Federal Flood Commission

ADDENDUM TO EXISTING BUND MANUAL

PREFACE

Sindh and Punjab provinces employ the 2008 and 2017 editions of Bund Design Manual, respectively. However, considering the damages to bunds caused by the large-scale floods of 2010 and 2022, the Federal Flood Commission (FFC) has recognized the need for bund strengthening. Accordingly, it was decided that the Bund Design Manual be reviewed through JICA's Project for *Capacity Development of Effective River Dikes Management (PERDM)* response to 2022 flood.

By comparing the Bund Design Manual of Sindh and Punjab, this "Supplement" report is compiled to cover and capture the important yet unidentified or unclear aspects of both the manuals. The objective is to optimize the construction and maintenance of bunds in accordance with Japanese standards. Key issues related to the construction and maintenance of Indus River bunds were identified based on results of field surveys around vulnerable areas of the bunds, interviews with PID and FFC staff, and reviews of past bund inspections records.

Bund Manual (Fourth Edition) of Sindh province was published in 1936 to improve the bund maintenance capability of the PID staff in Sindh Province. Afterward, in 1954 and 1978, changes were made to the bund design standards and specifications. It was further reviewed by the United States and other countries, and the revised version was approved during the 2008 meeting of the Indus River Commission.

Guidelines for bund design in Punjab are outlined in the *Manual of irrigation practices* (in two volumes). The first edition was published in 1943 which served as guidance document for staff, similar to the Sindh Bund Manual. In 1963, the first edition was republished. In 2015, the World Bank provided support for a revision, and the revised version was subsequently prepared and approved by the Indus River Commission in 2017.

The Federal Flood Commission established the 1st, 2nd and 3rd National Flood Protection Project (NFPP-I, II, III) to address the relatively large floods of 1978, 1988 and 1998. Later on, based on the lessons learned from the extensively damaging flood of 2010, the FFC began reviewing the project in June 2013 and established NFPP-IV in January 2015. Bund design standard is provided in Annex 3 Design Criteria of NFPP-IV Task A report. These criteria are reflected in the design guidelines of Punjab province.

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CHAPTER -1

OVERVIEW OF MANUAL AND GUIDELINE SUPPLEMENT

CHAPTER 1 Overview of Manual and Guideline Supplement

1.1 Overview

Based on Chapter 4 of "Report on Comparative Analysis of Design Manuals of Bunds in Punjab & Sindh Provinces of Pakistan and Japan (*The Comparative Analysis Report*)" compiled by JICA-PERDM, a collection of supplementary items for the Sindh and Punjab bund manuals and guidelines has been prepared. These supplementary analyses and examinations are primarily derived from issues described in Chapter 3 of the report and cover important matters related to bund construction and maintenance cycle. Table 1.1.1 and Table 1.1.2 outline the key supplementary items for Sindh and Punjab bund manuals and guidelines.

Table 1.1.1: Overview of Key Supplementary Items for Sindh Province Bund Manual

Topic	Supplementary Item	Key-Supplement Contents
Bund Shape	Ch5-41 Standard Bund Shape	Propositions of basic bund shape that is uniform for all bunds along the Indus River
Quality Control	Ch6-51 Test Methods and Standard Values of Soils for Bund Construction Ch6-52 Soil Quality of Bund Material Ch6-55 Machinery and Equipment Used for Embankment	Equipment to use during construction, specification of standard values such as degree of compaction and air porosity, and countermeasures to be taken when the condition of standard values is not met
Safety Assessment	Ch5-31 Disaster Forms of Bund and Verification Items for Safety Assessment	Analysis methods on circular slip and seepage
Bund Improvement	Ch5-34 Seepage Countermeasures Ch11-119 Erosion Countermeasures	Countermeasures for seepage and erosion
Investigation on Spurs	Ch5-43 Design of Loop Band	Specific descriptions of investigation methods
Bund Management Plan	Ch16-159 (Additional Article) Data Organization for Bund Management Plan	The direction for improving the durability and strength of bunds as countermeasures based on accumulation of repair history
Maintenance Inspection (Monitoring of River Conditions)	Ch9, Ch10 Patrol, Inspection Period, Overview Ch9, Ch10 Patrol, Inspection Item, and Example of Inspection Form	The process from recording of inspection of bunds by visual and equipment survey through the preparation and storage of records
Information Management	Ch13 Information Management	Clear descriptions of regulations for structuring information storage to facilitate easy access to data on topography, equipment surveys, and satellite imagery
Artificial Breaching of Bund	Ch10-113 Immediate Action in Case of Bund Breach	Smooth communication system
Gaps Between the Manual and the Actual Practice	Ch13 Preparation, Storing and Viewing of Reports on Construction Management (Supervision)	The organization and storage of documents spanning bidding, construction testing, inspection results, and project completion, including clarification of the departments responsible for providing information on river construction

Note: Excludes items other than those with priority A in the Comparative Analysis Report.

Table 1.1.2: Overview of Key Supplementary Items for Punjab Province Bund Manual

Topic	Supplementary Item	Key Supplementary Content
Bund shape	Vol 2: Ch2-4.3.1.3 Design and Construction of Flood Bund	Propositions of allowable bund shape that is uniform for all bunds along the Indus River
Quality Control	Vol 2: Ch2-4.4 (Additional Article) Bund Materials Ch2-4.5 (Additional Article) Quality Control Ch2-4.6 (Additional Article) Machinery Used	Standards of bund material, specification of standard values such as degree of compaction and air porosity; and countermeasures to be taken when the condition of standard values is not met
Safety Assessment	Vol 2: Ch2-5.3 Erosion Ch2-5.4 Bund Seepage Ch2-6 Seepage Control	Surveys and evaluations based on numerical analysis of seepage
Bund Improvement	Vol 2: Ch2-6.2.7.10 (Additional Entry) Measures to Strengthen Bunds Against Seepage Ch2-6.2.7.11 (Additional Entry) Measures to Strengthen Bunds Against Erosion	Construction methods to counter circular slip, and the specific design method to counter seepage fl
Investigation on Spurs	Vol 1: Ch5-5.4.7 Spur	Basic concept of spurs
Bund construction	Vol 2: Ch11-1.9 Construction Related Documents	Construction related documents (permits, quality control, testing and inspection documents, etc.)
Bund Management Plan	Vol 2: Ch2-16 Countermeasure Planning Against Flood	The direction for improving the durability and strength of bunds as countermeasures based on accumulation of repair history
Maintenance Inspection (Monitoring of River Conditions)	Vol 1: Ch5-5.16.4 Inspection Team Ch5-5.16.6 Safety Inspection and Evaluation Ch5-16.8 Evaluation Report	The process from recording of inspection of bunds by visual and equipment survey through the preparation and storage of records
Information Management	Vol 1: Ch5-5.21 Maintenance Records	Clear descriptions of regulations for structuring information storage to facilitate easy access to data on topography, equipment surveys, and satellite imagery
Artificial Breaching of Bunds	Vol 2: Ch2-16.11 Operation of Bund Breach Location	Smooth communication system
Gaps Between the Manual and the Actual Practice	Vol 2: Ch10-1.3 Implementation of the M&R Annual Plan	Clarification of the departments that arrange and keep NESPAK information regarding bids, testing during construction, inspection results, and completion of river construction

Notes: Excludes items other than those with priority A in the Comparative Analysis Report.

1.2 Structure of the Addendum

The table below outlines the structure and contents of this supplementary document.

Structure and Description of the Addendum

Basic Layer for each Supplementary		Heading or Description Under the Heading
1	X.X: Main Heading	Main title of the supplementary subject
2	X.X.X: Subheading	Subtitle of the supplementary items
3	Box under the (sub-) headings	Indications of target chapter and articles of the current manual
4	(x): Items under (sub-)headings	Section numbers in the current manual where the supplementary items should be added/referred
5	<Reasons and Summary of Supplement>	Reasons and summary of supplement
6	<Content that should be added to manual> with BOX	Supplementary content is specifically written in text box
7	<Reference>	Reference information for understandings

CHAPTER -2

SUPPLEMENTARY ITEMS FOR THE SINDH PROVINCE BUND MANUAL

CHAPTER 2 Supplementary Items for the Sindh Province Bund Manual

The supplementary items and texts (in the text box) of the current bund manual *(Bund Manual Fourth Edition 2008 in Government of Sindh)* are presented below. Additionally, explanations of the main concepts are provided following the supplementary text.

2.1 Standard Shape of Bund

In the current manual, the shape is determined based on the height of the bund and its installation locations. However, the bunds along the main Indus River should be designed to withstand external forces while maintaining functionality.

Chapter and Article of Current Bund Manual
CHAPTER V: Design of New Bunds and Loop Bunds Article: 41. Standard sections or type designs of bunds
Relevant Articles in the Punjab Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 4.3.1.3.1. Marginal Bunds

(1) Subject of Supplementary Items: Ch 5-41 Standard Bund Shape

<Reasons and summary of supplement>

There are various standards for bund shape in the Indus River system, depending on location and use. For the main river bunds, crown width and freeboard of basic bund shape that is uniform for all bunds along the Indus River in Sindh and Punjab provinces are recommended. As for the slope of the bund, no changes will be made to the existing manual standard for Sindh.

<Content that should be added to manual>

Ch 5-41 Standard Bund Shape

For repair and new construction of bunds along the Indus River, the crown width and freeboard are set based on the following criteria.

- Bund Freeboard: More than 7.0 ft above design high flood level.
- Bund Crown Width: More than 25 ft.

The bund slope shall be set in accordance with the current manual.

Source: *Bund Manual Fourth Edition 2008 by the Government of Sindh, Manual of Irrigation Practice Volume 1 by the Government of Punjab*

<Reference information>

There is currently no uniformity in the freeboard and crown width of the main river bunds along the Indus River. The standard crown width of 25ft and freeboard of 7ft, which are recommended values for important bunds in Punjab, shall be set as the standard shape. As for the slope of the bund, the existing manual should be followed because of the regional characteristics of the bund material.

In the future, the bund shape, particularly in Sindh, should be examined in consideration of upstream bund breach effect which resulted in reducing flood impact along the Sindh stretch of Indus River.

2.2 Quality Control

Quality control is the most important aspect of constructing strong bunds to withstands floods. The quality of the bund itself determines the fundamental strength of the bund. Through selection of soil material suitable for bunds and reliable implementation of construction management *(such as ensuring degree of compaction is up to par),* a bund resistant to floods can be built. In addition, proper day-to-day maintenance will become easier, and efficient strengthening of bunds will be possible. A supplement addressing these points is provided with more specific explanations and standards.

2.2.1 Soil Quality of Bund Material

Chapter and Article of Current Bund Manual

CHAPTER VI: Construction of New Bunds or Loops
Article:
51. Requisites of suitable soils for bund building
52. Relative merits of different soils for bund building
60. Specifications for earthwork for river embankment

Relevant Articles in the Panjab Bund Manual

None

(1) Subject of Supplementary Items: Ch 6-52 Soil Quality Desirable as Bund Material

<Reasons and summary of supplement>

Since the current manual does not provide explicit criteria for bund material, the following supplements are added to section 52-1: (1) Standards for Desirable Bund Material, and (2) Examples of Countermeasures **in Case the Soil Quality is not Suitable** as Bund Material.

<Content that should be added to manual>

Ch 6-52 Soil Quality Desirable as Bund Material

1) Soil Desirable as Bund Material

To meet the basic conditions for bund material, the soil should have the following properties:

1. Soil with good particle size distribution: This is because a variety of grain sizes is desirable for adequate compaction. The coarse particles are effective in providing strength through particle interlocking, whereas the fine particles are necessary to reduce the permeability coefficient. Therefore, an appropriate combination of coarse and fine particles is desirable for bund materials.

2. The maximum dimension is 10-15 cm or less: This limitation is determined by the spreading depth during construction. However, caution is required because if the maximum dimension of the gravel diameter is too large, the effect of compaction may not be fully realized.

3. Fine particles (0.075 mm or smaller) make up at least 15% of the soil material (75 mm or smaller): This requirement ensures impermeability. It has been reported that many leaks occur in bunds constructed with material that does not meet this requirement.

4. Soil with not too many silt particles: Erosion due to rainfall and slope failure due to water seepage allow water to pass through the soil more easily. This results in increased moisture content and reduced shear resistance. The phenomenon is thought to be greatly influenced by the silt particles within the soil.

5. Soil with not too many fine particles (0.075 mm or smaller): Soil with fine particles of 50% or less is preferable, as soil with fine particles of 50% or more is at risk of cracking when dried.

2) Countermeasures in case the soil quality is not desirable as bund material

Materials with poor evaluation and materials whose trafficability cannot be ensured may be used as bund material provided that the following countermeasures are applied:

a) Mixing with Other Soil Types

This is intended to compensate for the poor particle size distribution of the soil. By mixing fine-grained soil with sandy soil to reduce the permeability coefficient and mixing cohesive soil with sandy

soil to reduce the moisture content, the strength of the soil can be increased to facilitate construction.

b) Soil Quality Improvement Using Additives

Soil quality can be improved by adding improving agents such as lime and cement.

(i) Particle size adjustment by mixing with other soil types

This method improves the properties of the soil with poor particle size distribution by adding different soil types that can supplement the lacking particle size of the original soil. For river bunds, the particle size of the embankment material is adjusted to ensure appropriate compaction by mixing fine-grained soil with sandy and gravelly soil. For instance, sand is mixed into cohesive soil to get sandy soil.

As described above, grain size adjustment involves mixing two or more types of soil with different properties to improve the grain size distribution, resulting in soil suitable for use as bund material. Therefore, the adjusted soil can be evaluated by looking at properties of the improved soil and may be regarded as the same as a typical soil desirable as materials for a stable bund.

(ii) Soil stabilization treatment using additives

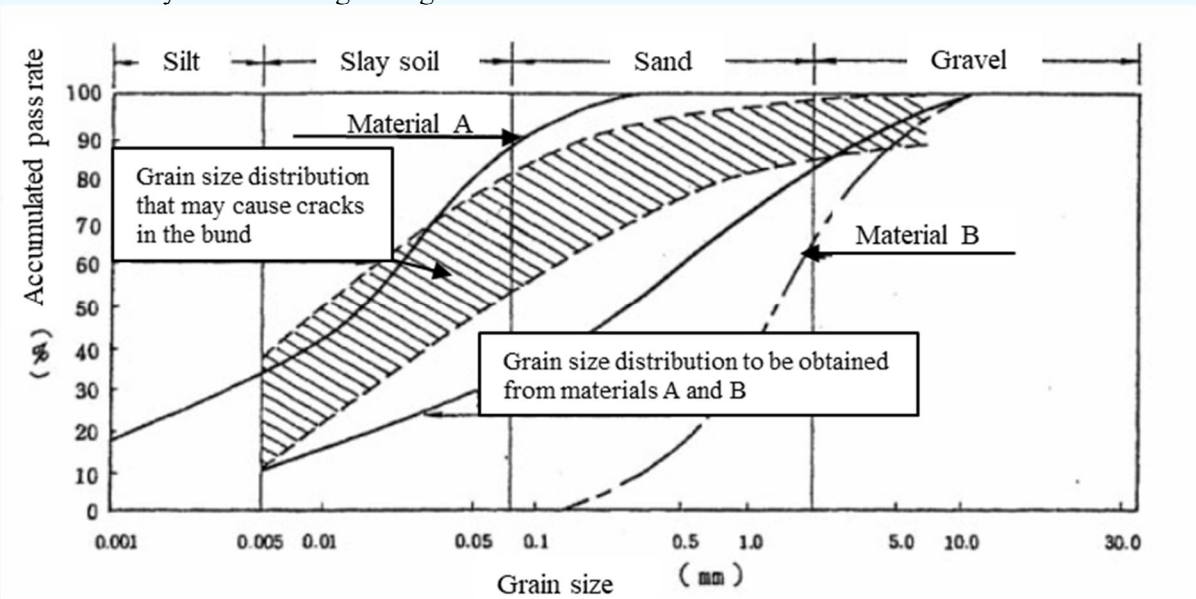
This method attempts to stabilize soil quality using lime or cement for soils with insufficient trafficability, such as cohesive soils with high moisture content.

The stabilization mechanism of each additive is as follows.

- **Lime:** Lime reacts with soil water, which causes water absorption as well as heat generation, and results in dehydration of the surrounding soil. In the long term, it is chemically bonded by the pozzolanic reaction. For this reason, the reaction time with lime is required to be longer than that of cement.
- **Cement:** Cement reacts with soil water to produce hydration hardening, which hardens through chemical bonding with soil particles. In the long term, although there is also an enhancement of hardening by the pozzolanic reaction, most of the hardening action is due to hydration hardening.

The hardening time of cement is shorter than that of lime, with most hardening completed within about 3~7 days after mixing with soil.

In addition, after the bund are constructed with soil that employed the soil stabilization treatment, fine cracks due to dry shrinkage may develop on the bund depending on the soil type, additive materials, mixing ratio, and mixing method. Therefore, it is advisable to determine the construction method based on preliminary examination through laboratory testing and, if feasible, verify the method by on-site testing during construction.



Schematic Diagram of Particle Size Adjustment

Source: *Civil Engineering Manual 3.1.3 Selection of bund materials*

<Reference information>

The concept of desirable bund material does not significantly differ from the current manual. Soil with silt content of 50% or less, and sand content of 50% to 70% or 80% is considered suitable as bund material. The bund material used for the Indus River bunds has a high fine particle content, which can cause scouring and erosion of the bunds. During construction, it is desirable to adjust the grain size during construction by mixing sand to reduce the fine particle content to 50% or less.

Soil stabilization treatment with additives is not expected to be actively adopted due to issues with financial cost and the need to set the optimal mixing ratio, but it should be employed for critical structures and when a high level of bund strengthening is required.

2.2.2 Standards for Degree of Compaction

Chapter and Article of Current Bund Manual

CHAPTER VI: Construction of New Bunds or Loops
Article: 51. Requisites of suitable soils for bund building

Relevant Articles in the Punjab Bund Manual

Vol.2:
Chapter 2: River Training & Flood Management
4.3.1.2. Planning

(1) Subject of Supplementary Items: Ch 6-51 Test Methods and Standard Values of Soils for Bund Construction

<Reasons and summary of supplement>

Standard values for degree of compaction and air porosity are described. In addition, the main soil tests and water content control for bund material are specified.

<Content that should be added to manual>

Ch 6-51 Test Methods and Standard Values of Soils for Bund Construction

1) Standard Values of Soil Material for Bund Construction

The degree of compaction is defined according to the ratio of fine grain particles (0.075 mm or less) within the soil material (particles of 75 mm or less), and this ratio can be obtained by conducting a sieving test.

Regulation of Degree of Compaction

Soil Classification Name	Coarse-Grained	Sandy soil {SF} (15%≦-74μm<25%)	Sandy soil {SF} (25%≦-74μm<50%)	Cohesive soil CS
Degree of Compaction (DC)	*DC* =90%	*DC* =90%	—	—
Construction moisture content (ωn)	—	—	Within the scope of trafficability	Within the scope of trafficability
Air porosity (Va)		—	Va≦15%	2%≦Va≦10%
Saturation (Sr)		—	—	85%≦Sr≦95%
Quality pass rate (%)	—	—	90%	90%
Quality lower limit	*DC* =80%		—	—

○ *The standard compaction laboratory test shall be performed using the A-a method.*
(Reference: https://kikakurui.com/a1/A1210-2020-01.html#google_vignette)

Trafficability requirements for construction equipment are shown below. Basically, the embankment's trafficability should be sufficient to allow dump trucks to pass without obstruction.

Trafficability of Construction Machinery

Construction Machinery	Installation pressure of construction machinery	Cone Index QC
	(k N/m^2)	(k N/m^2)
Wetland bulldozer	22~43	≥300
Ordinary bulldozer	50~60	≥500
Ordinary bulldozer	60~100	≥700
Towed scraper	130~140	≥600
Self-propelled scraper	400~450	≥1,000
Dump Truck	350~550	≥1,200

Source: *Japan Road Association, "Civil Engineering Guidelines for Roads"*

2) Soil Material Management

a) Soil Quality Test

For bund material, soil compaction tests shall be conducted in advance to determine the maximum dry density as well as optimum moisture content and establish the quality control standard values. In addition, the following tests shall be conducted as needed to determine the suitability of the soil for use as bund material.

Main Soil Quality Tests of Bund Material

Test Name	Objective	Method
Particle size test of soil	Investigate the distribution of soil particle size distribution	Sieve method, Sedimentation method
Density test of soil particles	Investigate the density of soil particle	Pycnometer method
Moisture content test of soil	Investigate the soil moisture content	Drying method
Liquid and plastic limit test of soil	Investigate the plastic characteristic of soil	Atterberg limit test
Uniaxial compression test of soil	Investigate the compressive strength of soil	Uniaxial compression test apparatus
Tri-axial compression test of soil	Investigate the shear strength of soil	Tri-axial compression test apparatus
Density test of soil	Investigate the compressive property of soil	Consolidation test apparatus
Shear test of soil	Investigate the shear strength of soil	Direct shear test, Tri-axial compression test
Permeability test of soil	Investigate the permeability of soil	Constant head permeability test, Falling head permeability test

Source: *Civil Engineering Manual 3.1.4 Regulation of degree of compaction, 5.3.1 Quality Control*

b) Optimum Moisture Content Standard

During the soil compaction testing, the moisture content is adjusted. The moisture content when the dry density is highest is regarded as the optimum moisture content (OMC). The density at this point is called the maximum dry density.

Although dependent upon the soil type, the typical value is around 70-95% for saturation degree and less than 15% for air porosity (often less than 10%).

c) Adjustment of Moisture Content for Dryness and Wetness

To achieve the specified compaction degree during bund construction, it is important to control the moisture content as part of the quality control process for bund materials. The following methods can be used to adjust the moisture content of bund material.

(i) Natural drying

Natural drying is used to reduce the moisture content of the embankment material. In this method, the material is spread out, left undistributed, and periodically stirred before compaction

to allow it to dry naturally.

(ii) Trench excavation, etc.

In this method, before the bund material is collected at the borrow pit, a trench is excavated below the collection base to lower the underground water level and reduce the moisture content of the bund material. This method has been proven to be relatively effective and is commonly used.

(iii) Water sprinkling

Water sprinkling is used to adjust the moisture content of the bund material to the optimal value and is performed after leveling but before compaction. The amount of water applied is determined by the difference between the natural moisture content of the material to be leveled and the moisture content required for proper compaction.

Source: *Civil Engineering Manual 3.1.4 Regulation of degree of compaction, 5.3.1 Quality Control*

<Reference information>

For bund material, the degree of compaction target is Dc=90% or more and the air porosity (Va) target is Va≦15%. Since the current manual does not specify the testing method, quality control will be performed based on the results of the compaction test currently conducted in Sindh province. The standardized laboratory compaction test of Japan is the A-a soil compaction test method (JIS A 1210-2009). (Reference: https://kikakurui.com/a1/A1210-2020-01.html#google_vignette)

Prior to the start of construction, soil quality tests of the bund material should be conducted to determine its characteristics. In case of unfavorable soil properties, countermeasures are considered. In addition, soil compaction tests are conducted to establish the standard for maximum dry density and optimum moisture content, and construction management shall be carried out.

2.2.3 Construction Machinery Used

Chapter and Article of Current Bund Manual CHAPTER VI: Construction of New Bunds or Loops Article 55. Mechanical equipment for construction of embankment
Relevant Articles in the Panjab Bund Manual NONE

(1) Subject of Supplementary Items: Ch 6-55 Machinery and Equipment Used for Embankment

<Reasons and summary of supplement>

The current manual does not provide clear guidance on the construction equipment to be used. Therefore, specific machinery and equipment required for bund embankment construction are now clarified.

<Content that should be added to manual>

Ch 6-55 Machinery and Equipment Used for Embankment

1) The table shows the standard machinery used for various operations in bund embankment construction.

Work Type and Applicable Machinery

Type of work	Type of Construction Machinery
Excavation	Shovel-typed excavator (power shovel, backhoe, drag line, clamshell), bulldozer, ripper, and breaker
Loading	Shovel-typed excavator (power shovel, backhoe, drag line, clamshell), and continuous loader
Drilling and Loading	Shovel-typed excavator (power shovel, backhoe, drag line, clamshell), crawler loader, wheel loader, and continuous loader
Drilling and Transportation	Bulldozer, scrapedozer, scraper, and dredger
Transportation	Bulldozer, dump truck, and belt conveyor
Spreading	Bulldozer, and motor grader
Compaction	Bulldozer, tire roller, rammer, tamper, vibrating compactor, vibrating roller, and road roller

Source: *Civil Engineering Manual, 4.2.5 Selection of Construction Machinery 1) Work Type*

2) The general applicability of bund material and compaction machinery is shown below.

General Applicability of Compaction Machinery for Different Soil Types

Machinery / Soil type	Ordinary bulldozer	Tire roller	vibrating rollers,	Vibrating compactor	Tamper	Remark
Sand Gravel and sand	○	○	○	△	△	Single grained sand, unscreened gravel, dune sand, etc.
Sand Sandy soil Sandy soil with gravel	◎	◎	○	△	△	Mixed soil with appropriate grain size, decomposed granite soil, mountain gravel, etc.
Clay Clay with gravel	○	○	○	×	△	Sensitive soil with few fine particles, loams with low moisture content, crumbly mudstone, etc.
Sandy soils with high moisture content Clay soils with high moisture content	○	×	×	×	×	Soils with difficult-to-adjust moisture content or difficult-to-sufficiently-ensure permeability, silty soils, etc.

Legend: ◎ Applicable

○ Can be used
△ Can be used, but dependent upon site conditions such as area restrictions
× Cannot be used

Source: *Civil Engineering Manual, 4.3.4 Embankment 3) Embankment and compaction*

3) Changes to the Current Manual (Recommendation)

In section 55 (Mechanical Equipment for Construction of Embankments) of the current manual, it is stated that *"Bunds have so far been constructed in Sindh, with rare exceptions, using donkey labor"*. However, considering the current circumstances, this should be revised to "*Bunds have been constructed in Sindh using backhoes, bulldozers and other construction machinery"*.

Source: *Civil Engineering Manual, 4.2.5 Selection of Construction Machinery 1) Work Type and Applicable Machinery; 4.3.4 Embankment 3) Embankment and compaction*

<Reference information>

Section 55 of the current manual provides examples of machinery used for bund construction. As a supplementary item, the actual construction machinery commonly used in civil engineering is summarized in the table. As for shovel-typed excavators and bulldozers are concerned, they are capable of operating in wetlands.

Different compaction machinery is used depending on the soil quality' however, bulldozers and tire rollers are typically the most commonly used equipment in Pakistan.

2.3 Safety Assessment

In the current manual, paragraph 31-50 (Chapter 5, Design of New Bunds and Loop Bunds) only partially describes the concept of safety of each facility. Since understanding the overall process is important for comprehensive safety assessment, this information is compiled as supplementary items.

2.3.1 Disaster Forms (Types) of Bund and Verification Items for Safety Assessment

Chapter and Article of Current Bund Manual

<Seepage>
CHAPTER V: Design of New Bunds and Loop Bunds
Article
31. Factors governing design of safe earth embankments
34. Line of saturation within downstream toe and to have sufficient cover
35. Piping
36. Leaks or free passage of water
37. Stability of Section
38. Cracks due to unequal settlement and wetting
39. Design of wetting channels

<Erosion>
CHAPTER IV: Proposals for new Bunds, Loops and Bund Sluices
Article
20. Cutting of erosion lines and spacing of erosion ordinates
21. Instructions regarding pegging and measurements of erosion ordinates
CHAPTER XI: Emergent Measures or Causes of Failures of Bunds and Methods used to Combat Them
Article
125. Slips and their treatment
CHAPTER XV: Design of Stone Spurs or Stone Apron and Stone Pitching on Front Bunds as Protection Against Erosion.
156. Necessity of stone spurs and stone apron
APPENDIX V: Miscellaneous River Works.
2. Revetment

Relevant Articles in the Punjab Bund Manual

Vol.2:
Chapter 2: River Training & Flood Management
5. Failure of flood embankment
5.3. Erosion
5.4. Seepage through the embankment body
6. Seepage control

(1) Subject of Supplementary Items: Ch 5-31 Disaster Forms of Bund and Verification Items for Safety Assessment

<Reasons and summary of supplement>

The disaster form of the bund is shown, and the verification methods of safety evaluation such as arc slip and seepage analysis method are presented.

<Content that should be added to manual>

Ch 5-31 Disaster Forms of Bund and Verification Items for Safety Assessment

1) Disaster Form of Bund (Concept)

Displacement and deformation of bunds, along with changes in properties due to water seepage, leakage, and other damages, result from disaster-induced external forces such as rainfall, river water, ground subsidence, and earthquake. These factors contribute to various forms of disasters, as shown in the figure below.

Various Forms of Disasters

Natural Phenomenon	Disaster	Location	Disaster Form
Rainfall	River runoff	High water channel, low water channel scouring	Water leakage, bund scouring
		Bund	Slippage
			Seepage
			Erosion, scouring
Earthquake	Liquefaction	Bund	Slippage

Source: *Created based on related materials*

2) Verification Items for Safety Assessment (Concept)

During prolonged period of rising river water levels and flooding, disasters such as seepage, overflow, scouring and erosion become more likely. In the worst-case, inundation due to a breach could occur.

To assess the safety of the bund, assuming its cross-sectional shape aligns with the design specification, the following performance criteria should be established and verified.

a) Integrity under normal conditions

Regarding the stability verification against slip failure under normal conditions, various allowable parameters such as slip safety factor have been established. The soil properties of the foundation and the bund were then considered, and safety was evaluated from values such as safety factor against slip failure under self-weight. Stability verification is based on confirming that the condition of the allowable values is satisfied. If the ground is not considered soft based on past results, the verification can be omitted.

b) Seepage resistance performance

Regarding verification of seepage resistance performance, the allowable values of safety factors for slip failure and piping failure, etc., have been set. Next, the safety factors (with regards to slip and piping failure) of the bunds are then evaluated based on the water level fluctuations, rainfall patterns, soil quality of the foundation ground and bund, etc. These factors are compared with the allowable values and safety is verified if the specific conditions are met.

c) Erosion resistance performance

Erosion resistance performance is essentially verified by setting the allowable values for erosion ultimate flow velocity of the bund slope or erosion value of high-water channel based on past damage records, condition of revetment installation and width of flood channel at the front surface of the bund. Next, flow velocity or erosion amount due to flood action, considering flat and longitudinal profiles of the river channel, are evaluated to verify that the condition of allowable values is satisfied.

d) Seismic performance

The verification of seismic performance is fundamentally based on setting the allowable height of the bund to prevent water flow under normal conditions or design tsunami from overflowing after an earthquake. Next, height of the bund after earthquake-induced deformation is evaluated and verified to check whether the condition of allowable values is satisfied.

e) Safety against waves, etc.

The safety of bund against erosion, significantly influenced by waves and tsunamis, should be checked and verified based on past damage experiences. In case of a high tide, erosion of bund due to water flowing below the design storm surge level is checked. In case of wind and wave, erosion of bund due to water flowing below the high flood level or the river level when winds and waves are most developed is checked. In case of a tsunami, erosion to the bund due to water flowing below the design tsunami water level is checked.

If verification found the safety performance to be lacking, strengthening methods will be explored. In essence, verification methods are methods based on appropriate knowledge, such as methods considered reasonable based on past experiences and results, or methods where actual condition of damage of the river in question or the equivalent river can be reproduced.

***Source:** Technical Criteria for River Works: Practical Guide for Designing Chapter 1 Section 2 Bund*

3) Verification External Force and Verification Standards for Safety Assessment

Verification external force and verification standards for safety assessment are set as follows.

a) Seepage Verification (Standard)

For seepage resistance function verification, the external forces are defined as the verification outer water level and verification rainfall.

Verification outer water level refers to the high flood level (if indicated, the water level during the flood that was set as immediate maintenance target). Verification rainfall refers to the rainfall associated with design flood (if indicated, the rainfall during the flood that was set as immediate maintenance target).

The verification standards include target safety factor for slippage and mechanical limit state for piping, as shown below.

(i) Safety against slip fracture

a. Safety against slip fracture at the back surface

$Fs \geqq 1.2 \times \alpha 1 \times \alpha 2$

Fs: Safety factor against slip fracture

α1: Multiplicative factor for the complexity of bund construction history

If the bund construction history is complex α1= 1.2

If the bund construction history is simple α1= 1.1

If the bund is a new construction α1= 1.0

α2: Multiplicative factor for the complexity of ground foundation

If there is a history of damage or if the terrain requires attention α2= 1.1

If there is no history of damage or if the terrain does not require attention α2= 1.0

※ Cases of complex bund construction history include scenarios where the initial construction dates back a long time with multiple subsequent modifications, or when the construction history is undocumented or unclear.

Terrain requiring attention: Flood control terrain that is linked to bund destabilization,

such as old river channels and excavation sites

b. Safety against slip fracture at the front surface

$Fs \geqq 1.0$

Fs: Safety factor against slip fracture

(ii) Safety against piping failure of ground foundation

a. In case ground foundation and soil cover layer at sheltered area is permeable

$i<0.5$

i: Maximum local hydrodynamic gradient of ground foundation near toe of back slope

b. In case ground foundation is permeable and soil cover layer at sheltered area is not permeable

$G>W$

G: Weight of the soil cover layer

W: Lifting pressure acting on the base surface of the soil cover layer

b) Verification Against Erosion (Standard)

In the verification study of erosion resistance, the representative flow velocity is set as the external force to be verified. The representative flow velocity is calculated by multiplying the fastest average flow velocity at the water level below the high flood level (if indicated, the flood water level that was set as the immediate maintenance target) by the correction factor due to the curvature, etc.

The following are the standard verification criteria; however, these do not apply when appropriate measures, such as riverbank protection, have been implemented.

(i) Regarding direct erosion of front and toe of bund slope

Surface erosion capacity > external erosion force evaluated from representative flow velocity

(ii) Lateral erosion and scouring from main channels (low channels, etc.)

High-water channel width > width of the high-water channel eroded during the verification period

(iii) Regarding scouring

Height of foundation pile at the front slope of bund > height of riverbed scoured by one flood

***Source:** River Bund Design Guidelines 5. Verification of safety*

c) Verification Against Earthquake (Reference)

(i) Verification Items

The safety of bunds against earthquakes is verified by evaluating the potential for secondary disasters, such as flooding due to bund subsidence. The verification items are broadly divided into two categories: deformation of the bunds due to liquefaction and inertial forces. This section summarizes inspection methods that link both deformation to the subsidence phenomenon.

(ii) Inspection Criteria

According to The Japanese Ministry of Land, Infrastructure, Transport and Tourism's revised draft of "Technical Criteria for River Works: Practical Guide for Designing [I]", it is required to investigate the possibility of secondary disasters based on the estimated amount of subsidence, taking into account the outer water level and the conditions of the hinterland. In the guideline, the possibility of secondary disasters due to flooding is determined by comparing the height of the deformed river bund (after an earthquake) with the river water level set considering the emergency recovery period.

In this case, it is considered appropriate to set the height of the deformed river bund (after an earthquake) as the height that ensures that the condition of required crown width (design or existing crown width) is met.

On the other hand, the estimated river water level is set according to the period of time required for emergency recovery (approximately two weeks), the characteristics of the river, and the conditions of the surrounding hinterland. For reference, the water level can be set as follows:

- Mean monthly highest water level (normal flood level of the flooded section upstream from the lakes and weirs) + α (m)
- High water level based on return period (1/1 equivalent water level) + α (m)
- Design tsunami height

Here, α is set in accordance with tidal deviation and wave height, with 1 to 2 meters considered

as the guideline value.

The possibility of secondary disasters is verified based on the comparison between the post-earthquake height of bund and the river water level set. If the bund's height is lower than the latter, it is evaluated that secondary disasters, such as flooding may occur.

***Source**: Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 6*

4) Verification Methods of Safety Assessment

a) Seepage Verification

The safety of bund against seepage is evaluated using unsteady seepage flow calculation and stability calculation using circular slip method. The unsteady seepage flow calculation tracks the position of the seepage surface and the change of the head of water over time by applying a non-stationary external force. As such, the shape of the seepage surface at an arbitrary time can be known, and the local hydraulic gradient can be calculated from the head distribution. On the other hand, in the stability calculation using circular slip method, the safety factor against slip failure during flooding can be obtained by extracting the seepage surface that is assumed to be the most critical for each of front and the back slope surface and setting this as the cross-section to be inspected.

(i) Method of Unsteady Seepage Flow Calculation

There are two methods of seepage flow calculation: (a). Steady analysis method and (b). Unsteady analysis method. The latter contains saturated analysis and saturated-unsaturated analysis. This guide emphasizes conducting unsteady saturated and unsaturated seepage flow calculations to simulate realistic conditions.

The basic equation for the calculation of unsteady saturated and unsaturated seepage flow is as follows.

$$\frac{\partial\psi}{\partial x}\left(k\frac{\partial\psi}{\partial x}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial\psi}{\partial z}+k\right)=(C+\alpha.S_s)\frac{\partial\psi}{\partial t}$$

Here,
- x: Horizontal axis of the bund cross-section
- z: Vertical axis of the bund cross-section
- k: Hydraulic conductivity (m/hr)
- ϕ : Pressure head (m)
- C: Specific water capacity (1/m)
- α: 1 for saturated region, 0 for unsaturated region
- Ss: Specific retention coefficient (1/m)
- t: Time (hr)

Here, the specific water capacity C is given as a tangential gradient of the soil water characteristic curve, and the specific retention coefficient Ss is Ss = 1×10^{-4} (1 / m) for sandy soil, and Ss = 1×10^{-3} (1/m) for cohesive soil.

The calculation of unsteady saturated and unsaturated infiltration flow is performed by setting soil constants, initial conditions, and calculation conditions for the modeled bund (bund and ground foundation), and entering boundary conditions. During the calculation, results at important points in assessing the safety of the bund, such as the river water level (outer water level) at the end of rainfall and its peak, are recorded in a file and carried out until the end of the flood.

Figure A shows an example of comparing the seepage surface calculated using the aforementioned method with the seepage surface observed in the seepage experiment of a full-scale embankment, and it can be seen that the actual seepage phenomenon is well reproduced.

