MINISTRY OF FOOD & AGRICULTURE (MOFA)
GHANA COMMERCIAL AGRICULTURE PROJECT
(GCAP)

Standard Operating Procedures Manual

For

Tono Dam
Kassena Nankana Municipality, Upper East Region of Ghana

Prepared By:

INTERNATIONAL POWER COMPANY LIMITED

DECEMBER 2018
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3.2 Periodic Inspections

3.3 Special Inspections

3.4 Checklist for Routine and Periodic Inspections

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Chapter 1– Introduction

Dams are important water resources infrastructures that contribute to the socio-economic development of populations. At the same time, they pose serious threat to society, in particular life and property of nearby communities in the event of a breach. This document is the Standard Operating Procedures (SOP) Manual for Tono Dam. It is part of Safety Assessment conducted on the Dam and seeks to provide procedures, guidance and standard practice for the normal operation of the dam and its appurtenant structures.

The operation and maintenance as well as thorough and consistent monitoring should be practiced throughout the lifetime of the dam. This will help in the proper functioning, cost efficiency, and compliance with safety regulations. Continuing these management activities will help to prolong the life of the dam provided a detailed Operations and Maintenance Program that includes routine, adequate inspections etc. are followed by management [1].

It was observed that no documentation existed in respect of operations and maintenance since the dam was constructed. However, a culture of documentation of consistent operation, maintenance, and monitoring leads to a sound record of baseline conditions of the dam. As a result, deviation from normalcy becomes apparent. Because signs of potential risk and failure often manifest prior to occurrence of a breach, early detection of such issues through proper operation, maintenance and inspection is essential. Early detection of potential dam incidents provides critical period for the appropriate response measure to be executed [1].

1.1 Background

The Ghana Commercial Agriculture Project (GCAP), financed by the International Development Association and USAID, is Ghana’s flagship agricultural project. The project was restructured in 2015 with the following revised Project Development Objective (PDO):

to improve agricultural productivity and production of both smallholder and nucleus farms in selected project intervention areas with increased access to reliable water, land, finance, and agricultural input and output markets.

The restructured GCAP consists of seven components as follows: (i) Strengthening investment promotion infrastructure and facilitating secure access to land; (ii) Securing PPPs and smallholder linkages in the Accra Plains; (iii) Securing PPPs and small-holder linkages in the SADA Zone; (iv) Project Management including M&E and impact analysis; (v) Investments in physical rehabilitation and modernisation of existing public irrigation and drainage infrastructure; (vi) restructuring and strengthening of public irrigation and drainage institutions of the Government of Ghana; and (vii) development of Water Users’ Associations and private scheme management.

Under Component 5 of the Project, GCAP is supporting the design review, rehabilitation and modernisation of the scheme including an assessment of the economic rates of return and poverty reduction impacts of the Tono Irrigation Scheme Project.

1.1.1 Tono Dam and Irrigation Scheme

The Tono scheme was established by the Government of Ghana to promote production of food crops by small scale farmers within organised and managed irrigation schemes. The secondary purpose of the dam is to provide water for treatment to serve populations of nearby towns. However, this aspect is yet to be operationalised. The dam is located on the Tono River, a secondary tributary of the main White Volta River, with capacity of about 92 Mm$^3$ and constructed between the elevations 164m and 184m. Construction of the dam started in 1975 and was completed in 1977. However, development of the irrigation field was completed in 1985.
The Figure 1 is a cross section of the Tono Dam.

![Figure 1 Cross section of the Tono Dam](image)

The dam facility provides water to serve an irrigation scheme with potential irrigable area of 2,680 ha of which 2,490 ha has been developed. The Figure 2 is the Area-Volume-Elevation curves of Tono dam.

![Area - Volume - Elevation Curve for Tono Dam](image)

**Figure 2 Water level and reservoir volume of Tono dam**
Some rehabilitation of the gravity scheme was carried out in 2008 by replacing the sandcrete slabs in the Main Gravity Canal (including the Left and Right Bank Canals) with insitu concrete. The Figure 3 is the layout of Tono Dam with appurtenant structures and access roads. The dam facility serves 8 surrounding communities, providing water for all year round irrigation. Also, groups of fishermen undertake fishing activities in the reservoir. To this end, 9 Village Committees have been established by the public scheme managers, Irrigation Company of Upper Region (ICOUR), to support operations and management of the irrigation scheme.

1.2 Inventory of the Dam and Gaps
This section provides a summary of basic information related to the Tono dam. This inventory is based on information provided in the TOR and confirmed during the visit to the dam site in February and March 2017, during the Dam Safety Assessment study (2017). It presents the physical features and installed mechanical equipment of the dam in Table 1.

Table 1: Key Features of Tono Dam

<table>
<thead>
<tr>
<th>Item</th>
<th>Section</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Remarks/Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dam</td>
<td>Earth Dam</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reservoir Capacity</td>
<td>Million cu.m</td>
<td>92.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catchment Area</td>
<td>Sq. km</td>
<td>650</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Top Water Level</td>
<td>MASL</td>
<td>179.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design Flood</td>
<td>MASL</td>
<td>181.69</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Section</td>
<td>Description</td>
<td>Unit</td>
<td>Quantity</td>
<td>Remarks/Condition</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------</td>
<td>------------------------------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Level</td>
<td></td>
<td>Maximum Water Depth</td>
<td>m</td>
<td>15.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum Height of Embankment</td>
<td>m</td>
<td>18.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lowest Ground Level in River Bed</td>
<td>MASL</td>
<td>163.98</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Top of Embankment</td>
<td>MASL</td>
<td>182.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Top of Wave Wall</td>
<td>MASL</td>
<td>183.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reservoir Surface Area</td>
<td>Ha</td>
<td>1860</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Dam crest</td>
<td>Level</td>
<td>MASL</td>
<td>182.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width</td>
<td>m</td>
<td>5.7</td>
<td>Good condition.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Camber</td>
<td>%</td>
<td>6</td>
<td>Camber not maintained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length</td>
<td>km</td>
<td>3.471</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gravel Surface</td>
<td>-</td>
<td></td>
<td>Good condition.</td>
</tr>
<tr>
<td>3.</td>
<td>Upstream embankment</td>
<td>Slope</td>
<td></td>
<td>1:3</td>
<td>Maintained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rip-rap slope protection</td>
<td>-</td>
<td></td>
<td>Good condition. Tree stumps observed but controlled and prevented from growing tall.</td>
</tr>
<tr>
<td>4.</td>
<td>Downstream embankment</td>
<td>Slope</td>
<td></td>
<td>1:2.5</td>
<td>Maintained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slope protection</td>
<td>-</td>
<td></td>
<td>Gullies observed on the slope. Need to be filled with earth material and grassed. Also, open paved drains along the sloping surface filled partially with earth and seem non-functional.</td>
</tr>
<tr>
<td>5.</td>
<td>Offtake</td>
<td>Invert</td>
<td>MASL</td>
<td>171.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chamber</td>
<td>No.</td>
<td>1</td>
<td>Good but filled with water at the time of visit. Need to drain the water.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Valve</td>
<td>No.</td>
<td>2</td>
<td>One gate and one butterfly.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spindle</td>
<td>No.</td>
<td>2</td>
<td>In good condition.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outlet</td>
<td>No.</td>
<td>1</td>
<td>In good condition.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width</td>
<td>m</td>
<td>60</td>
<td>Verified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crest Level</td>
<td>MASL</td>
<td>179.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design Flow</td>
<td>cu.m</td>
<td>496</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Channel</td>
<td>-</td>
<td>-</td>
<td>Good. However, some side walls have tilted thereby creating gaps. Walls need</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Item</th>
<th>Section</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Remarks/Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Scour Tower Valve</td>
<td>Chamber</td>
<td></td>
<td></td>
<td>Chamber filled with water. May be due to leakage from the walls and valves.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Access bridge</td>
<td>No.</td>
<td>1</td>
<td>In good condition but signs of settlement affected hinge support, noting wider than normal expansion joint of Scour Tower walkway.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Valve</td>
<td>No.</td>
<td>1</td>
<td>Submerged continuously. Not operated for over 25 years.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spindle</td>
<td>No.</td>
<td>1</td>
<td>In good condition.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outlet</td>
<td>No.</td>
<td>1</td>
<td>Blocked with earth.</td>
</tr>
<tr>
<td>8.</td>
<td>Provision for Domestic Water</td>
<td>Valve</td>
<td>No</td>
<td>3</td>
<td>Water is abstracted at three different elevations into a 400mm pipe for domestic use. Not yet utilized.</td>
</tr>
</tbody>
</table>

