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About GWSP

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Appendix 3
Operation and Maintenance Plan
(Sample Framework)

Introduction
This sample framework of the Operation and Maintenance Plan (O&MP) outlines the general operation and maintenance (O&M) requirements of the dam and associated facilities to allow the users to define such requirements in the context of their projects. The O&MP should cover the following: (a) organizational management structure, including staffing, key staff qualification, training, and funding arrangements; (b) operation plan, including the reservoir operation rule and procedures, as well as the operating system or procedure of flow control equipment; (c) maintenance program for civil structures and electric and mechanical equipment; and (d) surveillance program, including visual surveillance, instrumentation monitoring, periodic safety inspection, and reporting and archiving procedures. Annex A provides a sample table of contents for the O&MP.

The O&MP is one of four dam safety plans required for certain dams1 by the World Bank Environmental and Social Framework/Environmental and Social Standard 4/Annex 1 on safety of dams, which include (a) Construction Supervision and Quality Assurance Plan (CSQAP), (b) Instrumentation Plan (IP), (c) O&MP, and (d) Emergency Preparedness Plan (EPP). In the World Bank project's cycle, the preliminary O&MP is required at appraisal.

The full-fledged O&MP should be submitted not less than six months before starting the first reservoir filling. The plan should reflect as-built conditions of the dam; associated facilities and equipment; and supplier’s O&M manual of electrical and mechanical equipment.

If a new or upgraded O&MP is required for existing dams, on which World Bank–funded downstream projects rely, the full-fledged plan should be completed before undertaking major investment in downstream areas. The O&MP should also be updated when any significant changes are introduced to the dam operating system and procedures.

Key Features of the Dam and Reservoir
Key features of the dam should be provided, including

- Purpose, type, height, crest length, reservoir capacity, and so on of the dam;

- Type and discharge capacity of spillway, outlet works, and so on, along with their operational modalities;

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1 As per ESS4 – Annex 1, para 2, these are “large dams” and “small dams” that could cause safety risks or are expected to become large dams during their operating life.
• Main features of other associated facilities, such as power generation plant, water intake, and so on;

• Location of the dam, catchment or reservoir area, and their access; and

• Key potential hazards of the dam and surrounding areas

In case upgrading the O&MP for existing dams is necessary, the dam’s operational records, results of previous dam safety inspection and assessment reports, and identified major deficiencies and repair works to date should be properly filed and reflected in the surveillance and inspection program.

Management Structure

Overall Management Structure
Detailed management structure required for undertaking the O&M activities should be specified in the plan, including the following:

• Legislative and regulatory requirements

• Management structure, reporting line, and organization chart

• Roles and responsibilities of managers and technical staff

• Coordination with other relevant entities (regulator, owner, and other stakeholders)

Key Technical Staff Qualification and Training Program
The operational staffing plan for undertaking all O&M activities should be prepared, covering the operation and maintenance, surveillance, monitoring, and inspection aspects of the dam and reservoir. The plan should describe the number of staff, required qualifications, roles and responsibilities, and reporting lines.

The level of qualifications and training of the operational staff should be commensurate with the complexity of the dam and associated structures. Adequate training should be specified, covering safe operation of various equipment, maintenance, and surveillance, which should be illustrated both through theoretical offsite and practical onsite training sessions.

The nature of the dam’s potential failure modes—in particular those related to inappropriate operation or accidental misoperation—and the consequences of unintentional flow release and dam failure should be clearly explained and understood by the operational staff.

Funding Arrangement for O&M
The required budget and funding arrangements for undertaking the long-term O&M works, including periodic rehabilitation and refurbishment works, should be assessed and secured.
Overview of O&M Activities

Main O&M Tasks

The main O&M activities that should be covered by the plan include the following:

- Dam and reservoir operation plan for normal and drought periods (water supply, irrigation, hydropower generation, in-stream flow requirement, and so on), flood period (hydromet monitoring, flood forecasting, downstream warning, and so on), and emergency situations

- Maintenance program for the civil works and electromechanical equipment

- Surveillance program, including visual surveillance, instrumentation monitoring, and inspection

- Long-term asset management, including sediment management in the reservoir and nearby areas of the intake and bottom outlet, and operational reliability of electromechanical equipment

- Emergency preparedness, including a sudden release of water from the dam (with reference to the EPP)

Other Relevant Elements

The plan should also cover other relevant elements as follows:

- Communications (onsite normal telephones, contact list and mobile phone numbers of key staff, radio, and so on)

- Access routes to the dam and management office (primary and secondary)