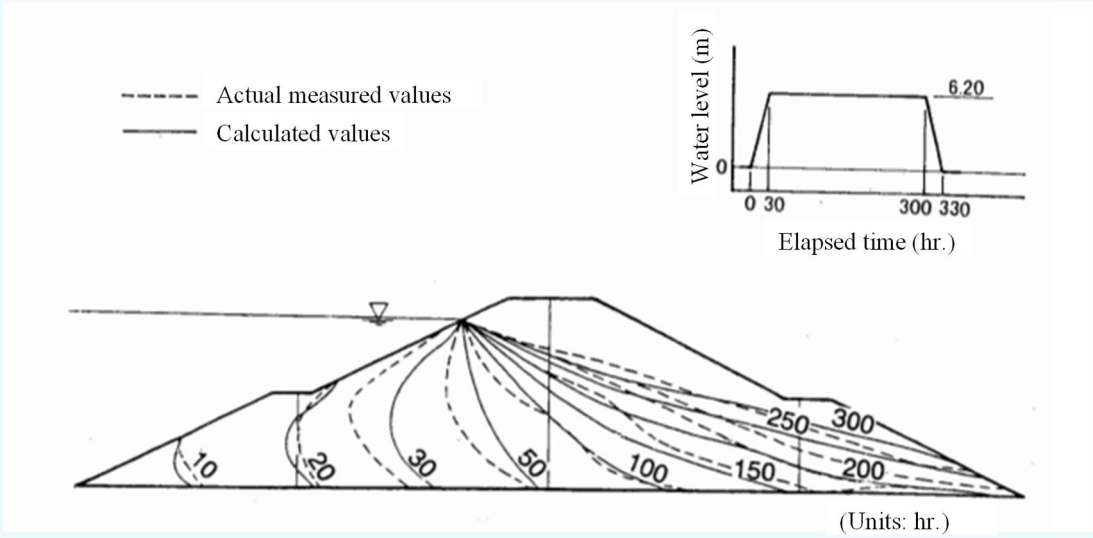
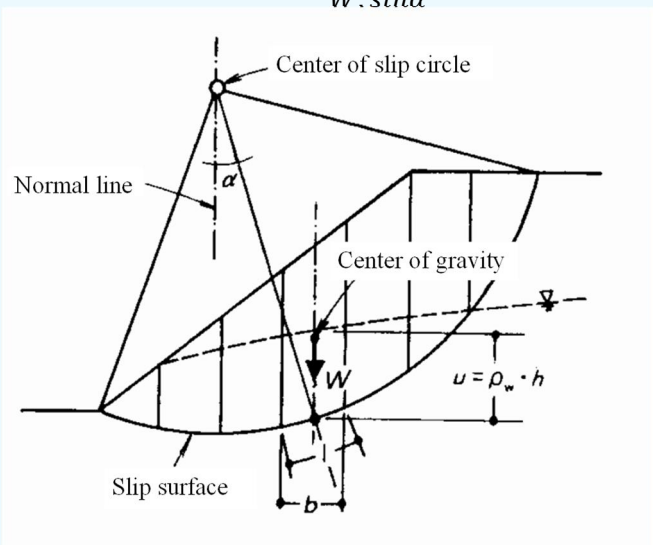


Figure. A. Validation of Seepage Experiment on a Full-Scale Bund Results using Seepage Flow Calculation

(ii) Stability calculation method by circular slip method

The most critical seepage surface identified through seepage flow calculation is selected, and the minimum safety factor against slip failure is calculated based on general total stress method using the following equation.

$$F_s = \frac{\Sigma\{c1 + (W - ub).cos\alpha.tan\phi\}}{W.sin\alpha}$$



Here,

Fs:	Safety factor
u:	Pore water pressure (kPa) of slip surface
W:	Divider weight (kN/m)
c:	Cohesion strength of soil along the slip surface (kPa)
l:	Arc length (m)
ϕ:	Internal friction angle of soil along the sliding surface (°)
b:	Divider width (m)

General total stress method is a method in which a shear test is performed under the same stress condition and drainage condition as in the actual case. The so-called apparent strength constant c and ϕ are obtained, and stability calculation is performed using the pore water pressure of slip surface. The strength constant and pore water pressure used in the general total stress method are

shown below. Pore water pressure includes pore water pressure due to seepage and drainage of rainfall and river water, and pore water pressure due to volume expansion or contraction of soil due to shear. The pore water pressure at the slip surface in the above equation refers to the pore water pressure due to seepage and drainage, which Terzaghi describes as the 'neutral pore water pressure'. In the general total stress method, pore water pressure due to shear is not considered in the above equation because the pore water pressure due to shear is already reflected in the soil test for determining the strength constant.

Various methods have been proposed for stability calculations using the circular slip method; however, the formula presented here is called the modified Fellenius formula.

In the stability calculation, the minimum safety factor is calculated for several arc centers, and the minimum value among them is the minimum safety factor for the calculated cross-section.

Strength Constant and Pore Water Pressure

Condition of Divider Base	Strength Constant	Pore Water Pressure
Non-drainage condition (if water permeability is low)	Cohesive force cU (internal friction angle ϕ U ≈ 0) or cohesive force cCu, internal friction angle ϕ CU	Pore water pressure due to seepage and drainage u
Drainage condition (if water permeability is high)	Cohesive force C D ≈ C', Internal friction angle ϕ D ≈ φ'	By seepage and drainage

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 4*

(iii) Verification Software for Seepage

Regarding the verification of seepage, comprehensive analysis software such as SEEP / W, ANSYS, and HYDRUS is generally used for seepage flow analysis. Dedicated software for analysis includes tools such as PLAXIS, MODFLOW, SVFLUX, and FEFLOW. For circular slip analysis, Software like Rocscience Slide2 and GeoStru Slope are commonly used. Among them, the representative seepage flow analysis software SEEP/W and the arc-slip software Rocscience Slide2 are shown in the URL for reference.

SEEP/W ：It is part of the GeoStudio suite developed by Seequent.
https://www.seequent.com/getting-started-with-seep-w/

Slide2 by Rocscience ：It is a powerful software tool used for analyzing the stability of slopes.
https://www.rocscience.com/software/slide2

(Source: *Created based on related materials)*

b) Erosion Verification

(i) Safety Verification Against Direct Erosion of Front and Toe Surface of Bund (Reference)

River bund is assessed assuming that the bund is covered by vegetation such as grass. Erosion resistance of front and toe surface is assessed by comparing the erosive external force (evaluated based on the representative flow velocity V_0 and the flow action time) with the erosion resistance of the slope surface covered with vegetation.

Regarding the surface erosion resistance of slope covered with vegetation (erosion resistance of vegetation), in cases where plants are not very tall, the main part among the bund vegetation that exhibits erosion resistance is the rhizome. The root layer, which is washed out of the ground by erosion due to flowing water, slows the velocity of flow near the ground surface, thereby reducing the scouring force.

Assuming:

1. The maximum erosion depth achieved in the design where the erosion prevention effect of vegetation is present is defined as the allowable erosion depth. The erosion prevention effectiveness is only exerted within the time it takes for erosion to progress to the allowable erosion depth.

2. Higher erosion resistance increases with a higher density of vegetation roots near the surface. That is to say erosion resistance of plants varies with the number of rhizomes near the surface (average root hair amount)

With duration of the shear force exerted by the water flow (t) and average root hair amount (σ_0) as parameters, surface erosion resistance (u_{*c}) due to vegetation can be determined from the

following equation:

$$\mu_{*c} = \frac{Z_{brk}}{\alpha} \cdot \frac{1}{\log t} \qquad (1)$$

Here,
- u_{*c}: Friction velocity (m/s)
- t: Duration of shear stress (min)
- Z_{brk}: Allowable erosion depth (cm)
- α: Parameters Representing Erodibility (= −50σ_0+9)
- σ_0: Average root hair amount (gf/cm³), defined as "the total weight of roots and rhizomes contained in the soil per unit volume up to a depth of 3 cm from the ground surface."

Equation (1) can be applied under the condition that the flow velocity is constant over time. Figure B plots a graph of Equation (1) with the allowable erosion depth set at Z_{brk}=2.0cm.

For cases where the flow velocity changes over time, the following simplified method for safety verification is adopted. This method is based on the following assumptions:

1. The water level waveform can be approximated as a triangular shape with the peak water level as the vertex.
2. The flow velocity increases or decreases with changes in water level.

If these assumptions are not applicable, an evaluation considering the time variation shown in Reference 3) must be conducted.

First, set the duration of the erosion force (t) and the average friction velocity (u_{*ave}) within that time. The duration (t) is determined as the period of time the water level exceeds the high-water channel elevation. In the simplified method, (u_{*ave}) is calculated using the following equation.

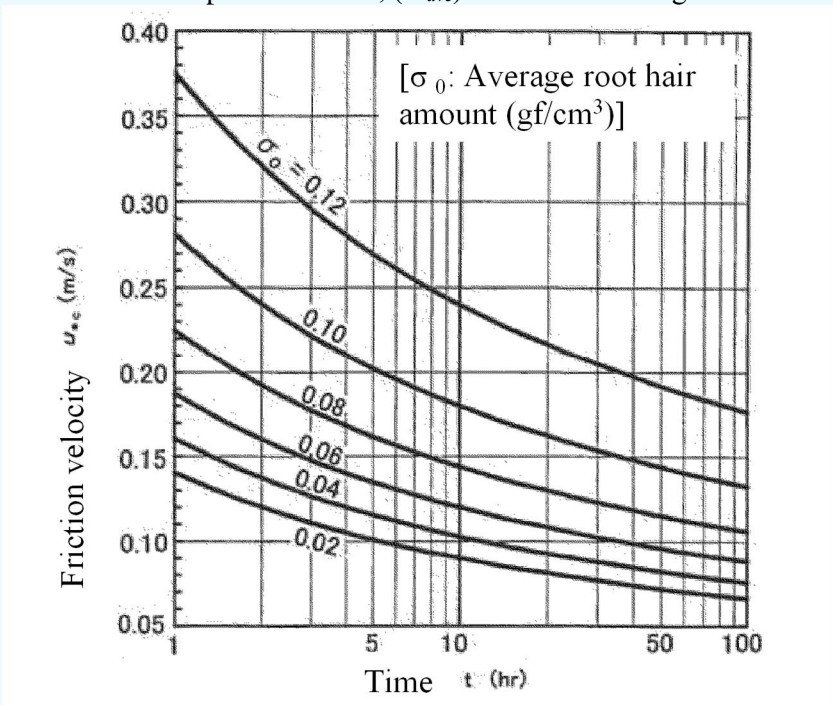


Figure B：Surface Erosion Resistance Due to Vegetation (Root Hair Amount and Friction Speed)

$$\mu_{*ave} = 0.82\mu_{*max} \qquad (2)$$

In other words, the simplified method proposes that if assumptions (1) and (2) apply, (u_{*ave}) corresponds to approximately 82% of the peak value. In this guideline, (u_{*max}) is set as (u_*) at the high flood level. (u_{*max}) is calculated using the following equation.

$$\mu_{*max} = V_{0\,max}/\psi \qquad (3)$$

Here, (V_{0max}) is the representative flow velocity at the high flood level, and (ψ) is the velocity

coefficient can be calculated as follows.

$$\psi = (1/n).(H_d^{1/6}/\sqrt{g}) \quad (4)$$

Here, n: Manning's roughness coefficient

H_d: Water depth (m)

g: Gravitational acceleration (m/s^2)

Next, the duration (t) is substituted into equation (1) to determine the surface erosion resistance (u_{*c}). From this, if ($u_{*c} > u_{*ave}$), it is evaluated that the safety against direct erosion of the bund's front and toe surface is ensured.

It is necessary to calculate the representative flow velocity (V_0) used in checking the safety of the bund against erosion by multiplying the maximum value of the average flow velocity obtained from an appropriate method with the correction factor for curvature. For details on the calculation method of the representative flow velocity (V_0), please refer to Reference 2).

Note that equation (1) can be applied under the following conditions:

- A thriving community of plants that are dominantly within the Poaceae classification (with rhizome diameters of up to 1 mm).
- The area is uniformly covered with vegetation, with almost no bare spots, such as mole holes.
- The ground material is silt or silt-mixed sand.
- The friction velocity (u*) is approximately 27 cm/s or less.
- The average root hair amount (σ_0) is within the range of 0.02 to 0.12 gf/cm^3.

The average root hair amount (σ_0) can be measured as follows:

1. Drive a PVC pipe into the slope at the selected survey site.
2. Push out the soil packed in the PVC pipeline up to 3 cm from the surface and cut it off with a cutter or similar tool.
3. Wash out the roots and rhizomes contained in the soil with water and measure their total weight.
4. Calculate the average root hair amount by dividing the total weight by the volume of the cut soil.
5. Perform the above measurement three times and take the average value as the average root hair amount for the survey site.

If it is difficult to measure the root hair amount, the erosion resistance of the embankment can also be evaluated using the relationship between the friction velocity and time for each coverage degree of Zoysia grass.

The erosion resistance at the front and toe surface of bund slope is generally considered to be ensured if the representative flow velocity is 2 m/s or less (rough estimate).

(ii) Safety Verification Against Lateral Erosion and Scouring

In the event of a flood, lateral erosion and scouring from the main channels (such as low water channels) may damage the bunds. The rate of lateral erosion depends on the form of erosion, the external forces acting on the riverbank and the duration of the action, which are closely related to the river channel characteristics and plane shape. Erosion progresses through repeating cycle of multiple floods. Therefore, with regards to the evaluation of erosion width, it is necessary to establish the period of the flood before employing the method for evaluating the erosion rate corresponding to the characteristics of the river channel and the form of erosion. It is necessary to comprehensively consider the conditions of the target river during the period of the flood and determine the verification time frame. The minimum verification time frame is one flood (one occurrence of flood), and if the verification time frame is set to one flood, inspection and response are necessary after every flood.

The method for evaluating the erosion rate from the perspective of hydraulic and soil engineering is not yet sufficient. Thus, the "Guideline" sets the width of the high-water channel eroded during the inspection target period as the inspection standard. Table A below shows the approximate width of erosion of flood channels due to one flood.

The values shown in Table A are estimates of the amount of lateral erosion and scouring from the main channels (such as low water channels) expected to occur after one flood. The values were obtained from actual data of erosion due to a single flood (all of which are below the high flood level) collected in local rivers. In addition, if the width of high-water channel erosion along the

target river due to past flooding has been accounted for, verification must be conducted based on the results.

Table A: Verification Criteria for Safety Against Scouring of the Front Toe of Slope

River Channel Segment Classification	Verification Criteria (Estimated width of high-water channel eroded by one flood)
1	About 40m
2-1	Width of high-water channel *b*> Five times the low water riverbank height *H*
2-2 and 3	Width of high-water channel *b*> Two to three times the low water riverbank height *H*

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5*

The middle and lower part of the Indus River is generally considered to be 3 and 2-2 (partially) according to the segment classification.

Typical Segment Types and Characteristics of Alluvial River Channel Sections in Japan

Segment Classification	Topographic Classification	Representative Particle Size of Riverbed Material dR	Materials of Riverbank	Riverbed Gradient
1	Alluvial fan	2 cm or more	Sand and silt may be placed on the surface layer; thin and consists of the same substance as the riverbed material	1/60~ 1/400
2-1	Natural Bund Zone	3cm~1cm	Mixed material of fine sand, silt and clay. However, the lower part is the same as the riverbed material	1/400~ 1/5,000
2-2	Natural Bund Zone	1cm~0.5mm	Mixed material of fine sand, silt and clay. However, the lower part is the same as the riverbed material	1/400~ 1/5,000
3	Delta	0.5mm~	Silt, clay	1/5,000~ Horizontal

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5*

(iii) Earthquake Verification (Reference)

The acceleration due to earthquake is selected on the basis of fifty percent reduction for the horizontal and vertical components for calculation by the pseudostatic method. For example, the effect of a maximum ground acceleration (in central Punjab area) due to an Open Basis Earthquake (OBE) of 0.16g (pseudostatic) in the free field issued for the stability analysis. Thus, on the basis of 0.16g OBE and fifty percent reduction in accelerations the earthquake loads adopted for analysis will be:

Horizontal acceleration = 0.08g

Vertical acceleration= 0.04g

These earthquake forces act at the center of gravity of each slice.

For OBE values no major damages may be expected for the hydraulic structures in general. The OBE values for particular scheme is adopted on the basis of specific related earthquake zone criterion.

a. Critical Conditions for Stability Analysis

The stability analysis of the embankment is carried out by using laboratory test values and characteristics of selected materials for determining the "Safety Factors" under critical conditions relating to the various parameters under design requirements. The recommended minimum safety factors against shear failures are listed in the table below:

Minimum Safety Factors

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
Design flood	1.5	1.2

Original Source: HASKONING and Delft Hydraulics
*(**Source:** Manual of irrigation practice volume 2 chapter 2- 6.2.2 in Government of Punjab)*

Source: *Indicated in the text box*

<Reference information>

Bunds along the Indus River are particularly vulnerable to damage from seepage and erosion. Therefore, it is especially important to evaluate the safety against seepage and erosion.

Verification against seepage involves checking the safety against slip failure and piping failure of ground foundation. The constants, safety factors, etc. are based on Japanese standards. If a revision becomes necessary in the future, changes will be considered.

The maximum external force for verification against seepage is the river flow velocity. Essentially, the structure of slope surface protection work and foot protection (revetment) work are examined with accordance to the representative flow velocity. By calculating the unsteady seepage flow, the seepage path is verified and countermeasures are considered. Verification of circular slip is conducted and countermeasures are considered. Regarding seepage flow analysis software, verification can be conducted using currently available software. For reference, an overview of the main software was provided.

2.4 Maintenance of Bund

In the current manual, bund maintenance is partially discussed in Chapter 5 (Paragraph 31-50) , Chapter 6 (Paragraph 51-60), and Chapter 9 (Paragraph 92-102); thus, it is difficult to understand the whole picture. The entire flow of information on seepage and erosion is important and should be compiled as supplementary items.

2.4.1 Seepage Countermeasures

Chapter and Article of Current Bund Manual
CHAPTERV: Design of New Bunds and Loop Bunds Article 34. Line of Saturation within downstream toe and to have sufficient cover 37. Stability of Section 41. Standard sections or type designs of bunds
Relevant Articles in the Punjab Bund Manual
Vol.2: Chapter 2: River training & flood management 6. Seepage control

(1) Subject of Supplementary Items: Ch 5-32 Seepage Countermeasures

<Reasons and summary of supplement>

Description and specific design method of seepage countermeasures of bunds are given.

<Content that should be added to manual>

Ch 5-32 Seepage Countermeasures (Concept)

1) Basic Policy on Bund Seepage Countermeasures

The basic policy of seepage countermeasure works on river bunds is as follows:

1. Minimize water from seeping into the bund as much as possible.
2. Safely drain the water that has seeped into the bund.
3. Reduce the hydraulic gradient.
4. Increase the shear strength of the bund.

2) Considerations for Seepage Countermeasures

The main considerations for seepage countermeasure works are as follows:

1. Examine the function and effectiveness of material used, along with applicable construction methods, workability, and durability.
2. Consider life cycle costs, such as countermeasure work and maintenance costs.
3. Consider maintenance and risk management method.
4. Examine the impact on the river environment, landscape, living conditions, culture, climate, and other surrounding factors.
5. Consider seismic countermeasures when the ground foundation is evaluated as being vulnerable to earthquakes or liquefaction (due to soft foundation or loose sand layer) and that seepage would be affected.

3) Basic Countermeasure Works

The countermeasure works corresponding to the above four basic policy items are as follows:

a) Methods to control and reduce water seepage into the bund and ground foundation

Surface slope seepage prevention method, full coverage method, blanket method, cut-off wall method, and foundation improvement method.

b) Drainage of water seepage in the bund

Drain work of bund interior, drain work at the back of the bund, drainage method at the back of the bund.

c) Methods of reducing hydraulic gradient.

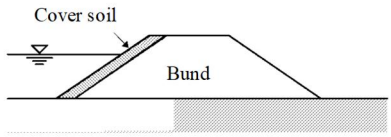
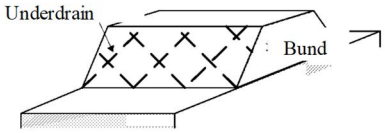
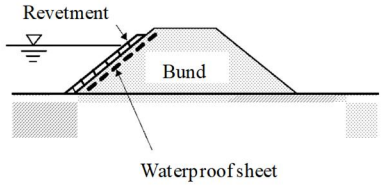
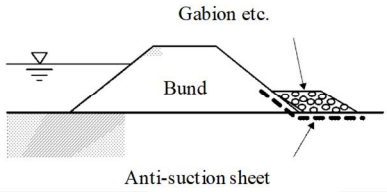
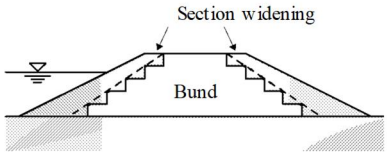
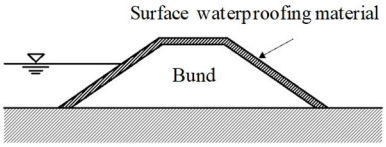
Loading berm at the back of the bund, blanket method, cut-off wall method, cross-sectional enlargement method, and river volume expansion method

d) Bund strengthening method

Full surface coating, loading berm, cross-sectional enlargement, surface slope seepage prevention, drainage, stabilization, soil quality improvement, and grouting methods.

The main countermeasures are shown in the following table.

Types and applications of seepage countermeasure works (Bund)

Countermeasure method			Purpose	Problems and matters to consider	Countermeasure model
Bund Countermeasure works	Seepage at front surface prevention method	Covering work of good quality soil	・Reduce seepage from bund surface	・Consider long-term stabilization measures in terms of deterioration due to waves and construction method ・Consider measures to prevent scouring and erosion during times of high water	
		Slope drainage work	・Quickly drain rain water	・Has a large effect on rainfall countermeasures ・No effect on flooded areas	
		Water cut-off revetment work	・Prevent seepage from bund surface ・Prevent scouring of front slope surface and prevent soil runoff	・Consider slippage of water cut-off materials such as sheets, and consider measures to prevent floating due to residual water at the back of revetment ・Consider environmental and landscape countermeasures such as soil covering and vegetation	
	Drainage method at toe of slope		・Drain water that had seeped into toe of bund slope and prevent slippage ・Reduce seepage pressure	・Need to secure land at the back slope ・If drainage is considered, investigate the selection of drainage material and measures to prevent suction	
	Section widening method		・Widen the section of the bund and lengthen the seepage path	・Makes the slope as gentle as possible to prevent slippage ・As the section of the bund expands, rainwater is more likely to seep through, so consider making the bund less permeable and implement drainage countermeasures ・Consider measures to prevent uneven subsidence	
	Surface waterproofing method		・Make it such that river water and rainfall do not easily seep into the bund ・Increase shear strength by covering the entire surface with soil, increasing the stability of the bund ・Protect bund surface with waterproofing material	・The bund should be an overflow-resistant structure if it has to also serve to counter overflow ・If the structure is highly watertight, consider measures to exhaust and drain water from within the bund ・Consider measures to prevent damage to the waterproofing material due to uneven subsidence which would allow water to seep through the damaged areas ・Consider measures to prevent cavities from forming under the waterproofing material.	

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Countermeasures Against Leakage of Levees, Chapter 7 Design and Construction Method of Water Leakage Countermeasures*

<Reference information>

The current manual also includes descriptions of countermeasure works. When selecting a countermeasure for seepage, it is important to identify the seepage problem and then comprehensively consider its applicability, including complete reconstruction, fully taking into accounts the soil conditions and external force conditions at the bund site, as well as the history of damage. In addition, when considering countermeasures against seepage, it is necessary to consider a combination of several countermeasures, since it is sometimes difficult to demonstrate the full effect of a single countermeasure. In cases where bunds are extremely vulnerable to seepage, and where strengthening the bunds would require a large amount of money, complete reconstruction should be considered as a viable option for reinforcing the bunds.

2.4.2 Erosion countermeasures

Chapter and Article of Current Bund Manual
CHAPTER VI: Construction of New Bunds or Loops Article 59. Construction of stone pitching and its specifications CHAPTER XI.: Emergent Measures or Causes of Failures of Bunds and Methods used to Combat Them Article 119. River erosion CHAPTER XV: Design of Stone Spurs or Stone Apron and Stone Pitching on Front Bunds as Protection against Erosion Article 157. Design of stone apron on front bunds
Relevant Articles in the Punjab Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 6.2.2. Slope Stability 8.1.7. Closing process for a Large River Breach

(1) Subject of Supplementary Items: Ch 11-119 Erosion countermeasures

<Reasons and summary of supplement>

Description and specific design method of erosion countermeasures of bunds are given.

<Content that should be added to manual>

Ch 11-119 Erosion countermeasures

1) Basic approach to bund erosion countermeasures (Concept)

The basic concept of erosion countermeasures is to consider the river channel characteristics at select sections along with the safety verification results, and comprehensively look for appropriate strategies.

The bund's resistance to erosion is evaluated separately for scenarios with and without a revetment.

(a) If there is no revetment, the safety against direct erosion on front and toe of bund slope, along with the safety against lateral erosion and scouring from the main channels (such as low water channel) are examined.

(b) When a revetment is present, the surface lining, foundation, and foot protection works of the existing revetment are checked to ensure they are mechanically stable against the expected external forces.

Based on the results of the evaluation, countermeasures will be investigated.

2) Selection of basic countermeasure methods (Standard)

Erosion countermeasures against erosion can be broadly divided into (1) capacity strengthening, (2) reducing erosive external forces, and (3) a combination of both (1 and 2). The strengthening of capacity in (1) is to strengthen by installing revetment work, for example, when the capacity of the bund front slope is greatly lacking. If there are concerns for the capacity of the front surface, such as concerns about the vegetation management on bund surface, it is possible to install an erosion prevention sheet as a method of strengthening the capacity. On the other hand, when the flow velocity in the vicinity of the revetment is high and the safety of the surface lining is insufficient, reinforcement (2) such as spur installation, which lessens the external force of erosion and reduces the flow velocity near the revetment, may be effective. Furthermore, depending on the degree of danger of bund, method (3), which combines (1) and (2), may be appropriate.

Depending on the existing conditions of the river channel, measures such as modifying the channel alignment shape, installation of spur with a splashing effect, constructing flood channels, and installation of vanes may be effective in reducing the flow velocity and scouring depth. Although these measures can be considered as ways to reduce erosion and scouring, they may have unexpected effects on the downstream side and should be considered in conjunction with the river channel planning study. In addition, sufficient study by numerical calculations and model experiments is necessary for this type

of bund strengthening. Major countermeasure works are listed in the table below.

Example of the relationship between safety verification results and bund strengthening methods

Safety Verification Result			Bund Strengthening Method	
			① Capacity Strengthening	② Reduction of Erosive External Force
No revetment work	Direct erosion of front surface and toe of bund slope		• New construction of high water revetment • Laying of erosion prevention sheets • Thorough management of bund vegetation	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
No revetment work	Lateral erosion and scouring from main channel (low water channel, etc.)		• Construction of low-water and bund revetments • Installation of (embedded) spurs • New construction or widening of high water channels that do not affect upstream and downstream • Installation of vertical spurs	・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Insufficient thickness of surface lining		• Renovation of revetment work • Widening of surface lining work • Converting hollow stone piling to kneaded stone piling • Converting hollow block piling to kneaded block piling	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Insufficient penetration of foundation work		• Renovation of revetment work • Foundation underpinning • Installation of foot protection work	• Installation of foot protection work ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Foot protection work	Insufficient weight	• Renovation of foot protection work • Integration of foot protection blocks (linkage and secure layer stacking) • Addition of foot protection blocks	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Foot protection work	Insufficient installation width	• Renovation of foot protection work	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method

Note: ⬚ represents measures that should be investigated in conjunction with river channel planning

***Source**: Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5 5.4*

***Source:** Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5 5.4*

<Reference information>

In the absence of revetment, erosion countermeasures are often considered in the form of slope protection with a revetment as the primary measure. The decision on whether or not to construct a revetment is based on a comprehensive judgment of the topographical conditions, the importance of the bund including budget, and the urgency of the embankment strengthening.

2.5 Investigation of Spur

The current manual includes list of diagrams and concepts of various spurs. However, descriptions of the necessity of spurs, structure, function, shape, and design are scattered throughout the manual, making it difficult to understand the series of steps from confirmation of current situation to design. To address this, a dedicated discussion of spurs should be added, with a clarification of the examination procedure from basic concept to design stage.

(1) Subject of Supplementary Items: Ch 5-43 Spur Countermeasures

Chapter and Article of Current Bund Manual
CHAPTERV: Design of New Bunds and Loop Bunds Article 43. Design of loop bunds CHAPTER XV: Design of Stone Spurs or Stone Apron and Stone Pitching on Front Bunds as Protection against erosion Article 156. Necessity of stone spurs and stone apron APPENDI XV: Miscellaneous River Works. 4. Tree groynes 5. Type (a) tree groyne for local deflection of current 6. Type (b) tree groyne for closing up one river channel and opening out another 7. Type (c) tree groyne for silting a bye-river at its off take 8. Type (c). Another example 9. Stone spurs i.e. impermeable groynes
Relevant Articles in the Punjab Bund Manual
Vol.1: Chapter 5: River Training & Flood Management 5.4.7. Spurs (or Groynes) Vol.2: Chapter 2: River Training & Flood Management 15.5.5. Spurs 15.5.6. The Negative side of Flood Embankments and spurs

<Reasons and summary of supplement>

The basic concept and structure of spur are presented.

<Content that should be added to manual>

Ch 5-43 Spur Countermeasures (Standard)

1) Basic Concept of Spur

The shape and structure of a spur are determined according to its intended function. Functions of a spur include protection of bund, low water channel riverbank erosion and scouring control, preservation and creation of river environment and scenery, and maintenance of water route. At the same time, based on channel characteristics of the target river, structural durability, ease of maintenance, ease of construction, economic efficiency, and ease of use by the public, etc., are to be comprehensively considered. It is important to design spurs, whether individually or in groups, with due consideration given to its impact on the surrounding river channel.

2) Basic Structure of Spur

There are two types of spurs: (1). permeable and (2). impermeable spurs. The structure of permeable spurs allows for the passage of flowing water; thus, the spurs themselves act as a rough element that reduces flow velocity. This prevents scouring and can promote sediment deposition if the spurs are properly arranged. On the other hand, impermeable spurs prevent the flow of water from pass through. Although the water splashing effect is large, the head and the downstream part of the spurs are particularly susceptible to scouring, so it is often necessary to install foot protection around the spurs. In

addition, impermeable spurs are further classified either as non-overflow or overflow spurs. The height of an overflow spur varies depending on its purpose.

- *Overflow spur:* spurs submerged by floods with average annual water level
- *High water spur:* average annual flood level is set as its height
- *Low water spur:* normal water level is set as its height

3) Functions and Shapes of Spurs

The following spur structures are chosen based on their purposes:

a) For the purpose of reducing flow velocity

- Their height is low.
- They are either permeable or impermeable with low height relative to water depth.
- They are lightweight and are constructed mainly through pile work.
- Several (or tens) of them are placed side by side and they function as one.

b) For the purpose of splashing water

- They are tall structures.
- They can be either semi-permeable or impermeable.
- They are mainly made of earth, stone, concrete, etc., and have a large volume. Structurally, they are considered heavy.
- They are installed either as individual units or arranged side by side in small numbers.

4) Concept of Spur Design

Compared to revetment, spur is more difficult to design based on a theoretical interpretation. Therefore, it is designed based on past experiences and actual implementation at similar rivers or the results of test construction, model experiments, and research studies related to new types of work. Workability, economic efficiency, maintenance, and safety of river users are also considered. River channel can drastically change, so it is difficult to accurately predict the various characteristics (e.g., riverbed height and flow velocity during a flood) of river channel where spurs are installed. Therefore, the following points should be considered for a more rational spur design.

a) Local Scouring Around the Spur

Spur is installed in the river channel and acts as an obstacle that reduces flow velocity closer to the river bank and splashes water. This results in the concentration of flowing water at the spur head, leading to scouring around the spur. While this scouring serves as a function to secure the water depth of the spur head, it also causes damage to the spur. Therefore, it is necessary to evaluate in advance what the scouring depth around the spur and the scouring range are.

b) Effect of Reducing Flow Velocity Through Spur

There are two methods for evaluating the flow velocity reducing effect of spurs: (1) expressing the group of spurs as an equivalent roughness, and (2) calculating the drag force acting on the spurs. While the flow velocity reducing effect of the group of spurs along the river can be fundamentally evaluated according to this concept, but it poses the following problems.

- Experimental studies have not been conducted for various shapes of spurs. For spurs with complex shapes, various theoretical coefficients must be obtained through experiments.
- The method of assessing the flow velocity near the boundary between the spur area and the main channel is unclear.
- The effect of water control should not be evaluated by the average flow velocity of the spur area, but by the relationship with the action of sediment within the group of spurs. However, this relationship is not clear.

c) Conditions for Sediment Accumulation Within Spur Area

Since installation of spurs can cause sediment accumulation in the spur area, making it crucial to assess their effects and impacts. In this case, since the mode of sediment transport differs depending on the material deposited in the spur area, it is necessary to evaluate the amount of sediment accumulation and erosion for each sediment particle size group.

d) Movement Limit Flow Velocity of Spur Materials

Material used for spurs, such as cobblestones, split stones, and concrete odd-shaped blocks, etc. should not significantly change their position or shape due to the action of flowing water. This ensures that they can maintain the function of spurs. In other words, weight, size and shape of spur materials need to be set such that they are not moved by the water flow.

e) Spur and River Shore Lines

In case a high-water channel is forms due to sediment is deposition in between tall spurs, or when the riverbed in between the spurs is reclaimed artificially, it is necessary to investigate the changes to river shore lines.

5) Spur Design

An overview of spur design is presented.

a) Direction

The direction of spurs can be upward, perpendicular, and downward relative to flow direction. Based on past results, the upward direction is considered preferable because it reduces scouring downstream from the spurs and accumulates sediment in between the spurs. For splashing spurs installed in the middle of the river, the perpendicular direction is considered to be fine. However, if it is turned slightly upward, water would flow over the spurs which reduces downstream scouring and promotes sediment accumulation in between the spurs.

b) Length, Height and Spacing

The length, height, and spacing of spurs should be determined based on literature and past examples, taking into account the condition of river channel, the purpose of spur installation, the impact onto the up and downstream area and the opposite shore, as well as the safety of the structure itself.

(i) Foot Protecting Spur for Riverbank Erosion Prevention

Generally, employing a single strong spur to resist water flow increases turbulence and often leads to large scouring within its vicinity, and complicates the maintenance of the spur itself. Therefore, it is important to structure and arrange spurs such that flow velocity is reduced by the overall effect of group of spurs over a specific section, and each spur exerts equal resistance. With this perspective in mind, there are examples of the shortening of spur length at the upstream side to lessen the burden of the water current on the upstream spur.

As for the basic shape of spurs installed to reduce the flow velocity, the length is often set to be less than 10% of river width. The height is typically 0.2 ~ 0.3 times the water depth during design flood flow. The spacing is often 2 ~ 4 times the length and 10 ~ 30 times the height. For river with concave shoreline, the spacing of the spurs is often less than twice the length.

In general, during the spur and revetment co-design process, spurs are often not placed too far out for ease of maintenance, construction cost and economic reasons.

(ii) Water Splashing Spur for Riverbank Erosion Prevention

When installing tall and impermeable spurs, they should not be used as foot protecting spurs. Instead, they should be positioned so that the line connecting the tips of spurs forms the boundary line of riverbank protection. In addition, excessively long impermeable spurs should be avoided due to high construction costs.

Water level in front of the spurs only rises up until the flow velocity head of the spur tip. Therefore, strong and kneaded revetment should be installed up to a sufficient height to account for the different water level before and after the installation of spurs.

For this type of spur, spacing should be about 1/2~1/3 of the length of the sandbar that forms at the target section. Moreover, the direction should be perpendicular to the river bank or slightly downward.

Source: *Technical Criteria for River Works: Practical Guide for Designing Chapter 1 Section 4 Revetment and Spur*

<Reference information>

Japan and Pakistan have somewhat different views on the main function of spurs. In Japan, the common purpose of spurs is reducing flow velocity (promoting sedimentation, etc.) and secure water routes.

However, the main purpose of spurs along the Indus River in Pakistan is to splash water.

2.6 Bund Management Plan

A new chapter on bund management plan will be established since there is no overall specific description. Explanation and criteria are supplemented.

(1) Subject of Supplementary Items: Ch 16-159 Bund Management Plan

Chapter and Article of Current Bund Manual
CHAPTER II: Constitution and Functions of the Indus River Commission Article 3. Functions of the Indus River Commission
Relevant Articles in the Punjab Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 15.5.6. The Negative side of Flood Embankments and spurs 16. Outline of flood fighting plans 17. Timeline for flood preparedness Vol.2: Chapter 8: Asset Management Plan 1.1. Asset Management 1.2. Framework for Preparing an Asset Management Plan

<Reasons and summary of supplement>

An overview of bund maintenance plan and concept of cycle-type maintenance are presented.

<Content that should be added to manual>

Ch 16-159 (New) Bund Management Plan (Standard)

1) Basic Concept of Maintenance Plan

Maintenance of bund will be systematically carried out over several years, incorporating flood history and lessons learned from other rivers. Plan of bund maintenance are planning related to river development and bund maintenance. The contents of bund maintenance shall be stipulated to clarify the overall picture of river development, including the maintenance of rivers. The bund maintenance plan will outline the contents of bund maintenance to provide a clear picture with regards to river development. It will specify the aspects of bund maintenance in relation to overall river development.

2) Matters Stipulated in the Plan

In determining the goal and implementation of bund maintenance, the frequency and density of bund maintenance must be set according to the river characteristics at each section.

The assessment of bund condition is conducted through river patrols and inspections to determine whether there are interference to the goals set for the bund, such as flood control, water use, and environment functions, as well as illegal acts in river management. Methods and frequencies, specific maintenance countermeasures, regional cooperation, and other initiatives for efficiency and improvement will be determined. Specifically, the followings are performed.

a) River Outline

The following items are outlined based on the characteristics of the river.

- Various specifications such as river basin area, main river course length, management length, and riverbed gradient, etc.
- Natural and social characteristics of river basin
- State of river channel characteristic, including damage history, topography, geology, and tree condition, etc.
- State of sediment movement characteristics from sediment production areas to estuary
- State of river environment that should be noted during management, such as living organisms, water quantity and quality, landscape, and usage of river space

- Other relevant matters as necessary

b) Matters to Be Considered for Bund Maintenance

From the standpoint of bund maintenance (such as river channel maintenance and facility management), matters that should fundamentally be considered include state of river channel's characteristic, region's characteristic and deterioration of river management facility.

c) Sectional Division of Bund

River is divided into sections to facilitate appropriate maintenance. The division is set in accordance with flood type, river hinterland population, condition of assets, river channel's characteristics, etc.

In general, river is divided into two sections: important section, described as "being alluvial rivers; having a large population and assets in flooded area; having hinterland that should be protected by bunds", and normal section.

d) Bund Maintenance Target

For each bund section, the basic principle is to set goals for bund maintenance based on current state of river and immediate goal of river development. Goals should be stated quantitatively if possible and qualitatively otherwise.

e) Assessment of Bund Condition

Method and frequency of bund condition assessment should be specifically set according to the sectional division, maintenance targets, etc.

Referring to the points below, it is recommended to describe the basic concept, location, frequency, timing, and key consideration points of the implementation to be described.

- Basic Concept of Implementation: Describe, for each item to be implemented, what policies are to be implemented for river patrol, inspection, etc. based on characteristics of sectional division.
- Location, frequency, and timing of implementation: Based on the basic concept of implementation, describe the specific condition assessment method for each item to be implemented.
- Consideration points of implementation: Describe the basis for determining the location, frequency, and timing of implementation, as well as any specific points of consideration, such as the state of river use or the presence of important living organisms.

Details of the implementation at the same section do not have to all match each other and instead should be determined based on bund characteristics.

f) Specific Maintenance Measures

The basic principle is to describe the details of specific maintenance measures-such as measures against illegal activities, maintenance work, and repair/renewal of facilities- that should be implemented when results of river patrol and inspection indicate that river management may have been hindered. These specific maintenance measures are described in the chapter on Inspection Maintenance.

g) Initiatives for Efficiency and Improvement

Important matters regarding efforts aimed at improving river development, conservation and bund maintenance efficiency though further regional cooperation as well as efforts to promote the optimization and betterment of bund maintenance are described.

3) Cycle-type maintenance

Regarding river management, knowledge obtained from revolving day to day inspection (such as river patrol, condition assessment through inspection, and maintenance countermeasure) is analyzed and evaluated. It is important that the knowledge is reflected in the planning or the implementation of river maintenance. Traditionally, in river management, safety has been ensured adaptively through the repeating cycle of the occurrence of river deformation along with its response, the occurrence of disasters due to water discharge along with their countermeasures and various new improvement. This makes up the cycle of "Plan", "Do", "Check", and "Action", and is importantly linked to appropriate and efficient bund maintenance.

It is also necessary to feed the findings from the PDCA cycle of river management back to the river

management plan and link them to the development and revision of the plan as necessary.

The following is an example of PDCA cycle for the maintenance, design, inspection, and repair of bunds.

Example of PDCA cycle for bund maintenance, design, inspection, and repair

Phase	Content	Specific Activity		Indications
		Maintenance	Design & Repair	
P (Plan)	Planning	• Evaluation of current bund state • Setting maintenance target • Formulation of specific maintenance plan • Budget, personnel planning	• Establishment of bund design standards for bund • Collection and analysis of topographical and hydrological data • Necessity Evaluation of repair and formulation of plan • Preparation of design drawing	1. Standard Bund Shape 3. Safety Assessment 4. Bund Maintenance
D (Do)	Execution	• Implementation of inspection and maintenance work as planned • Implementation of necessary repair and renovation work • Regular collection of data	• Construction of bund based on design • Implementation of repair work • Construction management and quality check	2. Quality control 4. Bund Maintenance 8. Information Management
C (Check)	Evaluation	• Recording inspection results • Effectiveness evaluation of work performed • Degree of completion check • Problem identification	• Performance evaluation of the completed bund • Post repair effectiveness check • Identification of problems and issues	3. Safety Assessment 7. Inspection Maintenance (River Condition Monitoring) 10. Gaps with manuals
A (Act)	Improvement	• Formulation of improvement measures based on evaluation results • Reflection onto next stage plan • Review of maintenance system	• Review of design and construction methods based on evaluation results • Reflection onto next stage design and repair plan • Strengthening maintenance system	1. Standard Bund Shape 4. Bund Maintenance 6. Bund Management Plan

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 2 Section 1 River Maintenance Plan*

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 2 Section 1 River Maintenance Plan*

<Reference information>

It is desirable that bund maintenance plan specifies the detailed actions for bund maintenance to be carried out over a period of about five years.