### 1.3 Purpose of the SOP
This SOP Manual is developed to guide Tono dam operation, maintenance and management to ensure the safety of the facility and consequently, populations living in and around the catchment of the dam, in particular, downstream communities.
Chapter 2 – Tono Reservoir and Operations

A reservoir operation is an important aspect of water resources planning and management. Often, a reservoir operation plan is formulated that guides the quantities of water to be stored or released under various conditions.

The operation plan provides a set of rules and strategies for reservoir releases based on its level, hydrological conditions, water demand and time of the year [2]. From Figure 4, the Tono reservoir can be divided into four (4) sections: (i) inactive zone - the zone in the reservoir that is lost to sediments trapped in the dam; (ii) buffer zone – the zone where water releases is limited and prioritized; (iii) conservation zone – the zone where water releases is unlimited, supplying all demands including irrigation and fishing; (iv) flood control – the zone for flood protection [10].

Further, the flood control zone is divided into controlled and uncontrolled zones. In the former zone, a flood wave can be channeled through the spillway structure in a manner that is less harmful to the structural integrity of the dam. However, the latter could lead to overtopping of dam, which is most undesirable and should be avoided. The buffer and conservation zones constitute the active storage of the reservoir, ensuring that the flood control zone is kept vacant [10]. Thus a reservoir can be multipurpose, serving water supply or flood protection or a combination of uses.

![Figure 4 Tono Reservoir storage zones, volumes and elevations](image)

The reservoir storage at normal full pool is about 92.6Mm$^3$. This corresponds to 18.6km$^2$ of surface area and an elevation of 179.22m. The minimum water level occurs at an elevation of 172.47m, corresponding to a reservoir surface area of 5.6km$^2$ and capacity of about 13.9Mm$^3$. The dead storage of the reservoir is at an elevation of 171.6m with storage capacity of about 10.4Mm$^3$, covering an area of about 4.8km$^2$. The minimum water level requirement in the reservoir at a specific time, more often than not, is followed except during periods of extreme drought when operation is mostly public interest driven. However, in a typical case at Tono dam, there was no irrigation in the dry season of 2014/5 when the area experienced severe drought in 2014.
Records of reservoir water levels indicate the occurrence of spills in the peak of the rainy season, usually in September. According to managers of the facility, flooding occurs between two (2) to four (4) weeks which needs to be managed to eliminate/minimize losses be it life or property. This was reiterated by some members of communities the consulting team interacted with. The Tono reservoir operation related to inflows and outflow measurements as well as siltation management are discussed in the (sub) sections following.

2.1 Inflows
The inflow into Tono reservoir is the volume of water that flows/comes into the reservoir. The inflows result from the runoff from the catchment area of the dam as well as direct rainfall onto the reservoir. The annual rainfall in the area ranges between 700 and 1010 mm using data from 1971 to 2015 with the peak occurring usually in August. [11]

![Average rainfall graph](image)

*Figure 5 Average monthly rainfall data at the Navrongo Synoptic Station (1971-2015)*
(Source: GCAP, ESIA Report, 2018)

2.1.1 Measuring water level in the reservoir
A staff gauge is used to measure the reservoir water level. A simple manual instrument is the standard D50 staff gauge installed on the Scour Tower in the reservoir, and the corresponding markings organised according to site elevations in meters.

Additionally, the proposed Supervisory Control and Data Acquisition (SCADA) system will monitor, gather and process real time water level through the automatic water level sensors to improve efficiency, process data for smarter decisions and communicate system issues to help mitigate downtime. This allows for human-machine interface software, enabling data acquisition from a remote location.

The procedure suggested to operate the staff gauge are the following;
1. Places logbooks at appropriate locations.
2. Takes readings of water level (in a bottom-up manner) on the graduated scale.
3. Enter readings in the appropriate logbooks and database.

**Responsibility:** *It is the primary responsibility of the Water bailiff to collect data on reservoir water levels on the staff gauge and ensure that related documentations are kept up to date.*
the case of the automatic water level sensors and the flow meter, data will be transmitted and stored at the control center.

Further, the operations of the Water Bailiff needs to be tracked as follows:
1. Inspects logbook at appropriate times.
2. Takes the necessary correctional action(s) on the readings.

**Responsibility:** It is the responsibility of the Project Irrigation Engineer.

### 2.1.2 Measuring peak flows into the Tono reservoir

The peak flows into the Tono reservoir poses a hydrologic hazard to the safety of the dam. To properly manage flood risk, it is essential to characterise the inflows from a stream gauge installed upstream of the river draining into the reservoir. This will enable determination of a hydrograph that best characterises the inflow volume and consequently analyse the impacts. If the stream gauge(s) is/are automated, it will inform appropriate decisions in time. 

**Refer to Appendix 2 on inflow hydrographs.**

The procedure suggested to operate the stream gauge(s) are the following:
1. Liaises with Hydrological Services Department (HSD) to install/retool stream gauge(s) into automatic systems at strategic locations on the Tono River.
2. Analyzes the hydrograph to ascertain the inflow volume and impact on the dam.
3. Takes the necessary action(s) on the readings, in consultation with Managing Director.
4. Ensures that data on peak flows is kept appropriately.

**Responsibility:** It is the primary responsibility of the Project Irrigation Engineer to observe and analyze data on peak flows to ensure safety of dam.

### 2.2 Outflow Measurement

A key aspect of flood hazard analysis of dams entails a focus on reservoir outflows. As a result, the measurement of outflows from a reservoir is a relevant step towards acquiring information to support dam operations. Tono reservoir outflow is in two forms notably (i) the normal releases from the main outlet canal, and (ii) flood water evacuation through the spillway.