- Public safety (gates, fences, warning signs, sirens, awareness training and education program, and so on)

- Site security (patrols, regulation on the entrance, access restriction to off-limit areas, sign posts, and so on)

Dam and Reservoir Operation Plan

Reservoir Operational Rules and Procedure

The dam and reservoir operation plan should cover the following:

- Flow discharges under normal and drought conditions, in line with water supply, power generation, and other discharge requirements, along with the reservoir rule curves (for example, reservoir water level to be kept during different seasons)

- Flow discharges under flood conditions, including systems and procedures for hydrometeorological monitoring data acquisition, flood forecasting, and decision-support system for reservoir operation
• Flow discharges under unusual conditions (such as cases of deviations from routine operations as a result of flow control equipment failure, debris blockage, and so on) and emergency reservoir drawdown and other operational procedures

• Notification procedures and early warning system for downstream areas and communication protocols with other cascade facilities

• Other reservoir operation needs, including in-stream flow release, sediment flushing and sluicing through bottom outlets, selective water intake, and so on

• Operational monitoring and records keeping, including rainfall, reservoir water level, and inflow and outflow volume data

• Integrated reservoir operation with other cascade dams when required

• In case of new dams, the first reservoir impoundment plan, including reservoir filling sequence, monitoring and surveillance procedures, and results to be incorporated after completion

Operating System and Procedure of Flow Control Equipment

The dam and reservoir operation plan should also provide the details of the operating system and procedure of the gates, valves, and other water flow control equipment, including the following:

• Overview of the operating system and procedures for flow control equipment (local, remote or automatic control, and staged gate opening) and alarms

• Upper and lower limits of discharge and allowable limits of opening rates of gates and valves

• Time and staffing requirements for conducting various operations

• Backup power supply system (remote and local) and corresponding operational procedure

• Manufacturers’ operating manual, technical specification, and design and installation reports of the flow control equipment

• Technical specification and operating procedures of other associated equipment, such as boom, trash screens, cleaning machine, and so on

• Periodic excavation and dredging of sediment deposits near the intake, and so on

The reservoir elevation-area-capacity curve, rating curve of the spillway and other outlet works, and the reservoir rule curve should be attached in appendixes. The reservoir area-capacity curve should be updated when sediment accumulation is surveyed.
Maintenance Program

Maintenance Program Overview

The maintenance program for the dam and appurtenant structures should define all tasks to be undertaken as scheduled to ensure: (a) reliable and safe operation, (b) regular inspection, (c) early detection of deterioration, and (d) repair or rehabilitation to be carried out in a timely manner to ensure all structures and facilities are kept in good condition.

The maintenance program should indicate the components of the dam and appurtenant structures requiring scheduled maintenance activities and record of what is done, when, and by whom. Routine maintenance is that which can typically be scheduled based on time (weekly, monthly, and so on); usage (number of cycles hours of operation, and so on); or observed condition from periodic visual inspections that identify excessive wear, corrosion, dump areas, and so on.

Civil Works Maintenance Program

The civil work-related maintenance program may include repair of cracks and joint sealing system; repair of concrete damage and reinforcement of steelwork corrosion; repair of seepage-induced erosion and slumping; repair of wave-induced upstream surface erosion; cleaning of internal drainage system; repair of scouring, erosion, and cracking damage of spillway chutes; stilling basin; repair of monitoring instruments; removal of vegetation, aquatic weed, and debris; and so on. The monitoring and maintenance works for stabilizing the reservoir rim slopes and downstream river banks may also be required in special cases.

Electromechanical Equipment Maintenance Program

The maintenance program for mechanical and electrical equipment, such as gates or valves, lifting equipment, and power supplies should include required maintenance and testing procedures to confirm that the equipment is in good working order and capable of normal and emergency operation. Maintenance works may range from a simple change of lubricants to a complete overhaul. It is also necessary for operators to be familiar with the performance of this equipment, especially if it is infrequently used. It is important that the equipment manufacturers’ maintenance recommendations are considered and integrated with the maintenance program.

Surveillance Program

The objectives of surveillance are to (a) compile an accurate history of observations relevant to the assessment of dam safety, (b) allow the safety performance of the dam to be regularly assessed and reported, and (c) facilitate the early detection and reporting of potential deficiencies or adverse trends.