2.7 Inspection Maintenance (River Condition Monitoring)

In the current manual, inspection maintenance is discussed separately in Chapter 9: Pre-Abkalani (flood season) Maintenance (Paragraph 92-102) and Chapter 10: Ordinary Maintenance during Abkalani (Paragraph 103-117), making it difficult to understand the whole picture. The entire flow related to patrol and inspection maintenance is important and is compiled as supplementary items.

Chapter and Article of Current Bund Manual CHAPTER IX: Pre-Abkalani Maintenance Article 92. Leveling of bund tops and slopes 93. Items of earthwork in annual repairs 94. Specifications for earthwork for annual repairs 95. Opening up and refilling leaks 96. Annual repairs to masonry work on bunds 97. Plantations on bunds 98. Inspection of river course and proposals for measures 99. Proposals for wetting of bunds during the ensuing Abkalani 100. Filling up of old borrow pits on land side 101. Miscellaneous items of pre-abkalani maintenance 102. Non-abkalani establishment CHAPTERX: Ordinary Maintenance during Abkalani Article 103. Presence of maintenance establishment required on bunds 104. When the Executive Engineers are required to be on bunds 105. Unremitting patrolling during high abkalani essential 106. Shifting system in patrol establishment 107. Organization for patrolling and duties of members of staff 108. Strength of annual and abkalani establishment normally Necessary 109. Abkalani materials 110. Wetting of front bunds and loop bunds with wetting channels 111. Wetting loops and filling compartments 112. Filling compartment where front bund is likely to be eroded 113. Cutting of a front bund in the event of breach 114. Other cases of relieving pocketing 115. Miscellaneous items of maintenance during abkalani 116. Opening up and re-filling leaks 117.Employment of Zamindari labour in connection with bund work APPENDIX VIII: Article 2. I.R.C. Forms
Relevant Articles in the Punjab Bund Manual Vol.2: Chapter 8: Asset Management Plan 1.1. Asset Management 1.2. Framework for Preparing an Asset Management Plan 1.9. Preparation of a Revised/Updated or Fresh AMP

2.7.1 Patrol

(1) Subject of Supplementary Items: Ch 9, Ch 10 Patrol

<Reasons and summary of supplement>

Concept and purpose of patrol are discussed.

<Content that should be added to manual>

Ch 9, Ch 10 Patrol (Standard)

1) Concept and Purpose of Patrol

River patrols are generally conducted to assess the condition of river channel, and river management facility, etc., to detect illegal activities and violations in river areas, to collect information on river space utilization, and to collect information on natural environment of rivers.

River patrol of river channel, and river management facility, etc., shall be carried out at an appropriate time, taking into account the structure, maintenance or repair status of river management facility, river condition, weather condition in the area of the management facility, and other conditions. In addition, in order to conduct an efficient and effective patrol, adoption of new technologies such as image analysis using UAVs should be considered.

2) Ordinary River Patrol

Ordinary river patrol forms the basis of river maintenance, and is carried out in order to patrol river as regularly scheduled and to comprehensively assess any abnormalities and changes.

If an abnormality is found during the patrol, it is important to immediately evaluate the situation, record it in river records, etc., and rectify it appropriately. Ordinary river patrol is mainly carried out for the following items.

- Identify relatively large-scale deformation that can be visually confirmed in river channel and river management facility
- Confirm whether there are any illegal acts or violations regarding occupation of land and installation status of structures in river area, river conservation area, and projected river area
- Assess the daily use of river
- Monitor the daily condition of natural environment, such as status of riffles, pools, water routes, location of sandbars, condition of trees in the river channel, the impact of trees on flood flow, and state of non-native vegetation on bund and riverbanks

3) Response to Abnormalities and Anomalies Found During Ordinary River Patrol

Detailed patrol and inspection are conducted as necessary for the abnormalities and anomalies confirmed during river patrol.

- Area with a history of inspection should be patrolled with special attention
- If it is determined that the detected deformation interferes with the function of facility, an individual inspection will be carried out to look for countermeasures
- If any unauthorized or prohibited activity is discovered, situation is to be assessed and necessary action is to be taken

4) River Patrol During a Flood

During a flood, situation can change rapidly, making it necessary to take swiftly and appropriate measures in response. Therefore, river patrol is carried out to comprehensively and quickly assess conditions of bund, flood flow, trees in river channel, river management facility, etc. as well as the inundation of area protected by bunds. It is also necessary to assess the state of flood prevention operation and inner water drainage. To conduct river patrol during a flood, it is desirable to employ the usage of all-weather UAVs.

When abnormalities such as leaks or collapses are detected during the river patrol, appropriate measures such as flood mitigation work or emergency repair must be taken immediately. Therefore, it is necessary to maintain close communication with relevant organizations. In addition, leaks and collapses should be recorded in river records, etc., as they provide important information for future river maintenance. Whilst conducting river patrol during a flood, collecting records is important.

Based on past results of river patrol and inspection, damage history, etc., conditions for conducting river patrols, such as sections where there is a possibility of bund damage, are set. Those sections are considered as target flooded sections and river patrol will be conducted there.

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 4 River Patrol*

<Reference information>

In general, river patrol is performed to visually check for abnormalities and anomalies. Detailed patrol and inspection are carried out as necessary.

2.7.2 Inspection Maintenance

(1) Subject of Supplementary Items: Ch 9, Ch 10 Inspection Maintenance

<Reasons and summary of supplement>

Concept, purpose, implementation, method, etc. of inspection maintenance are provided.

<Content that should be added to manual>

Ch 9, Ch 10 Inspection Maintenance (Standard)

1) Inspection Before Flooding

a) Concept and Purpose of Inspection

Inspection is conducted for the purpose of discovering, observing, and measuring abnormalities and changes in the flood control function at the target river channel and individual river management facility. In addition, inspection is also conducted to assess the deformation and deterioration of river facility. The assessment is useful as basic data for countermeasures against abnormalities.

In addition, it is important to grasp the condition of individual facility and comprehensively judge the necessity and priority of countermeasures against flooding in the river as a whole. Accordingly, a more appropriate maintenance can be conducted.

The maintenance of river channels and river management facilities have been carried out based on the accumulation of experience from patrol and inspection over many years. It is important to employ experienced managers to conduct the inspections appropriately and ensure the transfer of skills and knowledge to new staff members.

b) Inspection Timing and Frequency

Inspection of river management facility shall be carried out at an appropriate time, taking into account the structural state, maintenance or repair condition of the facility, river condition, weather condition at the area where the river management facility is located, and other conditions. It should be conducted at least once a year before the monsoon season.

c) Inspection Method

(i) Outline of Inspection

Judgement criteria for evaluating the inspection results of each deformation point shall be set for each river individually according to its characteristics. For reference, this section shows examples of judgement of deformation based on past literature and results of river management facility maintenance to date. However, in the future, the content will be reviewed and improved as necessary, based on further accumulation of knowledge as well as collection and issue sorting of cases where this guideline has been applied.

In particular, since bunds are earth structures that have been repeatedly built and repaired many times from the past to the present, quality of the constituting material is often uneven. For this reason, there is not enough technical data at this time to indicate quantitative evaluation criteria. Inspection of bunds and evaluation of the results have been carried out based on the experience of engineers, and this will continue into the future. Quantitative evaluation criteria will be established when useful technical data have been sufficiently collected and analysis become possible.

In the inspection, based on improvement of existing technology and progress of new technology of recent years, non-destructive inspection of the back of revetment by radar cavity exploration, river topographic monitoring technology using aviation lasers, and topographic surveying technology using Unmanned Aerial Vehicles (UAVs) are to be utilized as necessary. In the future, displacement of bund topography will be assessed using a Mobile Mapping System (MMS).

(ii) Inspection Items

a) Basic Items

Evaluation of bunds shall focus on the following functions to determine the state of function deterioration.

State of Function Deterioration of Earth Bund

Function	State of Function Deterioration
Overflow Prevention	[Subsidence] The necessary height cannot be secured due to subsidence of bund or ground foundation, and the overflow prevention function is impaired.
Seepage Resistance	[Slip Failure] The increase in pore water pressure due to seepage of river water or rainfall into bund during a flood lowers bund strength and causes bund slippage. This results in impairment of seepage resistance function.
	[Occurrence of Piping] The increase in pore water pressure due to seepage of river water into ground foundation during a flood moves soil particles and causes piping. This results in impairment of seepage resistance function.
Erosion Resistance	[Erosion] The sweeping force of rainwater and flowing water during a flood erodes the front and toe of bund slope. This results in impairment of corrosion resistance function.

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

b) Inspection Items

Focusing on the overflow prevention, seepage resistance, and erosion resistance functions of earth bund, the following inspection items will be evaluated.

Inspection Items of Earth Bund

Function	State of Function Deterioration	Type of Deformation	Description of Bund, River Management Facility and River Channel Inspection		
			Item	Location	Inspection item
Overflow Prevention	Subsidence	[1] Crack	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
				Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette?
				Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[4] Subsidence	Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[6] Protrusion	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund		- Are there openings in the bund due to groups of holes for small animals such as moles?
					- Is there a cave-in due to groups of holes for small animals such as moles?
Seepage Resistance	Slip Failure	[1] Crack	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette?
					- Is there a cave-in due to groups of holes for small animals such as moles?
			Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[3] Slope Collapse	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[5] Deformation of Bund Foot Protection Work	Bund		- Are there any deformations of the bund foot protection work (or is it more developed than before the flood season)?
		[6] Protrusion	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[7] Slope Failure	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund	Slope and Banquette	- Are there openings in the bund due to groups of holes for small animals such as moles?
					- Is there a cave-in due to groups of holes for small animals such as moles?
		[9] Poor Drainage	Bund	Slope and Banquette	- Are there any inverted slopes or locally low areas at the banquette that are causing problems with rainwater drainage?
					- Are there any areas where the slope and banquette are muddy?
	Piping Failure	[1] Crack	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette?
			Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund	Slope and Banquette	- Are there openings in the bund due to groups of holes for small animals such as moles?
					- Is there a cave-in due to groups of holes for small animals such as moles?
		[9] Poor Drainage	Bund	Slope and Banquette	- Are there any inverted slopes or locally low areas at the banquette that are causing problems with rainwater drainage?
					- Are there any areas where the slope and banquette are muddy?
					- Are there local clusters of vegetation species that prefer moisture?
			Bund	Toe of slope	- Is there any seepage due to poor drainage near the bund base?
					- Is there any area where groundwater always seeps through?
		[12] Water Leakage and Sand Boil	Bund	Toe of slope	- Are there any water leakage or sand boil near the toe of slope?
Erosion resistance	Erosion	[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette?
					- Is there a cave-in due to groups of holes for small animals such as moles?
			Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund	Slope and Banquette	- Are there openings in the bund due to groups of holes for small animals such as moles?
					- Is there a cave-in due to groups of holes for small animals such as moles?
		[10] Tree Invasion	Bund	Slope and Banquette	- Has there been any invasion or expanding of trees?
		[11] Erosion (Gully) and Vegetation Anomalies	Bund	Slope and Banquette	- Are there any abnormalities in the condition of bund vegetation and topsoil, such as peeling of upholstered turf? (or are they more developed than before the flood season)?
					- Is there scouring or erosion due to concentrated surface drainage at the slope and stair?
			Bund	Crown	- Is there any erosion at the top of the slope (or is it more developed than before the flood season)?

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

Technical terms (Protrusion and Slope Failure) are illustrated below.

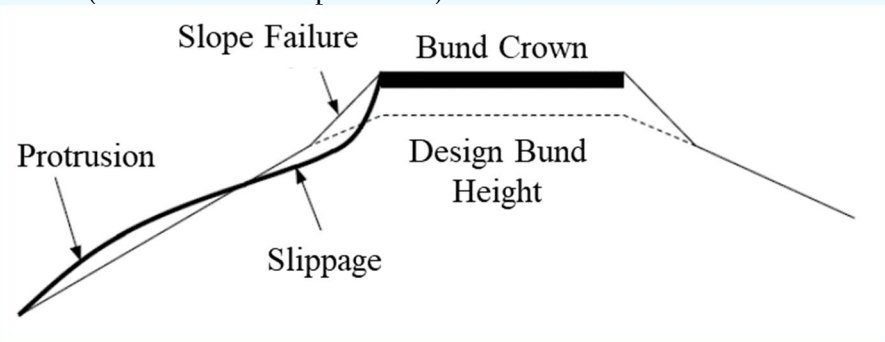


Diagram of Protrusion and Slope Failure

(i) Evaluation Items

Judgement criteria for evaluating the inspection results of each deformation point should be established for each river individually based on specific characteristics. For reference, this section provides examples of deformation judgement based on past literature and results of river management facility maintenance to date.

Judgement Criteria of Earth Bund's Inspection Result Evaluation Classification (reference)

Evaluation Classification by Deformation Type		Evaluation of Each Deformation ※1												Overall Rating	
		[1] Crack	[2] Cave-in and Unevenness	[3] Slope Collapse	[4] Subsidence ※2	[5] Deformation of Bund Foot Protection Work ※3	[6] Protrusion	[7] Slope Failure ※4	[8] Holes for Small Animals such as Moles	[9] Poor Drainage	[10] Tree Invasion	[11] Erosion (Gully) and Vegetation Anomalies	[12] Water Leakage and Sand Boil	Evaluation Classification	Condition
		Deformation Photo Example (Ground-1) P67	Deformation Photo Example (Ground-2) P68	Deformation Photo Example (Ground-3) P69	Deformation Photo Example (Ground-4) P70	Deformation Photo Example (Ground-5) P71	Deformation Photo Example (Ground-6) P72	Deformation Photo Example (Ground-7) P73	Deformation Photo Example (Ground-8) P74	Deformation Photo Example (Ground-9) P75	Deformation Photo Example (Ground-10) P76	Deformation Photo Example (Ground-11) P77	Deformation Photo Example (Ground-12) P78		
a	No abnormalities	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	A	No Deformation
b	Monitoring Required Stage	- Cracks have appeared, but functions of bund have not been disrupted - Includes minor repairs	- There is unevenness of terrain, but functions of bund have not been distrupted - Includes minor repairs	- Slope collapse has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Subsidence has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Deformation of bund foot protection work (opening of joints, etc.) has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Protrusion has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Slope failure has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Holes for small animals such as moles can be confirmed	- Poor drainage can be confirmed at the time of flooding, after flooding, or after rainfall - Includes minor repairs	- Existence of short trees can be confirmed (those that can be easily cut down with a mower, etc.)	- The ground is bare, but functions of bund have not been distrupted - Vegetation causing the ground to be bare(e.g., Japanese knotweed) can be identified	- When wetland vegetation grows at the toe of slope, but the cause of wetland is not river water that seeps into the bund or ground foundation	B	- Functions of bund are not distrupted, but a deformation capable of progressing has been identified and its progress needs to be monitored
c	Preventive Maintenance Stage	Bund may deform rapidly due to the flood, etc., thus it is difficult to predict the deterioration. As such, "C" rating is fundamentally not set for (1) ~ (7). However, to date, repairs have been carried out for deformation over a certain scale. If the cause of deformation is unknown or if it is difficult to evaluate based only on visual examination results, a detailed inspection (including survey) shall be carried out as necessary.							- Holes for small animals such as moles are expected to cause the collapse within their vicinity. - In the case of molehills, stepping on them causes the ground to greatly sink.	- Even though a few days have passed after the rainfall, the bund is still wet. - There is gushing of water from the bund.	- There is invasion of trees, but no change in the shape of bund. However, there is a risk that the trees will grow and interfere with bund functions.	- Erosion (gully) has occurred on the bund. - There is an abnormality in the bund vegetation such as peeling (which can be easily repaired) - If abnormalities of bund vegetation exist and slack within the bund body is confirmed, a detailed inspection (including survey) will be carried out and necessary measures will be taken.	- The toe and back surface of bund slope have become wetland, and wet vegetation can be seen. Because the cause of wetland is unknown, a detailed inspection (including survey) is necessary.	C	- There is no distruption to bund functions, but the situation can progress. Therefore, from the standpoint of preventive maintenance, it is desirable to carry out countermeasures - A detailed inspection (including survey) is required to reassessment of the degradation of bund.
d	Take Action Stage	- There are cracks that interfere with bund functions. - There are cracks extending below the H.W.L, etc.	- There is cave-in that interfere with bund functions. - Cave-in and unevenness extend below H.W.L. Water ways are formed.	- Bund functions are hindered due to slope collapse.	- Bund functions are hindered due to subsidence.	- Bund functions are hindered due to deformation of bund foot protection work. - There is a large deformation or misalignment which causes concerns for slippage at the back slope.	- Other complex deformations such as cracks and slope collapse due to protrusion hinder bund functions.	- Cracks caused by slope failure and the occurrences of slope collapse hinder bund functions.	- Holes for small animals such as moles and foxes cause [Changes in (1) ~ (4) conditions] and hinder bund functions. Alternatively, there is a risk that the holes will deepen into the bund and interfere with its functions.	- Poor drainage causes [Changes in (1) ~ (7) conditions] and hinder bund functions. - Soil movement near bund foot causes the deformation and collapse at the toe of slope.	- Tree invasion causes [Changes in (1) ~ (7) conditions] and hinder bund functions.	- Due to erosion (gully), erosion resistance function is lost, and bund functions are hindered.	- Leak and sand boil can be confirmed. - Leak and sand boil were confirmed after the flood.	D	- Bund functions were hindered and countermeasures such as repair, renovation, etc., are necessary.

*1: Taking into account the scale of bund and past damage history, it is set for each river (general deformation).
*2: Excludes areas around structures such as gutter gates.
*3: Whether this can cause the deformation of bund and ground foundation should be checked.
*4: In addition to slope slippage, slope failure may also occurr due to sliding when embankment is made for road occupancy. Therefore, when evaluating slope failure, it is necessary to check the history records, etc.

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

(ii) Preservation of Inspection Results

Patrol and inspection results of river bund and river channel conditions shall be recorded. The inspection results shall also be stored until the next inspection or longer period as needed.

2) Inspection After Flooding

a) Purpose and Concept of Inspection After Flooding

The purpose of inspection after flooding is to assess the deformation of river channels and river management facilities after a flood, storm surge, tsunami, etc. At the time of the inspection, conditions of water discharge following a flood, storm surge and tsunami are determined according to the state of river, with a focus on the damage of river management facilities as well as the deformation of river channels. Inspecting whether the water level has surpassed the level that may reach the high flood level is done visually. In addition, if there is a flood whose scale exceeds the high flood level, a more detailed inspection of the damage to bunds and other structures will be carried out depending on the situation.

In particular, the assessment of river channel condition is assessing the conditions of riverbed scouring and sedimentation, riverbank erosion, falling trees, driftwood, living organism habitat and breeding place, etc. The assessment is conducted to gather important data for the review of future river channel planning, maintenance planning, etc. The content is to be recorded to the river records.

b) Inspection Items After Flooding

Main items to be inspected after flooding are listed below.

(i) River channel condition assessment

For large rivers, depending on the situation, longitudinal and cross-sectional surveys are carried out. Detailed surveys are carried out in the event of localized deep scouring or sedimentation. In the event of large-scale river bank erosion, aerial photography will be carried out as necessary.

(ii) Flood level survey

Flood mark, which is the height of the flood level reached, is an important data for the investigation of river flood control planning. Flood level surveys are conducted when a significant amount of water is released (e.g. exceeding the water level that may reach the high flood level) and consecutive marks remain on bunds. It is also desirable to investigate the mark on the inland area of the bund in the event of overflow.

(iii) Bund deformation record

It is fundamental to assess the deformation that interferes with the erosion resistance and seepage resistance functions that should be maintained for bunds. The assessment should be recorded and organized in the river records.

3) Post-Earthquake Inspections

It is fundamental to conduct necessary inspection of river with consideration to earthquake scale. When bunds, weirs, sluice gates, etc., are damaged by an earthquake, it is necessary to quickly assess the condition of facilities that could particularly impact local communities (important river management facilities, etc.). Therefore, these target facilities should be selected in advance and special inspection is to be conducted.

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

<Reference information>

By accumulating appropriate knowledge on river patrol and inspection, overall river maintenance technology can be enhanced. It is crucial to improve the abilities of individual engineers while also collecting and sharing data records.

2.7.3 River Records

(1) Subject of Supplementary Items: Ch 9, Ch 10 River Records

<Reasons and summary of supplement>

Concept, overview, and the importance of information on river records (used as river ledger and facility ledger) are presented.

<Content that should be added to manual>

Ch 9, Ch 10 River Records

1) Purpose and Concept of River Record Document

River records continuously document the results of river patrols and inspections as well as the content of maintenance and river construction. They importantly serve as the basis for assessing the condition of river management facilities (such as bunds) and river channels, and for investigating appropriate responses. They also serve as fundamental information for the embodiment of the PDCA river management cycle. In addition, in order to efficiently update and utilize river records, a river maintenance management database system will be constructed and managed.

2) Information Collected in River Record Document

Important information to be passed on should confirmed during cross-sectional coordinating meetings attended by the relevant departments of the PID office. This information shall be gathered and compiled into the river records.

In addition to the modification caused by river construction, the following changes related to the state of river management facility (such as bund, sluice, flood gate, barrage, ground sill, drainage machinery) and river channel shall be obtained through from river patrol, inspection, information from the community, etc. Each change is to be recorded along with location information on the plan, so that change over time can be checked.

- Changes in water route (sandbar), abnormalities and deformation of river channels at water exposed point and scoured area, and abnormalities and deformations of bunds
- Illegal activities that disrupt river management, such as illegal occupation, unauthorized construction, illegal dumping, and illegal embankment, etc.)
- Abnormalities and deformations at the facility itself as well as its surroundings that can interfere with river management
- Status of measures against deformation, etc.
- Basic specifications of the facility
- Construction history, damage history
- Status of implementation of sediment removal, tree cutting, etc.
- Matters that require periodic measures
- Coordination with local communities
- Other important information that should be passed on, etc.

3) Management of River Records

River records are based on database system (hereinafter abbreviated as DS) and fundamentally aim to gather information.

Administrator of DS river records information (hereinafter referred to as "Administrator") is essentially appointed by PID Chief Engineer. In addition, the Administrator shall appoint an Assistant to manage river record information, a person to input the information, etc. (including the administrator) as necessary.

The Administrator shall also store river records created in the past in accordance with the prescribed document management rules. In addition, if the river records created in the past are transferred to DS, the DS data shall be used as the original, and the river records created in the past may be treated as "copies".

In addition, even after the creation of DS database system, efforts to ensure reliable storing of the data, including protecting registered information data from unnecessary editing and deletion, should be made.

River records will be made available for sharing within PID and FFC through DS. In addition to usual

sharing information, information will be shared within PID and FFC whenever there is a serious change. In addition, for changes that have been newly discovered or confirmed to be progressing during the pre-monsoon and post-monsoon inspection, content update of river records shall be confirmed and decided at cross-sectional coordination meetings participated by relevant departments of PID.

4) Creation of River Records

River records shall be created with the following points in mind and managed as a database.

- In addition to the location of facilities (sluice, flood gate, barrage, ground sill, drainage machinery, etc.), the floor plan shows relevant location of river management facilities' and river channels' deformation discovered during inspection and usual river management. In addition, if necessary, position of permitted structures is to be indicated.
- Information regarding the date and time when a deformation occurred as well as when it was checked is to be included. Efforts will be made to quantitatively assess the deformation so that changes over time can be determined. In addition, the aim is also to be able to determine whether deformation state is continuing or whether response is completed.
- Onsite photographs of each deformation should include close-up photographs that show deformation state, as well as distant images that allow for the identification of the deformation location and surrounding conditions.
- If a measure has been taken for each deformation, the outline of its method, the reasoning behind its implementation, and a photograph showing the situation after the measure are to be provided.

a) Structuring and Main Content of River Records

(i) Basic Records (Form-1):

- Basic information on the actual state of the river is entered onto the floor plan, and inspection results (survey location's symbol and main inspection content) are added.
- The name of the bund and the location ([1], [2], [3].) of the facilities (barrage, flood gate and sluice, bridge, inverted siphon, tunnel crossing the riverbed, land lock, etc.) are indicated as items to be filled in in advance along with their titles. If the facilities are numbered, the facility number is to be used.
- Regarding the method of filling in the information at the time of inspection (and afterward), the relevant location ((1), (2), (3).) of river management facilities' and river channels' deformation discovered during inspection and usual river management are to be indicated, and the progress of inspection content is to be entered into the Chronological records. Information about the facility itself (excluding minor details of mechanical and electrical facilities) and its surroundings should be entered into the Facility record.
- In addition to deformation related to rivers and river management facilities, incidents regarding water quality and water-related accidents are also considered to be the entry contents for the records. At the minimum, deformation related to rivers and river management facilities are to be entered, whereas for other items, their importance is considered to vary depending on river characteristics. Based on the state of maintenance to date, the decision is to be made by head of department after consulting with PID manager, as necessary. As a guideline, the entry of basic records is considered to be content confirmed during inspection and content of the river patrol reports.
- The date and month of deformation occurrence recorded in the basic records. In addition, it should be indicated whether the state of deformation is continuing or whether the response has been completed.
- The state of rivers and river management facilities should be clearly indicated.
- Based on the results of river patrol and inspection, information from the community, etc., abnormalities and deformations in river channels and facilities are to be cumulatively described in the floor plan.

(ii) Chronological Records (Form-2):

- For each deformation, content related to bunds, revetments, river channels, etc. is to be entered in the basic records such that changes over time can be checked. For cases when the cause of the deformation is found to be flooding, earthquake, illegal act, etc., circumstances of the cause

(such as rainfall amount) shall be described. Efforts shall be made to quantitatively assess the deformation, so that changes over time can be grasped. Photographs showing the state of deformation, including both distant and closeup views from which the location can be identified shall be attached. If a measure has been taken for any deformation, the outline of its method, the reasoning behind its implementation, and a photograph showing the situation after the measure are to be provided.

- Regarding the measures to be taken, in the case of river construction, name and period of the work carried out should be added. If continuous measures such as observation are required, the situation after the measure implementation should be added until response is no longer necessary.

(iii) Facility Records (Form-3):

Detailed information about the facility described in the basic records is to be provided. Items to be entered in advance are as follows.

- The number of the facility described in the basic records is written on the upper right side.
- Specifications and general drawings are provided.

As items entered in the basic records, details related to facilities (barrage, flood gate and sluice, bridge, inverted siphon, tunnel crossing the riverbed, land lock, etc.) are provided. If the cause of the deformation is known, circumstances of the cause (such as rainfall amount) shall be described. Efforts shall be made to quantitatively assess the deformation, so that changes over time can be grasped. Photographs showing the state of deformation (distant and closeup views from which the location can be identified) shall be attached. If a measure has been implemented, photographs showing the situation after the measure implementation are to be provided.

Source: *Ministry of Land, Infrastructure, Transport and Tourism River Records Creation Guidelines H5.3*

<Reference information>

Currently, existing data is being organized and Form-1 and Form-2 are being prepared. Construction of database basic structuring is progressing such that personnel in charge can add data to it. Integration with existing database and sharing of information are planned.

2.8 Information Management

The current manual lacks a clear explanation of the management methods and formats for storing and viewing basic data, inspection records, construction records, and other information related to the target river. In addition, it is difficult to grasp the whole sequence of information management. Therefore, the flow of information management and the contents related to information management activities based on specific examples are clarified.

Chapter and Article of Current Bund Manual

CHAPTER XIII.
Periodical Reports and Returns.
Article
143. Erosion statement (I. R. C. form No. I)
144. Abkalani report (I. R. C. form No. 2)
145. Reports on the state of bund sluices and regulators
146. Wetting of new bunds
147. Statement of specific levels on each mile of the bund (I. R. C. form No. 3)
148. Statement of H.F.Ls. on bund mile gauges and free-board available each year (I. R. C. form No. 4)
149. Sund register of consolidated statement for embodying data for river bunds (I. R. C. form No. 5)
150. Register showing incidence of leaks (I. R. C. form No. 6)
151. Report of leveling on bunds
152. Other I. R. C. forms (Indus bulletin and I. R. C. form No. 7)

Relevant Articles in the Punjab Bund Manual

Vol.1:
Chapter 5: Barrages
5.21 Records to be maintenance
Vol.2:
Chapter 2: River Training & Flood Management
16. Outline of flood fighting plans
17. Timeline for flood preparedness
Vol.2:
Chapter 8: Asset Management Plan
1.3. Asset Management Plan
1.9. Preparation of a Revised/Updated or Fresh AMP

(1) Subject of Supplementary Items: Ch 13 Information Management

<Reasons and summary of supplement>

Regulations regarding concept and type of information storing are clearly stated. (To ensure topography, exploration instrument, and satellite image data can be easily searched)

<Content that should be added to manual>

Ch 13 Information Management (Example)

1) Concept of Information Management

By promoting the creation of a database of vast and commonly formatted information on bund related river construction, damage, inspections, maintenance, etc., the goal of realizing a reliable gathering and smooth sharing system of information is set. Through the construction of an information management system, it becomes possible to save labor and manage bunds efficiently and effectively with limited personnel.

In addition, accumulation and sharing of information on river construction, bund inspections, and maintenance will lead to the improvement of river technology and play a very important role in enhancing flood control and safety.

2) Data collection and management

Data on river construction history, bund inspection, and maintenance results will be collected, stored and managed. This allows for the analysis of data over a long period of time, which is useful for the development of maintenance plan. The main information is shown below:

(i) River Basic Information: longitudinal profile and cross-section of the river over the years, detailed inspection of the bund, soil test results, topography, geological survey results, etc.

(ii) River Record Information:

a. Basic records: A floor plan showing the changing status of rivers and river management facilities due to river construction as well as natural external forces (such as water discharge) obtained from river patrols, inspections, and information from the community, etc.

b. Chronological records: Information that can confirm the changes over time of bunds, revetments, river channels, etc. that were described in the basic records

c. Facility records: Information that can confirm the changes over time of each river management facility (such as barrage, flood gate and sluice, bridge, inverted siphon, tunnel crossing the riverbed, land-lock, etc.)

(iii) River Patrol Information: Information entered onsite

(iv) Inspection Maintenance Information: Includes results of bund and river structure inspection, evaluation of the deformation and deterioration of bunds based on the inspection, and analytic results of ground surveys, aerial lasers, Unmanned Aerial Vehicles (UAVs), etc.

3) Information Sharing and Utilization

Regarding information sharing and utilization, the first step is to designate a management department that centrally manages existing construction records, river patrol results, and inspection and maintenance results. The department classifies and centrally stores the data from each division. At the same time, an information management system will be built, and for the second step, information is classified more efficiently and trial operation of the information management system will be conducted. For the third step, information entered onsite to a tablet is uploaded and stored on the web system via USB connection. In addition, information on the main server will be made available for staff of PID and FFC to view, share and use.

4) Information Management Case Study (RiMaDIS: River Management Data Intelligent System: Ministry of Land, Infrastructure, Transport and Tourism of Japan)

a) Reasons for Implementation

By conducting appropriate patrol and inspection on a daily basis, river facilities such as bunds can be maintained safely and securely. However, at river maintenance management sites, management of bunds with long length and a large number of facilities is necessary and it became difficult to maintain management level with limited personnel. Therefore, there was an increasing need for information collection to be optimized and a database to be created. This led to the implementation of a management system for river management information. The system was becoming operational in 2015 and is currently in use.

b) Overview of RiMaDIS

The overview of RiMaDIS is as follows.

(i) Information Handled by RiMaDIS

The information handled is shown in the table below.

Information Handled by RiMaDIS

Item		Detail
Maintenance Actions	River patrol	・General patrol ・Purpose-specific patrol
	Various inspection	・Bund inspection ・Structure inspection ・Safe use inspection ・River channel inspection
	Maintenance countermeasure	・Facility repair ・Tree cutting ・Removal of obstacles, etc.
River Records	Basic Records	・Important deformation information ・Damage history ・Construction history
	Facility Records	・Structure ledger ・Inspection history
Situational Assessment		・Patrol during a flood ・Post-earthquake inspection

Source:*Chubu Regional Development Bureau "Utilization of River Maintenance Database System RiMaDIS"*

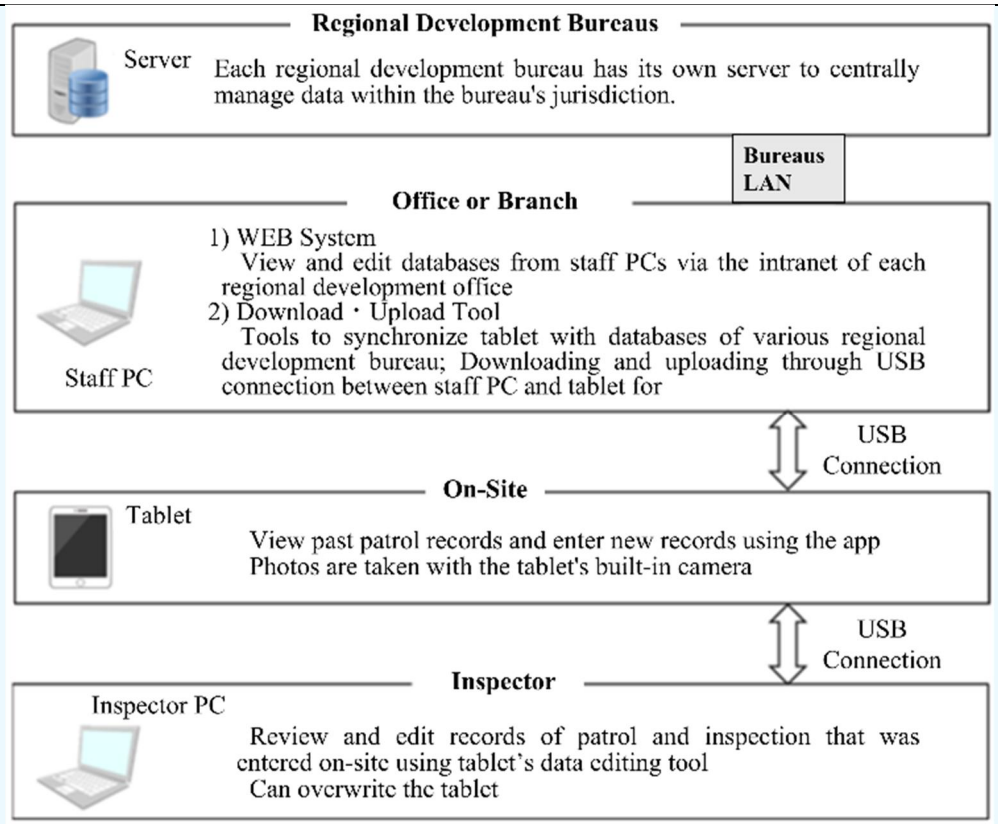
(ii) Basic Configuration

RiMaDIS consists of two main tools: *"web system"* for viewing data, extracting and organizing gathered information, and *"RiMaDIS tablet"* for collecting onsite information of patrol and inspection. Currently, RiMaDIS is deployed on the servers of each regional development bureau, and staff of the maintenance bureau, offices, and branch offices can access and use the web system through a PC connected to the maintenance bureau's LAN. The RiMaDIS tablet used onsite transfers latest data from the server in advance. Onsite, new information is added with reference to the server.

(iii) How to Use

During river patrol and inspection, information is essentially registered and gathered on-site using RiMaDIS tablets. The main target users are staff and contractors involved in on-site work. The main information to be recorded includes location information, patrol items, on-site photographs, type and degree of deformation, etc. To improve the efficiency of on-site recording, patrol items and types of deformations can be selected from a pull-down list. By unifying the expressions, it is possible to gather data that are useful for future analysis and evaluation (such as statistical processing). The deformation record can also be registered along with past record (continuous recording). This enables the collection of deformation changes over time.

The data recorded on the RiMaDIS tablet is uploaded to the web system and synchronized via a USB connection. On the other hand, the web system makes it possible for staff (who are the main target users) to use a PC to view, edit, and search the records of river patrol and inspection uploaded from each office. By assessing the server, staff members can check the information from each maintenance bureau and office. Therefore, information can be organized in a format that is unified within the jurisdiction, which allows for an efficient collection of information.



System structure of RiMaDIS ver2.3

Source: *Chubu Regional Development Bureau "Utilization of River Maintenance Database System RiMaDIS"*

Source: *Created based on related materials and Chubu Regional Development Bureau "Utilization of River Maintenance Database System RiMaDIS"*

<Reference information>

Regarding information management, a centralized management by designating a department for data storage and management, utilizing the system currently in operation is proposed. Basically, centralized management will be promoted to facilitate the sharing of construction history, inspection and maintenance results, etc. currently held by the person in charge can be shared. RiMaDIS is one example of such a management system.

2.9 Artificial Breaching of Bund

Artificial breaching of bund has been employed to mitigate flood damage to public facilities. However, the decision-making conditions for implementing artificial breaching of bunds and their validation are insufficient. Therefore, the following outlines the proposed requirements for implementing artificial bund breaching.

(1) Subject of Supplementary Items: Ch 10-113 Immediate Measures for Bund Breach

Chapter and Article of Current Bund Manual
CHAPTERX: Ordinary Maintenance During Abkalani Article 113. Cutting of a front bund in the event of breach CHAPTER XII: Breaches in River Bunds and how to Close them Article 132. Immediate action in the event of a breach
Relevant Articles in the Punjab Bund Manual
NONE

<Reasons and summary of supplement>

Artificial breaching of bund for the mitigation of damage to urban areas, etc., is presented.

<Content that should be added to manual>

Ch 10-113 Immediate Measures for Bund Breach (Example)

1) Basic Concept of Artificial Bund Breaching

In the event of a flood, bund breaches caused by rising river water levels pose a risk of significant damage to towns and urban areas. Artificial breaching of bund is carried out to reduce the rising water level of river and change the flood water flow, thereby minimizing damage to towns and urban areas.

2) Overview of Artificial Bund Breaching

Overview of artificial bund breaching process is provided.

(i) Simulation of Artificial Bund Breaching

Position and timing of artificial bund breaching should be determined in advance to ensure that the breaching is most effective in minimizing flood damage.

(ii) Procedure of Artificial Bund Breaching

Artificial bund breaching is fundamentally carried out at the discretion of PID management personnel. The procedure for the breaching is as follows.

1. Assumption of the time when severe damage to towns and urban areas may occur
2. Dispatching and placing construction machinery on standby (Request to construction contractors)
3. Arrangement of explosives and detonators (Request to the military)
4. Assessing the state of artificial bund breaching location
5. Assessing the condition of protected lowland downstream from artificial bund breaching
6. Evacuation guidance in areas where flow of flood is expected to reach
7. Regulation of road traffic
8. Execution of artificial bund breaching
9. Assessing flood situation
10. Confirmation of the state of flood containment: Lowering of water level, rainfall status
11. Provisional repair of the sections where bund was breached

At a later date, the main restoration work of the bund will be carried out promptly. The damage to the protected lowland areas is assessed. If necessary, disaster response will be conducted by PID.

Source: *Created based on related materials*

<Reference information>

In the future, artificial breaching of bund is to be avoided as much as possible. To this end, bund strengthening, and flood countermeasures will be implemented.

2.10 Gaps with the Manual

Although construction work is carried out according to the bund manual and construction specifications, the quality of the bund may not be ensured because standards or regulations for construction management (supervision), report preparation, confirmation, storage, etc. are not clear. Therefore, it is important to conduct construction supervision for quality assurance.