#### 2.2.1 Normal Releases

The normal releases depend on the cropping calendar and irrigation scheduling. This release from reservoir through the Gate and Butterfly valves system at the upstream. This valve system regulates flows through the outlet canal to the irrigation fields via the laterals and sub-laterals.

**Refer to sub-section 2.5.3 on Valve operations.**

The outlet canal is trapezoidal shaped open channel fitted with a metal spindle/wheel that is lowered or raised to control the flow going through the canal to the irrigated fields. A Parshall Flume installed on the canal is used to measure the flow discharge.
The procedures for manual operation of the gate are as follows;
1. Turns circular wheel/spindle clockwise to allow flow out of the reservoir to the irrigated fields.
2. Turns circular spindle anti-clockwise to shut flow out of reservoir.
3. Places logbooks at appropriate locations.
4. Takes readings of water level in the Parshall Flume.
5. Enters readings in the appropriate logbooks and database.

**Responsibility:** In the automatic mode, operation of the integrated gate will be done remotely from the control centre.
It is the responsibility of the Water Bailiff to operate the control gate in the manual mode and to collect data related to the discharge of flow and kept up to date.

Further, the operations of the Water Bailiff needs to be tracked as follows:
1. Inspects logbook at appropriate times.
2. Takes the necessary correctional action on the readings.

**Responsibility:** It is the responsibility of the Project Irrigation Engineer.

### 2.2.2 Flood Water Evacuation
Flood water is generated during high intensity rainfall events, generating increased runoff from the catchment areas. As a result, large volume of water flows into the reservoir. Evacuation of flood waters, depending on the expected volumes, may require the use of both outlet channels: main canal and spillway. A spillway is provided to evacuate the high flows and thereby avert overtopping of the dam.
As such, two (2) rules shall be considered for Tono dam. They are;
(i) Maximum Peak Flow Reduction Rule; and
(ii) Minimise Exceedence of Downstream Channel Capacity Rule.

Therefore, a good understanding of the catchment, coupled with foreknowledge of the inflow hydrograph is pre-requisite for the smooth operation of the reservoir. The nature (shape) of inflow hydrograph enables estimation of the inflow and informs the volume expected to reach the dam.
2.2.2.1 **Maximum Peak Flow Reduction Rule**

As the name suggests, this is targeted at reducing the impacts of peak flow into the reservoir. Thus the expected volume of inflow is analyzed against the available storage. As a result, managing inflows becomes very important and should guide the discharge from the dam. This may necessitate some fore releases in anticipation of the flood wave in order to accommodate and attenuate its impacts on the dam [10].

The procedure suggested to evacuate flood waters, based on anticipated inflow are:

1. Assesses the reservoir storage, taking into consideration the travel time of the flood wave to reach the dam.
2. Notifies duly superiors for the necessary action(s) to be taken
3. Takes the necessary action based on the anticipated inflows (initiate releases through the main canal outlet).
4. Places logbooks at appropriate locations.
5. Takes readings of water level of spills through the spillway.
6. Enters readings in the appropriate logbooks and database.

**Responsibility:** *It is the responsibility of the Project Irrigation Engineer to operate the reservoir using this rule and to collect data related to the discharge of flow through the spillway and kept up to date.*

2.2.2.2 **Minimize Exceedence of Downstream Channel Capacity Rule**

Recognizing the socioeconomic developments downstream of the dam, a more common rule for reservoir flood operations is to minimize exceedence of downstream channel capacity. The water to be released should be contained in the channel to avoid spills into adjoining lands, thus controlling the outflow. This way, the devastation of life and property is eliminated.

When the inflow is less than the downstream channel capacity, outflow equals reservoir inflow, so all inflow is released. The reservoir will begin to store the excess flow when inflow exceeds the channel capacity [10]. At full storage, outflow is again equal to the inflow. On the recession limb of the hydrograph, the reservoir begins to release water at the rate of the channel capacity once inflow is less than the downstream channel capacity [10].

Observably, flooding at Tono dam occurs between two (2) to four (4) weeks in the rainy season. As a result, it is critical that life and property are safeguarded during this period. Therefore, it is very important to adhere to the operating rules.

**Repeat the procedure in sub-section 2.2.2.1 for this Rule.**

**Responsibility:** *It is the responsibility of the Project Irrigation Engineer to operate the reservoir using this rule and to collect data related to the discharge of flow through the spillway and kept up to date.*

2.3 **Sedimentation Management**

Sedimentation refers to the process where organic and inorganic material are carried by run-off and deposited in the reservoir. Generally, sediment transport is dependent largely on the activities carried out upstream of a reservoir.

The procedure suggested for catchment area protection is as follows:
1. Engage communities committees to create buffer zones along the boundaries of reservoir as means of alternative livelihood.
2. Train nursery attendants to establish tree seedlings in communities.
3. Engage communities to grow vetiver grass and establish plantation of economic trees as buffer zone.
4. Establish agreements with communities to preserve the buffer zone.
5. Support alternative livelihood activities of farmers while limiting flood recession farming activities.
6. Monitor the progress of growth of the vetiver grass and the plantation.
7. Promote enactment of byelaws at District/Municipal Assemblies to secure the buffer zone.

The procedures suggested to manage sediment transport is similar to that for catchment area protection as shown in section 2.4.

Responsibility: The Managing Director takes primary responsibility to secure reservoir from siltation, and may delegate authority to a subordinate.

2.4 Catchment area protection
The catchment area of Tono dam is the adjoining lands that contribute runoff water stored in the reservoir. Upstream of the reservoir, Pepper, among other vegetables, is cultivated through flood recession agriculture in the dry season and has the tendency to promote erosion of the loose top soil into the reservoir.

Refer to procedure of section 2.3 and apply accordingly.

2.5 Valves
There are two 900 mm valves for control of water for irrigation. A gate valve used for opening and closing as well as a butterfly valve for control of the amount of water allowed into the conduit.

2.5.1 Gate Valves
Gate valves are primarily designed for on-off services. They are best used in systems which require infrequent use of the valve. The valves are designed for full-area flow to minimize the pressure drop and allow the passage of a pipe-cleaning pig. Since most of the flow change
occurs near the shutoff, the relatively high fluid velocity causes disk and seat wear and eventual leakage if the valve is used to regulate flow. A gate valve is shown in Error! Reference source not found..

![Figure 9: Gate Valve](image)

### 2.5.2 Butterfly Valves

A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. The disc is positioned in the center of the pipe; passing through the disc is a rod connected to an actuator on the outside of the valve. When the valve is closed, the disc is turned so that it completely blocks off the passageway. When the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the fluid. Rotating the actuator turns the disc either parallel or perpendicular to the flow. The disc is always present within the flow, so a pressure drop is always induced in the flow, regardless of valve position. The valve may also be opened incrementally to throttle flow. Operation of a butterfly valve allows for quick shut off. A butterfly valve is shown in Error! Reference source not found.10.

![Figure 10: Butterfly Valve [4]](image)
2.5.3 Valve Operation

To allow water into the conduit for irrigation:
1. Open the gate valve fully.
2. Open the butterfly valve to the desired position.