An adequate dam surveillance program should be established, including frequent and regular inspections of the dam and associated structures and instrumentation monitoring, data analyses, evaluation, and storage. The frequency of inspections and monitoring data analyses varies depending on their specific tasks, complexity of the system, and potential risk of dams.
Surveillance Types and Schedule

The surveillance program should be clearly detailed, including visual inspections and instrumentation monitoring. The plan should provide a list of all elements for the surveillance program of the dam and reservoir. The surveillance and monitoring instruments’ location drawings can be attached or referred to in the Instrumentation Plan to locate the visual observation and monitoring points, including the following items:

- Visual observations of the dam crest, upstream/downstream face, abutments, spillway, reservoir shoreline, and so on

- Deformation survey and monitoring with survey marks, plumb lines, inclinometers, settlement gauges, and joint and crack meters to assess the stability of the dam, associated facilities, and foundation

- Seepage monitoring by weirs or quantitative visual observations

- Internal water pressure and foundation uplift pressure by piezometers, open standpipes, and so on

- Accelerometers in high seismic areas (dam crest and foundation level)

- Reservoir water levels

Periodic Dam Safety Inspection

The periodic dam safety inspection plan should be outlined in a table format in a commensurate manner according to the potential risk of the dam. Check sheets for inspection of each feature of the project should also be attached, including postinspection action. Visual inspections are critical for comprehensive assessment and evaluation of the safety condition of dams and associated facilities and must be done by qualified and motivated engineers.

An inspection schedule of all structures should be developed, and the results should be maintained with good records. Important deficiencies and defects should be registered and photographed, and adequate survey should be conducted. This should be done monthly or yearly for routine inspection; periodically (for example, five years) for comprehensive inspection; and after critical events, such as severe floods, earthquake, and so on. Following each inspection, the inspection records and reports should be assessed by the maintenance supervisor for organizing the appropriate maintenance activity. It is important to take appropriate measures to address the findings and recommendations.

The engineers involved with routine inspections should be trained to be able to understand and assess the following: (a) What are the indicators of potential problems? (b) What are their possible causes? (c) What are their degree of deficiency? and (d) What are their potential effects on dam performance and safety?
**Monitoring Instrumentation**

Monitoring data and information will be collected, stored, and analyzed in comparison with long-term or seasonal trends and the design assumptions to detect any abnormal conditions. The analytical results and alarms should be communicated with dam safety experts as per a predefined protocol. This ensures that appropriate actions are taken in a timely manner. This can be detailed by and referred to the Instrumentation Plan (see Appendix 2).

The levels of alarm should be specified by a suitably qualified dam engineer when data involves instrumentation for data analysis. As an example, the levels can be set for:

*Level 1:* data check alarm  
*Level 2:* design and historical precedent/trends check alarm  
*Level 3:* alert alarm when structural behavior exceeds acceptable limits

The level of alarm should also include a visual observation significance rating to be applied by the inspector to determine when unusual conditions are observed.

**Reporting and Archiving Procedure**

The O&MP should provide a list of reports and submission procedure or schedule, such as monthly surveillance or monitoring report, annual safety assessment report, five-year dam safety examination report, and special inspection reports after major floods, earthquakes, and so on. The archiving procedure of all reports, data, and records should also be stipulated.
Annex A: A Sample Table of Contents of O&MP

The following is a sample table of contents, representing the essential elements of an Operation and Maintenance Plan (O&MP) for a dam project. Contents may be more extensive, depending on complexity and level of risk of the project.

1. Introduction
   1.1. Main Characteristics of Dam and Appurtenant Structures
   1.2. Potential Hazards of Dam and Surrounding Areas

2. Management Structure
   2.1. Overall Management Structure
   2.2. Key Staff Qualification and Training
   2.3. Funding Arrangements for O&M

3. Overview of O&M Activities
   3.1. Main O&M Tasks
   3.2. Other Relevant Elements

4. Operational Plan
   4.1. Reservoir Operational Rule and Procedure
   4.2. Operating System and Procedure of Flow Control Equipment

5. Maintenance Program
   5.1. Maintenance Program Overview
   5.2. Civil Works Maintenance Program
   5.3. Electrical Mechanical Equipment Maintenance Program

6. Surveillance Program
   6.1. Surveillance Types and Schedule
   6.2. Periodic Dam Safety Inspection
   6.3. Instrumentation Monitoring
   6.4. Reporting and Archiving Procedure
Appendixes

Maps, drawings, diagrams, check sheets, and so on should be attached as appendixes, including but not limited to the following:

- Location and dam site layout plans
- Reservoir storage and operational rule curves
- Gate and valve operating procedure diagram
- Periodic dam safety inspection and reporting procedure
- Routine surveillance schedule and check sheets
- Monitoring instrumentation layout and schedule
- Manufacturers’ operation and maintenance manuals for electrical and mechanical equipment and monitoring instruments