(1) Subject of Supplementary Items: Ch 13 Preparation, Storage, and Inspection of Construction Management (Supervision) Reports

Chapter and Article of Current Bund Manual

CHAPTER XIII: Periodical Reports and Returns.
Article
143. Erosion statement (I. R. C. form No. I)
144. Abkalani report (I. R. C. form No. 2)
145. Reports on the state of bund sluices and regulators
146. Wetting of new bunds
147. Statement of specific levels on each mile of the bund (I. R. C. form No. 3)
148. Statement of H.F.Ls. on bund mile gauges and free-board available each year (I. R. C. form No. 4)
149. Sund register of consolidated statement for embodying data for river bunds (I. R. C. form No. 5)
150. Register showing incidence of leaks (I. R. C. form No. 6)
151. Report of leveling on bunds
152. Other I. R. C. forms (Indus bulletin and I. R. C. form No. 7)

Relevant Articles in the Punjab Bund Manual

NONE

<Reasons and summary of supplement>

Description of the organization and storage of documents from bidding to construction testing, inspection results, and completion of construction (Clarification of the department that provides information on river construction).

<Content that should be added to manual>

Ch 13 Preparation, Storage, and Inspection of Construction Management (Supervision) Reports

1) Basic Concept of Preparation, Storage, and Inspection of Construction Management (Supervision) Reports

When river construction is completed, a completion report is submitted by PID to relevant organizations through construction contractors. The submitted reports are organized and stored, with the storage process managed through a database accessible to PID, FFC, and other related agencies.

2) Main Construction Management (Supervision)

The main construction management is as follows.

Types and Contents of Main Construction Management

Type of management	Content	Detail
Schedule management	Coordination of planning and implementation	Coordinate the project and manage its progress to ensure it proceeds as planned
Quality control	Checking and contrasting designed and constructed quality	Conduct inspection and testing to ensure the quality is as designed
Constructed configuration management	Checking and contrasting designed and constructed configuration	Confirm that the actual form of construction is as designed

Machinery management	Operation and maintenance of machinery	Manage machinery to improve its utilization rate and maintain its function
Safety management	On-site safety measures	Measures to ensure the safety of workers and third-party personnel
Environmental management	Environmental protection measures	Measures to minimize the impact of construction on the environment

Source: *Created based on related materials*

PID staff shall mainly supervise construction progress, conduct quality control (such as checking the standards of laboratory field test results of bund material), and check the configuration of the constructed bund's shape and structure. The results of inspection and supervision are compiled into a report, which shall be promptly prepared and submitted.

3) Summary of Required Construction Reports

The following documents are required for construction projects. However, depending on the scale of construction, some reports may be exempted. The exemptions shall be based on the standards set by each PID.

- Project execution plan (Construction plan PC-1): Covers quality control (standards, testing, survey, etc.), scheduling, construction management (supervision), safety management, environmental management, etc.
- Documents for project execution plan (PC-2): Includes specific details of testing and survey method, details on construction standards, etc., which form the basis of the project execution plan (construction plan) and must be attached to PC-1.
- Project progress reports (PC-3(A)): Annual/quarterly reports on items related to the project progress such as construction progress, status of various survey and testing, etc.
- Monthly reports (PC-3(B)): Monthly progress reports on financial status as well as construction progress, status of various survey and testing, etc.
- Construction completion reports (PC-4): Reports that must be submitted to the P&D Department when the river construction work is completed.
- Construction completion effectiveness reports (PC-5): Performance reports on site conditions and construction effectiveness that must be submitted every five years after the completion of project.

Source: *Created based on related materials*

<Reference information>

Details on preparation and viewing of reports are given in "2.7 Inspection Maintenance (River Condition Monitoring)", "2.7.3 River Records" and "2.8 Information Management".

CHAPTER -3

SUPPLEMENTARY ITEMS FOR THE PUNJAB PROVINCE BUND MANUA

CHAPTER 3 Supplementary Items for the Punjab Province Bund Manual

The supplementary items and texts (in the text box) of the current Punjab province bund manual are presented below. Additionally, explanations of the main concepts are provided after each supplementary text.

3.1 Standard Shape of Bund

In the current manual, the shape is determined by the freeboard height and location. However, the shape of the main Indus River bunds should be designed to have a certain level of functionality respond to external forces, such as those exerted by floods.

(1) Subject of Supplementary Items: Vol 2 Ch 2-4.3.1.3 Types of Flood Bunds

Chapter and Article of Current Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 4.3.1.3. Types of Flood Bunds 4.3.1.3.1. Marginal Bunds 4.3.1.3.2. Bunds Protecting Strategic Locations 4.3.1.3.3. Bunds along Open Rivers
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

The standard bund shape that is uniform for all bunds along the Indus River in Sindh and Punjab provinces is proposed.

<Content that should be added to manual>

Ch 5-41 Standard Bund Shape

For repair and new construction of bunds along the Indus River, the crown width and freeboard are set based on the following criteria.

- Bund Freeboard: More than 7.0 ft above design high flood level.
- Bund Crown Width: More than 25 ft.

The bund slope shall be set in accordance with the current manual.

Source: *Manual of Irrigation Practice Volume 1 of Punjab Government*

<Reference information>

The recommended values including a standard crown width of 25ft and the freeboard of 7ft, shall be established as a standard shape in Punjab.

3.2 Quality Control

Quality control is the most important aspect for constructing strong bunds that can withstands floods. The quality of the bund itself determines the fundamental strength of the bund. Through selection of soil material suitable for bunds and reliable implementation of construction management (such as ensuring degree of compaction is up to par), a bund that is resistant to floods can be achieved. In addition, this approach will facilitate easier day-to-day maintenance and enable more efficient strengthening of bunds over time.

3.2.1 Soil Quality of Bund Material

(1) Subject of Supplementary Items: Vol 2 Ch 2-4.4 (Addition) Soil Quality of Bund Material

Chapter and Article of Current Bund Manual Vol.2: Chapter 2: River Training & Flood Management NONE
Relevant Articles in the Sindh Bund Manual CHAPTER VI: Construction of New Bunds or Loops Article 51. Requisites of suitable soils for bund building 52. Relative merits of different soils for bund building 60. Specifications for earthwork for river embankments

<Reasons and summary of supplement>

The preferred standards of bund material are clarified. Examples of countermeasures in case the soil quality is not desirable as bund material are shown.

<Content that should be added to manual>

Vol 2 Ch 2-4.4 (Addition) Soil Quality of Bund Material (Standard)

1) Soil Desirable as Bund Material

To satisfy the basic conditions of bund material, the soil shall have the following properties:

1. Soil with good particle size distribution: This is because a variety of grain sizes is desirable for adequate compaction. The coarse particles are effective in providing strength through particle interlocking whereas the fine particles are necessary to reduce the permeability coefficient. Therefore, an appropriate combination of these is desirable for bund materials.
2. The maximum dimension is 10-15 cm or less: This is determined by the spreading depth limitation of during construction. However, caution is required because if the maximum dimension of the gravel diameter is too large, the effect of compaction may not be fully achieved.
3. Fine particles (0.075 mm or smaller) make up at least 15% of the soil material (75 mm or smaller): This requirement is to ensure impermeability. It has been reported that many leaks occur in bunds made from materials that do not meet this requirement.
4. Soil with not too many silt particles: Erosion caused by rainfall and slope failure due to water seepage allow easier passage of water through the soil. This causes the soil to have increased moisture content and lowered shear resistance. The phenomenon is thought to be greatly influenced by the silt particles within the soil.
5. Soil with not too many fine particles (0.075 mm or smaller): Soil with fine particles of 50% or less is preferable, since soil with fine particles of 50% or more is at risk of cracking when dried.

2) Countermeasures in Case the Soil Quality Is Not Desirable as Bund Material

Materials with low evaluation and materials whose trafficability cannot be ensured may be used as bund material provided that the following countermeasures have been implemented:

a) Mixing with Other Soil Types

This is to compensate for the poor particle size distribution of the soil. By mixing fine-grained soil

with sandy soil to reduce the permeability coefficient and mixing cohesive soil with sandy soil to reduce the moisture content, the strength of the soil can be increased to facilitate construction.

b) Soil Quality Improvement Using Additives

Soil quality can be improved by adding stabilizing agents such as lime and cement.

(i) Particle Size Adjustment by Mixing with Other Soil Types

This method improves the properties of the soil with poor particle size distribution by adding in a different soil that can supplement the lacking particle size of the original soil. For river bunds, the particle size of the embankment material is adjusted to ensure appropriate compaction by mixing fine-grained soil with sandy and gravel soil. As an example, sand is mixed into cohesive soil to get sandy soil.

As described above, grain size adjustment is a process of mixing two or more types of soil with different properties to improve the grain size distribution and obtaining soil suitable for the purpose of bund material. Therefore, the adjusted soil can be evaluated by looking at properties of the improved soil and may be regarded as the same as a typical soil desirable as materials for a stable bund.

(ii) Soil Stabilization Treatment Using Additives

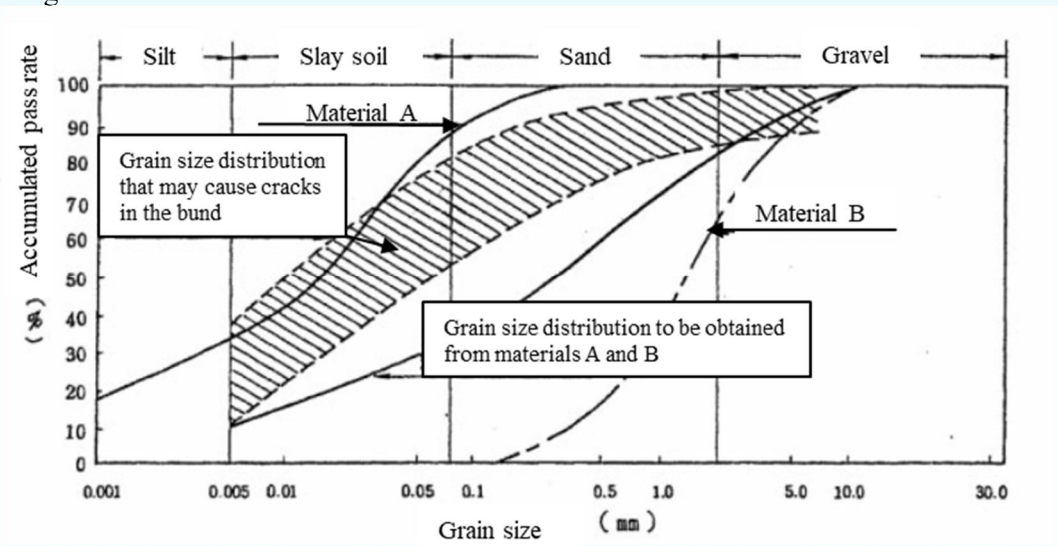
This method attempts to stabilize soil quality using lime or cement for soils with insufficient trafficability, such as cohesive soils with high moisture content.

The stabilization mechanism of each additive is as follows.

- **Lime:** Lime reacts with soil water, which causes water absorption as well as heat generation, and results in dehydration of the surrounding soil. In the long term, it is chemically bonded by the pozzolanic reaction. For this reason, the reaction time with lime is required to be longer than that of cement.
- **Cement:** Cement reacts with soil water to produce hydration hardening, which hardens through chemical bonding with soil particles. In the long term, although there is also an enhancement of hardening by the pozzolanic reaction, most of the hardening action is due to hydration hardening.

The hardening time of cement is shorter than that of lime, and most of its hardening is completed in about 3~7 days after mixing with soil.

In addition, after the bund is built with soil that employed the soil stabilization treatment, fine cracks due to dry shrinkage may develop on the bund depending on the soil type, additive materials, mixing ratio, and mixing method. Therefore, it is advisable to determine the construction method after conducting a basic examination through laboratory test and, if possible, verified by testing during construction.



Schematic Diagram of Particle Size Adjustment

Source: *Civil Engineering Manual 3.1.3 Selection of bund materials*

<Reference information>

Soil with silt content of 50% or less, and sand content of 50% to 70% or 80% is suitable as bund material. The bund material used for the Indus River bunds has a high fine particle content, which can cause scouring and erosion of the bunds. During construction, it is desirable to adjust the grain size by mixing sand to reduce the fine particle content to 50% or less.

Soil stabilization treatment with additives is not expected to be actively adopted due to issues with financial cost and the need to set the optimal mixing ratio, but it should be employed for critical structures and when a high level of bund strengthening is required.

3.2.2 Standards for Degree of Compaction

(1) Subject of Supplementary Items: Vol 2 Ch 2-4.5 Quality Control

Chapter and Article of Current Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 4.3.1.2. Planning
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

The current manual makes it difficult to understand the compaction criteria and soil test requirements, so standard values for degree of compaction, air porosity, and other relevant parameters are clearly defined.

<Content that should be added to manual>

Vol 2 Ch 2-4.5 Quality Control (Standard)

1) Standard Values of Soil Material for Bund Construction

The degree of compaction is defined according to the ratio of fine grain particles (0.075 mm or less) within the soil material (particles of 75 mm or less), and this ratio can be obtained by conducting a sieving test.

Regulation of Degree of Compaction

Soil classification name	Coarse-grained	Sandy soil {SF} (15%≦-74μm<25%)	Sandy soil {SF} (25%≦-74μm<50%)	Cohesive soil CS
Degree of Compaction (DC)	*DC* =90%	*DC* =90%	—	—
Construction moisture content (ωn)	—	—	Within the scope of trafficability	Within the scope of trafficability
Air porosity (Va)		—	Va≦15%	2%≦Va≦10%
Saturation (Sr)		—	—	85%≦Sr≦95%
Quality pass rate (%)	—	—	90%	90%
Quality lower limit	*DC* =80%		—	—

○ The standard compaction laboratory test shall be performed using the A-a method.
(Reference: https://kikakurui.com/a1/A1210-2020-01.html#google_vignette)

Trafficability for construction equipment is shown below. Basically, the trafficability of the embankment should allow dump trucks to pass through.

Trafficability of Construction Machinery

Construction Machinery	Installation pressure of construction machinery	Cone Index QC
	(kN/m²)	(kN/m²)
Wetland bulldozer	22~43	≥300
Ordinary bulldozer	50~60	≥500
Ordinary bulldozer	60~100	≥700
Towed scraper	130~140	≥600
Self-propelled scraper	400~450	≥1,000
Dump Truck	350~550	≥1,200

Source: *Japan Road Association, "Civil Engineering Guidelines for Roads"*

2) Soil Material Management

a) Soil Quality Test

For bund material, soil compaction tests should be conducted in advance to determine the maximum dry density, optimum moisture content, and establish the quality control standard values. In addition, the following tests should be conducted as necessary to determine the suitability of the soil as bund material.

Main Soil Quality Tests of Bund Material

Test Name	Objective	Method
Particle size test of soil	Investigate the distribution of soil particle size distribution	Sieve method, sedimentation method
Density test of soil particle	Investigate the density of soil particle	Pycnometer method
Moisture content test of soil	Investigate the soil moisture content	Drying method
Liquid and plastic limit test of soil	Investigate the plastic characteristic of soil	Atterberg limit test
Uniaxial compression test of soil	Investigate the compressive strength of soil	Uniaxial compression test apparatus
Triaxial compression test of soil	Investigate the shear strength of soil	Triaxial compression test apparatus
Density test of soil	Investigate the compressive property of soil	Consolidation test apparatus
Shear test of soil	Investigate the shear strength of soil	Direct shear test, tri-axial compression test
Permeability test of soil	Investigate the permeability of soil	Constant head permeability test, Falling head permeability test

Source: *Civil Engineering Manual 3.1.4 Regulation of degree of compaction*

b) Optimum Moisture Content Standard

During the test of soil compaction characteristics, as the soil is being compacted, its moisture content is adjusted. The moisture content when the dry density is highest is regarded as the Optimum Moisture Content (OMC). The density at this point is called the maximum dry density.

Although dependent upon the soil type, the typical value is around 70-95% for saturation degree and less than 15% for air porosity (often less than 10%).

c) Adjustment of Moisture Content for Dryness and Wetness

To satisfy the specified compaction degree during bund construction, it is important to control the moisture content as part of the quality control of the bund material. The following methods are used to adjust the moisture of bund material.

(i) Natural drying

Natural drying is used to reduce the moisture content. In this method, the embankment material is spread out and left to dry naturally, with periodic stirring before compaction.

(ii) Trench excavation, etc.

In this method, before the bund material is collected at the borrow pit, a trench is excavated below the collection base to lower the underground water level and reduce the moisture content of the bund material. This method has been proven to be relatively effective and is commonly employed.

(iii) Water sprinkling

Water sprinkling helps bring the moisture content of the bund material closer to the optimal value and is performed after leveling but before compaction. The amount of water applied is determined by the difference between the natural moisture content of the material to be leveled and the moisture content required for compaction.

Source: *Civil Engineering Manual 3.1.4 Regulation of degree of compaction*

<Reference information>

For bund material, the degree of compaction target is Dc=90% or more and the air porosity (Va) target is Va≦15%. Since the current manual does not specify the testing method, quality control will be performed based on the results of the compaction test currently conducted in Sindh province. The standardized laboratory compaction test of Japan is the A-a soil compaction test method (JIS A 1210-2009). (Reference: https://kikakurui.com/a1/A1210-2020-01.html#google_vignette)

Prior to the start of construction, soil quality tests of the bund material should be conducted to determine its characteristics. In case of unfavorable soil properties, countermeasures are considered. In addition, soil compaction tests are conducted to establish the standard for maximum dry density and optimum moisture content, and construction management shall be carried out.

3.2.3 Construction Machinery Used

(1) Subject of Supplementary Items: Vol 2 Ch 2-4.6 (Addition) Construction Machinery Used

Chapter and Article of Current Bund Manual
Vol.2: Chapter 2: River Training & Flood Management NONE
Relevant Articles in the Sindh Bund Manual
CHAPTER VI: Construction of New Bunds or Loops Article 55. Mechanical equipment for construction of embankment

<Reasons and summary of supplement>

The current manual does not clearly describe the construction equipment to be used. Therefore, the specific machinery and equipment required for bund embankment construction are now clearly defined.

<Content that should be added to manual>

Vol 2 Ch 2-4.6 (Addition) Construction Machinery Used

1) The table below outlines the standard machinery used for various work operations of bund embankment construction.

Work Type and Applicable Machinery

Type of work	Type of Construction Machinery
Excavation	Shovel-typed excavator (power shovel, backhoe, drag line, clamshell), bulldozer, ripper, breaker
Loading	Shovel-typed excavator (power shovel, backhoe, drag line, clamshell), continuous loader
Drilling and Loading	Shovel-typed excavator (power shovel, backhoe, drag line, clamshell), crawler loader, wheel loader, continuous loader
Drilling and Transportation	Bulldozer, scrapedozer, scraper, dredger
Transportation	Bulldozer, dump truck, belt conveyor
Spreading	Bulldozer, motor grader
Compaction	Bulldozer, tire roller, rammer, tamper, vibrating compactor, vibrating roller, road roller

Source: *Civil Engineering Manual 4.2.5 Selection of Construction Machinery 1) Work Type*

2) The general applicability of bund material and compaction machinery is shown below.

General Applicability of Compaction Machinery for Different Soil Types

Machinery / Soil type	Ordinary bulldozer	Tire roller	Vibrating rollers,	Vibrating compactor	Tamper	Remark
Sand Gravel and sand	○	○	○	△	△	Single grained sand, unscreened gravel, dune sand, etc.
Sand Sandy soil Sandy soil with gravel	◎	◎	○	△	△	Mixed soil with appropriate grain size, decomposed granite soil, mountain gravel, etc.
Clay Clay with gravel	○	○	○	×	△	Sensitive soil with few fine particles, loams with low moisture content, crumbly mudstone, etc.
Sandy soils with high moisture content Clay soils with high moisture content	○	×	×	×	×	Soils with difficult-to-adjust moisture content or difficult-to-sufficiently-ensure permeability, silty soils, etc.

Legend:
◎ Applicable
○ Can be used
△ Can be used, but dependent upon site conditions such as area restrictions
× Cannot be used

Source: *Civil Engineering Manual 4.3.4 Embankment 3) Embankment and compaction*

3) Changes to the current manual (recommended)

In section 55 (Mechanical Equipment for Construction of Embankments) of the current manual, it is stated that "Bunds have so far been constructed in Sindh, with rare exceptions, with donkey labor. However, considering the current situation, it should be changed to "Bunds have been constructed in Sindh using backhoes, bulldozers and other construction machinery.

Source: *Civil Engineering Manual 4.2.5 Selection of Construction Machinery 1) Work Type and Applicable Machinery; 4.3.4 Embankment 3) Embankment and compaction*

<Reference information>

Section 55 of the current manual describes examples of machinery used. As a supplementary item, the actual construction machinery used for civil engineering is summarized in the table. As for shovel-typed excavators and bulldozers, they are capable of operating in wetlands.

Different compaction machinery is selected based on the soil quality. However, in many cases in Pakistan, bulldozers and tire rollers are typically used.

3.3 Safety Assessment

In the current manual, Vol. 1 Chapter 5 and Vol. 2 Chapter 2 only partially describe the concept of safety of each facility. Understanding the overall process is important for safety assessment, so the information is compiled as supplementary items.

3.3.1 Disaster Forms of Bund and Verification Items for Safety Assessment

(1) Subject of Supplementary Items: Vol 2 Ch 2-5 Failure of Bunds, Ch 2-5.3 Erosion, Ch 2-5.4 Bund Seepage, Ch 2-6 Seepage Control

Chapter and Article of Current Bund Manual

Vol. 2:
Chapter 2: River Training & Flood Management
5. Failure of flood embankment
5.3. Erosion
5.4. Seepage through the embankment body
6. Seepage control

Relevant Articles in the Sindh Bund Manual

NONE

<Reasons and summary of supplement>

Verification methods of safety evaluation such as arc slip which illustrates the disaster form of bunds and seepage analysis method are presented.

<Content that should be added to manual>

Vol 2 Ch 2-5 Failure of Bunds, Ch 2-5.3 Erosion, Ch 2-5.4 Bund Seepage, Ch 2-6 Seepage Control (Standard)

1) Disaster Form of Bund (Concept)

Displacement and deformation of bunds, along with changes in properties due to water seepage, leakage, and other damages are caused by external forces induced by disasters (e.g. rainfall, river water, ground subsidence, and earthquakes). These factors can lead to various types of disasters, as illustrated in the figure below.

Various Forms of Disaster

Natural Phenomenon	Disaster	Location	Disaster Form
Rainfall	River runoff	High water channel, low water channel scouring	Water leakage, bund scouring
		Bund	Slippage
			Seepage
			Erosion, scouring
Earthquake	Liquefaction	Bund	Slippage

***Source**: Created based on related materials*

2) Verification Items for Safety Assessment (Concept)

During the prolonged period of rising river water level and flood, disasters such as seepage, overflow,

scouring and erosion are more likely to happen. In the worst case, inundation due to a breach could occur.

Regarding the safety performance of the bund, provided that the cross-sectional shape of the bund is as designed, the following performances shall be set and verified.

a) Integrity under normal conditions

Regarding the stability verification against slip failure under normal conditions, various allowable values such as slip safety factor have been set. The soil properties of the ground foundation and the bund were then considered, and safety was evaluated from values such as safety factor against slip failure under self-weight. The basis of stability verification is confirming that the condition of the allowable values is satisfied. If the ground is not considered soft based on past results, the verification can be skipped.

b) Seepage resistance performance

Regarding verification of seepage resistance performance, the allowable values of safety factors for slip failure and piping failure, etc., have been set. Next, the safety factors (with regards to slip and piping failure) of the bunds are evaluated based on the water level waveform, rainfall waveform, soil quality of the foundation ground and bund, etc., and compared with the allowable values. Safety is verified if the condition of the allowable value is met.

c) Erosion resistance performance

Erosion resistance performance is essentially verified by setting the allowable values for erosion ultimate flow velocity of the bund slope or erosion value of high-water channel based on past damage records, condition of revetment installation and width of flood channel at the front surface of the bund. Next, flow velocity or erosion amount due to flood action, considering flat and longitudinal profiles of the river channel, are evaluated to verify that the condition of allowable values is satisfied.

d) Seismic performance

The verification of seismic performance is fundamentally based on setting the allowable height of the bund to prevent water flow under normal conditions or design tsunami from overflowing after an earthquake. Next, height of the bund after earthquake-induced deformation is evaluated and verified to check whether the condition of allowable values is satisfied.

e) Safety against waves, etc.

The safety against erosion of bund significantly affected by waves and tsunamis shall be checked and verified based on past damage experiences. In case of a high tide, erosion of bund due to water flowing below the design storm surge level is checked. In case of wind and wave, erosion of bund due to water flowing below the high flood level or the river level when winds and waves are most developed is checked. In case of a tsunami, erosion to the bund due to water flowing below the design tsunami water level is checked.

If verification found the safety performance to be lacking, strengthening methods will be explored. In essence, verification methods are methods based on appropriate knowledge, such as methods considered reasonable based on past experiences and results, or methods where actual condition of damage of the river in question or the equivalent river can be reproduced.

***Source:** *Technical Criteria for River Works: Practical Guide for Designing Chapter 1 Section 2 Bund*

3) Verification External Force and Verification Standards for Safety Assessment

Verification external force and verification standards for safety assessment are set as follows.

a) Seepage Verification (Standard)

For seepage resistance function verification, verification outer water level and verification rainfall are set as verification external forces.

Verification outer water level refers to the high flood level (if indicated, the water level during the flood that was set as immediate maintenance target). Verification rainfall refers rainfall at the time of design flood (if indicated, the rainfall during the flood that was set as immediate maintenance target).

The verification standards include target safety factor for slippage and mechanical limit state for piping, as shown below.

(i) Safety against slip fracture

a. Safety against slip fracture at the back surface

$Fs \geqq 1.2 \times \alpha 1 \times \alpha 2$

Fs: Safety factor against slip fracture

α1: Multiplicative factor for the complexity of bund construction history

If the bund construction history is complex α1= 1.2

If the bund construction history is simple α1= 1.1

If the bund is a new construction α1= 1.0

α2: Multiplicative factor for the complexity of ground foundation

If there is a history of damage or if the terrain requires attention α2= 1.1

If there is no history of damage or if the terrain does not require attention α2= 1.0

※ Cases of complicated bund construction history: when the bund construction start date is old and several constructions have been done or when the history of construction is unknown.

Terrain requiring attention: Flood control terrain that is linked to bund destabilization, such as old river channels and excavation sites

b. Safety against slip fracture at the front surface

$Fs \geqq 1.0$

Fs: Safety factor against slip fracture

(ii) Safety against piping failure of ground foundation

a. In case ground foundation and soil cover layer at sheltered area is permeable

$i<0.5$

i: Maximum local hydrodynamic gradient of ground foundation near toe of back slope

b. In case ground foundation is permeable and soil cover layer at sheltered area is not permeable

$G>W$

G: Weight of the soil cover layer

W: Lifting pressure acting on the base surface of the soil cover layer

b) Verification Against Erosion (Standard)

In the verification study of erosion resistance, the representative flow velocity is set as the external force to be verified. The representative flow velocity is calculated by multiplying the fastest average flow velocity at the water level below the high flood level (if indicated, the flood water level that was set as the immediate maintenance target) by the correction factor due to the curvature, etc.

The following are the standard verification criteria. However, this does not apply when appropriate measures such as riverbank protection are taken.

(i) Regarding direct erosion of front and toe of bund slope

Surface erosion capacity > external erosion force evaluated from representative flow velocity

(ii) Lateral erosion and scouring from main channels (low channels, etc.)

High water channel width > width of high-water channel eroded during the verification timeframe

(iii) Regarding scouring

Height of foundation pile at the front slope of bund > height of riverbed scoured by one flood

***Source:** *River Bund Design Guidelines 5. Verification of safety*

c) Verification Against Earthquake (Reference)

(i) Verification Items

The safety of bunds against earthquakes is verified based on the possibility of secondary disasters such as flooding due to bund subsidence. The verification items are broadly divided into two categories: (a). deformation of the bunds due to liquefaction and (b). inertial forces. This section summarizes inspection methods that link both deformation to the subsidence phenomenon.

(ii) Inspection Criteria

According to The Japanese Ministry of Land, Infrastructure, Transport and Tourism's revised draft of "Technical Criteria for River Works: Practical Guide for Designing [I]", it is required to investigate the possibility of secondary disasters based on the estimated amount of subsidence,

taking into account the outer water level and the conditions of the hinterland. In the guideline, the possibility of secondary disasters due to flooding is determined by comparing the height of the deformed river bund (after an earthquake) with the river water level set considering the emergency recovery period.

In this case, it is considered appropriate to set the height of the deformed river bund (after an earthquake) as the height that ensures that the condition of required crown width (design or existing crown width) is met.

On the other hand, the estimated river water level is determined based on the period of time required for emergency recovery (approximately two weeks), the characteristics of the river, and the conditions of the hinterland. For reference, the water level can be set as follows:

- Mean monthly highest water level (normal flood level of the flooded section upstream from the lakes and weirs) + α (m)
- High water level based on return period (1/1 equivalent water level) + α (m)
- Design tsunami height

Here, α is set in accordance with tidal deviation and wave height, with 1 to 2 meters considered as the guideline value.

The possibility of secondary disasters is verified based on the comparison between the post-earthquake height of bund and the river water level set. If the former is lower than the latter, it is evaluated that secondary disasters can occur.

**Source*: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 6*

4) Verification Methods of Safety Assessment

a) Seepage Verification

The safety of bund against seepage is checked using unsteady seepage flow calculation and stability calculation based on the circular slip method. The unsteady seepage flow calculation tracks the position of the seepage surface and the change of the head of water over time by applying a non-stationary external force. As such, the shape of the seepage surface at an arbitrary time can be known, and the local hydraulic gradient can be calculated from the head distribution. On the other hand, in the stability calculation using circular slip method, the safety factor against slip failure during flooding can be obtained by extracting the seepage surface that is assumed to be the most critical for each of front and the back slope surface, and setting this as the cross-section to be inspected.

(i) Method of Unsteady Seepage Flow Calculation

There are two methods of seepage flow calculation: (a). steady and (b). unsteady analysis method. The latter contains saturated analysis and saturated-unsaturated analysis. In this guide, the principle is to perform unsteady saturated and unsaturated seepage flow calculations that can replicate realistic phenomena.

The basic equation for the calculation of unsteady saturated and unsaturated seepage flow is as follows.

$$\frac{\partial\psi}{\partial x}\left(k\frac{\partial\psi}{\partial x}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial\psi}{\partial z}+k\right)=(C+\alpha.S_s)\frac{\partial\psi}{\partial t}$$

Here,
- x: Horizontal axis of the bund cross-section
- z: Vertical axis of the bund cross-section
- k: Hydraulic conductivity (m/hr)
- ψ : Pressure head (m)
- C: Specific water capacity (1/m)
- α: 1 for saturated region, 0 for unsaturated region
- Ss: Specific retention coefficient (1/m)
- t: Time (hr)

Here, the specific water capacity C is given as a tangential gradient of the soil water characteristic curve, and the specific retention coefficient Ss is Ss = 1×10^{-4} (1 / m) for sandy soil, and Ss = 1×10^{-3} (1/m) for cohesive soil.

The calculation of unsteady saturated and unsaturated infiltration flow is performed by setting soil constants, initial conditions, and calculation conditions for the modeled bund (bund and ground

foundation), and entering boundary conditions. During the calculation, results at important points in assessing the safety of the bund, such as the river water level (outer water level) at the end of rainfall and its peak, are recorded in a file and carried out until the end of the flood.

Figure A shows an example of comparing the seepage surface calculated using the aforementioned method with the seepage surface observed in the seepage experiment of a full-scale embankment, and it can be seen that the actual seepage phenomenon is accurately reproduced.

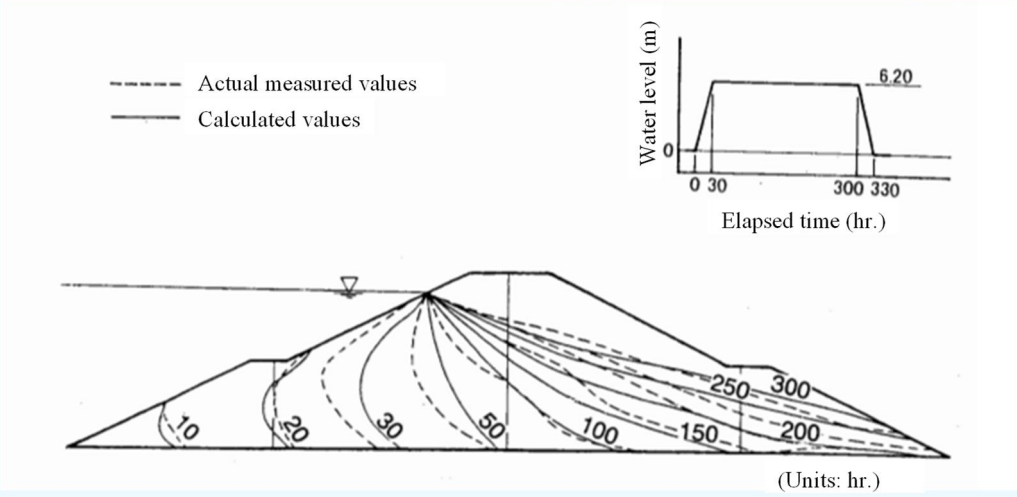
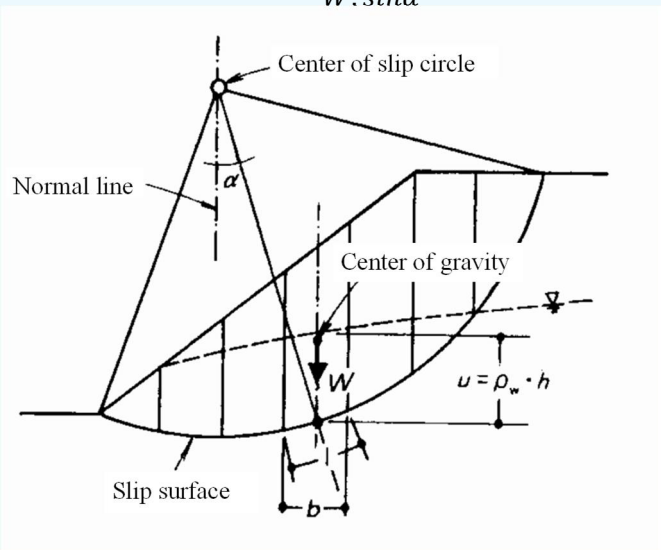


Figure A. Validation of Seepage Experiment on a Full-Scale Bund Results Using Seepage Flow Calculation

(ii) Stability calculation method by circular slip method

The most critical seepage surface obtained from the seepage flow calculation is selected and the minimum safety factor against slip failure is calculated based on general total stress method using the following equation.

$$F_s = \frac{\Sigma\{c1 + (W - ub).cos\alpha.tan\phi\}}{W.sin\alpha}$$



Here,

Fs:	Safety factor
u:	Pore water pressure (kPa) of slip surface
W:	Divider weight (kN/m)
c:	Cohesion strength of soil along the slip surface (kPa)
l:	Arc length (m)
ϕ:	Internal friction angle of soil along the sliding surface (°)
b:	Divider width (m)

General total stress method is a method in which a shear test is performed under the same stress

condition and drainage condition as in the actual case. The so-called apparent strength constant c and ϕ are obtained, and stability calculation is performed using the pore water pressure of slip surface. The strength constant and pore water pressure used in the general total stress method are shown below. Pore water pressure includes pore water pressure due to seepage and drainage of rainfall and river water, and pore water pressure due to volume expansion or contraction of soil due to shear. The pore water pressure at the slip surface in the above equation refers to the pore water pressure due to seepage and drainage, which Terzaghi describes as the 'neutral pore water pressure'. In the general total stress method, pore water pressure due to shear is not considered in the above equation because the pore water pressure due to shear is already reflected in the soil test for determining the strength constant.

Although many methods have been proposed for stability calculations using the circular slip method, the formula presented here is known as the modified Fellenius formula.

In the stability calculation, the minimum safety factor is calculated for several arc centers, and the minimum value among them is the minimum safety factor for the calculated cross-section.

Strength Constant and Pore Water Pressure

Condition of Divider Base	Strength Constant	Pore Water Pressure
Non-drainage condition (if water permeability is low)	Cohesive force cU (internal friction angle ϕ U ≈ 0) or cohesive force cCu, internal friction angle ϕ CU	Pore water pressure due to seepage and drainage u
Drainage condition (if water permeability is high)	Cohesive force C D ≈ C', Internal friction angle ϕ D ≈ φ'	By seepage and drainage

***Source**: Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 4*

(iii) Verification Software for Seepage

Regarding the verification of seepage, comprehensive analysis software such as SEEP / W, ANSYS, and HYDRUS are generally used for seepage flow analysis. Dedicated software for analysis includes tools such as PLAXIS, MODFLOW, SVFLUX, and FEFLOW. For circular slip, Rocscience Slide2 and GeoStru Slope are commonly used. For reference, the representative seepage flow analysis software SEEP/W and the arc-slip software Rocscience Slide2 are available at the provided URL.

SEEP/W ：It's part of the GeoStudio suite developed by Seequent.
https://www.seequent.com/getting-started-with-seep-w/

Slide2 by Rocscience ：It is a powerful software tool used for analyzing the stability of slopes.
https://www.rocscience.com/software/slide2

*(**Source**: Created based on related materials)*

b) Erosion Verification

(i) Safety Verification Against Direct Erosion of Front and Toe Surface of Bund (Reference)

River bund is verified assuming that the bund is covered by vegetation such as grass. Erosion resistance of front and toe surface is verified by comparing the erosive external force (evaluated based on the representative flow velocity V_0 and the flow action time) with the erosion resistance of the slope surface covered with vegetation.

Regarding the surface erosion resistance of slope covered with vegetation (erosion resistance of vegetation), when the plants are not very tall, the main component among the bund vegetation that exhibits erosion resistance is the rhizome. The root layer, which is washed out of the ground by erosion due to flowing water, slows the velocity of flow near the ground surface, thereby reducing the scouring force.

Assuming:

1. The maximum erosion depth achieved in the design where the erosion prevention effect of vegetation is present is defined as the allowable erosion depth. The erosion prevention effectiveness is only exerted within the time it takes for erosion to progress to the allowable erosion depth.

2. Higher erosion resistance is exhibited when there are more vegetation roots near the surface. That is to say erosion resistance of plants varies with the number of rhizomes near the surface (average root hair amount)

With duration of the shear force exerted by the water flow (t) and average root hair amount (σ_0) as parameters, surface erosion resistance (u_{*c}) due to vegetation can be determined from the following equation:

$$\mu_{*c} = \frac{Z_{brk}}{\alpha} \cdot \frac{1}{\log t} \qquad (1)$$

Here,
- u_{*c}: Friction velocity (m/s)
- t: Duration of shear stress (min)
- Z_{brk}: Allowable erosion depth (cm)
- α : Parameters Representing Erodibility (= $-50\sigma_0+9$)
- σ_0: Average root hair amount (gf/cm³), defined as "the total weight of roots and rhizomes contained in the soil per unit volume up to a depth of 3 cm from the ground surface."

Equation (1) can be applied under the condition that the flow velocity is constant over time. Figure 5.3.2 plots a graph of equation (1) with the allowable erosion depth set at Z_{brk}=2.0cm.

For cases where the flow velocity changes over time, the following simplified method for safety verification is adopted. This method is based on the following assumptions:

- The water level waveform can be approximated as a triangular shape with the peak water level as the vertex.
- The flow velocity increases or decreases with changes in water level.

If these assumptions are not applicable, an evaluation considering the time variation shown in Reference 3) must be conducted.

First, set the duration of the erosion force (t) and the average friction velocity (u_{*ave}) within that time. The duration (t) is determined as the period of time the water level exceeds the high-water channel elevation. In the simplified method, (u_{*ave}) is calculated using the following equation.