To shut off water from entering the conduit:
1. Close the butterfly valve.
2. Close the gate valve.

*Responsibility*: Valve operation is by Water Bailiff (see Error! Reference source not found.)

2.6 Spillway Management

The Spillway of Tono Dam is an uncontrolled broad crested weir (Ogee type). It consists of 3 sections: a broad crested weir, a chute and stilling chamber with boulder pack at downstream end. The efficient management of the spillway requires that all sections are well maintained to guarantee flow energy dissipation with ease.

*Responsibility*: The Project Irrigation Engineer takes charge of the Spillway management.

2.7 Instrumentation

Dam instrumentation refers to a variety of devices or equipment installed within, on, or near the dam to monitor structural behaviour during construction, initial filling and subsequent operation. It provides the means to measure critical parameters related to safety of the infrastructure. It consists of many electrical, structural and mechanical instruments or systems [5].

Instrumentation allows for maintenance and operation for dam safety, providing information to:
- Assess the performance of the dam.
- Warn of changes that could threaten the safety of a dam.

Table 2 presents the measurement type and the instruments required for early detection of dam failure.

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance of relief wells</td>
<td>Open standpipe piezometers</td>
</tr>
<tr>
<td>Reservoir Water Levels</td>
<td>Staff Gauge</td>
</tr>
<tr>
<td>Stage Flow in Spillway</td>
<td>Staff Gauge</td>
</tr>
</tbody>
</table>


In order to avoid the dangers enumerated above, minimum instrumentation should be provided on a dam to check its behavior over time. The number and types of instruments installed should be sufficient to provide a complete picture of the parameter being measured.
Usually, minimum instrumentation should be installed along longitudinal or transverse sections of a dam [6].

2.8 Visual Observation
Visual observation is a primary requirement to assess the general condition of a dam structure backed by instrumentation monitoring to enable assessment of its safety. This can detect indications of poor performance including offsets, misalignment, bulges, depressions, seepage, leakage, and cracking. Where visual observations give indications of potential problem, it will be useful to initiate a quantitative monitoring program. This effort will support identification of problem and assist in selecting optimum solution. As such instrumentation data complements visual observation, enabling engineers to evaluate the safety of a dam [6].

2.9 Recommended Instruments
The instruments recommended and the type of measurement used for are described as follows:

2.9.1 Open standpipe piezometer
Open standpipe piezometers are observation wells with subsurface seals that isolate the strata to be measured. They assist in measuring pore water pressures in dams as well as performance of relief wells. The seals are usually made of bentonite clay or cement grout and care must be taken during installation to develop a good seal. Riser pipe joints should be watertight to prevent leakage into or out of the pipe, which could change the water level in the pipe. The top of the standpipe should be vented and the inside diameter should be greater than about 8mm in order to be self-de-airing. A common version of the open standpipe piezometer is a wellpoint, which is a prefabricated screened section and riser pipe that is pushed into place. If the screened section is not adequately sealed, it will act like an observation well rather than a piezometer. The sensing zone (screened length or porous tip) of open standpipe piezometers is susceptible to clogging, which can increase lag time or result in failure of the instrument. The susceptibility is reduced by a properly designed filter pack that meets filter criteria with the surrounding soil and properly sized perforations that are compatible with the filter pack [6].

Open standpipe piezometers are the standard against which all other piezometers are judged. They are simple, reliable, inexpensive, and easy to monitor [6]. Data collection form is at Appendix 3.

2.10 Logbook
A logbook is a record book with periodic entries and serves as an essential tool for the operations of a dam. It should be kept at a designated location at a dam site. It gives an indication of how frequent the Officer responsible visits the facility and for what purpose. At the same time, it is a tool for management to monitor the work carried out by staff towards operation or maintenance of the dam. This will help early detection of problem(s) and possible averision.

For operationalization of logbooks, the following procedures are suggested:

1. Label appropriately logbooks and place at designated locations.
2. Communicate to all users, e.g. Water bailiffs, to complete logbooks with appropriate data.
3. Users complete logbook.
4. Transfers entries in logbooks into the electronic database system periodically.
4. Engineer/supervisor inspects logbook at appropriate times.
5. Takes all necessary correctional actions.

2.11 Management Structure and Responsibilities for the SOP Manual

The Standard Operation Procedures (SOP) Manual is designed to work in accordance with the management structure proposed in the Organisation and Management Systems Report (GCAP, 2017) and shown in Figure 11.

Each position in the management structure has responsibilities related to the dam operation, maintenance, surveillance and the line of reporting. Thus the SOP will enhance ICOUR’s way of doing things differently.

2.11.1 Personnel and responsibilities for Dam operation

The personnel involved in dam operation and their line of reporting (as arrow indicates) is presented in Figure 12.
The responsibilities for each position are as follows:

**Operations Manager**
1. Analyses operations of the dam to ascertain effectiveness of the SOP while working out strategies for improving same.
2. Produces reports on operations of dam while identifying gaps.
3. Sets and reviews budgets and manages costs of dam operations.
4. Plans and controls change in relation to operations of dam.
5. Tracks and measures staff performance related to dam operations.
6. Performs any other duty as may be assigned by supervisor.

**Scheme Manager**
1. Liaises with other departmental staff to implement joint schedules related to the SOP.
2. Assesses the economics of operations of the Scheme.
3. Manages the safety of the dam and related structures such as outlet canal and laterals.
4. Performs any other duty as may be assigned by supervisor.

**Project Irrigation Engineer**
1. Ensures that the rule curves of reservoir operations are duly respected to guarantee the safety of the dam and safeguard life and property.
2. Archives logbooks of inflows and outflows and other related records.
3. Determines the optimum scheduling of irrigation water to farmers for all scenarios.
4. Manages the application for irrigation water by farmers.
5. Records in logbook normal daily releases to farmers.
6. Performs any other duty as may be assigned by supervisor.

**Assistant Project Irrigation Engineer**
1. Assists the Project Irrigation Engineer.
2. Performs any other duty as may be assigned by supervisor.

**Water Bailiff**
1. Operates the control gate of the main outlet canal to release water to irrigated farmers.
2. Reads staff gauges and records them in the appropriate logbooks.
3. Performs any other duty as may be assigned by supervisor.

2.11.2 Personnel and responsibilities for maintenance of dam and appurtenant structures
For maintenance of the dam and appurtenant structures, the personnel involved and reporting line is presented in the Figure 13.
**Managing Director**
1. Sanctions maintenance works to be carried out on the dam and appurtenant structures.
2. Engages contractors/consultants to carry out works/services related to dam and appurtenant structures.
3. Performs any other duty as may be assigned by Board of Directors.

**Operations Manager**
1. Makes recommendations to Managing Director for dam and/or appurtenant structures maintenance.
2. Prepares bidding documents for contractors of maintenance works.
3. Reviews reports of maintenance works carried out by contractors.
5. Performs any other duty as may be assigned by supervisor.

**Scheme Manager**
1. Provides estimates of cost of repair works on the dam.
2. Performs any other duty as may be assigned by supervisor.

