquakes.	C
Revetment	There are mentions of the revetment types, but there is no description of the specific design method. Hence, adding the contents is recommended so that practitioners can make design.	B			It is recommended to include Concrete Block(connectd type, articulated type) and Filter Cloth.	B
	Since there is no description regarding the design of foundations that takes into account seepage control and scouring, it is recommended that this be added.	B			In addition to recommending the development of an inexpensive surface covering material to replace the grass sodding, it is recommend to add a slope protection with stone pitching etc. as an immediate measure.	B
					For each model, it is recommended to add the description of a concrete design method that allows practitioners to perform the design.	B
Spur(Stone Groyne)					It is recommended to add specific design items other than the installation interval.	B
Construction Works	Since there is no description of Construction Works (Permission, Quality Control, Documents, etc.), it is recommended to add descriptions of them. The durability and strength of an embankment varies depending on its structure, materials, and construction. Standards for constructing embankments with a certain level of strength are necessary.	A	It is necessary to add the description of Construction Works (Permission, Quality Control, Documents, etc.	A		
Management Plan	Based on the statement of the concept of the Asset Management Plan and that bunds need to be strengthened periodically, it is necessary to introduce the concept of the bund management with a multi-year outlook.	A			Instead of inspections and repairs with in a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years. Current description is like an emergency annual plan. It is necessary to create a plan that improves the durability and strength of the bunds by repair and reinforcement.	A

Item	Recommendation by JICA Project Team					
	Based on the Analysis on the Manual	Priority	Based on the Comparison with the Manual in Sindh	Priority	Based on the Comparison with the Japanese standards	Priority
Monitoring of River Conditions					It is necessary to include the description not only to conduct visual inspections, but also to carry out inspections and exploration with equipment as needed and to collect basic data such as hydrological data and topographic surveys.	A
					It is necessary to verify that the inspection sheet format, storage, and viewing system are functioning. If something is not working properly, it may be necessary to create a system with reference to the Japanese one.	B
Inspection Ledger	There is a provision that the sub-divisional officer in charge of the barrage should keep all materials, but it is preferable to improve it, since it has little relevance to the bunds.	A	It is recommended to add ledgers other than the outline of the bunds.	B	It is recommended to inspect and record the deformation of each part of the embankment with the improvement of the ledgers.	B
	Although there is a description of river channel monitoring, it covers only the upstream and downstream of the barrages. Hence, it is recommended to expand the scope to the area around Vulnerable Points.	A	Since it is unclear what should be input for each item, it is also recommended to improve the ledgers of the bunds.	B	In addition to preparing inspection ledgers for each site, it is recommended to perform a graded evaluation based on the observed deformations to score the degree of soundness, and then use it as an index of priority for repair and improvement.	B
	There is an inspection ledger and many items are listed, but since there is little explanation of the necessary information for each item, the input information may varies depending on the individual knowledge and experience, It is recommended to improve the ledger.	B			In the case of vulnerable points against erosion, it is necessary to analyze and evaluate the transition of river channels using surveys and satellite images.	A
	There is no clear provision for the storage of inspection ledgers, and it is stated that the sub-divisional officer in charge of the barrage is responsible for keeping all documents, but it is preferable to improve it because it has little relevance to the bunds.	A				
River Ledger					It is recommended to prepare the river ledgers for the purpose of accumulating data aimed at improving the efficiency of bund management.	B
Bund Breach	Description should be updated to communication methods based on the latest technology.	A				
	For the purpose of preventing variation of the information and continuous monitoring, it is recommended to prepare with unified forms and to accumulate information.	B				
	Since it is not clearly mentioned who and how to analyze the flood route and who and how to divert flood flow, It is recommended to be clearly stated.	B				
	It is desirable to include multiple examples of the closure.	C				
Gap between the Manual and the Actual Practice	Since it is not clear which division is in charge of information on river construction, it takes time to grasp the details. Also, information is not shared properly because the responsibility system is not clear. Improvement is necessary.	A				
	Since the records of constructions are not accumulated, improvement is recommended. It may be necessary to create reference samples for collection and organization of documents.	C				
	Since the records of constructions are not accumulated, improvement is recommended. It may be necessary to create reference samples for collection and organization of documents.	B				
	Improvements are recommended as there is no description of information sharing between NESPAK and PID, which is outsourced for construction supervision, and understanding of construction details, lists, etc. within PID.	B				

Legend: *A* : *1st Priority, Necessary*
It is relating with the current issues to be urgently dealt with and is deemed highly effective to improving bund management.

B : *2nd Priority, Recommended.*
It is relating with the issues which have not been recognized serious at present or which have been considered partially, but it is highly effective to improving bund management.

C : *3rd Priority, Desirable.*
It is relating with the issues which are not recognized fatal at present, but it is desirable to be dealt with considering the future.

4.2 Proposed Policy for the Preparation of the Supporting Document to the Current Manuals on Bund

In Table 4.1.1 and Table 4.1.2, mainly following recommendations are set to the priority A, which are relating with quality control, safety evaluation, management plan and monitoring & inspection.

- ✓ Improve descriptions of embankment works for bunds such as equipment to be used, compaction criteria, requirement of the embankment material.
- ✓ Improve descriptions of safety evaluation especially against seepage flow and erosion(and scouring) to incorporate the concrete methods such as a numerical analysis with setting the analysis conditions.
- ✓ Improve description of bund improvement method for seepage flow and erosion(and scouring) considering the items which can be introduced in Pakistan.
- ✓ Newly add the contents about management plan considering not only a single year but also multiple years for the bunds and the PDCA cycle.
- ✓ In order to enhance organizing and seeking the necessary documents, specify the storage method of reports and ledgers on the bund inspections in more detailed such as who, how, where to record or to keep. This will lead to make the PDCA cycle type bund management effective.

This project is including “Preparation of supplementary materials to existing Pakistani technical manuals on bund management (Activity 3-2 in this project)” as one of the activities. In the following this activity, the proposed supplementary material would be prepared focusing on the abovementioned items mainly.

About the items with priority B and C indicated in Table 4.1.1 and Table 4.1.2, it is recommended to incorporate them to the manuals with studying the concrete contents when they are updated or revised next time. Hence, this revision and update of the current manuals would be included in the other activity such as “Arrangement and formulation of short- and medium-term action plans for the bund management (Activity 3-3 in this project).”