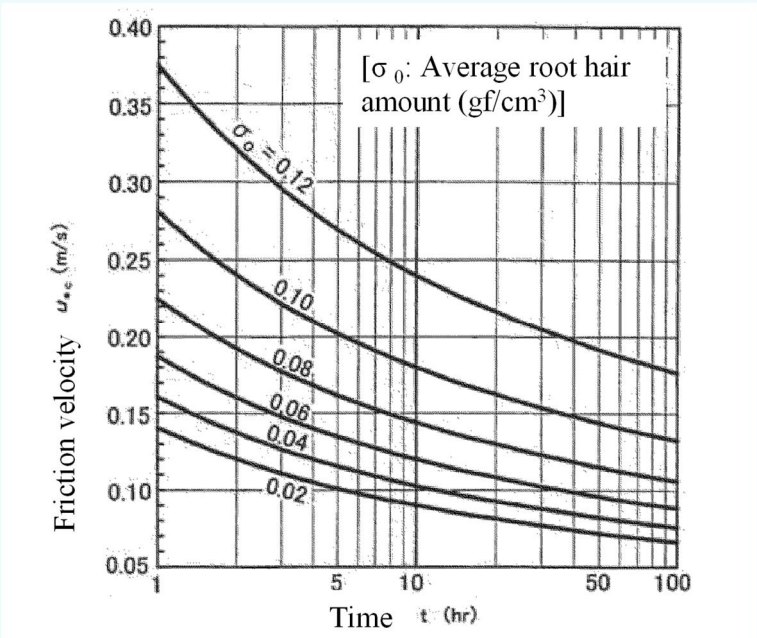


Figure A：Surface Erosion Resistance Due to Vegetation (Root Hair Amount and Friction Speed)

$$\mu_{*ave} = 0.82\mu_{*max} \quad (2)$$

In other words, the simplified method proposes that if assumptions (1) and (2) apply, (u_{*ave}) corresponds to approximately 82% of the peak value. In this guideline, (u_{*max}) is set as (u_*) at the high flood level. (u_{*max}) is calculated using the following equation.

$$\mu_{*max} = V_{0\,max}/\psi \quad (3)$$

Here, (V_{0max}) is the representative flow velocity at the high flood level, and (ϕ) is the velocity coefficient can be calculated as follows.

$$\psi = (1/n).(H_d^{1/6}/\sqrt{g}) \quad (4)$$

Here, n: Manning's roughness coefficient
H_d: Water depth (m)
g: Gravitational acceleration (m/s^2)

Next, the duration (t) is substituted into equation (1) to determine the surface erosion resistance (u_{*c}). From this, if ($u_{*c} > u_{*ave}$), it is evaluated that the safety against direct erosion of the bund's front and toe surface is ensured.

It is necessary to calculate the representative flow velocity (V_0) used in checking the safety of the bund against erosion by multiplying the maximum value of the average flow velocity obtained from an appropriate method with the correction factor for curvature. For details on the calculation method of the representative flow velocity (V_0), please refer to Reference 2).

Note that equation (1) can be applied under the following conditions:

- A thriving community of plants that are dominantly within the Poaceae classification (with rhizome diameters of up to 1 mm).
- There are almost no bare areas, such as mole holes, and the area is uniformly covered by plants.
- The ground material is silt or silt-mixed sand.
- The friction velocity (u*) is approximately 27 cm/s or less.
- The average root hair amount (σ0) is within the range of 0.02 to 0.12 gf/cm³.

The average root hair amount (σ_0) can be measured as follows:

1. Drive a PVC pipe into the slope at the selected survey site.
2. Push out the soil packed in the PVC pipe up to 3 cm from the surface and cut it off with a cutter or similar tool.
3. Wash out the roots and rhizomes contained in the soil with water and measure their total weight.
4. Calculate the average root hair amount by dividing the total weight by the volume of the cut soil.
5. Perform the above measurement three times and take the average value as the average root hair amount for the survey site.

If it is difficult to measure the root hair amount, the erosion resistance of the embankment can also be evaluated using the relationship between the friction velocity and time for each coverage degree of Zoysia grass.

The erosion resistance at the front and toe surface of bund slope is generally considered to be ensured if the representative flow velocity is 2 m/s or less (rough estimate).

(ii) Safety Verification Against Lateral Erosion and Scouring

In the event of a flood, lateral erosion and scouring from the main channels (such as low water channels) may damage the bunds. The rate of lateral erosion depends on the type of erosion, the external forces acting on the riverbank, and the duration of their impact, which are closely related to the river channel characteristics and plane shape. Erosion progresses in a repeating cycle, acerbated by multiple floods. Therefore, with regards to the evaluation of erosion width, it is necessary to establish the period of the flood before employing the method for evaluating the erosion rate corresponding to the characteristics of the river channel and the form of erosion. It is necessary to comprehensively consider the conditions of the target river during the period of the flood and determine the verification timeframe. The minimum verification timeframe is one flood (one occurrence of flood), and if the verification timeframe is set to one flood, inspection and response are necessary after every flood.

The method for evaluating the erosion rate from the perspective of hydraulic and soil engineering is not yet sufficient. Thus, the "Guideline" sets the width of the high-water channel eroded during the inspection target period as the inspection standard. Table A shows the approximate width of erosion of flood channels due to one flood.

The values shown in Table A are estimates of the amount of lateral erosion and scouring from the main channels (such as low water channels) expected to occur after one flood. The values were obtained from actual data of erosion due to a single flood (all of which are below the high flood level) collected in local rivers. In addition, if the width of high-water channel erosion along the target river due to past flooding has been accounted for, verification must be conducted based on the results.

Table A Verification Criteria for Safety Against Scouring of the Front Toe of Slope

River Channel Segment Classification	Verification Criteria (Estimated width of high-water channel eroded by one flood)
1	About 40m
2-1	Width of high-water channel *b*> Five times the low water riverbank height *H*
2-2 and 3	Width of high-water channel *b*> Two to three times the low water riverbank height *H*

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5*

The middle and lower part of the Indus River is generally considered to be 3 and 2-2 (partially) according to the segment classification.

Typical Segment Types and Characteristics of Alluvial River Channel Sections in Japan

Segment Classification	Topographic Classification	Representative Particle Size of Riverbed Material dR	Materials of Riverbank	Riverbed Gradient
1	Alluvial Fan	2 cm or more	Sand and silt may be placed on the surface layer; thin and consists of the same substance as the riverbed material	1/60~ 1/400
2-1	Natural Bund Zone	3cm~1cm	Mixed material of fine sand, silt and clay. However, the lower part is the same as the riverbed material	1/400~ 1/5,000
2-2	Natural Bund Zone	1cm~0.5mm	Mixed material of fine sand, silt and clay. However, the lower part is the same as the riverbed material	1/400~ 1/5,000
3	Delta	0.5mm~	Silt, clay	1/5,000~ Horizontal

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5*

<Reference information>

Bunds on the Indus River are particularly experiencing damage due to seepage and erosion. For this reason, it is especially important to evaluate the safety against seepage and erosion.

Verification against seepage involves checking the safety against slip failure and piping failure of ground foundation. The constants, safety factors, etc. are based on Japanese standards. If a revision becomes necessary in the future, changes will be considered. The maximum external force for verification against seepage is the river flow velocity. Essentially, the structure of slope surface protection work, and foot protection (revetment) work are examined with accordance to the representative flow velocity.

By calculating the unsteady seepage flow, the seepage path is verified and countermeasures are considered. Verification of circular slip is conducted and countermeasures are considered.

Regarding seepage flow analysis software, verification can be conducted using currently available software. For reference, an overview of the main software was provided.

The vegetation method for erosion control has not been employed to protect the slope of bunds in the Indus River, partly due to climatic conditions. This will be used as a reference when considering slope protection by vegetation in the future.

3.4 Maintenance of Bund

In the current manual, bund maintenance is partially discussed in Vol. 1 Chapter 5、Vol. 2 Chapter 6; thus, it is difficult to understand the whole picture. The entire flow of information on seepage and erosion is important and should be compiled as supplementary items.

3.4.1 Seepage Countermeasures

(1) Subject of Supplementary Items: Vol 2 Ch 2-6.2.7.10 (Addition) Seepage Countermeasures for Bund Strengthening

Chapter and Article of Current Bund Manual Vol. 2: Chapter 2: River Training & Flood Management 6. Seepage control
Relevant Articles in the Sindh Bund Manual NONE

<Reasons and summary of supplement>

Description and specific design method for seepage countermeasures of bunds are given.

<Content that should be added to manual>

Vol 2 Ch 2-6.2.7.10 (Addition) Seepage Countermeasures for Bund Strengthening (Standard)

1) Basic Policy on Bund Seepage Countermeasures

The basic policy of seepage countermeasure works on river bunds is as follows.

1. Minimize water seeping into the bund as much as possible.
2. Safely drain the water that has seeped into the bund.
3. Reduce the hydraulic gradient.
4. Enhance the shear strength of the bund.

2) Considerations for Seepage Countermeasures

The main considerations for seepage countermeasure works are as follows.

1. Examine the function, effectiveness, workability, and durability of the materials used and applicable construction methods.
2. Consider life cycle costs such as countermeasure work costs and maintenance expenses.
3. Consider maintenance strategies and risk management methods.
4. Examine the impact on the river environment, landscape, living environment, culture, climate, etc. of the surrounding area.
5. Consider seismic countermeasures when the ground foundation is evaluated as being vulnerable to earthquakes or liquefaction (due to soft foundation or loose sand layer), as this could affect seepage.

3) Basic Countermeasure Works

The countermeasure actions corresponding to the above four basic policy items are outlined as follows.

a) Methods to control and reduce water seepage into the bund and ground foundation

Surface slope seepage-controlled method, full coverage method, blanket method, cut-off wall method, and foundation improvement method

b) Drainage of water seepage in the bund

Drain work of bund interior, drain work at the back of the bund, drainage method at the back of the bund

c) Methods of reducing hydraulic gradient

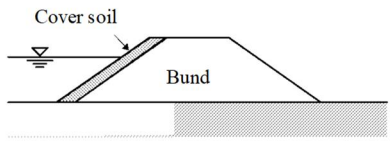
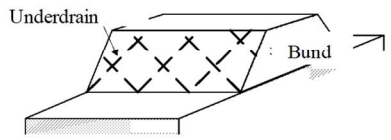
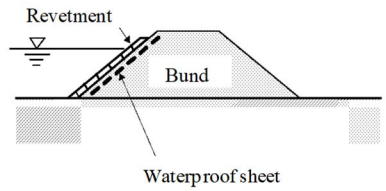
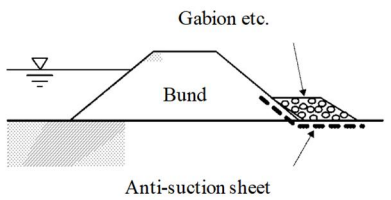
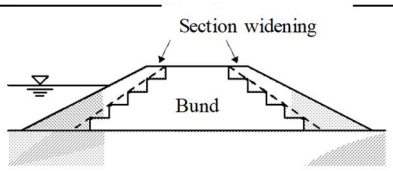
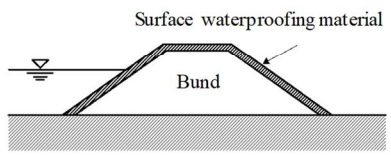
Loading berm at the back of the bund, blanket method, cut-off wall method, cross-sectional enlargement method, and river volume expansion method

d) Bund strengthening method

Full surface coating method, loading berm method, cross-sectional enlargement method, surface slope seepage-controlled method, drain method, stabilization method, soil quality improvement method, and grouting method

The main countermeasures are shown in the table.

Types and Applications of Seepage Countermeasure Works (Bund)

Countermeasure method			Purpose	Problems and matters to consider	Countermeasure model
Bund Countermeasure works	Seepage at front surface prevention method	Covering work of good quality soil	• Reduce seepage from bund surface	• Consider long-term stabilization measures in terms of deterioration due to waves and construction method • Consider measures to prevent scouring and erosion during times of high water	
		Slope drainage work	• Quickly drain rain water	• Has a large effect on rainfall countermeasures • No effect on flooded areas	
		Water cut-off revetment work	• Prevent seepage from bund surface • Prevent scouring of front slope surface and prevent soil runoff	• Consider slippage of water cut-off materials such as sheets, and consider measures to prevent floating due to residual water at the back of revetment • Consider environmental and landscape countermeasures such as soil covering and vegetation	
	Drainage method at toe of slope		• Drain water that had seeped into toe of bund slope and prevent slippage • Reduce seepage pressure	• Need to secure land at the back slope • If drainage is considered, investigate the selection of drainage material and measures to prevent suction	
	Section widening method		• Widen the section of the bund and lengthen the seepage path	• Makes the slope as gentle as possible to prevent slippage • As the section of the bund expands, rainwater is more likely to seep through, so consider making the bund less permeable and implement drainage countermeasures • Consider measures to prevent uneven subsidence	
	Surface waterproofing method		• Make it such that river water and rainfall do not easily seep into the bund • Increase shear strength by covering the entire surface with soil, increasing the stability of the bund • Protect bund surface with waterproofing material	• The bund should be an overflow-resistant structure if it has to also serve to counter overflow • If the structure is highly watertight, consider measures to exhaust and drain water from within the bund • Consider measures to prevent damage to the waterproofing material due to uneven subsidence which would allow water to seep through the damaged areas • Consider measures to prevent cavities from forming under the waterproofing material.	

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Countermeasures Against Leakage of Levees, Chapter 7 Design and Construction Method of Water Leakage Countermeasures*

<Reference information>

The current manual also includes descriptions of countermeasure works. When selecting a countermeasure for seepage, it is important to clarify the problem of seepage, and then comprehensively consider its applicability, including complete reconstruction, fully taking into accounts the soil conditions and external force conditions at the bund site, as well as the history of damage. In addition, when considering countermeasures against seepage, it is necessary to consider a combination of several countermeasures, since it is sometimes difficult to demonstrate the full effect of a single countermeasure. In cases where bunds are extremely vulnerable to seepage, and where strengthening the bunds would require a large amount of money, it is necessary to consider complete reconstruction when strengthening the bunds.

3.4.2 Erosion countermeasures

(1) Subject of Supplementary Items: Vol 2 Ch 2-6.2.7.11 (Addition) Seepage Countermeasures for Bund Strengthening

Chapter and Article of Current Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 6.2.2. Slope Stability 8.1.7. Closing process for a Large River Breach
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

Description and specific design methods of erosion countermeasures of bunds are given.

<Content that should be added to manual>

Vol 2 Ch 2-6.2.7.11 (Addition) Seepage Countermeasures for Bund Strengthening

1) Basic Approach to Bund Erosion Countermeasures

The basic concept of erosion countermeasures is to consider the river channel characteristics at select sections along with the safety verification results, and comprehensively look for appropriate strategies.

The safety of the bund against erosion is evaluated separately for cases when there is a revetment and for cases when there is no revetment.

(a) If there is no revetment, the safety against direct erosion on front and toe of bund slope, along with the safety against lateral erosion and scouring from the main channels (such as low water channel) are examined.

(b) If there is a revetment, surface lining, foundation, and foot protection works of the existing revetment are checked to determine whether they are mechanically stable against the expected external force. Based on the results of the evaluation, countermeasures will be investigated.

2) Selection of Basic Countermeasure Methods

Erosion countermeasures against erosion can be broadly divided into (1) capacity strengthening, (2) reduction of erosive external forces, and (3) a combination of both ((1) and (2)). The strengthening of capacity in (1) is to strengthen by installing revetment work, for example, when the capacity of the bund front slope is greatly lacking. If there are concerns for the capacity of the front surface, such as concerns about the vegetation management on bund surface, it is possible to install an erosion prevention sheet as a method of strengthening the capacity. On the other hand, when the flow velocity in the vicinity of the revetment is high and the safety of the surface lining is insufficient, reinforcement (1) such as spur installation, which lessens the external force of erosion and reduces the flow velocity near the revetment, may be effective. Furthermore, depending on the degree of danger of bund, method (2), which combines (1) and (2), may be appropriate.

Depending on the existing conditions of the river channel, modification of the channel alignment shape, installation of spur with a splashing effect, construction of flood channel, and installation of vane may be effective in reducing the flow velocity and scouring depth. Although these measures can be considered as ways to reduce erosion and scouring, they may have unexpected effects on the downstream side and should be considered in conjunction with the river channel planning study. In addition, sufficient study by numerical calculations and model experiments is necessary for this type of bund strengthening. Major countermeasure works are listed in the table below.

Example of the Relationship Between Safety Verification Results and Bund Strengthening Methods

Safety Verification Result			Bund Strengthening Method	
			① Capacity Strengthening	② Reduction of Erosive External Force
No revetment work	Direct erosion of front surface and toe of bund slope		• New construction of high water revetment • Laying of erosion prevention sheets • Thorough management of bund vegetation	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
No revetment work	Lateral erosion and scouring from main channel (low water channel, etc.)		• Construction of low-water and bund revetments • Installation of (embedded) spurs • New construction or widening of high water channels that do not affect upstream and downstream • Installation of vertical spurs	・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Insufficient thickness of surface lining		• Renovation of revetment work • Widening of surface lining work • Converting hollow stone piling to kneaded stone piling • Converting hollow block piling to kneaded block piling	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Insufficient penetration of foundation work		• Renovation of revetment work • Foundation underpinning • Installation of foot protection work	• Installation of foot protection work ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Foot protection work	Insufficient weight	• Renovation of foot protection work • Integration of foot protection blocks (linkage and secure layer stacking) • Addition of foot protection blocks	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method
Revetment work is present	Foot protection work	Insufficient installation width	• Renovation of foot protection work	• Installation of spurs to reduce flow velocity ・Backfill using replacement method ・Adjustment of alignment shape ・Installation of spurs to create water splash effects ・Vane method

Note: ⬚ represents measures that should be investigated in conjunction with river channel planning

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5 5.4*

Source: *Guide for the Structural Study of River Bunds (Revised Edition) H28 Chapter 5 5.4*

<Reference information>

In the absence of revetment, erosion countermeasures typically involve slope protection, with the construction of revetment as the primary measure. The decision on whether or not to construct a revetment is based on a comprehensive judgment of the topographical conditions, the importance of the bund including budget, and the urgency of strengthening the embankment.

3.5 Investigation of Spur

The current manual includes a list of diagrams and concepts for various spurs. However, necessity and concept of spurs are not clearly explained. Therefore, a detailed discussion on spurs should be added, with clarification of the examination process from basic concept to design stage.

(1) Subject of Supplementary Items: Vol 1 Ch 5- 5.4.7 Spur

Chapter and Article of Current Bund Manual
Vol.1: Chapter 5: River Training & Flood Management 5.4.7. Spurs (or Groynes) Vol.2: Chapter 2: River Training & Flood Management 15.5.5. Spurs 15.5.6. The Negative Side of Flood Embankments and Spurs
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

The basic concept and structure of spur are presented.

<Content that should be added to manual>

Vol 1 Ch 5- 5.4.7 Spur (Standard)

1) Basic Concept of Spur

The shape and structure of a spur are designed based on its intended functions. Functions of a spur include protection of bund, low water channel riverbank erosion and scouring control, preservation and creation of river environment and scenery, and maintenance of water route. At the same time, based on channel characteristics of the target river, structural durability, ease of maintenance, ease of construction, economic efficiency, and ease of use by the public, etc., are to be comprehensively considered. It is important to design spur, either individually or grouped, with due consideration given to its impact on the surrounding river channel.

2) Basic Structure of Spur

There are two types of spurs: (a). permeable and (b). impermeable spurs. The structure of permeable spurs allows for the passage of flowing water; thus, the spurs themselves act as a rough element that reduces flow velocity. This prevents scouring and can promote sediment deposition if the spurs are properly arranged. On the other hand, impermeable spurs do not allow flowing water to pass through. Although the water splashing effect is large, the head and the downstream part of the spurs are particularly susceptible to scouring, so it is often necessary to install foot protection around the spurs. In addition, impermeable spurs are further classified either as non-overflow or overflow spurs. The height of an overflow spur varies depending on its purpose.

- Overflow spur : spurs submerged by floods with average annual water level
- High water spur: average annual flood level is set as its height
- Low water spur: normal water level is set as its height

3) Functions and Shapes of Spurs

The following spur structures are chosen based on their purposes:

(i) For the purpose of reducing flow velocity

a) Their height is low.
b) They are either permeable or impermeable with low height relative to water depth.
c) They are lightweight and are constructed mainly through pile work.
d) Several (or tens) of them are placed side by side and they function as one.

(ii) For the purpose of splashing water

a) They are tall.

b) They are either semi-permeable or impermeable.
c) Spurs are mainly constructed from materials such as earth, stone, or concrete, etc., and have a large volume. Structurally, they are considered heavy.
d) They are installed either individually or in small groups arranged side by side.

4) Concept of Spur Design

Compared to revetment, spur is more difficult to design based on a theoretical interpretation. Therefore, it is designed based on past experiences and actual implementation at similar rivers or the results of test construction, model experiments, and research studies related to new types of work. Workability, economic efficiency, maintenance, and safety of river users are also considered. River channel can drastically change, so it is difficult to accurately predict the various characteristics (e.g., riverbed height and flow velocity during a flood) of river channel where spurs are installed. Therefore, the following points should be considered for a more rational spur design.

(i) Local Scouring Around the Spur

Spur is installed in the river channel and acts as an obstacle that reduces flow velocity closer to the river bank and splashes water. This leads to the concentration of flowing water at the spur head, which causes scouring around the spur. While this scouring serves as a function to secure the water depth of the spur head, it also causes damage to the spur. Therefore, it is necessary to evaluate in advance what the scouring depth around the spur and the scouring range are.

(ii) Effect of Reducing Flow Velocity Through Spur

There are two methods for evaluating the flow velocity reduction effect of spurs: (1) representing the group of spurs as an equivalent roughness, and (2) calculating the drag force acting on the spurs. While the flow velocity reduction effect of the group of spurs along the river can be fundamentally evaluated according to this concept, but it poses the following challenges.

a) Experimental studies have not been conducted for various shapes of spurs. For spurs with complex shapes, various theoretical coefficients must be obtained through experiments.
b) The method of assessing the flow velocity near the boundary between the spur area and the main channel is unclear.
c) The effect of water control should not be evaluated by the average flow velocity of the spur area, but by the relationship with the action of sediment within the group of spurs. However, this relationship is not clear.

(iii) Conditions for Sediment Accumulation Within Spur Area

Since installation of spurs can cause sediment accumulation in between the spur area, assessing their effects and impacts is important. In this case, since the mode of sediment transport differs depending on the material deposited in the spur area, it is necessary to evaluate the amount of sediment accumulation and erosion for each sediment particle size group.

(iv) Movement Limit Flow Velocity of Spur Materials

Cobblestones, split stones, concrete irregular-shaped blocks, etc. used as spur materials should not significantly change their position or shape due to the action of flowing water. This ensures that the spur can maintain the function of spurs. In other words, weight, size and shape of spur materials need to be set such that they are not moved by the water flow.

(v) Spur and River Shore Lines

In case a high-water channel is created when sediment is deposited in between tall spurs, or when the riverbed in between the spurs is reclaimed artificially, it is necessary to investigate the changes to river shore lines.

5) Spur Design

An overview of spur design is presented.

(i) Direction

The direction of spurs can be upward, perpendicular, and downward relative to flow direction. Based on past results, the upward direction is considered most preferable, as it helps reduce scouring downstream of the spurs and accumulates sediment in between the spurs. For splashing spurs installed in the middle of the river, the perpendicular direction is considered to be fine. However, if it is turned

slightly upward, water would flow over the spurs which reduces downstream scouring and promotes sediment accumulation in between the spurs.

(ii) Length, Height and Spacing

The length, height, and spacing of spurs shall be determined with reference to literature and past examples, taking into account the condition of river channel, the purpose of spur installation, the impact onto the up and downstream area and the opposite shore, as well as the safety of the structure itself.

a) Foot Protecting Spur for Riverbank Erosion Prevention

Generally, employing a single strong spur to resist water flow increases turbulence and often leads to large scouring within its vicinity, and complicates the maintenance of the spur itself. Therefore, it is important to structure and arrange spurs such that flow velocity is reduced by the overall effect of group of spurs over a specific section, and each spur exerts equal resistance. With this perspective in mind, there are examples of the shortening of spur length at the upstream side to lessen the burden of the water current on the upstream spur.

As for the basic shape of spurs installed to reduce the flow velocity, the length are often set to be less than 10% of river width. The height is typically 0.2 ~ 0.3 times the water depth during design flood flow. The spacing is often 2 ~ 4 times the length and 10 ~ 30 times the height. For river with concave shoreline, the spacing of the spurs is often less than twice the length.

In general, during the spur and revetment co-design process, spurs are often not placed too far out for ease of maintenance, construction cost and economic reasons.

b) Water Splashing Spur for Riverbank Erosion Prevention

When installing tall and impermeable spurs, they should not be positioned as foot protecting spurs, and instead be positioned such that the line connecting the tips of spurs forms the boundary line of riverbank protection. In addition, it is not a good idea to employ excessively long impermeable spurs due to construction costs.

Water level in front of the spurs rises only to the flow velocity head of the spur tip. Therefore, a strong and well-compacted revetment should be installed to a sufficient height, taking into account the difference in water levels before and after the installation of spurs.

For this type of spur, spacing should be about 1/2~1/3 of the length of the sandbar that forms at the target section. Moreover, the direction should be perpendicular to the river bank or slightly downward.

Source: *Technical Criteria for River Works: Practical Guide for Designing Chapter 1 Section 4 Revetment and Spur*

<Reference information>

Japan and Pakistan have somewhat different perspectives on the main function of spurs. In Japan, the common purpose of spurs are to reduce flow velocity (promotion of sedimentation, etc.) and secure the water route. However, the main purpose of spurs along the Indus River in Pakistan is to facilitate in splashing water.

3.6 Bund Management Plan

A new chapter on bund management plan will be established since there is no overall specific description. Additionally, explanation and criteria will be provided to supplement the existing information.

(1) Subject of Supplementary Items: Vol 2 Ch 2-2.16 Flood Countermeasures Planning

Chapter and Article of Current Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 15.5.6. The Negative side of Flood Embankments and spurs 16. Outline of flood fighting plans 17. Timeline for flood preparedness Vol.2: Chapter 8: Asset Management Plan 1.1. Asset Management 1.2. Framework for Preparing an Asset Management Plan
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

An overview of bund maintenance plan and concept of cycle-type maintenance are provided.

<Content that should be added to manual>

Vol 2 Ch 2-2.16 Flood Countermeasures Planning (Standard)

1) Basic Concept of Maintenance Plan

Maintenance of bund will be carried out systematically over multiple years, taking into account flood history and relevant experiences at other rivers. Plan of bund maintenance are planning related to river development and bund maintenance. The contents of bund maintenance shall be stipulated to clarify the overall picture of river development, including the maintenance of rivers. The bund maintenance plan shall be stipulated to specify the contents of bund maintenance with regards to river development.

2) Matters Stipulated in the Plan

In determining the goal and implementation of bund maintenance, the frequency and density of bund maintenance must be set according to the river characteristics at each section.

The assessment of bund condition is conducted through river patrols and inspections to determine whether there is interference to the goals set for the bund, such as flood control, water use, and environment functions, as well as illegal acts in river management. Methods and frequencies, specific maintenance countermeasures, regional cooperation, and other initiatives for efficiency and improvement will be determined. Specifically, the followings are performed.

(i) River Outline

Based on river characteristics, the following items are referred to as the river outline.

1. Various specifications such as river basin area, trunk river course length, management length, riverbed gradient, etc.
2. Natural and social characteristics of river basin
3. State of river channel characteristic, damage history, topography, geology, vegetation, and other relevant factors.
4. State of sediment movement characteristics from sediment production area to estuary
5. River environment consideration for management, such as living organisms, water quantity and quality, landscape, and usage of river space
6. Other necessary matters

(ii) Matters to Be Considered for Bund Maintenance

From the standpoint of bund maintenance (such as river channel maintenance and facility

management), matters that should fundamentally be considered include state of river channel's characteristic, regional characteristics, and the deterioration of river management facilities.

(iii) Sectional Division of Bund

River is divided into sections to facilitate appropriate maintenance. The division is set in accordance with flood type, river hinterland population, condition of assets, river channel's characteristics, etc.

In general, river is divided into two sections: important section, described as "being alluvial rivers; having a large population and assets in flooded area; having hinterland that should be protected by bunds", and normal section.

(iv) Bund Maintenance Target

For each bund section, the basic principle is to establish goals for bund maintenance based on current state of river and immediate goal of river development. Goals should be expressed quantitatively when possible and qualitatively when necessary.

(v) Assessment of Bund Condition

Method and frequency of bund condition assessment should be specifically set according to the sectional division, maintenance targets, etc.

Referring to the points below, it is desirable for basic concept, location, frequency, timing, and consideration points of the implementation to be described.

1. Basic Concept of Implementation: Describe, for each item to be implemented, what policies are to be implemented for river patrol, inspection, etc. based on characteristics of sectional division.
2. Location, frequency, and timing of implementation: Based on the basic concept of implementation, describe the specific condition assessment method for each item to be implemented.
3. Consideration points of implementation: Describe the basis for determining the location, frequency, and timing of implementation, as well as any specific points of consideration, such as the state of river use or the presence of important living organisms.

Details of the implementation at the same section do not have to all match each other and instead should be determined based on bund characteristics.

(vi) Specific Maintenance Measures

The basic principle is to describe the details of specific maintenance measures, such as addressing illegal activities, conducting maintenance work, and repairing/renewing facilities, to be implemented when results of river patrol and inspection results indicate potential hinderances to river management. These specific maintenance measures are described in the chapter on Inspection and Maintenance.

(vii) Initiatives for Efficiency and Improvement

Important matters regarding efforts aimed at improving river development, conservation and bund maintenance efficiency though further regional cooperation as well as efforts to promote the optimization and betterment of bund maintenance are described.

3) Cycle-type maintenance

Regarding river management, knowledge obtained from revolving day to day inspection (such as river patrol, condition assessment through inspection, and maintenance countermeasure) is analyzed and evaluated. It is important that the knowledge is reflected in the planning or the implementation of river maintenance. Traditionally, in river management, safety has been ensured adaptively through the repeating cycle of the occurrence of river deformation along with its response, the occurrence of disasters due to water discharge along with their countermeasures and various new improvement. This forms the cycle of "Plan", "Do", "Check", and "Action", which is crucial for ensuring appropriate and efficient bund maintenance.

It is also necessary to incorporate the findings from the PDCA cycle of river management into the river management plan and link them to the development and revision of the plan as necessary.

The following is an example of PDCA cycle for the maintenance, design, inspection, and repair of bunds.

Example of PDCA Cycle for Bund Maintenance, Design, Inspection, and Repair

Phase	Content	Specific Activity		Indications
		Maintenance	Design & Repair	
P (Plan)	Planning	• Evaluation of current bund state • Setting maintenance target • Formulation of specific maintenance plan • Budget, personnel planning	• Establishment of bund design standards for bund • Collection and analysis of topographical and hydrological data • Necessity Evaluation of repair and formulation of plan • Preparation of design drawing	1. Standard bund shape 3. Safety assessment 4. Bund maintenance
D (Do)	Execution	• Implementation of inspection and maintenance work as planned • Implementation of necessary repair and renovation work • Regular collection of data	• Construction of bund based on design • Implementation of repair work • Construction management and quality check	2. Quality control 4. Bund maintenance 8. Information management
C (Check)	Evaluation	• Recording inspection results • Effectiveness evaluation of work performed • Degree of completion check • Problem identification	• Performance evaluation of the completed bund • Post repair effectiveness check • Identification of problems and issues	3. Safety assessment 7. Inspection maintenance (river condition monitoring) 10. Gaps with manuals
A (Act)	Improvement	• Formulation of improvement measures based on evaluation results • Reflection onto next stage plan • Review of maintenance system	• Review of design and construction methods based on evaluation results • Reflection onto next stage design and repair plan • Strengthening maintenance system	1. Standard bund shape 4. Bund maintenance 6. Bund management plan

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 2 Section 1 River Maintenance Plan*

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 2 Section 1 River Maintenance Plan*

<Reference information>

It is desirable for the bund maintenance plan to specify the details of bund maintenance activities to be carried out over a period of about five years.

3.7 Inspection Maintenance (River Condition Monitoring)

In the current manual, inspection maintenance is individually discussed in Vol. 1 Chapter 5, Chapter 8, Vol. 2 Chapter 2, making it difficult to understand the whole picture. The entire flow related to patrol and inspection maintenance is important and is compiled as supplementary items.

Chapter and Article of Current Bund Manual
Vol.1: Chapter 5: Barrages 5.16 Inspection of river training works 5.19 Operation and maintenance 5.21 Records to be maintenance Vol. 2: Chapter 2: River Training & Flood Management 16. Outline of flood fighting plans 17. Timeline for flood preparedness Vol.2: Chapter 8: Asset Management Plan 1.1. Asset Management 1.2. Framework for Preparing an Asset Management Plan 1.9. Preparation of a Revised/Updated or Fresh AMP
Relevant Articles in the Sindh Bund Manual
NONE

3.7.1 Patrol

(1) Subject of Supplementary Items: Vol 1 Ch 5-5.16.4 Inspection Team

Chapter and Article of Current Bund Manual
Vol.1: Chapter 5: Barrages 5.16.3 Inspections and Overall Surveillance 5.16.4 The Inspection Team
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

Concept and purpose of patrol are discussed.

<Content that should be added to manual>

Vol 1 Ch 5-5.16.4 Inspection Team (Standard)

1) Concept and Purpose of Patrol

River patrols are generally conducted to assess the condition of river channels, and river management facilities, detect illegal activities and violations within river areas, collect information on river space utilization, and to collect information on natural environment of rivers.

River patrols of river channels, and management facilities, etc., should be carried out at appropriate times, taking into account the structure, maintenance or repair status of river management facility, river condition, weather condition in the area of the management facility, and other conditions. In addition, to enhance the efficiency and effectiveness of patrols, the adoption of new technologies, such as image analysis using UAVs, should also be considered.

2) Ordinary River Patrol

Ordinary river patrol forms the basis of river maintenance, and is carried out in order to patrol river as regularly scheduled and to comprehensively assess any abnormalities and changes.

If an abnormality is found during the patrol, it is important to immediately evaluate the situation, record

it in river records, etc., and rectify it appropriately. Ordinary river patrol is mainly carried out for the following items.

a) Identify relatively large-scale deformation that can be visually confirmed in river channel and river management facility
b) Confirm whether there are any illegal acts or violations regarding occupation of land and installation status of structures in river area, river conservation area, and projected river area
c) Assess the daily use of river
d) Understand daily condition of natural environment, such as condition of riffle, pool, water route, location of sandbar, condition of trees in the river channel, impact of trees on flood flow, and state of non-native vegetation on bund and river site

3) Response to Abnormalities and Anomalies Found During Ordinary River Patrol

Detailed patrol and inspection are conducted as necessary for the abnormalities and anomalies confirmed during river patrol.

a) Area with inspection history is to be patrolled with special attention
b) If it is determined that the detected deformation interferes with the function of facility, an individual inspection will be carried out to look for countermeasures
c) If any unauthorized or prohibited activity is discovered, situation is to be assessed and necessary action is to be taken

4) River Patrol During a Flood

During a flood, situation can change from moment to moment, so it becomes necessary to swiftly take appropriate measures in response. Therefore, river patrol is carried out to comprehensively and quickly assess conditions of bund, flood flow, trees in river channel, river management facility, etc. as well as the inundation of area protected by bunds. It is also necessary to assess the state of flood prevention operation and inner water drainage. To conduct river patrol during a flood, it is desirable to employ the usage of all-weather UAVs.

When abnormalities such as leaks or collapses are detected during the river patrol, appropriate measures such as flood prevention work or emergency repair must be taken immediately. Therefore, it is necessary to maintain close communication with relevant agencies. In addition, leaks and collapses should be recorded in river records, etc., as they are important information for future river maintenance. Whilst conducting river patrol during a flood, collecting records is important.

Based on past results of river patrol and inspection, damage history, etc., conditions for conducting river patrols, such as sections where there is a possibility of bund damage, are set. Those sections are considered as target flooded sections and river patrol will be conducted there.

Source: *Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 4 River Patrol*

<Reference information>

River patrols are generally performed to visually identify abnormalities and anomalies. Detailed patrols and inspections are carried out as needed.

3.7.2 Inspection Maintenance

(1) Subject of Supplementary Items: Vol 1 Ch 5-5.16.6 Safety Inspection and Evaluation

Chapter and Article of Current Bund Manual
Vol.1: Chapter 5: Barrages 5.16.5 Data Collection 5.16.6 Safety Inspection and Evaluation 5.16.7 Frequency of Safety Inspections
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

Concept, purpose, implementation, method, etc. of inspection maintenance are provided.

<Content that should be added to manual>

Vol 1 Ch 5-5.16.6 Safety Inspection and Evaluation (Standard)

1) Inspection Before Flooding

(i) Concept and Purpose of Inspection

Inspection is conducted to identify, observe, and measure abnormalities and changes affecting the flood control functions of the target river channel and individual river management facilities. In addition, inspection is also conducted to assess the deformation and deterioration of river facility. The assessment is useful as basic data for countermeasures against abnormalities.

In addition, it is important to assess the condition of individual facility and comprehensively judge the necessity and priority of countermeasures against flooding in the river as a whole. Accordingly, this approach enables more effective and appropriate maintenance.

The maintenance of river channels and river management facilities has been carried out based on years of accumulated of experience in patrol and inspection. It is important to employ experienced managers to ensure inspection are conducted appropriately, as well as to pass down the skills to newcomers.

(ii) Inspection Timing and Frequency

Inspection of river management facilities should be carried out at an appropriate time, taking into account the structural state, maintenance or repair condition of the facility, river condition, weather condition at the area where the river management facility is located, and other conditions. It should be conducted at least once a year, ideally before the monsoon season.

(iii) Inspection Method

(a) Outline of Inspection

Judgement criteria for evaluating the inspection results of each deformation point shall be set for each river individually according to its characteristics. For reference, this section shows examples of judgement of deformation based on past literature and results of river management facility maintenance to date. However, in the future, the content will be reviewed and enhanced as necessary based on further accumulation of knowledge as well as collection and issue sorting of cases where this guideline was applied.

In particular, since bunds are earth structures that have been repeatedly built and repaired many times from the past to the present, quality of the constituting material is often uneven. For this reason, there is not enough technical data at this time to indicate quantitative evaluation criteria. Inspection of bunds and evaluation of the results have been carried out based on the experience of engineers, and this will continue into the future. Quantitative evaluation criteria will be established once sufficient technical data has been collected and analysis becomes feasible.

In the inspection, based on improvement of existing technology and progress of new technology of recent years, non-destructive inspection of the back of revetment by radar cavity exploration,

river topographic monitoring technology using aviation lasers, and topographic surveying technology using Unmanned Aerial Vehicles (UAVs) are to be utilized as necessary. In the future, displacement of bund topography will be assessed using a Mobile Mapping System (MMS).

(b) Inspection Items

a) Basic Items

Evaluation of bunds shall focus on the following functions to determine the state of function deterioration.

State of Function Deterioration of Earth Bund

Function	State of Function Deterioration
Overflow Prevention	[Subsidence] The necessary height cannot be secured due to subsidence of bund or ground foundation, and the overflow prevention function is impaired.
Seepage Resistance	[Slip Failure] The increase in pore water pressure due to seepage of river water or rainfall into bund during a flood lowers bund strength and causes bund slippage. This results in impairment of seepage resistance function.
	[Occurrence of Piping] The increase in pore water pressure due to seepage of river water into ground foundation during a flood moves soil particles and causes piping. This results in impairment of seepage resistance function.
Erosion Resistance	[Erosion] The sweeping force of rainwater and flowing water during a flood erodes the front and toe of bund slope. This results in impairment of corrosion resistance function.

***Source**: Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

b) Inspection Items

Focusing on the overflow prevention, seepage resistance, and erosion resistance functions of earth bund, the following inspection items will be evaluated.

Technical terms (Protrusion and Slope Failure) are illustrated below.

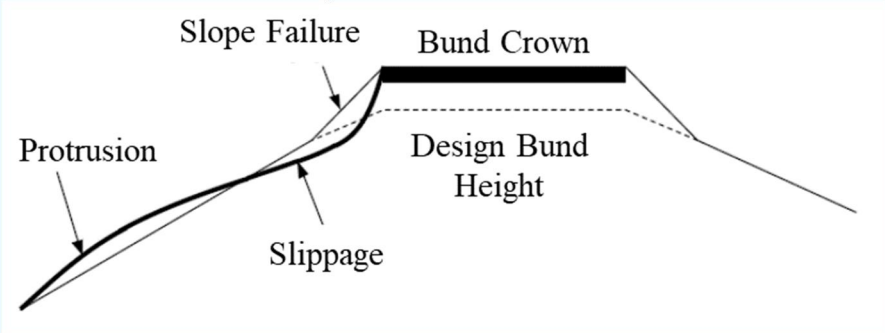


Diagram of Protrusion and Slope Failure

(iii) Evaluation Items

Judgement criteria for evaluating the inspection results of each deformation point shall be set for each river individually according to its characteristics. For reference, this section shows examples of judgement of deformation based on past literature and results of river management facility maintenance to date.