**Project Irrigation Engineer**
1. Conducts contractors round the dam site for maintenance works.
2. Supervises maintenance of irrigation related appurtenant structures including laterals and sub-laterals.
3. Makes proposals for maintenance of irrigation structures on site.
4. Performs any other duty as may be assigned by supervisor.

**Assistant Project Irrigation Engineer**
1. Assists the Project Irrigation Engineer.
2. Carry out any other duty to be assigned by supervisor.

**Water Bailiff**
1. Lubricates the spindles of gates to the outlet canal.
2. Carries out any other tasks as may be assigned by supervisor.

**Labourer**
1. Removes tree stumps from the embankment.
2. Ensures that downstream embankment is protected with grass.
3. Ensures that spillway channel is free of any debris.
4. Carries out any other tasks as may be assigned by supervisor.
2.11.3 Personnel and responsibilities for surveillance of dam site

For surveillance of the dam and appurtenant structures, the personnel involved and the line of reporting is presented in the Figure 14.

Managing Director
1. Monitors implementation of the SOP, providing guidance to stimulate performance.
2. Performs any other duty as may be assigned by Board of Directors.

Operations Manager
1. Undertakes periodic monitoring to assess safety of dam.
2. Reviews reports of surveillance submitted by subordinates.
3. Performs any other duty as may be assigned.

Scheme Manager
1. Monitors weekly the irrigation facility, especially in the dry season.
2. Performs any other duty as may be assigned.

Project Irrigation Engineer
1. Conducts monitoring of the dam and appurtenant structures on weekly basis.
2. Performs any other duty as may be assigned.

Assistant Project Irrigation Engineer
1. Assists the Project Irrigation Engineer.

Water Bailiff
1. Monitors control gates and outlet canal.
2. Carries out any other tasks as may be assigned.

Labourer
1. Monitors dam embankments.
2. Carries out any other tasks as may be assigned.

Security
1. Ensures that the dam site is free of any theft and vandalism during the day or night.
2. Performs any other duties assigned.

Table 3 presents the responsible persons and their contacts for reference.
Table 3 presents the contacts of persons responsible for operation maintenance and surveillance of Tono dam

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Position</th>
<th>Telephone at Work</th>
<th>Personal Telephone</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mr. Sebastian Bagina</td>
<td>Managing Director</td>
<td></td>
<td>0205358328</td>
<td>Box 70, Navrongo</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>Operations Manager</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>Scheme Manager</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>Project Irrigation Engineer</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>David Atujona</td>
<td>Asst. Project Irrigation Engineer</td>
<td></td>
<td>0245689985</td>
<td>Box 70, Navrongo</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>Water Bailiff</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Michael Awiah</td>
<td>Labourer</td>
<td></td>
<td>0246958517</td>
<td>Box 70, Navrongo</td>
</tr>
<tr>
<td>9</td>
<td>Richard Danlera</td>
<td></td>
<td></td>
<td>0245279931</td>
<td>Box 70, Navrongo</td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>Security</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
2.12 Training Programs
To effectively implement this SOP, staff of the Scheme Management Entity (ICOUR) shall have to be trained. The training must include, common causes of dam failures and incidents, identification of signs of potential distress by visual observation, and actions to be taken in the event of any unusual occurrence.
The training will cover the areas as follows:

1. Structural, mechanical and dam instrumentations and data acquisition.
2. Inspection, maintenance and repair work procedures.
3. Record keeping and data management.
4. Irrigation water management.
5. Geographic Information System (GIS) and remote sensing applications to catchment area management including planning and monitoring.

The training courses, coupled with attachment to a similar but high performing dam with stringent SOP will be useful to promote knowledge transfer towards efficient management of the Tono scheme.

2.13 Communication and Partnerships

2.13.1 Communication
Within I COUR, communication between levels, departments and among employees is crucial. However, intra-agency communication is as important as inter-agency communication, noting that the company (will) collaborate(s) with several stakeholders including local farmer groups, technical and research institutions and administrative authorities.
The activities to carry out include but not limited to the following:

1. Establish an intercom for the Offices at I COUR.
2. Make available in all Offices copy of the SOP Manual as well as all relevant external institutions.
3. Produce a leaflet of warning signs assigned to designated areas at the dam site.
4. Embark on sensitization campaigns, from time to time, in fringe communities of the warning signs installations at designated areas around the dam and the need for compliance by all and sundry.
5. Use radio announcements and/or District Information Service dissemination mechanism to alert communities downstream as well as those whose members commute nearby areas through the spillway of the expected spills of the dam.
6. Alert visitors and fringe communities of the use of appropriate swimming gadget during recreational activities.
7. Contact numbers of relevant stakeholders such as Kassena Nankana Municipal and Builsa North District Assemblies, District and Regional Offices of National Disaster Management Organisation, leaders of farmer groups and service providers, shall be posted for quick reference.

2.13.2 Partnerships
It is certain that I COUR will need the services of other institutions to effectively deliver on the provisions of the SOP Manual. The stakeholders to consider include but not limited to the following:
1. Ghana Irrigation Development Authority (GIDA), being the supervisory authority, for instance, will collaborate with ICOUR in providing technical support for operations of the Tono dam.

2. 9 Village Committees of the 8 surrounding communities undertaking irrigated farming downstream of the dam. More importantly, farmers and farmer groups in upstream communities should be engaged to work collaboratively towards winning their confidence. Any commitments arising from the engagements should be documented and strictly adhered to by parties to guarantee the life and safety of the dam.

3. Data generation institutions including the Ghana Meteorological Agency (Gmet) and Hydrological Services Department (HSD) should be engaged to provide seasonal weather information and the expected inflows into the reservoir.

4. The National Dam Safety Unit and White Volta Basin Secretariat of Water Resources Commission (NDSU-WRC) is the unit mandated to grant license to operators of dams following its inspection. It is useful to engage them without necessarily establishing any cooperation agreement. Whereas the unit will be engaged in the event of a breach of the provisions in the granted license or when the license renewal is due, the latter can support training efforts aimed at catchment protection and management.

5. Decentralised administrative authorities - Upper East Regional Coordinating Council, Kassena Nankana Municipal and Builsa North District Assemblies and Departments including Information Services, Gender and Food and Agriculture. These institutions will be needed at one time or another to implement interventions aimed at ensuring the safety of the dam.

6. Environmental Protection Agency (EPA) coordinates environmental related issues and grants permits for operation. In particular, environmental impact assessments guidelines, environmentally hazardous activities and health protection standards to guide on-site operations. Therefore, ICOUR should engage EPA to provide guidance and clarity on its operations as and when required.

2.14 Health and Safety Management
Safety and health issues are everyday need and require careful considerations at the workplace. Oftentimes, a company realises the benefits of good safety and health practices only after an accident has taken place. The lessons associated with the afterthought are often painful and costly to the organisation. Tono dam attracts a number of stakeholders to its site including the mainstream workers, visitors and fringe communities including farmers. Therefore, a standard practice of health and safety will be useful towards averting any accident on site.

Furthermore, the lack of knowledge on the use of an instrument often leads to its abuse and/or vandalism. To this end, all instruments or appurtenant structures should be protected from public theft or acts of vandalism while ensuring that the facility meets its operational demands.

2.14.1 Aims
The health and safety of personnel at Tono dam requires ICOUR to ensure that each personnel is aware of the roles and responsibilities regarding the prevention of accidents, risks to health or damage to any property. This includes protection and control measures for the security of employee, visitors and peasant farmers in fringe communities.

The aims for health and safety are the following:
1. To provide an employee with a safe work environment that is free from any hazard likely to cause death or serious harm in the operation of the dam and appurtenant structures;
2. To establish a health and safety culture in the Organisation;
3. To actively manage health and safety in proactive fashion, encouraging awareness on the part of staff of the aspects of health and safety issues related to their line of work and the environment within which they operate.

2.14.2 Activities
To effectively manage the health and safety needs of employees requires that mechanisms are established to guarantee the security of the latter.
Some activities to be carried out by management include the following:
1. Assess the health and safety mechanisms established to ascertain its suitability, adequacy and effectiveness through systems audit.
2. Suggest where appropriate, approaches for continual improvement in health and safety, while ensuring alignment with corporate objectives.
3. Provide training for all employees on health and safety at the work place, including the safe storage of materials in order to avoid struck by or crushed by hazards.
4. Ensure that the work environment is free of debris and waste materials. Where waste is to be disposed, carry out appropriately in an enclosed manner. Where heights exceed the norm, barricades are used to protect from any fall [7].
5. Install signs and warning systems at designated locations that present danger to workers, visitors such as slippery, steep or rip-rap covered slopes at the dam site. Given the cost to be incurred in the event of accidents and the consequences thereof, it is important to inform and possibly indulge every visitor of the company’s exoneration from any self-damages that may arise from non-observance of health and safety arrangements or tour guide’s instruction at the dam site.
6. Assess periodically, the health and safety system in place, measuring progress to ensure that targets set remain relevant while reviewing actions to implement.
7. Ensure use of protective equipment by employees to carry out operations at the dam site. It includes protective clothing, helmets, among others, designed to protect the wearer's body from injury or infection.
8. Evaluate requests of organisations to visit the dam site and to communicate feedback that highlights the issues of health and safety.
9. Carry out periodic health screening for staff.

Responsibility: The Managing Director (MD) is responsible for Health and safety of employees at the work place. The MD may delegate authority to the Operations Manager.
The nearest health facility is at Navrongo, about 10km from the dam site where any ill health related incident or accident should be reported for medical attention. The Dam site is easily accessible to the Navrongo Township.

2.14.3 Fringe communities and farmers
Aside the employees and visitors, fringe communities including commuters and farmers enjoying services of the dam facility one way or the other, should be considered in the health and safety planning. As a matter of urgency, commuters and farmers must act responsibly, and be health and safety conscious. Therefore, ICOUR should provide leadership and guide use of the facility and adjoining lands for their livelihood activities.
At Tono, commuters resort to various aids in the dry and rainy seasons. It was noted that commuters to nearby towns, in the rainy season, use boats to traverse the Tono spillway chute
and then drive their motorcycle on the dam crest. In the dry season, unlimited access is restored.

The following procedure to regulate activities of fringe communities is suggested:
1. Set up surveillance system at the dam downstream section.
2. Sensitize community members on when to cross spillway sections using motorbikes.
3. Install appropriate notices at crossings.
4. Discourage sand winning activities in the downstream area.
5. Keep record of sand winning activities halted in the area.
Chapter 3 – Dam Inspection and Maintenance

Disasters occur in the event of a dam breach and are usually costly in terms of loss of life and property. This happens owing to the lack of data obtained from inspections and monitoring of dam and appurtenant structures. Therefore, there is the need to conduct routine, periodic and emergency inspections to guarantee safety of a dam to forestall loss of life and property. After inspections, any anomaly detected on the dam features needs to be repaired or maintained.

3.1 Regular/Routine Inspections

A regular or routine inspection may be performed, either on daily or weekly basis, to appraise the operator/dam owner of the performance of the facility. Essentially, the inspector should look for evidences of the condition of dam and document appropriately to inform maintenance works duly. Table 4 presents the dam component or aspect of dam, what to look out for and the things to record.

<table>
<thead>
<tr>
<th>Component/Aspect</th>
<th>What to Look For</th>
<th>What to record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Take safety seriously.</td>
<td>• Personnel on-site&lt;br&gt; • Weather conditions&lt;br&gt; • Reservoir water level</td>
</tr>
<tr>
<td>Reporting</td>
<td>Operations Log</td>
<td>File completed Operations Log in project O&amp;M Plan</td>
</tr>
<tr>
<td>Access</td>
<td>• Condition of gate and locks&lt;br&gt; • Condition of signage&lt;br&gt; • Evidence of vandalism</td>
<td>• Location&lt;br&gt; • Description of damage or state</td>
</tr>
<tr>
<td>Intake structure</td>
<td>Obvious problems and/or damage (erosion, cracks or spalling, deterioration, etc.)</td>
<td>• Location&lt;br&gt; • Description</td>
</tr>
<tr>
<td>Intake control device</td>
<td>Obvious problems of cracks, deterioration, etc.)</td>
<td>• Location&lt;br&gt; • Description</td>
</tr>
<tr>
<td>Outlet structure</td>
<td>Obvious problems or damage arising from erosion, cracks or spalling, deterioration, etc.)</td>
<td>• Location&lt;br&gt; • Description of damage/problem</td>
</tr>
<tr>
<td>Embankment (crest, slopes, toes)</td>
<td>Obvious problems and/or damage (erosion, excessive vegetation, riprap displacement gullies, etc.).</td>
<td>• Location (station and offset)&lt;br&gt; • Description&lt;br&gt; • Limits (length, width, depth, height)</td>
</tr>
<tr>
<td>Spillway</td>
<td>Obvious problems and/or damage (erosion, chute wall, stilling basin, baffle piers, etc.).</td>
<td>• Location (station and offset)&lt;br&gt; • Description&lt;br&gt; • Limits (length, width, depth, height)</td>
</tr>
<tr>
<td>Staff Gauges</td>
<td>Obvious deterioration or damage (peeling off of graduated markings / scale)</td>
<td>• Location (station and offset)&lt;br&gt; • Description</td>
</tr>
<tr>
<td>Reservoir</td>
<td>Obvious problems (debris buildup, upstream development, etc.).</td>
<td>• Location (station and offset)&lt;br&gt; • Description</td>
</tr>
</tbody>
</table>

3.2 Periodic Inspections

A periodic inspection may be performed, either quarterly, semi-annual or annual. In this type of inspection, the inspector should look for evidences of the condition of dam appurtenant structures such as laterals and sub-laterals, and document appropriately to inform
maintenance works duly. Table 5 presents the dam component aspect of dam, what to look out for and the things to record.