Inspection Items of Earth Bund

Function	State of Function Deterioration	Type of Deformation	Description of Bund, River Management Facility and River Channel Inspection		
			Item	Location	Inspection item
Overflow Prevention	Subsidence	[1] Crack	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
				Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette?
				Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[4] Subsidence	Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[6] Protrusion	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund		- Are there openings in the bund due to groups of holes for small animals such as moles? - Is there a cave-in due to groups of holes for small animals such as moles?
Seepage Resistance	Slip Failure	[1] Crack	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette? - Is there a cave-in due to groups of holes for small animals such as moles?
			Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[3] Slope Collapse	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[5] Deformation of Bund Foot Protection Work	Bund		- Are there any deformations of the bund foot protection work (or is it more developed than before the flood season)?
		[6] Protrusion	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[7] Slope Failure	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund	Slope and Banquette	- Are there openings in the bund due to groups of holes for small animals such as moles? - Is there a cave-in due to groups of holes for small animals such as moles?
		[9] Poor Drainage	Bund	Slope and Banquette	- Are there any inverted slopes or locally low areas at the banquette that are causing problems with rainwater drainage? - Are there any areas where the slope and banquette are muddy?
	Piping Failure	[1] Crack	Bund	Slope and Banquette	- Are there any crack, cave-in, protrusion, slope collapse, slope failure, erosion, etc. on the slope and banquette (or are they more developed than before the flood season)?
		[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette?
			Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund	Slope and Banquette	- Are there openings in the bund due to groups of holes for small animals such as moles? - Is there a cave-in due to groups of holes for small animals such as moles?
		[9] Poor Drainage	Bund	Slope and Banquette	- Are there any inverted slopes or locally low areas at the banquette that are causing problems with rainwater drainage? - Are there any areas where the slope and banquette are muddy? - Are there local clusters of vegetation species that prefer moisture?
			Bund	Toe of slope	- Is there any seepage due to poor drainage near the bund base? - Is there any area where groundwater always seeps through?
		[12] Water Leakage and Sand Boil	Bund	Toe of slope	- Are there any water leakage or sand boil near the toe of slope?
Erosion resistance	Erosion	[2] Cave-in and Unevenness	Bund	Slope and Banquette	- Are there any unevenness at the slope or banquette? - Is there a cave-in due to groups of holes for small animals such as moles?
			Bund	Crown	- Are there any deformations such as crack, cave-in, unevenness, subsidence, etc. at the bund crown and at the slope top (or are they more developed than before the flood season)?
		[8] Holes for Small Animals such as Moles	Bund	Slope and Banquette	- Are there openings in the bund due to groups of holes for small animals such as moles? - Is there a cave-in due to groups of holes for small animals such as moles?
		[10] Tree Invasion	Bund	Slope and Banquette	- Has there been any invasion or expanding of trees?
		[11] Erosion (Gully) and Vegetation Anomalies	Bund	Slope and Banquette	- Are there any abnormalities in the condition of bund vegetation and topsoil, such as peeling of upholstered turf? (or are they more developed than before the flood season)? - Is there scouring or erosion due to concentrated surface drainage at the slope and stair?
			Bund	Crown	- Is there any erosion at the top of the slope (or is it more developed than before the flood season)?

***Source**: Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

Judgement Criteria of Earth Bund's Inspection Result Evaluation Classification (reference)

Evaluation Classification by Deformation Type		Evaluation of Each Deformation ※1												Overall Rating	
		[1] Crack	[2] Cave-in and Unevenness	[3] Slope Collapse	[4] Subsidence ※2	[5] Deformation of Bund Foot Protection Work ※3	[6] Protrusion	[7] Slope Failure ※4	[8] Holes for Small Animals such as Moles	[9] Poor Drainage	[10] Tree Invasion	[11] Erosion (Gully) and Vegetation Anomalies	[12] Water Leakage and Sand Boil	Evaluation Classification	Condition
		Deformation Photo Example (Ground-1) P67	Deformation Photo Example (Ground-2) P68	Deformation Photo Example (Ground-3) P69	Deformation Photo Example (Ground-4) P70	Deformation Photo Example (Ground-5) P71	Deformation Photo Example (Ground-6) P72	Deformation Photo Example (Ground-7) P73	Deformation Photo Example (Ground-8) P74	Deformation Photo Example (Ground-9) P75	Deformation Photo Example (Ground-10) P76	Deformation Photo Example (Ground-11) P77	Deformation Photo Example (Ground-12) P78		
a	No abnormalities	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	No Deformation	A	No Deformation
b	Monitoring Required Stage	- Cracks have appeared, but functions of bund have not been disrupted - Includes minor repairs	- There is unevenness of terrain, but functions of bund have not been distrupted - Includes minor repairs	- Slope collapse has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Subsidence has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Deformation of bund foot protection work (opening of joints, etc.) has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Protrusion has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Slope failure has occurred, but functions of bund have not been distrupted - Includes minor repairs	- Holes for small animals such as moles can be confirmed	- Poor drainage can be confirmed at the time of flooding, after flooding, or after rainfall - Includes minor repairs	- Existence of short trees can be confirmed (those that can be easily cut down with a mower, etc.)	- The ground is bare, but functions of bund have not been distrupted - Vegetation causing the ground to be bare(e.g., Japanese knotweed) can be identified	- When wetland vegetation grows at the toe of slope, but the cause of wetland is not river water that seeps into the bund or ground foundation	B	- Functions of bund are not distrupted, but a deformation capable of progressing has been identified and its progress needs to be monitored
c	Preventive Maintenance Stage	Bund may deform rapidly due to the flood, etc., thus it is difficult to predict the deterioration. As such, "C" rating is fundamentally not set for (1) ~ (7). However, to date, repairs have been carried out for deformation over a certain scale. If the cause of deformation is unknown or if it is difficult to evaluate based only on visual examination results, a detailed inspection (including survey) shall be carried out as necessary.							- Holes for small animals such as moles are expected to cause the collapse within their vicinity. - In the case of molehills, stepping on them causes the ground to greatly sink	- Even though a few days have passed after the rainfall, the bund is still wet. - There is gushing of water from the bund.	- There is invasion of trees, but no change in the shape of bund. However, there is a risk that the trees will grow and interfere with bund functions.	- Erosion (gully) has occurred on the bund. - There is an abnormality in the bund vegetation such as peeling (which can be easily repaired) - If abnormalities of bund vegetation exist and slack within the bund body is confirmed, a detailed inspection (including survey) will be carried out and necessary measures will be taken.	- The toe and back surface of bund slope have become wetland, and wet vegetation can be seen. Because the cause of wetland is unknown, a detailed inspection (including survey) is necessary.	C	- There is no distruption to bund functions, but the situation can progress. Therefore, from the standpoint of preventive maintenance, it is desirable to carry out countermeasures. - A detailed inspection (including survey) is required to reassessment of the degradation of bund.
d	Take Action Stage	- There are cracks that interfere with bund functions. - There are cracks extending below the H.W.L, etc.	- There is cave-in that interfere with bund functions. - Cave-in and unevenness extend below H.W.L. Water ways are formed.	- Bund functions are hindered due to slope collapse.	- Bund functions are hindered due to subsidence.	- Bund functions are hindered due to deformation of bund foot protection work - There is a large deformation or misalignment which causes concerns for slippage at the back slope.	- Other complex deformations such as cracks and slope collapse due to protrusion hinder bund functions.	- Cracks caused by slope failure and the occurrences of slope collapse hinder bund functions.	- Holes for small animals such as moles and foxes cause [Changes in (1) ~ (4) conditions] and hinder bund functions. Alternatively, there is a risk that the holes will deepen into the bund and interfere with its functions.	- Poor drainage causes [Changes in (1) ~ (7) conditions] and hinder bund functions. - Soil movement near bund foot causes the deformation and collapse at the toe of slope.	- Tree invasion causes [Changes in (1) ~ (7) conditions] and hinder bund functions.	- Due to erosion (gully), erosion resistance function is lost, and bund functions are hindered.	- Leak and sand boil can be confirmed. - Leak and sand boil were confirmed after the flood.	D	- Bund functions were hindered and countermeasures such as repair, renovation, etc., are necessary.

*1: Taking into account the scale of bund and past damage history, it is set for each river (general deformation).
*2: Excludes areas around structures such as gutter gates.
*3: Whether this can cause the deformation of bund and ground foundation should be checked.
*4: In addition to slope slippage, slope failure may also occurr due to sliding when embankment is made for road occupancy. Therefore, when evaluating slope failure, it is necessary to check the history records, etc.

***Source**: Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

(iv) Preservation of Inspection Results

The results of patrols and inspections of river bund and river channel conditions shall be recorded. The inspection results must also be stored until the time of the next inspection or for a longer period as necessary.

2) Inspection After Flooding

(i) Purpose and Concept of Inspection After Flooding

The purpose of inspection after flooding is to assess the deformation of river channels and river management facilities after a flood, storm surge, tsunami, etc. At the time of the inspection, conditions of water discharge following a flood, storm surge and tsunami are determined according to the state of river, with a focus on the damage of river management facilities as well as the deformation of river channels. Inspecting whether the water level has surpassed the level that may reach the high flood level is done visually. In addition, if there is a flood whose scale exceeds the high flood level, a more detailed inspection of the damage to bunds and other structures will be carried out depending on the situation.

In particular, the assessment of river channel condition is assessing the conditions of riverbed scouring and sedimentation, riverbank erosion, falling trees, driftwood, living organism habitat and breeding place, etc. The assessment is conducted to gather important data for the review of future river channel planning, maintenance planning, etc. The content is to be recorded to the river records.

(ii) Inspection Items After Flooding

Main items to be inspected after flooding are shown below.

(a) River Channel Condition Assessment

For large rivers, depending on the situation, longitudinal and cross-sectional surveys are carried out. Detailed surveys are carried out in the event of localized deep scouring or sedimentation. In the event of large-scale river bank erosion, aerial photography will be carried out as necessary.

(b) Flood Level Survey

Flood mark, which is the height of the flood level reached, is an important data for the investigation of river flood control planning. Flood level surveys are conducted when a significant amount of water is released (e.g. exceeding the water level that may reach the high flood level) and consecutive marks remain on bunds. It is also desirable to investigate the mark on the inland area of the bund in the event of overflow.

(c) Bund Deformation Record

It is essential to assess any deformation that affects the erosion resistance and seepage resistance functions that bunds are meant to maintain. The results of this assessment should be recorded and organized in the river records.

3) Post-Earthquake Inspections

It is essential to conduct necessary inspections of river, taking into account to potential of earthquake scale. When bunds, weirs, sluice gates, etc., are damaged by an earthquake, it is necessary to quickly assess the condition of facilities that could particularly impact local communities (important river management facilities, etc.). Therefore, these target facilities should be selected in advance and special inspection is to be conducted.

***Source**: Ministry of Land, Infrastructure, Transport and Tourism, Technical Criteria for River Works: Practical Guide for Maintenance (River Edition) Chapter 4 Section 5 Inspection*

<Reference information>

By accumulating appropriate knowledge on river patrol and inspection, the overall river maintenance technology can be improved. Improving the skills of individual engineers, along with collecting and sharing data records are important for this process.

3.7.3 River Records

(1) Subject of Supplementary Items: Vol 1 Ch 5-5.16.8 Evaluation Reports

Chapter and Article of Current Bund Manual
Vol.1: Chapter 5: Barrages 5.16.8 Inspection / Evaluation Report 5.21 Records to be maintenance
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

The concept, overview, and importance of the information in river records necessary for the implementation of continuous river maintenance management will be presented.

<Content that should be added to manual>

Vol 1 Ch 5-5.16.8 Evaluation Reports (Standard)

1) Purpose and Concept of River Record Document

River records continuously record the results of river patrol and inspection as well as the content of maintenance and river construction. They importantly serve as the basis for assessing the condition of river management facilities (such as bunds) and river channels, and for investigating appropriate responses. They also serve as fundamental information for the embodiment of the PDCA river management cycle. In addition, in order to efficiently update and utilize river records, a river maintenance management database system will be constructed and managed.

2) Information Collected in River Record Document

Important information that should be passed on shall be confirmed at the cross-sectional coordinating meetings attended by the relevant departments of the PID office. It shall be gathered and compiled for the river records.

In addition to the modification caused by river construction, the following changes related to the state of river management facility (such as bund, sluice, flood gate, barrage, ground sill, drainage machinery) and river channel shall be obtained through from river patrol, inspection, information from the community, etc. Each change is to be gathered together with location information on the plan so that change over time can be checked.

- Changes in water route (sandbar), abnormalities and deformation of river channels at water exposed point and scoured area, and abnormalities and deformations of bunds
- Illegal acts that interfere with river management (illegal occupation, illegal construction, illegal dumping, illegal embankment, etc.)
- Abnormalities and deformations at the facility itself as well as its surroundings that can interfere with river management
- Status of measures against deformation, etc.
- Basic specifications of the facility
- Construction history, and damage history
- Status of sediment removal, tree cutting, and other maintenance activities.
- Matters that require periodic measures
- Coordination with local communities
- Other important information to be passed on, etc.

3) Management of River Records

River records are based on database system (hereinafter abbreviated as DS) and fundamentally aim to

gather information.

Administrator of DS river records information (hereinafter referred to as "Administrator") is essentially appointed by PID Chief Engineer. In addition, the administrator shall appoint an assistant to manage river record information, a person to input the information, etc. (including the administrator) as necessary.

The Administrator shall also maintain river records developed in the past in accordance with the prescribed document management rules. In addition, if the river records created in the past are transferred to DS, the DS data shall be used as the original, and the river records created in the past may be treated as "copies".

In addition, even after the creation of DS database system, efforts to ensure reliable storing of the data, including protecting registered information data from unnecessary editing and deletion, should be made.

River records will be made available for sharing within PID and FFC through DS. In addition to regular information sharing, any significant changes will be shared within PID and FFC. In addition, for changes that have been newly discovered or confirmed to be progressing during the pre-monsoon and post-monsoon inspection, content update of river records shall be confirmed and decided at cross-sectional coordination meetings participated by relevant departments of PID.

4) Creation of River Records

River records shall be created with the following points in mind and managed as a database.

・ In addition to the location of facilities (sluice, flood gate, barrage, ground sill, drainage machinery, etc.), the floor plan shows relevant location of river management facilities' and river channels' deformation discovered during inspection and usual river management. In addition, if necessary, position of permitted structures is to be indicated.

・ Information regarding the date and time when a deformation occurred as well as when it was checked is to be included. Efforts will be made to quantitatively assess the deformation so that changes over time can be determined. In addition, the aim is also to be able to determine whether deformation state is continuing or whether response is completed.

・ Each onsite photographs of deformation should be accompanied by close-up photographs that show deformation state and photographs from which the location of deformation and the its surrounding conditions.

・ If a measure have been taken for each deformation, the outline of its method, the reasoning behind its implementation, and a photograph showing the situation after the measure are to be provided.

(i) Structuring and Main Content of River Records

(a) Basic Records (Form-1):

・Basic information on the actual state of the river is entered onto the floor plan, and inspection results (survey location's symbol and main inspection content) are added.

・The name of the bund and the location ([1], [2], [3].) of the facilities (barrage, flood gate and sluice, bridge, inverted siphon, tunnel crossing the riverbed, land lock, etc.) are indicated as items to be filled in advance along with their corresponding titles. If the facilities are numbered, the facility number is to be used.

・Regarding the method of filling in the information at the time of inspection (and afterward), the relevant location ((1), (2), (3).) of river management facilities' and river channels' deformation discovered during inspection and usual river management are to be indicated, and the progress of inspection content is to be entered into the Chronological records. Information on the facility itself (excluding minor content of mechanical and electrical facilities) and the surroundings is to be entered into the Facility record.

・In addition to deformation related to rivers and river management facilities, incidents regarding water quality and water-related accidents are also considered to be the entry contents for the records. At the minimum, deformation related to rivers and river management facilities are to be entered, whereas for other items, their importance is considered to vary depending on river characteristics. Based on the state of maintenance to date, the decision is to be made by head of department after consulting with PID manager, as necessary. As a guideline, the entry of basic records is considered

to be content confirmed during inspection and content of the river patrol reports.

・The date and month of deformation occurrence is to be stated in the basic records. In addition, it should be possible to determine whether the state of deformation is continuing or whether the response is completed.

・The state of rivers and river management facilities should to be indicated.

・Based on the results of river patrol and inspection, information from the community, etc., abnormalities and deformations in river channels and facilities are to be cumulatively described in the floor plan.

(b) Chronological Records (Form-2):

・ For each deformation, content related to bunds, revetments, river channels, etc. is to be entered in the basic records such that changes over time can be checked. For cases when the cause of the deformation is found to be flooding, earthquake, illegal act, etc., circumstances of the cause (such as rainfall amount) shall be described. Efforts shall be made to quantitatively assess the deformation, so that changes over time can be grasped. Photographs showing the state of deformation (distant and closeup views from which the location can be identified) shall be attached. If a measure has been taken for any deformation, the outline of its method, the reasoning behind its implementation, and a photograph showing the situation after the measure are to be provided.

・Regarding the measures to be taken, in the case of river construction, name and period of the work carried out should be added. If continuous measures such as observation are required, the situation after the measure implementation should be added until response is no longer necessary.

(c) Facility Records (Form-3):

・ Detailed information about the facility described in the basic records is to be provided.

・ Items to be entered in advance:

1) The number of the facility described in the basic records is written on the upper right side.

2) Specifications and general drawings are provided.

・As items entered in the basic records, details related to facilities (barrage, flood gate and sluice, bridge, inverted siphon, tunnel crossing the riverbed, land lock, etc.) are provided. If the cause of the deformation is known, circumstances of the cause (such as rainfall amount) shall be described. Efforts shall be made to quantitatively assess the deformation, so that changes over time can be grasped. Photographs showing the state of deformation (distant and closeup views from which the location can be identified) shall be attached. If a measure has been implemented, photographs showing the situation after the measure implementation are to be provided.

Source: *Ministry of Land, Infrastructure, Transport and Tourism River Records Creation Guidelines H5.3*

<Reference information>

Currently, existing data is being organized and Form-1 and Form-2 are being prepared. Construction of database basic structuring is progressing such that personnel in charge can add data to it. Integration with existing database and sharing of information are planned.

3.8 Information Management

Regarding information management in the current manual, there is no clear explanation of management method and format for information storage and viewing of basic data, inspection records, construction records, and other information on the target river. The importance of information management is clarified.

(1) Subject of Supplementary Items: Vol 1 Ch 5-5.21 Information Management

Chapter and Article of Current Bund Manual
Vol.1: Chapter 5: Barrages 5.21 Records to be maintenance Vol.2: Chapter 2 River Training & Flood Management 16. Outline of flood fighting plans 17. Timeline for flood preparedness Vol. 2: Chapter 8: Asset Management Plan 1.3. Asset Management Plan 1.9. Preparation of a Revised/Updated or Fresh AMP
Relevant Articles in the Sindh Bund Manual
Periodical Reports and Returns. Article 143. Erosion statement (I. R. C. form No. I) 144. Abkalani report (I. R. C. form No. 2) 145. Reports on the state of bund sluices and regulators 146. Wetting of new bunds 147. Statement of specific levels on each mile of the bund (I. R. C. form No. 3) 148. Statement of H. F. Ls. on bund mile gauges and free-board available each year (I. R. C. form No. 4) 149. Sund register of consolidated statement for embodying data for river bunds (I. R. C. form No. 5) 150. Register showing incidence of leaks (I. R. C. form No. 6) 151. Report of levelling on bunds 152. Other I. R. C. forms (Indus bulletin and I. R. C. form No. 7)

<Reasons and summary of supplement>

Regulations regarding concept and type of information storing are clearly stated. (To ensure topography, exploration instrument, and satellite image data can be easily searched)

<Content that should be added to manual>

Vol 1 Ch 5-5.21 Information Management (Standard)

1) Concept of Information Management

By promoting the creation of a database of vast and commonly formatted information on bund related river construction, damage, inspections, maintenance, etc., the goal of realizing a reliable gathering and smooth sharing system of information is set. Through the construction of an information management system, it becomes possible to save labor and manage bunds efficiently and effectively with limited personnel.

In addition, accumulation and sharing of information on river construction, bund inspection, and maintenance will lead to the improvement of river technology and play a very important role in flood control and safety.

2) Data Collection and Management

Data on river construction history, bund inspection, and maintenance results will be collected, stored and managed. This allows for the analysis of data over a long period of time, which is useful for the development of maintenance plan. The main information is shown below:

(i) River Basic Information: longitudinal profile and cross-section of the river over the years, along with a detailed inspection of the bund, soil test results, topographical data, geological survey results, etc.

(ii) River Record Information

a) Basic records: A floor plan showing the changing status of rivers and river management facilities due to river construction as well as natural external forces (such as water discharge) obtained from river patrols, inspections, and information from the community, etc.

b) Chronological records: Information that can confirm the changes over time of bunds, revetments, river channels, etc. that were described in the basic records

c) Facility records: Information that can confirm the changes over time of each river management facility (such as barrage, flood gate and sluice, bridge, inverted siphon, tunnel crossing the riverbed, land lock, etc.)

(iii) River Patrol Information: Information entered onsite

(iv) Inspection Maintenance Information: Includes results of bund and river structure inspection, evaluation of the deformation and deterioration of bunds based on the inspection, and analytic results of ground surveys, aerial lasers, Unmanned Aerial Vehicles (UAVs), etc.

3) Information Sharing and Utilization

Regarding information sharing and utilization, the first step is to designate a management department that centrally manages existing construction records, river patrol results, and inspection and maintenance results. The department classifies and centrally stores the data from each division. At the same time, an information management system will be built, and for the second step, information is classified more efficiently and trial operation of the information management system will be conducted. For the third step, information entered onsite to a tablet is uploaded and stored on the web system via USB connection. In addition, information on the main server will be made accessible to the staff of PID and FFC for viewing, sharing and use.

4) Information Management Case Study (RiMaDIS: River Management Data Intelligent System: Ministry of Land, Infrastructure, Transport and Tourism of Japan)

(i) Reasons for Implementation

By conducting appropriate patrol and inspection on a daily basis, river facilities such as bunds can be maintained safely and securely. However, at river maintenance management sites, management of bunds with long length and a large number of facilities is necessary and it became difficult to maintain management level with limited personnel. Therefore, there was an increasing need for information collection to be optimized and a database to be created. This led to the implementation of a management system for river management information. The system was built and became operational in 2015 and is currently in use.

(ii) Overview of RiMaDIS

The overview of RiMaDIS is as follows:

(a) Information handled by RiMaDIS

The information handled is shown in the table below.

Information handled by RiMaDIS

Item		Detail
Maintenance actions	River patrol	・General patrol ・Purpose-specific patrol
	Various inspection	・Bund inspection ・Structure inspection ・Safe use inspection ・River channel inspection
	Maintenance countermeasure	・Facility repair ・Tree cutting ・Removal of obstacles, etc.
River Records	Basic Records	・Important deformation information ・Damage history ・Construction history
	Facility Records	・Structure ledger ・Inspection history
Situational Assessment		・Patrol during a flood ・Post-earthquake inspection

Source: *Chubu Regional Development Bureau "Utilization of River Maintenance Database System RiMaDIS"*

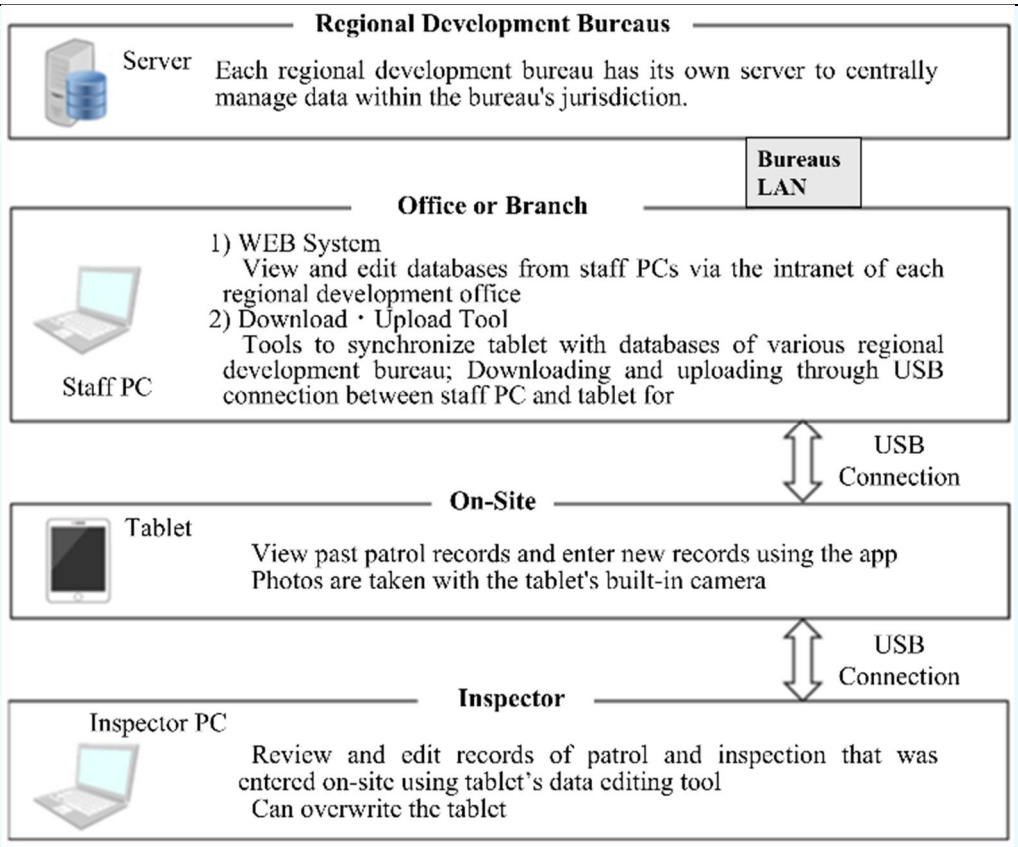
(b) Basic Configuration

RiMaDIS consists of two main tools: *"web system"* for viewing data, extracting and organizing gathered information, and *"RiMaDIS tablet"* for collecting onsite information of patrol and inspection. Currently, RiMaDIS is deployed on the servers of each regional development bureau, and staff of the maintenance bureau, offices, and branch offices can access and use the web system through a PC connected to the maintenance bureau's LAN. The RiMaDIS tablet used onsite transfers latest data from the server in advance. Onsite, new information is added with reference to the server.

(c) How to Use

During river patrol and inspection, because information is essentially registered and gathered on-site through RiMaDIS tablets, the main target users are staff and contractors who perform on-site work. The main information to be recorded includes location information, patrol items, on-site photographs, type and degree of deformation, etc. To improve the efficiency of on-site recording, patrol items and types of deformations can be selected from a pull-down list. By unifying the expressions, it is possible to gather data that are useful for future analysis and evaluation (such as statistical processing). The deformation record can also be registered along with past record (continuous recording). This allows for the change of deformation over time to be collected.

The data recorded on the RiMaDIS tablet is uploaded to the web system and synchronized via a USB connection. On the other hand, the web system makes it possible for staff (who are the main target users) to use a PC to view, edit, and search the records of river patrol and inspection uploaded from each office. By assessing the server, staff members can check the information from each maintenance bureau and office. Therefore, information can be organized in a format that is unified within the jurisdiction, which allows for an efficient collection of information.



System structure of RiMaDIS ver2.3

Source: *Chubu Regional Development Bureau "Utilization of River Maintenance Database System RiMaDIS"*

Source: *Created based on related materials and Chubu Regional Development Bureau "Utilization of River Maintenance Database System RiMaDIS"*

<Reference information>

Regarding information management, a centralized management by designating a department for data storage and management, utilizing the system currently in operation is proposed. Basically, centralized management will be promoted so that the construction history, inspection and maintenance results, etc. currently held by the person in charge can be shared. In addition, information will be shared with NESPAK and made searchable and viewable by PID to clarify information storage, and centralized management will be promoted within PID so that construction history and inspection maintenance results, which are held by the person in charge, can be shared. RiMaDIS is one example of such management system.

3.9 Artificial Breaching of Bund

Artificial breaching of bund has been employed to mitigate flood damage to public facilities. However, the decision-making conditions for implementing artificial breaching of bunds and their validation are not sufficient. Therefore, the following is an example of the proposed requirements for implementing artificial bund breaching.

(1) Subject of Supplementary Items: Vol 2 Ch 2-16.11 Operation of Bund Breach Location

Chapter and Article of Current Bund Manual
Vol.2: Chapter 2: River Training & Flood Management 7. Breaching sections 16.11. Operation of Breaching Sections
Relevant Articles in the Sindh Bund Manual
NONE

<Reasons and summary of supplement>

Artificial breaching of bund for the mitigation of flood damage is presented.

<Content that should be added to manual>

Vol 2 Ch 2-16.11 Operation of Bund Breach Location (Standard)

1) Basic Concept of Artificial Bund Breaching

In the event of a flood, bund breach caused by rising river water level poses a risk of devastating damage to towns and urban areas. Artificial breaching of bund is done to reduce the rising water level of river and change the flood water flow, thereby minimizing damage to towns and urban areas.

2) Overview of Artificial Bund Breaching

Overview of artificial bund breaching process is provided.

(i) Simulation of artificial bund breaching

Position and timing of artificial bund breaching are to be set in advance such that the breaching is most effective in minimizing flood damage.

(ii) Procedure of artificial bund breaching

Artificial bund breaching is fundamentally carried out at the discretion of PID management personnel. The procedure for the breaching is as follows.

1. Assumption of the time when severe damage to towns and urban areas may occur
2. Dispatching and placing construction machinery on standby (Request to construction contractors)
3. Arrangement of explosives and detonators (Request to the military)
4. Assessing the state of artificial bund breaching location
5. Assessing the state of protected lowland downstream from artificial bund breaching
6. Evacuation guidance in areas where flow of flood is expected to reach
7. Regulation of road traffic
8. Execution of artificial bund breaching
9. Assessing flood situation
10. Confirmation of the state of flood containment: Lowering of water level, rainfall status
11. Provisional repair of the sections where bund was breached

At a later date, the main restoration work of the bund will be carried out promptly. The damage to the protected lowland areas is assessed. If necessary, disaster response will be conducted by PID.

Source: *Created based on related materials*

<Reference information>

In the future, artificial breaching of bund is to be avoided as much as possible. To this end, bund strengthening, and flood countermeasures will be implemented.

3.10 Gaps with the Manual

Although construction work is carried out according to the bund manual and construction specifications, the quality of the bund may not be ensured because standards or regulations for construction management (supervision), report preparation, confirmation, storage, etc. are not clear.

(1) Subject of Supplementary Items: Vol 2 Ch 10-1.3 Implementation of Annual M&R Work Plans

Chapter and Article of Current Bund Manual

Vol.2:
Chapter 2: River Training & Flood Management
7. Breaching sections
16.11. Operation of Breaching Sections
Vol.2:
Chapter 10: Preparing Annual M&R Work Plans and their Implementation
1.3 Implementation of annual M&R Work Plans
1.4 Monitoring of M&R Work Plans
1.5 Supervision of the M&R Schemes
1.6 Documentation
Vol.2:
Chapter 11: Project Management
1.6 Documentation for Public sector Projects in Pakistan

Relevant Articles in the Sindh Bund Manual

CHAPTER XIII: Periodical Reports and Returns.
Article
143. Erosion statement (I. R. C. form No. I)
144. Abkalani report (I. R. C. form No. 2)
145. Reports on the state of bund sluices and regulators
146. Wetting of new bunds
147. Statement of specific levels on each mile of the bund (I. R. C. form No. 3)
148. Statement of H. F. Ls. on bund mile gauges and free-board available each year (I. R. C. form No. 4)
149. Sund register of consolidated statement for embodying data for river bunds (I. R. C. form No. 5)
150. Register showing incidence of leaks (I. R. C. form No. 6)
151. Report of levelling on bunds
152. Other I. R. C. forms (Indus bulletin and I. R. C. form No. 7)

<Reasons and summary of supplement>

Description of the organization and storage of documents from bidding to construction testing, inspection results, and completion of construction (Clarification of the department that provides information on river construction).

<Content that should be added to manual>

Vol 2 Ch 10-1.3 Implementation of Annual M&R Work Plans

1) Basic Concept of Preparation, Storage, and Inspection of Construction Management (Supervision) Reports

For river construction, NESPAK is responsible for placing the order, supervising the construction, and verifying the completion. The contractor submits the required reports from the start of construction to completion to NESPAK, which is responsible for organizing and archiving the submitted reports. The stored reports are accessible to and shared with the PID, FFC, and other related agencies. NESPAK along with relevant agencies will establish a database system for this purpose.

2) Main Construction Management (Supervision)

The main construction management is as follows.

Types and Contents of Main Construction Management

Type of management	Content	Detail
Schedule management	Coordination of planning and implementation	Coordinate the project and manage its progress to ensure it proceeds as planned
Quality control	Checking and contrasting designed and constructed quality	Conduct inspection and testing to ensure the quality is as designed
Constructed configuration management	Checking and contrasting designed and constructed configuration	Confirm that the actual form of construction is as designed
Machinery management	Operation and maintenance of machinery	Manage machinery to improve its utilization rate and maintain its function
Safety management	On-site safety measures	Measures to ensure the safety of workers and third-party personnel
Environmental management	Environmental protection measures	Measures to minimize the impact of construction on the environment

***Source**: Created based on related materials*

NESPAK's engineers shall mainly supervise construction progress, conduct quality control (such as checking the standards of laboratory field test results of bund material), and check the configuration of the constructed bund's shape and structure. The results of inspection and supervision are compiled into a report, which shall be promptly prepared and submitted to PID.

3) Summary of Required Construction Reports

The following documents are required for construction projects. However, depending on the scale of construction, some reports may be exempted. The exemption shall be based on the standards of each PID.

- Project execution plan (Construction plan PC-1): covers quality control (standards, testing, survey, etc.), scheduling, construction management (supervision), safety management, environmental management, etc.
- Documents for project execution plan (PC-2): includes specific details of testing and survey method, details on construction standards, etc., which form the basis of the project execution plan (construction plan) and must be attached to PC-1.
- Project progress reports (PC-3(A)): Annual/quarterly reports on items related to the project progress such as construction progress, status of various survey and testing, etc.
- Monthly reports (PC-3(B)): Monthly progress reports on financial status as well as construction progress, status of various survey and testing, etc.
- Construction completion reports (PC-4): Reports that must be submitted to the P&D department when the river construction work is completed.
- Construction completion effectiveness reports (PC-5): Performance reports on site conditions and construction effectiveness that must be submitted every five years after the completion of project.

***Source**: Created based on related materials*

<Reference Information>

Details on preparation and viewing of reports are given in "3.7 Inspection Maintenance (River Condition Monitoring)", "3.7.3 River records" and "3.8 Information Management".

Federal Flood Commission

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

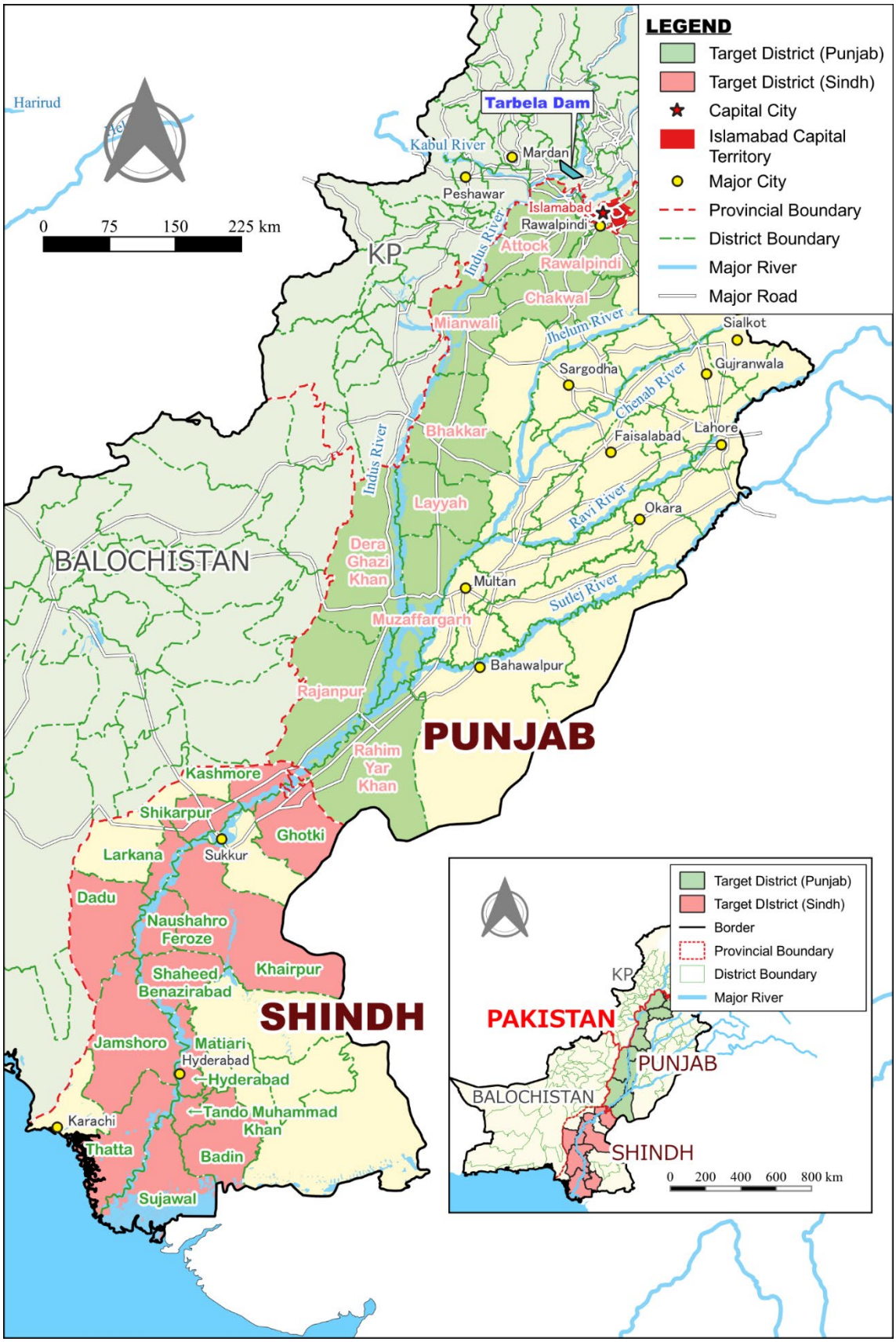
THE PROJECT FOR CAPACITY DEVELOPMENT OF EFFECTIVE RIVER DIKES MANAGEMENT RESPONSE TO 2022 FLOOD

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

August 2024

JAPAN INTERNATIONAL COOPERATION AGENCY

CTI ENGINEERING INTERNATIONAL CO., LTD.



PROJECT LOCATION MAP

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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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 maintenance and improvements of river facilities.

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 total area and causing extensive damages 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 barrages.

Since the time of British era, bund on the main Indus River has been maintained, to ensure its proper function 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 structures as a priority intervention mentioned 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 "PDNA 2022".) 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 to “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 a 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 a 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.

- ✓ Compare the technical manuals of each province, lacking items or contents mentioned in only one of the manuals will be picked up and a necessity for the addition will be analyzed to enhance the ability and capacity of the bund management in both Sindh and Punjab Province.
- ✓ Extract the issues on the existing manual considering the gap between the regulation of 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 result of the analysis, measures to improve the existing technical manual will be recommended. Also, the contents will be included as supplementary materials for the existing manuals which will be prepared under "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 are shown in Table 1.3.1 are collected. Those will be compared and analyzed in this report. Also, the Japanese technical standards on bunds shown in 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, preservation of the river environment, management of water rights, rules 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 and 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 and maintenance of river structures. These criteria cover design details of river structures such as dikes, revetments, spurs, weirs, sluiceways, floodgates, tunnel rivers, pumping stations, and 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 as 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 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 earthquakes. 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 1 INTRODUCTION..... 1-1
1.1 Outline of the Project 1-1
1.2 Objectives of This Report..... 1-2
1.3 Collected Document..... 1-2

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Table 1.3.1 Standards Related to Bund in Pakistan..... 1-3
Table 1.3.2 Major Standards Related to Bund in Japan 1-3

図表目次項目が見つかりません。

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

2.1 Current Practice in Sindh-PID

The bunds in Sindh are maintained 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

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

Table 2.1.1 Outline of Pre-Flood Inspection

Items	Contents
Implementation Period	March to April
Implementation Agency	Local offices of PIDs
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 follows: 1. Heights of the bunds: the comparison with the mile gauges and/or heights of the bunds for upstream and downstream are carried out by 200m (= 1fur) intervals. 2. Deformation of the 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 the bunds: the leakage and seepage conditions of the bunds are checked. 4. Tree conditions on the bunds: Weakening of the bunds due to tree roots during winds and rains and hollowing out due to decay are checked. 5. Animal habitat status of the bunds: The holes and hollowing out by rats and moles are checked. 6. Vegetation conditions on the slope of the bunds: Clumping plants with a short stature provide excellent protection against slope erosion. 7. Tree conditions on the bottom of the bunds: The trees on the bottom of the bunds both river side and land side affect the conditions of the 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 event 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 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 follows: 1. Erosion, leakage and seepage conditions: Continuous inspection and monitoring are conducted for the area likely to occur the bund breaches. 2. Deformation of the bunds: if any abnormalities are found, 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 follows: 1. Erosion, leakage and seepage conditions: Detailed inspection is conducted for the area in which the bund breaches occurred or is likely to occur. 2. Deformation of the 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

According to the Sindh-PID, they have conventional survey equipment such as total stations and level machines. However, equipment with 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 2024, they don't have any plan to procure or introduce such equipment. 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 lessons learned from the experience in Punjab-PID is preferable.

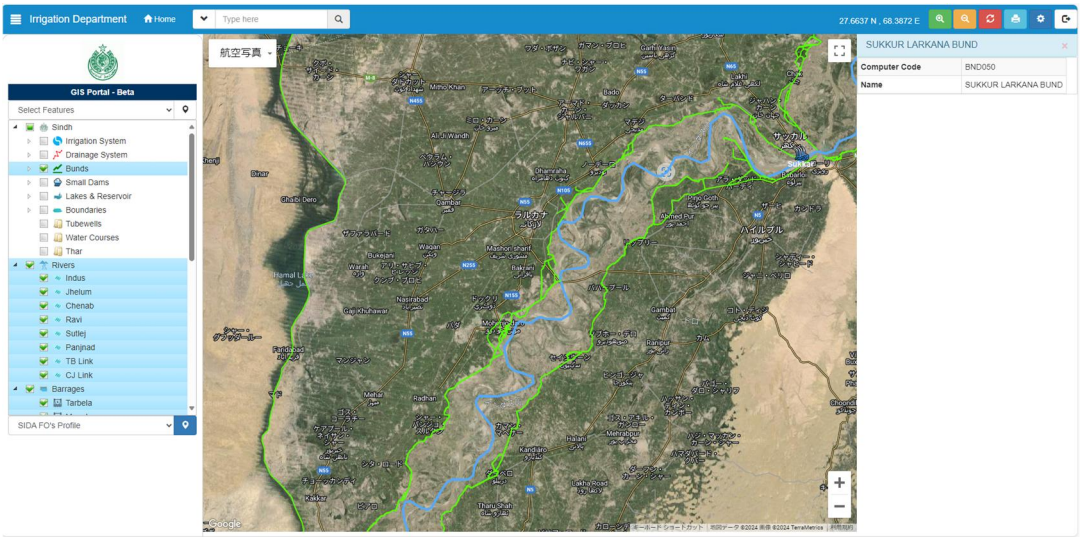
2.1.3 Other Activity Relating to Bund Management

(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 software. The GIS Cell is responsible for the operation and management of the "Irrigation GIS Portal2" that is publicly available on the Sindh-PID website. This system was originally developed with the primary purpose of serving as a database for irrigation facilities, but it also includes information on the bunds and rivers. Currently, only the alignments and names are registered for the bunds (refer to Figure 2.1.1).

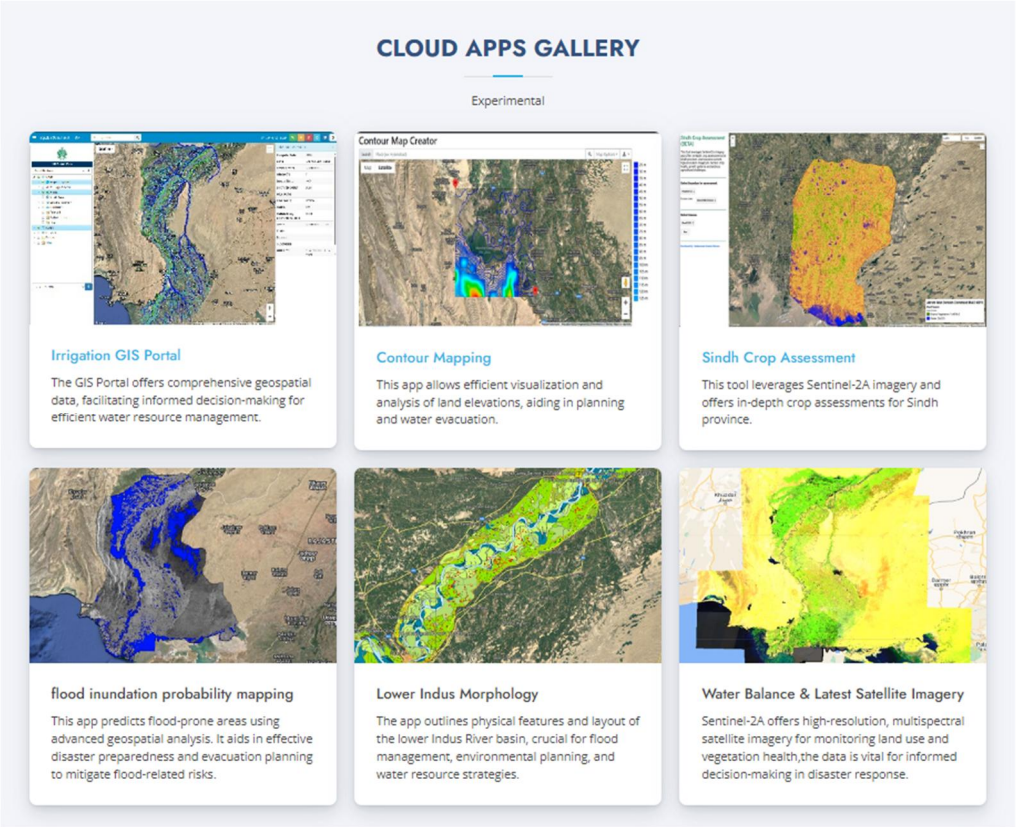
Additionally, although not publicly available on the web, the GIS Cell also performs analysis on Flood Inundation Probability Mapping and Indus Morphology (refer to Figure 2.1.2). The main focus of SIDA is irrigation facilities, these flood-related analyses and considerations are seen as the next step. 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 personnel and equipment is limited.

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



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)

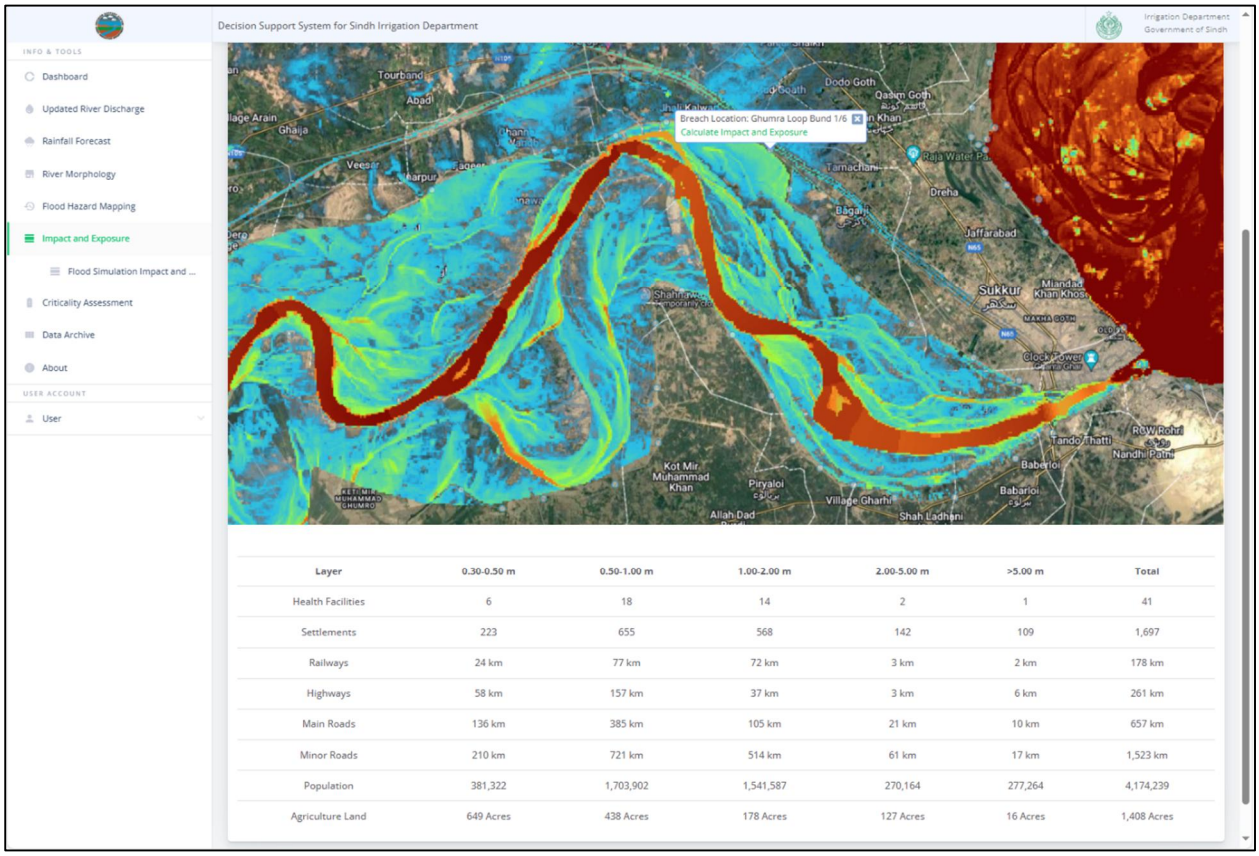
As part of the Sindh Resilience Project (SRP) supported by the World Bank (WB), the Decision Support System (DSS) assist Sindh-PID's decision-making in flood events. This DSS was developed by the Asian Institute of Technology (AIT) Thailand in August 2021 and the function shown in Table 2.1.4 is available 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 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 outflow 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 intervals from 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 comparison with other breach points
8	Data Archive	✓ Showing the inflow and outflow at the 5 barrages from 2021 to the present

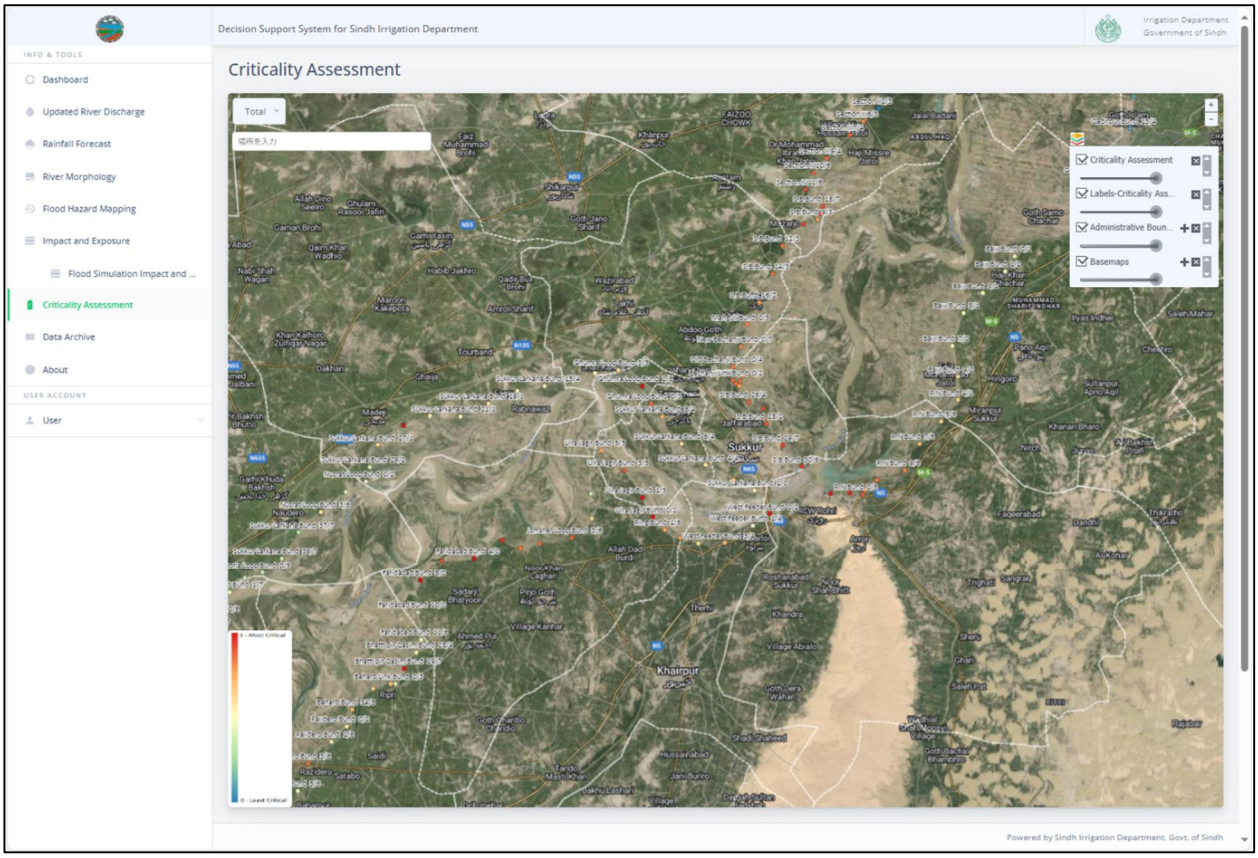
Source: JICA Project Team summarized from the website of DSS.



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

- It is not easy 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 considered regarding record management.

- Records of inspection results are not organized because of inadequate management.
- The report submission cannot be confirmed.
- The storage situation is not standardized.

Currently, improving countermeasures based on vulnerabilities and deterioration diagnosis is difficult because the history based on the accumulation of records and the creation of ledgers still needs to be confirmed.

(2) Relating Documents

Following related 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.

- A uniform inspection sheet should be created. (It also should be operated with a mobile phone)
- The location of the inspection history should be displayed on the map. (It also should be operated with a mobile phone)
- Relating documents should be created and storage based on the manual.
- Database of the status of the bunds should be established, which makes stakeholders easily obtain the information.
- The local situation should be shared during floods.

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 are 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 the bunds are also expected to be the same. The executive engineer (XEN) prepares a work plan and submits it to the Circle Office. 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 of 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 preparing 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 the 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 follows: 1. Basic Shapes of the bunds: the confirmation of the width, slope and height is conducted and the comparison with the mile gauges and/or heights of the bunds for upstream and downstream is carried out. 2. Deformation of the 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 the bunds and land side: the leakage and seepage conditions of the bunds and landside are checked. 4. Tree conditions on the bunds: Weakening of the bunds due to tree roots during winds and rains and hollowing out due to decay are checked. 5. Animal habitat status of the bunds: The holes and hollowing out by rats and moles are checked. 6. Tree conditions on the bottom of the bunds: The trees on the bottom of the bunds both river side and land side affect the conditions of the 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 Geo-tech	Team Leader

Date:

Source: Manual of Irrigation Practice Vol.1 chapter 5, Annex-H, Punjab

2) During-Flood Inspection

In the event of floods, the status of the bunds is continuously inspected and monitored according to the interview with 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 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 follows: 1. Erosion, leakage and seepage conditions: Continuous inspection and monitoring are conducted for the area likely to occur the bund breaches. 2. Deformation of the 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 follows: 1. Erosion, leakage and seepage conditions: Detailed inspection is conducted for the area in which the bund breaches occurred or likely to occur. 2. Deformation of the 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 with 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 to riverbank erosion, infiltration and groundwater levels related to seepage in the bund body. Additionally, According to an HSSEU engineer, a 3D model can be generated 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 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

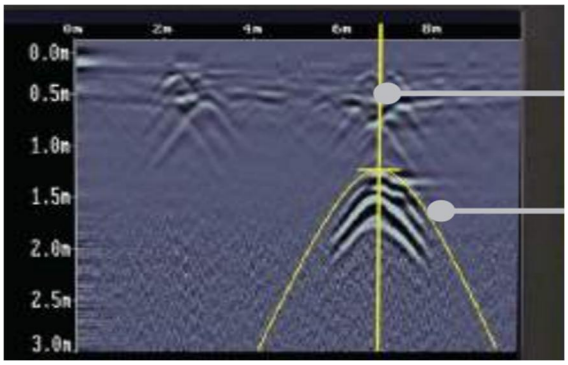
Photo 2.2.4 Radio Control Boat for Surveying the Riverbed

(2) Portable Ground Penetrating Radar

The ground penetrating radar is equipment that 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

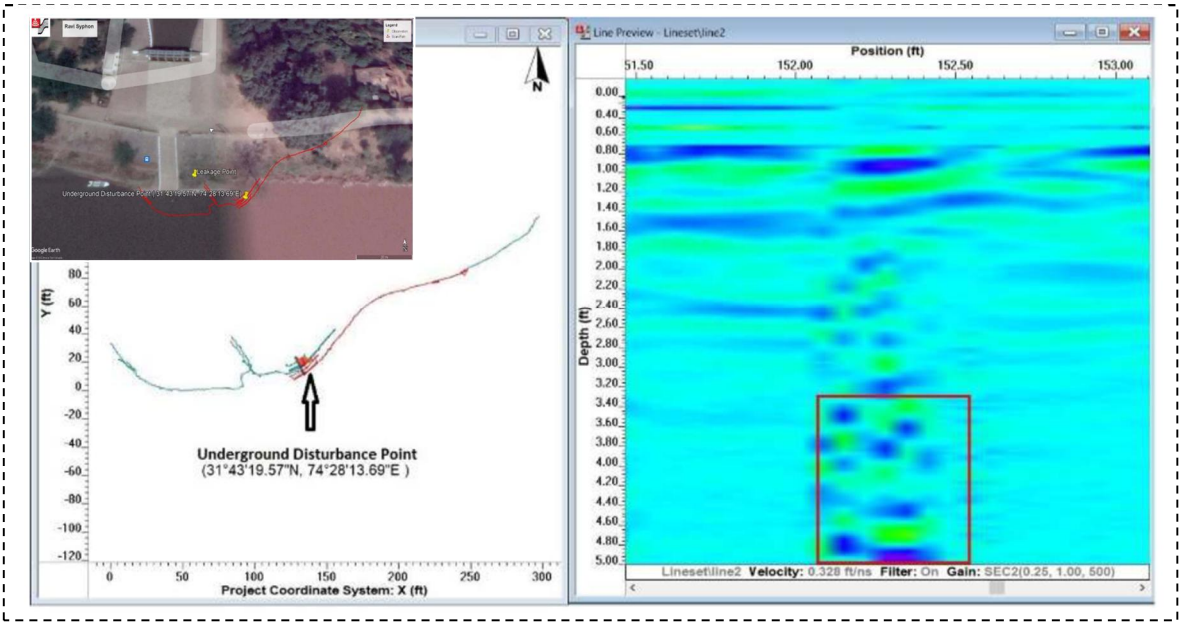
Photo 2.2.5 Work at Site with Portable Ground Penetrating Radar



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 a geophysical investigation with this equipment at Ravi Syphon. Following 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.

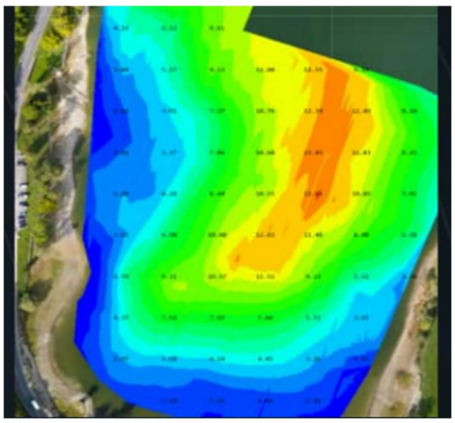
(3) Drone and Survey Equipment with LiDAR and Single Beam

By changing the attachment on a drone, this set of equipment can survey the ground and riverbed elevation. For the ground elevation, LiDAR is used, and an 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 a 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

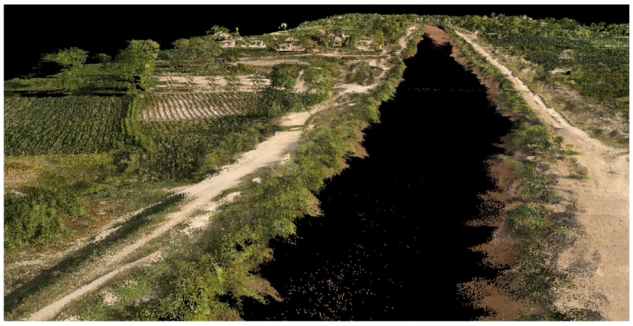
Source: Supplier

Photo 2.2.6 Work at Site with Single Beam Sonar



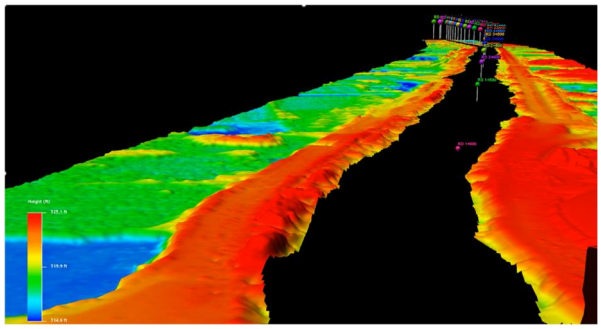
Source: Supplier

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 equipment is effective in monitoring 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 to 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 areas 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 to bund management are owned by them.

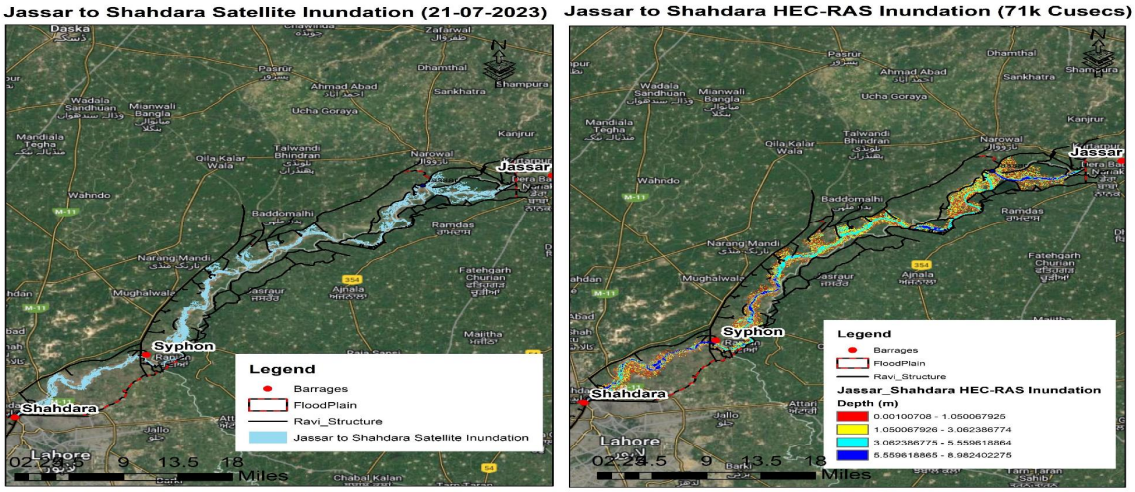
Table 2.2.10 GIS Data Owned by FRAU

No	Description of Data	Remarks
1	Alignment of the Bunds, Spurs and Studs Along Indus River with the bund names	The whole of 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 on each side.

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

(2) Flood Inundation Analysis by FRAU

FRAU has a team in charge of hydrological modeling and hydraulic modeling. They are conducting flood inundation analysis and making a model for the prediction of flood. Their analysis is currently focusing on the river area. For further improvement to analyze the inundation on 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

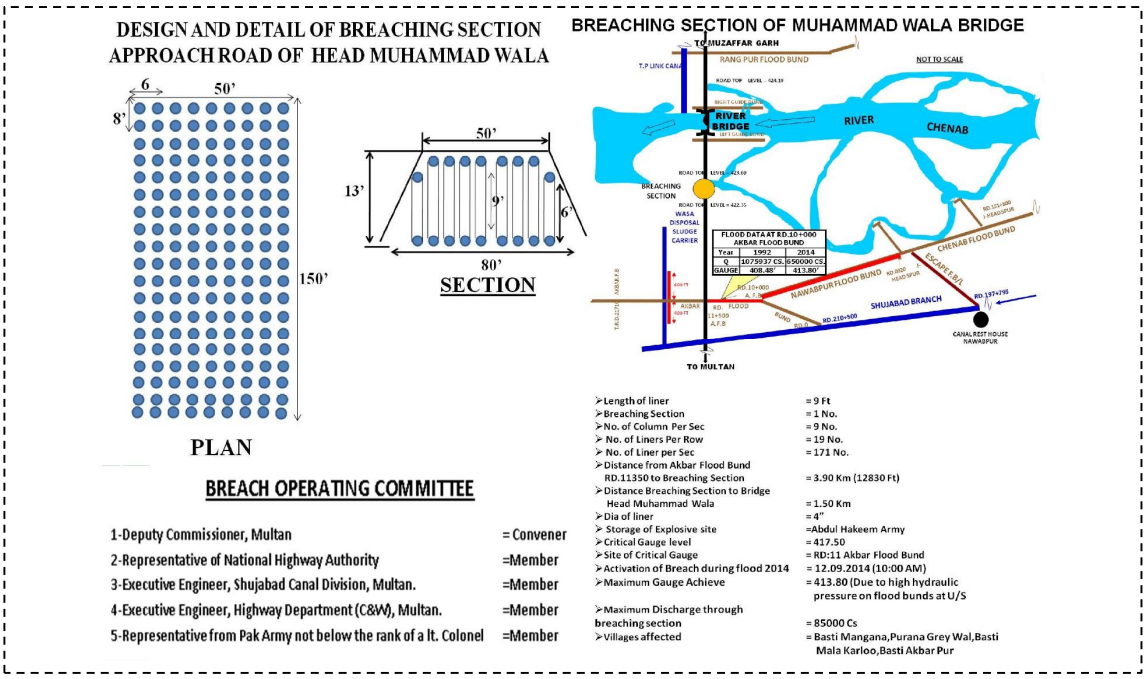
In the current model, the bund height is assumed about 4m from the ground elevation and the ground elevation is based on the digital elevation model(DEM) obtained from the open source. Vulnerability against overflow from the river is depending on the relation between HFL and the bund height considering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

To obtain the top elevation of the existing bund, collaboration with HSSEU is recommended. HSSEU has the equipment and capacity to take the top elevation of the bund with a drone survey and FRAU has the alignment of 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 have only rough location and does not have the specific conditions 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 behind the bund.

To analyze the flood inundation area on the land side, this information is recommended to be considered.

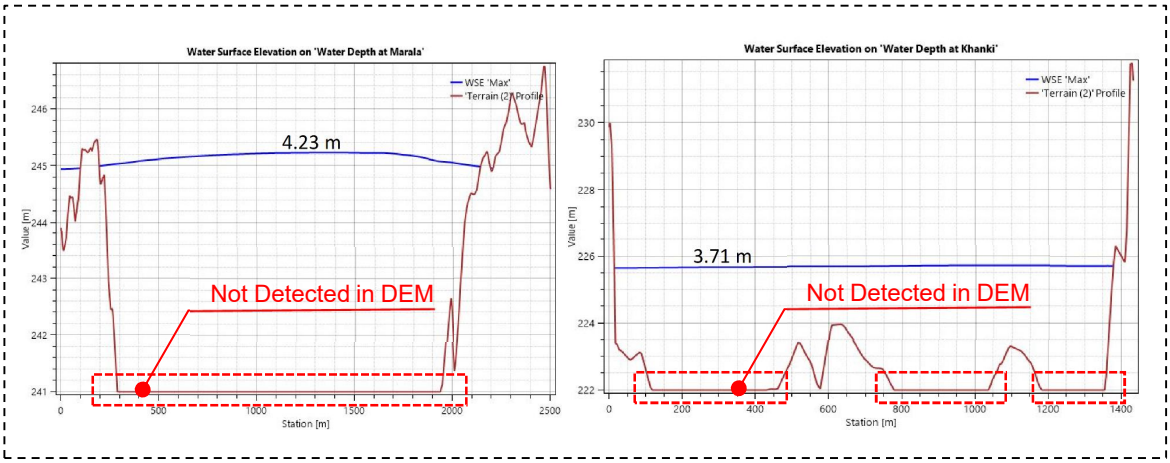


Source: PRE-FLOOD BRIEF ON FLOOD PROTECTION FLOOD BUNDS & BREACHING SECTIONS, Punjab-PID

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 reflected in 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 of Sindh Province, the manual has been revised as the flood conditions change. The manual stipulates the measures against seepage and erosion, quality of the 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.
- Report submission status is not managed.
- 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 records and the creation of ledgers is not confirmed.

(2) Relating Documents

As the case in Sindh Province, following related 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, PC-4, as a completion report should be submitted.

2.2.5 Summary

- The following are challenges for maintaining and managing the bunds in Punjab Province. A uniform inspection sheet should be created. (It also should be operated with a mobile phone)
- The location of the inspection history should be displayed on the map. (It also should be operated with a mobile phone)
- Relating documents should be created and stored based on the manual.
- A database of the bunds' status should be established so stakeholders can easily obtain the information. The local situation should be shared during floods.

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2.1.1 Basic Practice for O&M 2-1
2.1.2 Owned Equipment for Inspection/Investigation 2-2
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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, 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. The table of contents is shown in **Table 3.1.1**. The structure of the bunds is mainly described in Chapter 5, while the maintenance is mainly described in Chapters 9 and 10.

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

Chapter	Title
Chapter 1	Glossary of terms used in connection with River Bunds in Sindh.
Chapter 2	Constitution and Functions of the Indus River Commission.
Chapter 3	Classification of expenditure on Bund Works and powers of Officers Subordinate to Government to accord Administrative.
Chapter 4	Proposal for new Bunds, Loops and Bund Sluices.
Chapter 5	Design of new Bunds and Loop Bunds.
Chapter 6	Construction of new Bunds or Loops.
Chapter 7	Design and construction of Sand Cores and Diaphragm Walls.
Chapter 8	Design and construction of Bund Sluices.
Chapter 9	Article Pre-Abkalani Maintenance.
Chapter 10	Ordinary Maintenance during Abkalani.
Chapter 11	Emergent Measures or Causes of Failures of Bunds and Methods used to Combat Them.
Chapter 12	Breaches in River Bunds and how to Close them.
Chapter 13	Periodical Reports and Returns.
Chapter 14	Flood Management Practices on Mississippi River USA.
Chapter 15	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. The table of contents is shown in **Table 3.1.2**. The structure of the bunds is mainly described in Chapters 5.16 & 5.20 of Volume 1 and Chapter 2 of Volume 2, and the maintenance is mainly described in Chapters 9 and 10 of Volume 2.

Table 3.1.2(1) Table of Contents of the Manual of Irrigation Practice Volume 1

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 Volume 2

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)”.

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

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 suffering 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 design based on hydrological, geotechnical, and structural considerations and specify 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 are 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 earthquakes. 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

Before the analysis in this report, there are some major issues that have been already recognized. Based on these major issues, the related 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 is a lot of damage caused by seepage flow and erosion.	➢ Methods of Patrol and Inspection ➢ Methods of Safety Verification Analysis ➢ Countermeasures anddesign methods
✓ 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 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
✓ Enhancement 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 into the following. These are analyzed and 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 of 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 following are summary of the contents for each item.

(1) Definition of a Bund

The definition of 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 the 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 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 Design Height	To allow settlement and compaction
	With Scrapers/Foot Roller	6 1/4 % of Design Height	

Source: JICA Project Team summarized from Bund Manual.

Regarding the alignment of the bunds, the manual describes the consideration. It is mainly focusing on cost efficiency and the prevention of damage by erosion. However, there are less descriptions about the determination of the alignment considering the influence on the river flow conditions and prevention of the turbulent flow.

(3) Quality Control

1) Material

In the manual, the desirable material is described 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 water tightness and toughness of the clay.)*

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

Following 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 cases, the material which can obtained along the 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 a Clay Cover, due to the flat saturation, a 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 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 describes the importance of embankment with uniformed material without contamination of foreign mattes. When the material is containing organic matter 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 a 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, the 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, 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 smooth access by the maintenance vehicles.

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 factors 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 originate which is deemed essential and the distance apart that should be kept between the two consecutive ordinates is 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 instructs 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 no mention of consideration of seismic conditions. Along the 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 on the landside are expected to increase, demand for the consideration of seismic conditions 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 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 another method, 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 following 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 the stone apron by it.
2	Revetment	• As a feasible option in Sindh, it is introduced without a 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.
4	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 the 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, and seepage cut-off walls with sheet piles.

This may increase the initial cost, but due to the improvement in durability and strength, the number of rehabilitations will be reduced, and the scale of damage will also be reduced. Eventually, the total cost will be expected to be 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 in 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 a practical level to design revetments only based on this manual. Hence, adding such contents are recommended so that practitioners can make designs.

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

The foundation of the revetments is not mentioned in the manual. 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 are 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 content 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 a practical level to design revetments only based on this manual. Additional descriptions are required so that practitioners can make designs.

(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 the 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, and 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 following 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, the 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 are stated, and there is no mention of middle and long term management plans.

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 the water comes against a bund, patrolling by beldars should commence. Beldars work in pairs on a six-hour 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, regarding the physical inspection of the bund after a flood, the 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 concrete planning or design consideration for the listed solutions. The extraction of the page in the guideline is shown 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 no mention of the river profile, inspection reports and damage records. There are contents

on vulnerable sites along the 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 are 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 shows 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 of the Indus River Commission, copied 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 regarding the 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 ledgers/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 instructions are 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. While, in case an unfavorable river course or river setting 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 a 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 regulations about 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**. Regarding 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 Remaining Uncrowded ・ 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 Extrapolated 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 Touch the Bund • Corresponding Gauge Reading at the barrage • RL, and width of the 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 ones which are obtained from physical inspection (by eyes) and past records. As the items are 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, 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 influences caused due to erosion or seepage flow and by the natural factors. As a cause of breaches, artificial bund breach is not listed in the manual.

According to the results of an interview 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. Following to that, 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 zamindars 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 a local inquiry 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 are 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 immediately after a breach and the following reporting is clearly instructed. However, as a method of communication, a telegram is introduced and updated considering the latest technology is recommended. Regarding the report, the items are clearly introduced, but it is recommended to include a form to be filled out. This will make it easier to accumulate and extract information. Additionally, considering the impending shift towards digitalization, using a standardized 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 a 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 depends 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 the case as a 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 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. Improving such a 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 the case of the construction supervision by PID staff, etc., the test results and construction status records were not confirmed (In the Manual, there is a description of the submission of reports, etc.).
- ✓ Inspection documents related to construction management are not stored properly or stored but need to be 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 management 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 related 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 has been confirmed.

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

3.4.1 Analysis of the Manual

(1) Definition of a Bund

The definition of 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

Regarding 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 the Manual of Irrigation Practice.

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 the 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 account for a reasonable safety margin against unexpected water level rises, such as waves or river course shortening.
	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 approximately 40 years ago and has not 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.

About the alignment of the bunds, the manual is describing the general concept of considering the influence of the river flow to prevent the erosion of the bunds. However, there are less description to determine the alignment considering the influence on the river flow condition and prevention of the turbulent flow.

(3) Quality Control

Quality control is not mentioned in the manual.

(4) Service Road/ Maintenance Road

The manual does not mention the service road or maintenance road.

Considering the current conditions of the top of the bunds 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

[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.

smooth access by the maintenance vielles.

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

(5) Safety Evaluation

1) Slope Stability (Slip Circle)

In the manual, concrete methods and factors 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 follows;*
  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 an 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 are 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 a 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

The manual does not describe the methods for evaluating safety.. However, the estimated 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 descriptions are 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 of 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 improved methods, the following countermeasures are introduced in the manual as major options.

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

No.	Item	Remarks
1	Stone Apron	The concrete 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 concrete 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 concrete 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 aprons 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 for each type is not clearly mentioned in the manual.

3) Seepage Flow

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

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 a 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 the land side toe are 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, concrete 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 it 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 concrete 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 determining 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 concrete 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 the 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, and Chapter 5 5.5.7 in Vol.1.

2) Safety Verification

Since there is no mention of the specification and design method for all types 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 a practical level to design revetments only based on this manual. Hence, adding the contents is recommended so that practitioners can make designs.

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 aprons. 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 following conditions 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

The manual describes a typical cross-section and types of spurs, and includes the following information.

- ✓ *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 inches of thickness.

4) Design Method

In the manual, only recommended space is described and the concrete design method is not introduced. The following spaces are 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 are 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.

- ✓ *In Punjab, riverbanks typically need to be reinforced every 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 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 the 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. The manual should state the relationship between the inspection of river training work and flood preparedness 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 no mention of the river profile. However, the inspection report which includes 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 includes 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
- Patrol road and section maintenance
- Unauthorized traffic
- Slumping or settlement
- Body materials suitability is determined through analysis at various depths and locations.
- Any visible/apparent runnels, caused by old tree roots
- Rodent, holes, burrows and dens
- Evidence of solutions
- Evidence of piping
- Evidence of heavy seepage, springs and boils on the landside
- 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
- Flood warning and information system
- Investigation carried out
- Analysis of observations and investigations

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 vary 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 Survey and Investigation Item for River Channel in Punjab

No.	Item	Interval	Description
1	Topo Survey	Yearly	· Survey area extends to 15000 x afflux[9] feet on the 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 are 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 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 sub-divisional officer in charge of the barrage has little relevance to the bunds.

(13) River Ledger

1) Contents

The manual does not include ledgers outlining the river or bund.

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;*

[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.

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

Moreover, the main cause of breach 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 gauge 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

Regarding the immediate action, the 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 that will come in the 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.

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 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 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 management 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 related 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 of the Design Criteria of NFPP-IV

3.5.1 Analysis of 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.
Side Slope (River Side) (Land Side)	Bund		
	-do-	3:1	
	-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 are 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 cobbles or boulders 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 of 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 their 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 tons 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 activities.

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.

The following equations are used to calculate the factor of safety for under seepage:

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

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

Where,

FOS = Factor of Safety
I_c = Critical hydraulic gradient
I_e = Calculated exit gradient
Υ_s = Saturated unit weight of blanket layer
Υ_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 a 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. The factor of safety for stability analysis of flood embankments is given in **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 critical flood protection and river training structures is 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 riverbeds 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 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 on 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. The main factors for choosing between flood walls and embankments are summarized in the below **Table 3.5.4**:

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 can 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 Factors 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.

The 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 Factors of Safety

The primary concern for the design of flood retaining wall structures is described in **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.
2	Against Sliding	1.5	

Sr. No.	Stability Parameter	Factor of Safety	Verification/Remarks
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 the 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. A checklist should be prepared to ensure that the subsequent site visits and field testing cover 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 from erosion attack or vulnerability 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 the 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 close to the spur or equal to a 100-year return period flood, or the highest recorded flood event, whichever is of a greater magnitude.

Spurs may be aligned either normally to the flow direction or at an 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, and 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	The 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 tons capacity. The design requirements with respect to bearing capacity should be achieved and verified before proceeding further. The 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 so 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 an 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 pockets which should be filled with smaller size stone

(8) Monitoring of River Conditions

Flood bunds require 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 structures 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 about 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 checklist, field observation sheet and site inspection report is provided in NFPP-IV in tables 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 of 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 before high flow season, the entire flood protection system should be inspected in detail.
3	Low Water Inspection	This 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 an 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, and bridges. This is a planned breach and is provided to cater a situation where flood endangers the safety of hydraulic structures and bridges such as barrages, headworks, and bridges. Taunsa Barrage is an exception and does not have a breach section due to canals on both sides.