Table 5 Summary of Periodic inspection activities – Tono Dam

<table>
<thead>
<tr>
<th>Component</th>
<th>What to Look For</th>
<th>What to Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Take safety seriously.</td>
<td>• Personnel on-site&lt;br&gt; • Weather conditions&lt;br&gt; • Reservoir water level</td>
</tr>
<tr>
<td>Reporting</td>
<td>Dam Safety Inspection Form</td>
<td>File completed Dam Safety Inspection Form in project O&amp;M Plan</td>
</tr>
<tr>
<td>Access</td>
<td>• Condition of gates and locks&lt;br&gt; • Condition of signage&lt;br&gt; • Evidence of vandalism&lt;br&gt; • Condition of crest road</td>
<td>• Location&lt;br&gt; • Description of condition</td>
</tr>
<tr>
<td>Intake structure</td>
<td>• Obstructions or blockage hampering flow&lt;br&gt; • Structural integrity of concrete&lt;br&gt; • Damage, deterioration or malfunction of valve</td>
<td>• Location&lt;br&gt; • Description of condition</td>
</tr>
<tr>
<td>Intake control device</td>
<td>• Obstructions, blockage, leakage or significant structural cracks&lt;br&gt; • Deterioration and structural integrity of concrete&lt;br&gt; • Evidence of any abnormal settlements, heaving, deflections or lateral movements in the concrete channel</td>
<td>• Location (station and offset)&lt;br&gt; • Description of condition&lt;br&gt; • Limits (length, width, depth, height)&lt;br&gt; • Flow rate in channel</td>
</tr>
<tr>
<td>Outlet, laterals and sub-laterals</td>
<td>• Obstructions or blockage hampering flow&lt;br&gt; • Structural integrity of concrete</td>
<td>• Location&lt;br&gt; • Description of condition</td>
</tr>
<tr>
<td>Embankment (crest, slopes, toes)</td>
<td>• Settlement, depressions, gullies, sinkholes, cracking, slides, sloughing, erosion, crest and downstream alignment seepage&lt;br&gt; • Piping, boils, low spots on crest&lt;br&gt; • Unauthorized activity (construction, excavation, etc.) on or adjacent to the dam&lt;br&gt; • Displacement of riprap&lt;br&gt; • Excessive vegetation&lt;br&gt; • Rodent activity</td>
<td>• Location (station and offset)&lt;br&gt; • Description of condition&lt;br&gt; • Limits (length, width, depth, height)&lt;br&gt; • Flow rate (if applicable)</td>
</tr>
<tr>
<td>Spillway</td>
<td>• Erosion or lining damage (loss, disturbance, weathering or abrasion of lining material)&lt;br&gt; • Sloughing or cracking on side slopes&lt;br&gt; • Erosion or scour of upstream or downstream ends</td>
<td>• Location (station and offset)&lt;br&gt; • Description of condition&lt;br&gt; • Limits (length, width, depth, height)</td>
</tr>
<tr>
<td>Staff Gauges (reservoir and spillway)</td>
<td>Damage or deterioration (peeling off of graduated markings / scale)</td>
<td>• Location&lt;br&gt; • Description of condition</td>
</tr>
<tr>
<td>Reservoir</td>
<td>• Changes to the surface of the drainage basin (changed agriculture practices, etc.)&lt;br&gt; • Evidence of any abnormal settlements, heaving, deflections or lateral movements</td>
<td>• Location (station and offset)&lt;br&gt; • Description of condition&lt;br&gt; • Limits (length, width, depth, height)</td>
</tr>
</tbody>
</table>
3.3 Special Inspections
The level of inspection is triggered by occurrence of critical events, such as severe rain or wind as it pertains in the area of dam. As a result, a technical service center is consulted to carry out emergency inspection of the impacts of any critical event and to ascertain the integrity of the dam. Emergency situations arise in erosion that threatens the life of the dam, seepage that is cloudy or excessive high water surfaces will require some assessment of the Dam condition. A qualified engineer should perform this assessment.

Table 6 Summary of Special inspections – Tono Dam

<table>
<thead>
<tr>
<th>Types</th>
<th>Inspection items</th>
<th>Operational duties</th>
</tr>
</thead>
<tbody>
<tr>
<td>High water conditions</td>
<td>• Conduct during floods and high water events&lt;br&gt;• Monitor performance of flood control works&lt;br&gt;• Monitor embankment slopes and dam toe for excessive seepage and piping problem</td>
<td>Initiate and take corrective actions, as required.</td>
</tr>
<tr>
<td>Post flood</td>
<td>Conduct after a flood event</td>
<td>Inspect and assess condition of flood control works.</td>
</tr>
</tbody>
</table>

3.4 Checklist for Routine and Periodic Inspections
Regular dam inspection and review of inspection records are essential in assessing the need for carrying out reparation works on a dam and related structures. Inspecting a dam on a regular basis brings to the fore the observable changes in the structure over time that requires attention of the owner. Very often, existence of a problem is not as important as its rate of development or a sudden change in its condition or extent. It is imperative therefore that the dam owner keeps records of all routine and special inspections. Usually, this takes the form of notes, photographs and/or sketches. The inspection checklist provided in the Appendix 4 of this Manual will assist the dam owner to carry out consistently and efficiently routine inspections [9].

3.5 Maintenance Schedules (Mechanical, Structural and Dam Instrumentations)
It is worth noting that regular maintenance leads to avoidance of costly repairs. Table 7 presents the component, maintenance activity, and related operational schedules for Tono dam.
### Table 7 Summary of Maintenance Activity - Tono Dam

<table>
<thead>
<tr>
<th>Component</th>
<th>Maintenance Activity</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intake structure</strong></td>
<td>Repair or replace damaged lining and components.</td>
<td>Outsource</td>
</tr>
<tr>
<td></td>
<td>Remove sediment that has accumulated to maintain capacity of the channel.</td>
<td>Outsource</td>
</tr>
<tr>
<td></td>
<td>Vegetation shall be maintained and trees and brush controlled by chemical or mechanical means. Control noxious weeds</td>
<td>Labourer</td>
</tr>
<tr>
<td></td>
<td>Keep machinery away from steep side slopes. Keep equipment operators informed of all potential hazards.</td>
<td>Scheme Manager</td>
</tr>
<tr>
<td><strong>Intake control device</strong></td>
<td>Repair or replace damaged components (bolts, etc.).</td>
<td>Asst. Project Irrigation Engineer</td>
</tr>
<tr>
<td></td>
<td>Exercise gate and butterfly valves regularly.</td>
<td>Project Irrigation Engineer</td>
</tr>
<tr>
<td></td>
<td>Lubricate in accordance with manufacturer’s recommendations.</td>
<td>Asst. Project Irrigation Engineer</td>
</tr>
<tr>
<td></td>
<td>Repair deteriorated concrete as soon as possible.</td>
<td>Outsource</td>
</tr>
<tr>
<td><strong>Outlet</strong></td>
<td>Exercise regularly.</td>
<td>Project Irrigation Engineer</td>
</tr>
<tr>
<td></td>
<td>Lubricate in accordance with manufacturer’s recommendations.</td>
<td>Water Bailiff</td>
</tr>
<tr>
<td></td>
<td>Promptly repair or replace damaged components.</td>
<td>Water Bailiff</td>
</tr>
<tr>
<td><strong>Embankment</strong></td>
<td>Fill rills and gullies that occur on the embankment slopes and in the vegetated spillway and reseed the filled areas.</td>
<td>Outsource</td>
</tr>
<tr>
<td></td>
<td>Prevent trees and brush from growing on embankment slopes, crest, or toe. Control tree and bush growth by hand cutting, mowing, or chemicals. Avoid damaging grass with herbicide sprays.</td>
<td>Labourer</td>
</tr>
<tr>
<td></td>
<td>Maintain a fencing to keep livestock of embankment, where applicable.</td>
<td>Security</td>
</tr>
<tr>
<td><strong>Spillway</strong></td>
<td>Do not graze livestock during establishment of vegetation and when soil conditions are wet.</td>
<td>Security</td>
</tr>
<tr>
<td></td>
<td>Protect spillway from damage by farm equipment and trucks/vehicles.</td>
<td>Scheme Manager</td>
</tr>
<tr>
<td></td>
<td>Prevent trees and brush from growing in the spillway.</td>
<td>Labourer</td>
</tr>
<tr>
<td></td>
<td>Reestablish vegetative cover immediately where scour erosion has removed established seeding.</td>
<td>Scheme Manager</td>
</tr>
<tr>
<td></td>
<td>Where there is rock lining, replace any dislodged rock and fill back to grade if displacement or settlement occurs.</td>
<td>Outsource</td>
</tr>
<tr>
<td><strong>Staff gauges</strong></td>
<td>Promptly repair or replace damaged components</td>
<td>Water Bailiff</td>
</tr>
</tbody>
</table>