(11) Limitations of NFPP-IV Design Criteria

The 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 envelopes shall be defined for different typical cases.
- For the slope stability of the bunds, a 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 passing the material or standard is not mentioned.
- Operating Basis Earthquake (OBE), and Maximum Considered Earthquake (MCE) seismic criteria for slope stability are not mentioned.

3.6 Comparison Analysis of 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 to 20 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 the 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 the 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 to 4 ft and that in Punjab is 6 ft (minimum)/ 7 ft or as determined by analysis whichever is greater (Desirable).. Regarding this, the most recent Bund Manual in Sindh was issued in 2008, 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 better access for the O&M.

(5) Safety Evaluation

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

[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.

1) Slope Stability

The concrete method to evaluate the safety for slope stability is described only in the manual in 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, regarding the scour depth calculation, the Bund Manual in Sindh introduced methods based on the highest discharge, on the other hand, the Manual of Irrigation Practice in Punjab described the detailed 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 concrete 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 describes the seepage through the bund body and the foundation stability. About the seepage through the bund body, the manual introduces the concrete 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,. both standards introduce similar methods.

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	<For a Bund Body> ・ Installation of Drainage Material; Pervious

[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 Manual in Punjab introduced an 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 Manual in Punjab, revetment is introduced by the term slope protection.

Item	Bund Manual (Sindh)	Manual of Irrigation Practice (Panjab)
	・ Installation of Drainage Material at the Land Side Toe ・ Expansion of the Rear Section to Cover the Saturation Line	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 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 Manual in Punjab. 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 Manual in Punjab 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 Manual in Punjab

Material	Bund Manual in Sindh	Manual in Punjab
	Slope : 3:1 to 2:1	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*

Material	Bund Manual in Sindh Slope : 3:1 to 2:1	Manual in Punjab Slope : 3:1 to 2:1
Gabion	-	• Gabions
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 Pitching

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 has a 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 Sindh and Manual in Punjab

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 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 the stone aprons 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 regarding 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 on the landside.

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 are stated, but there is no mention on the 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 a 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.

Regarding 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.

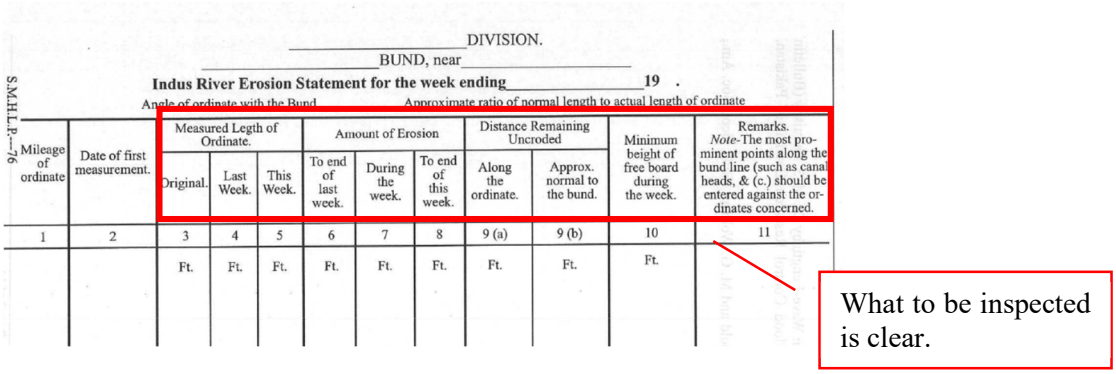
About the Inspection Report / Damage Record and Analysis / Evaluation, there is a concrete description only in the Manual of Irrigation Practice in Punjab. It is recommended that the Bund Manual in Sindh incorporate these methods.

[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. 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 .

S.M.H.L.P.—76

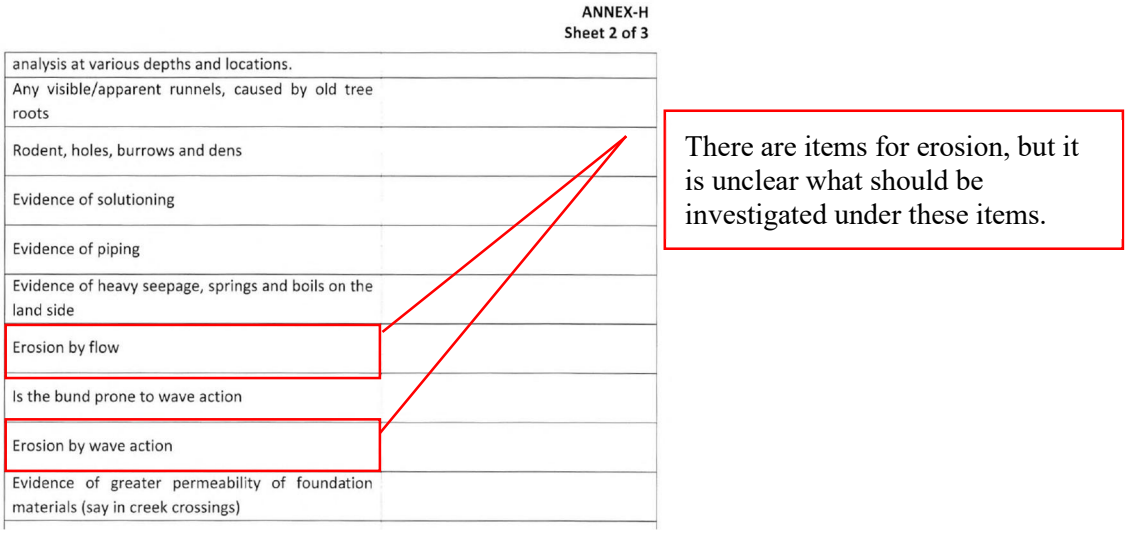
Angle of ordinate with the Bund — Approximate ratio of normal length to actual length of ordinate

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 canal 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 records 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 ledger is not included in either the Sindh or 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 breaches is listed in both the Sindh and Punjab manuals. Also, the Manual of Irrigation Practice in Punjab states the main cause of the breach in addition to the 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 contents are almost the 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 the 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 protect 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	Riverside	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.
		Landside	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 · Landdide: 5 ft(=1.53m) *8 to 9 ft below 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 landslide) is provided to keep the hydraulic gradient within the cross-section. · The hydraulic gradient line should lie at least 2ft below the 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 the sudden unforeseen rise of water level such as waves, and 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 concrete 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 Embankment		7	Chapter VI, Page 3 of 14 53. Method of good construction	· Normal: 12 1/2 % of Design Height · With Scrapers/Foot Roller: 6 1/4 % of Design 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.
	Alignment			25. Considerations Governing Alignment and Spacing of Bund	· The loop should be far enough from the existing bund to ensure safety from erosion for several years. · The loop should not exclude more valuable land than necessary to minimize costs and maximize protection. · The cost of protection should be justified by the benefits derived, similar to practices in the USA. · The bund should not be close to a river bend to avoid undermining and erosion from high-velocity currents.	VOL.2 Chapter 15.5.2, p259	· Flood retaining embankments should be placed parallel to the meandering axis of the river, at a fair distance from the meandering belt. · Alignment depends on topography, infrastructure, and geo-technical parameters of the foundation soil. · In special cases, embankments may require protection with revetments, aprons, and armored spurs. · The goal is to minimize active parallel flow along the embankment to avoid erosion and scour.	· The contents are focusing on the erosion of the bund and cost efficiency. · It is necessary to describe the consideration of the influence on river flow condition and turbulent flow due to the improper alignment.

Item	Sub Item	Sub-Sub-Item	No.	Sindh		Punjab		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
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 desirable. * The sand in the clay will prevent shrinkage and cracks without destroying the watertightness and 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.
		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 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,	-	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/ Maintenance 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 the Simplified Bishop Method with relevant computer software.
· The needed information is as follows.
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 an assumed fully launched stone apron.
· Loading conditions are “Gravity”, “Seepage (or Pore water pressure), and “Earthquake”.
· The 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 the “pore pressure ratio” and “depth of soil from the top surface”.
· The potential failure surfaces are 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 a 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 Punjab.</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 estimated 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 gradients 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 concrete methods of scour depth calculation based on the Manual of Irrigation Practice in Punjab
· The manual in 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>Permeability-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, the 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 that the Bund Manual in Sindh 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 purposes. 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 of 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 based on 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.
Improvement 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	-	No description	· The Manual of Irrigation Practice in Punjab is strongly recommended additionally introduce the improvement method as well as the Bund Manual in Sindh.
	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 concrete 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 a 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, a Geotextile filter can be used instead of it. The requirement conditions 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 concrete 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 concrete design method is not described	
	Seepage Control (Newly Constructed)	Types of Improvement 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 concrete 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 · Riverside impervious blankets · Pervious toe trenches · Pressure relief wells · Landside seepage berms *The concrete 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 among these 3 countermeasures is 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 · Landside Seepage 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 sandbags 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 type	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 type 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 desirable 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 assumes 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 about 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 about 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 has 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, the Manual of Irrigation Practice in Punjab should 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 a 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 following are required. · Creating slack flow to silt up the area in the vicinity. · Protecting the riverbank by keeping the flow away from it.	· The Bund Manual of Sindh mentions that a spur is installed when the available land is limited.
	Basic Shape		31	-	No description	VOL.1 Chapter 5, 5.4.7.4, p5-49	· The typical cross-section is the 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 spurs 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 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 follows. · The minimum spacing in a straight reach should thus be five (5) to six (6) times the length of the spur. · Convex bends; 2.5 to 3.0 times the length of the spur · Concave bends; equal to the length of the 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 the angle of the spur with respect to the current axis requires a 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 add this item based on the Bund Manual in Sindh.

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, and 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 from 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 ordinary 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 framework are the following. 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 several 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 Manual in Punjab, 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 following. · They are inspected before the advent of flood season every year for assessing their reliability to withstand flood onslaught. · Their deficiencies are removed before 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 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	The 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 Manual in Punjab is recommended to describe the patrol structure with reference to 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-ment / Investi-gation / Exploratio n		43	-	No description	VOL.2 Chapter 2, 4.3.1.2, p87	Not mentioned *Although it is not intended for monitoring, the following 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 the 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, the location of the training works, analysis of design parameters, physical inspection results i.e. observation and findings, conclusions, and recommendations.	· It is recommended for the Bund Manual in Sindh to incorporate the description of Inspection Report / Damage Record 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 Manual in Punjab 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 manual in Punjab is recommended to expand the area of river course inspection and erosion not to limit the area around the barrages 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 records regularly at prescribed intervals. *The 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. · 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 · Distance Remining Uncroded · Minimum Beight of free board during the week ABKALANI REPORT(BUND) · Breach · Leak · Erosion · Works in Progress · 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 touch the Bund · Corresponding Gauge Reading at the barrage · RL, and width of the 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 season · Special patrol is required during the next season. 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	-	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 in both Sindh and Manual in Punjab.
	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 desirable because it is more reliable. The success rate of explosives 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 the Sub-Divisional Officer and Executive Engineer, and the items reported to them is clearly listed in 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 a report. · To prevent the breach from 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 a report. · To prevent the breach from widening, a groin should be constructed.	· The contents are almost the 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 the 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 standards, a bund is basically an earthen structure which is aiming at protecting the country from inundation by the river spills, during floods.

While the target water level which shall be protected by a bund, high water level (HWL) based on a probabilistic analysis is used in Japanese standards, 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 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

The top width is defined as 20 ft(=6.1m) in the Bund Manual in Sindh, this is almost the same as the rivers which have 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 is stated in the Bund Manual in Sindh is 4 ft (=1.22m), and it is almost the same as the rivers which have 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 levels, and the available earthen material around the Indus River, a 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 a long duration in the 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 riverside immediately in front of the bund. In the Japanese standard, the necessity of fine particle contents is also mentioned. However, the recommendations stated in each are different a little.

Since 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 the Indus River. On the other hand, it is recommended that 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 size) is desirable. • Maximum particle size is not larger than 10 to 15 cm. • A soil which has a 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, the Japanese standard describe 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 are 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.
Sand Sandy Soil Sandy soil with Gravel	◎	◎	○	△	△	Good particle size mixed soil that contains moderately fine particles, decomposed granite soil, mountain gravel, etc.
Clay Clay with Gravel	○	○	○	×	△	Sensitive Soil with a few fine particles, 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% on 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 mention the 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 the slip circle by a numerical analysis with software. ・ The 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 software ・ Verify the stability against the 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 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 recommended 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 walls in the Japanese standard. In addition, the areas or lengths of each countermeasure are verified with numerical analysis.

It is recommended that 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 countermeasures against seismic force and liquefaction are indicated in the Japanese standard. In addition, the countermeasure against earthquakes 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 for the improvement of 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 that the Bund Manual to include it.

(7) Revetment

1) Material

The materials used for revetments vary and concretes, rocks, woods and vegetation 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 are 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 uniform in a certain stretch. Hence, adding these types of revetment is recommended as an option.

In addition, there are a lot of cases that the existing revetment has 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 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 (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 conditions 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)

Regarding the site condition in which spurs are needed, a 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 lengths. 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 spur 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 spur 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 the 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 areas and particular stretches of class A rivers.

According to River Law in Japan, somebody who has 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, the 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 the Bund Manual of 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

[18] River Law, Article 20

inspections and 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 deemed to be included in technical specifications in each contract.

(10) Management Plan

In the Bund Manual of Sindh, "Pre-abrakani Maintenance" and ordinary maintenance are 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, items 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 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 over multiple years. The 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 of Sindh, patrolling during floods is described. While, 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, 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, enhancing data sharing from other authorities 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 in the items to be recorded in a report or a ledger. In accordance with the Japanese guidelines, 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 shown in **Table**

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

3.6.13. Considering the evaluation for each inspection item and number of deformations in a certain stretch, the condition 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).	OBSERVED	NO
C	Needs Preventive Maintenance	✓ Although the functions of river management facilities such as bunds are 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).	OBSERVED	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.	OBSERVED	OBSERVED

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 setting is indicated, it must be informed with a full report. On the other hand, a 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 an increase in estuary sand bar height?

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

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 stores and keeps all records, then it is consolidated at Zonal level and all Field CEs take care of storing the consolidated records.

On the other hand, the method and responsibility of storing the inspection ledgers are specified in Japanese standards 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 responsibilities for storing the inspection ledgers and reports like in 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 a similar type of ledger to 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 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 acknowledged as important.

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

Such a situation is not preferable, and the important information is dependent on the individual knowledges. However, as of now, few people seem to be recognizing that such a 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. It is not preferable to take time to gather 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

<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>Definition of a Bund</td><td>Definition</td><td></td><td>1</td><td>Chapter I, Glossary of terms used in connection with River Bunds in Sindh, Page 3 of 15</td><td>· An earthen embankment parallel to the river banks
· To protect the country from inundation by the river spill, during floods</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 17～Article 19</td><td>· 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.</td><td>Contents are almost same in both manuals.
In Sindh Province, once the highest water level due to a flood is updated, the target water level for the bund design will increase.</td></tr>
<tr><td rowspan="5">Standard Shape of a Bund</td><td>Crest Width</td><td></td><td>2</td><td>Chapter V, Page 13 of 18
41. Standard sections or type designs of bund</td><td>· Main Bund: 20 ft (=6.1m)
· Trendh Bund: 10 ft (=3.05m)</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 21</td><td>Depending on the design discharge as shown in the following table
<table>
<tr><th>Discharge</th><th>Width</th></tr>
<tr><td>Under 17,657 cusecs (=500 m3)</td><td>9.8 ft (= 3 m)</td></tr>
<tr><td>17,657 to 70,629 cusecs (=500 to 2,000 m3)</td><td>13.1 ft (= 4 m)</td></tr>
<tr><td>70,629 to 176,573 cusecs (=2,000 to 5,000 m3)</td><td>16.4 ft (= 5 m)</td></tr>
<tr><td>176,573 to 353,146 cusecs (=5,000 to 10,000 m3)</td><td>19.7 ft (= 6 m)</td></tr>
<tr><td>Over 353,146 cusecs (=10,000 m3)</td><td>23.0 ft (= 7 m)</td></tr>
</table></td><td>Considering the discharge during floods, duration of high water level and the available earthen material around Indus River, higher value is preferable.</td></tr>
<tr><td>Side Slope</td><td>River side</td><td>3</td><td>Chapter V, Page 13 of 18
41. Standard sections or type designs of bund</td><td>· 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)</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 22</td><td>· Gentler than 2:1 except for the bund with a heigh of 2.0 ft (=0.6 m)</td><td>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.</td></tr>
<tr><td></td><td>Land side</td><td>4</td><td>Chapter V, Page 13 of 18
41. Standard sections or type designs of bund</td><td>· Bund,: 3:1 without Berm
· Medium Bund: 3:1 without Berm
· High Bund: 2:1 (Top to Back Berm), 6:1(Berm to Ground)</td><td>Same as the above.</td><td>· Same as the above.
· *The gradients on the land side and the river side are not determined separately.</td><td>Same as above</td></tr>
<tr><td>Berm</td><td></td><td>5</td><td>Chapter V, Page 13 of 18
41. Standard sections or type designs of bund</td><td>High Bund
· River Side: Not Specified
· Land Side: 5 ft (=1.53m)
*8 to 9 ft below the top depending on the front slope</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 22</td><td>· Larger than 3 m</td><td>Considering the discharge during floods, duration of high water levels and the available earthen material around the Indus River, a higher value is preferable.</td></tr>
<tr><td>Freeboard</td><td></td><td>6</td><td>Chapter V, Page 5 of 18
33. Freeboard
Chapter V, Page 13 of 18
41. Standard sections or type designs of bund</td><td>· 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.</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc. Article 20</td><td>Depending on the design discharge as shown in the following table
<table>
<tr><th>Discharge</th><th>Freeboard</th></tr>
<tr><td>Under 7,062 cusecs (=200 m3)</td><td>2.0 ft (= 0.6 m)</td></tr>
<tr><td>7,062 to 17,657 cusecs (=200 to 500 m3)</td><td>2.6 ft (= 0.8 m)</td></tr>
<tr><td>17,657 to 70,629 cusecs (=500 to 2,000 m3)</td><td>3.3 ft (= 1.0 m)</td></tr>
<tr><td>70,629 to 176,573 cusecs (=2,000 to 5,000 m3)</td><td>3.9 ft (= 1.2 m)</td></tr>
<tr><td>176,573 to 353,146 cusecs (=5,000 to 10,000 m3)</td><td>4.9 ft (= 1.5 m)</td></tr>
<tr><td>Over 353,146 cusecs (=10,000 m3)</td><td>6.6 ft (= 2.0 m)</td></tr>
</table></td><td>Same as Above</td></tr>
<tr><td>Extra Embankment</td><td>Levelling of Top of Bunds after Construction.</td><td>7</td><td>Chapter VI, Page 3 of 14
53. Method of good construction</td><td>· Normal: 12 1/2 % of Design Height
· With Scrapers/Foot Roller: 6 1/4 % of Design Height
*In order to allow settlement and compaction</td><td>Standard for Extra Embankment</td><td>Depends on the soil type and bund height as shown in the following table
<table>
<tr><th rowspan="3">Embankment Height</th><th colspan="4">Foundation Materials</th></tr>
<tr><th colspan="2">Normal Soil</th><th colspan="2">Sand / Gravel</th></tr>
<tr><th colspan="4">Extra Banking Materials</th></tr>
<tr><th></th><th>Normal Soil (cm)</th><th>Sand / Gravel (cm)</th><th>Normal Soil (cm)</th><th>Sand / Gravel (cm)</th></tr>
<tr><td>≤ 3 m</td><td>20</td><td>15</td><td>15</td><td>10</td></tr>
<tr><td>3m – 5m</td><td>30</td><td>25</td><td>25</td><td>20</td></tr>
<tr><td>5m – 7m</td><td>40</td><td>35</td><td>35</td><td>30</td></tr>
<tr><td>≥7 m</td><td>50</td><td>45</td><td>45</td><td>40</td></tr>
</table></td><td>This is almost the same value between Sindh Province and Japan.</td></tr>
</table>

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
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 desirable. *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 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 necessary to be revised.
		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 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,		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 a 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 of the embankment material, methodology of quality control, countermeasures for soft ground and environmental aspects are also introduced.	It is necessary to add a description of the construction equipment and the features of materials that is applicable. It is necessary to add descriptions about the method of embankment material survey and quality control. It is recommended to add a description of countermeasures for soft ground.
	Degree of Compact-ion		11	-	No description	River Earthwork Manual [3.1.4]	The degree of compaction needs to require the 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 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 are 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.

<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>Safety Evaluation</td><td>General</td><td></td><td>13</td><td>-</td><td>No description</td><td>Technical Criteria for River Works: Practical Guide for Designing [I] [2.7.2]</td><td>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</td><td>It is necessary to conduct studies and evaluations based on numerical analysis, taking into account river conditions and geological conditions.</td></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>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 software.
· The modified Fellenius Method is specified for slip circle analysis.</td><td>Same as above</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>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>Permabili-ty inspection</td><td>16</td><td>-</td><td>No description</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>Due to no mention, nothing is compared</td></tr>
<tr><td></td><td></td><td>Seepage analysis</td><td>17</td><td>-</td><td>No description</td><td>River Earthwork Manual [3.3.1]

Guide of Structural Analysis of River Embankment
- 4.3.2 Item and criteria for analysis</td><td>· 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</td><td>Same as above</td></tr>
<tr><td></td><td>Seismic Condition</td><td></td><td>18</td><td>-</td><td>No description</td><td>Performance Based Seismic Design Criteria for River Structures
II. Dike</td><td>· Verify if the top elevation of a bund after an earthquake is higher than the specific water level.
· Numerical analysis with software</td><td>It is recommended to study for adding the description of stability against earthquakes considering the future condition.</td></tr>
<tr><td>Improve-ment of a Bund</td><td>Slope Stability/Slip Circle</td><td></td><td>19</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
· Mangli or ringl bund around the slip
· Installation of drainage material at the land side toe</td><td>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</td><td>· 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</td><td>Similar types of methods are introduced in both standards.</td></tr>
</table>

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan			Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents		
	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 improvem ent 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.
	Earth-quake	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.		Same as above		Same as above
			23	-	No description	Guidelines for Seismic Performance Verification of River Structures Vol.2	· 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	It is recommended to add countermeasures against earthquakes.
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.	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.		There is no mention of the parts consisting of a revetment.
	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 type	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 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 slope protection with stone pitching etc. as an immediate measure.

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.	Sindh		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 Seismic: 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	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	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, and traction are considered.	Due to the mild slope of bunds, only liniting type revetment is considered in the manual of Sindh.
		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 rivers with steep gradients and to protect riverbanks and bunds from erosion. · They are also installed to maintain and preserve 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 include such detailed information relating with the practical design method.
	Basic Shape		31	-	No description	-	No description	The manual in Punjab is including the description.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	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.
	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 minor 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, and 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 Accomplishment (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: A 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 Sindh, 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 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 construction, 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	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 a 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.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
	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 within 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-ment / Investi-gation / Exploratio n		43	-	No description	Technical Criteria for River Works: Practical Guide for O&M(For River) [4.5]	<u>Inspection before Rainy Seasons and During Typhoons</u> · Technologies such as MMS (Mobile Mapping System) are used to assess the condition of long and extensive structures. · Radar void exploration is employed for non-destructive investigation of the rear side of revetment. · 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
	River Profile / Inspection Report / Damage Record		44	APPENDIX I. River Conditions and Flood Control Measures in Sindh	No description *There are contents on the 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-scale 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.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
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. Confirm that the river channel maintains the required flow capacity. 2. Ensuring that the river management facilities, such as bunds, maintain the necessary functions. I. Inspection Targets: a. Bund i. Earthen Bunds, Revetments, Steel Sheet Pile Revetments, Foot Protection Works, Spurs. ii. High Tide Wall, Special Type Bund, Land Gates. b. River Structures: Facilities equipped with sluice gates, culverts, water gates, weirs, and drainage pump stations. II. Inspection Timing: Before Rainy Season, During Typhoon Seasons, and After Flooding Events. III. Inspection Methods: Inspections are conducted using visual observation and other appropriate methods. IV. 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. V. 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.
	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 the 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 responsibilities for storing the inspection ledgers and reports like the case of Japan.

Item	Sub Item	Sub-Sub Item	No.	Sindh		Japan		Comments
				Technical Codes	Value/ Contents	Technical Codes	Value/ Contents	
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. · AmoW1t of Erosion · Distance Remaining Uncroded · Minimum Beight of free board during the week ABKALANI REPORT(BUND) · Breach · Leak · Erosion · Works in Progress · 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 Defense · Water Level · H.F.L · Max. Depth · Min. Freeboard · Date on which water touches the Bund · Corresponding Gauge Reading at the barrage · RL, and width of 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 season · Special patrolling is required during the next season.	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 similar type of a ledger to the river ledgers in Japan.
					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 responsibilities for storing the inspection ledgers and reports 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 standards, a bund is basically an earthen structure which is aimed at protect the country from inundation by the river's spills, during floods.

While the target water level which shall be protected by a bund, high water level (HWL) based on a probabilistic analysis is used in Japanese standards, 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 detailed 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 have over 353,146 cusecs (=10,000 m^3/s) in discharge in the Japanese standard.

The width of a berm is not 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 is 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 have 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 levels and the available earthen material around the 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 stated as follows. The Manual of Irrigation Practice in Punjab must 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 the 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 software. · Simplified Bishop Method is specified for slip circle analysis.	· Verify the stability against slip circle by a numerical analysis with 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 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 software
Earthquake	・ Verify the stability against slip circle in the event of an earthquake	・ Verify if the top elevation of a bund after an earthquake is higher than the specific water level. ・ Numerical analysis with 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 Manual in Punjab 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 Manual in Punjab, 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

Regarding 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.

Regarding erosion, vegetation on the slope is one of the most popular measures for slope protection. However, it is difficult to use in Punjab due to its climate which has only small amount of rain throughout 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 an erosion control mat or a vegetation which can resist such severe climate in Punjab at 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 of obtaining the rock material with large sizes 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 that the Manual of Irrigation Practice in Punjab to include more content 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 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 countermeasures against seismic force and liquefaction are indicated in the Japanese standard. In addition, the countermeasures against earthquakes 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 recommended to the manual to include it.

[24] The Manual in Punjab 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 vary and concretes, rocks, woods and vegetation 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 a 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 uniform 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 has 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 an 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 conditions 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 that 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)

Regarding the site condition in which spurs are needed, a 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 creating slack flow. There is a mention of the purposes of spurs with the types such as permeable and impermeable ones in Japanese standards. 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 that the Manual of Irrigation Practice in Punjab to include such detailed information relating to 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 areas and particular stretches of class A rivers.

According to River Law in Japan, somebody who has 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 the 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 be strengthened periodically after about 5 years based on the manual. It is important to incorporate the concept of the asset management plan into 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 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 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 Manual for Punjab 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 guidelines, concrete inspection items on the deformation of the existing bunds are described in detail in 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 records 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 of river channels. However, they seem to be focusing on only the area around the barrages.

As it is stated 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 standards 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 responsibilities for storing the inspection ledgers and reports like in 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 on 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 as 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, few people seem to be recognizing that such a 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. It is not preferable to take time to gather 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 protect 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 cusecs (=500 m3) / 9.8 ft (= 3 m) 17,657 to 70,629 cusecs (=500 to 2,000 m3) / 13.1 ft (= 4 m) 70,629 to 176,573 cusecs (=2,000 to 5,000 m3) / 16.4 ft (= 5 m) 176,573 to 353,146 cusecs (=5,000 to 10,000 m3) / 19.7 ft (= 6 m) Over 353,146 cusecs (=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	· A back berm (Pushta) (on landside) is provided to keep the hydraulic gradient within the cross-section. · The hydraulic gradient line should 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 f t(=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 concrete 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 cusecs (=200 m3) / 2.0 ft (= 0.6 m) 7,062 to 17,657 cusecs (=200 to 500 m3) / 2.6 ft (= 0.8 m) 17,657 to 70,629 cusecs (=500 to 2,000 m3) / 3.3 ft (= 1.0 m) 70,629 to 176,573 cusecs (=2,000 to 5,000 m3) / 3.9 ft (= 1.2 m) 176,573 to 353,146 cusecs (=5,000 to 10,000 m3) / 4.9 ft (= 1.5 m) Over 353,146 cusecs (=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.

<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>Extra Embank-ment</td><td>Levelling of Top of Bunds after Constructi on.</td><td>7</td><td>-</td><td>No description</td><td>Standard for Extra Embankment</td><td>Depends on the soil type and bund height as shown in the following table
<table>
<tr><th rowspan="3">Embankment Height</th><th colspan="4">Foundation Materials</th></tr>
<tr><th colspan="2">Normal Soil</th><th colspan="2">Sand / Gravel</th></tr>
<tr><th colspan="4">Extra Banking Materials</th></tr>
<tr><th>Normal Soil (cm)</th><th>Sand / Gravel (cm)</th><th>Normal Soil (cm)</th><th>Sand / Gravel (cm)</th></tr>
<tr><td>≤ 3 m</td><td>20</td><td>15</td><td>15</td><td>10</td></tr>
<tr><td>3m – 5m</td><td>30</td><td>25</td><td>25</td><td>20</td></tr>
<tr><td>5m – 7m</td><td>40</td><td>35</td><td>35</td><td>30</td></tr>
<tr><td>≥7 m</td><td>50</td><td>45</td><td>45</td><td>40</td></tr>
</table></td><td>It is recommended for the Manual in Punjab to describe this item with reference to the Japanese guideline.</td></tr>
<tr><td rowspan="4">Quality Control</td><td rowspan="2">Material</td><td>Desirable Material</td><td>8</td><td>-</td><td>No description</td><td>River Earthwork Manual
[3.1.3]</td><td>· 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.</td><td rowspan="2">It is recommended for the Manual in Punjab to describe this item with reference to the Japanese guideline.</td></tr>
<tr><td>Available Material</td><td>9</td><td>-</td><td>No description</td><td></td><td>Same as above</td></tr>
<tr><td>Construct-ion Method</td><td></td><td>10</td><td>-</td><td>No description</td><td>River Earthwork Manual
[4.2.5], [6.1] to [6.4], [3.4.5], [5,6]</td><td>· 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 a 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 of the embankment material, methodology of quality control, countermeasures for soft ground and environmental aspects are also introduced.</td><td>Same as the above.</td></tr>
<tr><td>Degree of Compact-ion</td><td></td><td>11</td><td>-</td><td>No description</td><td>River Earthwork Manual
[3.1.4]</td><td>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.</td><td>Same as the above.</td></tr>
<tr><td>Service Road/ Mainte-nace Road</td><td></td><td></td><td>12</td><td>-</td><td>No description</td><td>Cabinet Order Concerning Structural Standards for River Administration Facilities, etc.
Article 27</td><td>· 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.</td><td>It is recommended for the Manual in Punjab to describe this item with reference to the Japanese guideline.</td></tr>
<tr><td>Safety Evaluation</td><td>General</td><td></td><td>13</td><td>-</td><td>No description</td><td>Technical Criteria for River Works: Practical Guide for Designing [I]
[2.7.2]</td><td>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</td><td>It is necessary to conduct studies and evaluations based on numerical analysis, taking into account river conditions and geological conditions.</td></tr>
</table>

<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 follows.
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 an 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 are 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 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 estimated 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 gradients 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>Permeability-ty 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 purposes. 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 components. 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 software	It is recommended 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 Manual in Punjab 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	As a foot protection work, it is recommended to introduce concrete blocks and net gabion.
				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 conditions 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 concrete 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 concrete 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 Improvem ent 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 geotextile layer at the foundation of revetment / gabion hydraulic structure · Where required, provision of a suitable cut-off *The concrete 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 concrete 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 among these 3 countermeasures is where the drainage material is located.			
		Existing Bund	22	VOL.2 Chapter 2 6.2.4, p205 to 206	Seepage through Body · Land side Seepage 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 recommended 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 type 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. 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)	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 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 assumes 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.			

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 a 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, and 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 randomly 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 following are required. · Creating slack flow to silt 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 gradients and to protect riverbanks and bunds from erosion. · They are also installed to maintain and preserve 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 spurs 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 follows. ・ 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 the 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: A 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 following. 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 following. · They are inspected before the advent of flood season every year for assessing their reliability to withstand flood onslaught. · Their deficiencies are removed before 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 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	The 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 Items are the following. 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-ment / Investi-gation / Exploratio n		43	VOL.2 Chapter 2, 4.3.1.2, p87	Not mentioned *Although it is not intended for monitoring, the following 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 and shoals 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 records 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 responsibilities for storing the inspection ledgers and reports 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 in the current manuals are as follows.
Considering these issues, the recommendation to improve the bund management in Pakistan will be studied in the following Chapter.

From the Analysis of the Manual Itself	✓ Description of the determination of the bund alignment to minimize the adverse effect on the river flow condition and generation of the turbulent flow. ✓ Description of 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. ✓ The design method of each type of revetment is not described. ✓ Description of 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 methods, considering river conditions and geological conditions. ✓ With regard to the impact on earthquakes, it is recommended 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 that 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 over multiple years. ✓ A Method or an indicator to evaluate the priority for the bund improvement is needed. ✓ Data storage and sharing must be strengthened.

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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 item indicated below, which are basically the same as the items used in Chapter 3 for the analysis. These recommendations are extracted considering the major issues which have already been recognized in Pakistan (See Sub-section **3.2.1 Extraction of Items 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 for updating the current manuals in each province, as proposed by the JICA Project Team, are presented 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 addresses current issues that require urgent attention and is considered highly effective in 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, yet it is highly effective in improving bund management.

C : 3rd Priority, Desirable.
It is relating with the issues that are not currently recognized as critical, but it is advisable to address them with future considerations in mind..

Table 4.1.1 presents the proposed recommendations for updating the Bund Manual in Sindh Province, , while **Table 4.1.2** provides the recommendations for the Manual for Irrigation Practice in Punjab Province 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	In addition to the shape of the bund, the descriptions of alignment of bunds are needed to minimize the turbulent flow and adverse effect on the river flow condition	A	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 limited description of the equipment used for embankment, it is necessary to include additional details..	A			It is recommended to describe the maximum particle size and the range of particle size distribution in the specification of the embankment material.	B
	Since there is no description of the degree of compaction (including the required value, and what to do in case it cannot be satisfied), it is necessary to include this information .	A			About the embankment material, it seems necessary to describe what to do when there is no suitable embankment material nearby.	A
	Since material obtained along river channels is often unsuitable for embankment, hence it is necessary to revise the description of material sources to ensure that materials meeting the requirements can be used without restricting the source to those found along river channels.	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 of countermeasures for soft ground.	B
Service Road/ Maintenance Road	It is recommended 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			To ensure smooth passage for maintenance vehicles, it is recommended to include a description of the pavement on the top.	B
Safety Evaluation	Since the cross-section shapes of the embankment have been determined only from the 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 considered effective for examining vulnerability as variations in the bund body material are anticipated.	A	It is necessary to add a description 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 of 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 against earthquakes.	C
	Earthquakes are not described, however it would be beneficial to include them for future considerations.	B	It is necessary to add a description of the specific method of seepage flow analysis.	A		
			It is necessary to add a description of slope stability in consideration of earthquakes.	A		
Improvement of a Bund	It is recommended to enhance the description of countermeasures, such as steel sheet piles, etc. to address the 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 an 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	Regarding countermeasures against seepage flow, it is necessary to consider the measures for the foundation grounds.	A	It is recommended to include improvement methods that are applicable to Sindh Province, such as seepage cut-off walls and impervious sheets, as seepage control works.	B
	Since there is no specific description of the design methods and design conditions for materials other than Stone Apron, it is recommended to include this information.	B			It is recommended to include countermeasures for earthquakes.	B
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 designs.	B	Gabion needs to be added.	A	It is recommended to include Gabion, Concrete Block (connected type, articulated type) and Filter Cloth.	B
	Since there is no description of the revetment foundation, it is recommended to include it.	B			In addition to recommending the development of an inexpensive surface covering material to replace the grass sodding, it is recommended to add 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 include 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 designs.	A	It is necessary to add a description of how to determine the basic shape and the other dimensions.	A		
Construction Works	Due to the limited 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 depends on its structure, materials, and construction. Standards for constructing embankments with a certain level of strength are necessary.	B				

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
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 bund management with a multi-year outlook.	A	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."	A
Monitoring of River Conditions	In the "SAFTY EVALUATION OF FLOOD BUND", there is a description of visual inspection items and countermeasures for bund deformations. However, it is the concepts only. For practitioners to be able to design countermeasures, it is recommended to add a description of specific planning and designing methods.	B	Regarding physical inspection, it is necessary to add the description of Survey Team Member and and the person responsible	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.	A	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 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 regulations 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 store them so that they can be easily searched.	A	Additional descriptions are required for monitoring of river channels through ground surveys 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 a description of 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 conduct a graded evaluation based on the observed deformations to assess the degree of soundness, and then use this assessmentas an index of priority for repairs and improvements.	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	The description should be updated to communication methods based on the latest technology.	A				
	To prevent variations in information and ensure continuous monitoring, it is recommended to use standardized forms and systematically accumulate data.	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 unclear which division is responsible for information on river construction, it takes time to understand 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 the 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 of 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
	In addition to the shape of the bund, the description of the alignment of bunds are needed to minimize the turbulent flow and adverse effect on the river flow condition	A				
Quality Control			It is necessary to include the complete contents of Quality Control.	A	It is necessary to add the entire contents of 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 standards.	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 include descriptions of the used for surveying embankment materials.	A
					It is recommended to add a description of 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 include a description of 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.	B
Improvement of a Bund	There is a specific description of the slope stability by slip surface, but the countermeasures are insufficiently described, so it is necessary to include additional details.	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 countermeasures 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 recommended to include countermeasures for earthquakes.	B
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 designs.	B			It is recommended to include Concrete Block (connected type, articulated type) and Filter Cloth.	B
	Since there is no description regarding the design of foundations that considersseepage control and scouring, it is recommended to include this information.	B			In addition to recommending the development of an inexpensive surface covering material to replace the grass sodding, it is recommended to add 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 can vary 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 entire contents 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 bund management with a multi-year outlook.	A			Instead of inspections and repairs within a single year, it is necessary to introduce PDCA cycle maintenance and management in multiple years. The 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 of 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 entered for each item, it is also recommended to improve the ledgers for 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 vary 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	The description should be updated to communication methods based on the latest technology.	A				
	To prevent 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 specified who is responsible for analyzing the flood route and who is in charge of diverting the flood flow, it is recommended to clarify these roles and procedures.	B				
	It is desirable to include multiple examples of the closure.	C				
Gap between the Manual and the Actual Practice	Since it is unclear which division is responsible for providing information on river construction, it takes time to acquire the details. Additionally, information is not shared effectively due to the unclear responsibility system is not clear. Improvement in this area is necessary.	A				
	Since the records of constructions are not accumulated, improvement is recommended. It may be necessary to create reference samples for the 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 Recommendations 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, and requirement of the embankment material.
- ✓ Improve descriptions of safety evaluation especially against seepage flow and erosion (and scouring) to incorporate 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 that can be introduced in Pakistan.
- ✓ Add new content on the management plan that considers not only a single year but also multiple years for the bunds, including the PDCA cycle To enhance organizing and seeking the necessary documents, specify the storage method of reports and ledgers on the bund inspections in more detail such as who, how, where to record or to keep. This will lead to making the PDCA cycle type bund management effective.

This project includes "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 activity, the proposed supplementary material will be prepared with a primary focus on the aforementioned items..

About the measures with priority B and C indicated in Table 4.1.1 and Table 4.1.2, it is recommended to incorporate them into the manuals by 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)."

CHAPTER 4 RECOMMENDED UPDATE ON THE MANUALS IN PAKISTAN 4-1
4.1 Recommendation on the Manuals 4-1
4.2 Proposed Recommendations for the Preparation of the Supporting Document to the Current Manuals on Bund 4-7

Table 4.1.1 Recommended Update on the Manual in Sind (Bund Manual) 4-2
Table 4.1.2 Recommended Update on the Manual in Punjab (Manual for Irrigation Practice) 4-4

図表目次項目が見つかりません。