2.14.4 Valve Maintenance

2.14.4.1 Gate Valves

2.14.4.1.1 Packing
The packing gland should be checked periodically in service and tightened as necessary to stop leakage around the stem. Tighten in a manner to develop uniform loading on the gland. Tighten only enough to stop the leak.

*Over tightening will cause the packing to fail prematurely as well as increasing the force required to operate the valve.*

If the leak cannot be stopped by tightening the gland nuts, it is necessary to add additional packing rings or completely repack the valve.

Where it is necessary to repack the valve in line, a compatible ribbon packing system or equivalent braided packing stock should be used. The joints in the packing rings should be diagonally cut. When installing the rings, care should be taken to stagger the ring joints.

Special care is to be placed in the tightening of gland nuts during installation, in order to get the proper packing adjustment and functionality.

2.14.4.1.2 Repairs
Due to the relatively low replacement cost of standard carbon steel gate valves, it is usually less expensive to replace the complete valve than to have maintenance personnel effect repairs. Generally, the only justifiable repairs are replacement of packing as previously described.

2.14.4.2 Butterfly Valves
Butterfly valves require only minimal regular maintenance. The preventive checklist is suggested as follows:
1. Check (and adjust if necessary) that the valve is operating properly in the full closed and full open position.
2. Visually inspect the valve and around the valve for any signs of leakage.
3. Visually inspect bolts, piping, and any other related equipment for problems that could hinder operation (such as loosening or corrosion).

2.14.5 Gate Maintenance
1. Check (and adjust, if necessary) that the gate is operating properly in the full closed and full open position.
2. Visually inspect the gate and around the gate for any signs of leakage.
3. Visually inspect gate guides, bolts, yoke nut, stem and any other related equipment for problems that could hinder operation (such as loosening or corrosion).

2.14.5.1 Stem Thread Lubrication
1. If gate is CLOSED:
   o Apply Grease below the yoke nut onto stem threads.
   o Open gate to the Full Open Position.
   o Apply Grease to the stem thread protruding above the Yoke Nut.
   o Close gate to the Full Close position.
o Cycle 1 additional time Full open to full close to evenly apply grease inside yoke nut.

2. If gate is OPEN:
   o Apply Grease above the yoke nut onto stem threads.
   o Close gate to the Full Close Position.
   o Apply Grease to the stem thread below the Yoke Nut.
   o Open gate to the Full Open position.
   o Cycle 1 additional time Full open to full close to evenly apply grease inside yoke nut.
Chapter 4 – Emergency and Security Management

Often, a Health and Safety regulations will establish requirement for preparation of Emergency and Security management. Generally, emergency and security management follows from occurrence of a serious event that poses danger to persons at the work place. The events include fire, natural disasters (floods, heat wave) and industrial accidents. Sometimes, its occurrence assumes national character. Therefore, ICOUR should liaise with the mandated institutions, notably Ghana National Fire Service and NADMO so that the necessary systems are put in place, and the same triggered in the event of a related disaster. The procedure, usually contains the actions to be carried out by various personnel who have a part to play from the time an event occurs or is detected up to when it is brought under control.

It is important to understand the pattern of usage of the dam facility and the occupancy levels. During day time (08:00am – 5:00pm), occupants at the facility are the staff and farmers in the irrigated farmlands downstream of the dam. Also, fringe community members commute to nearby towns using the crest of the facility. In the evenings and overnight (05:00pm – 08:00am), occupants on site are mostly a few staff and security personnel. Largely, security personnel and commuters access the facility during this time. At weekends, few technical staff and security personnel are present on site to ensure that farmers meet their water demand services.

4.1 Aims
The emergency and security requires ICOUR’s determination to implement a system capable of gathering information into a central point, and making decisions followed by appropriate actions. The aims of the emergency and security are the following:

1. To establish and maintain a system for responding to emergency at ICOUR’s premises and the areas of its operations.
2. To minimise impacts of emergency situations on environment, injury to people including employees, contractors on site and the general public.

4.2 Activities
Emergency and security related issues need to be managed on site. This requires that ICOUR carried out activities to ensure that the necessary response is received in the event of emergency. The activities to implement include the following:

1. Set up an emergency and security coordination team and establish a control point.
2. Restrict access to traffic, where necessary.
3. Provide adequate information for emergency services.
4. Supply first aid to affected persons and call for ambulance services, where necessary.
5. Facilitate the conduct of drills for employees and other workers on site as well as fringe communities.
6. Provide training to staff on emergency situations and response measures.
7. Secure ICOUR’s premises and properties in the event of emergencies.

4.3 Emergency Coordination – Designation and Responsibilities
There is need to set up emergency coordination unit, coordinated by the Operations Manager and assisted by the Scheme Manager. The personnel of Operations/Maintenance Engineering services Department will constitute the team to work in the event of emergency at dam site. Further, sub-teams or units should be formed and their responsibilities defined. They include (i) First Aid; (ii) Evacuation; and (iii) Security teams.
Figure 15 presents the suggested teams, membership and coordination unit.

Each of the units with membership outlined will lead related operations under the supervision of the Operations Manager and shall perform tasks including the following:

3.1.1 First Aid Unit
   1. Administers first aid to injured persons.
   2. Maintains first aid kit.

3.1.2 Evacuation Unit
   1. Sees to maintenance of emergency equipment.
   2. Helps to evacuate persons on site to areas of safety.
   3. Assists victims of accidents on site.

3.1.3 Security Unit
   1. Secures the premises and company properties.

3.2 Communication and emergency information flow
The following communication related issues shall be considered for emergency response:
   1. Set up an alert system for all forms of emergencies including flooding and fire outbreak, which is triggered at the onset of the event.
   2. Communication lines through radios, telephones and mobile phones shall be kept and maintained at all times, ensuring their readiness for use to facilitate communication with all relevant authorities.
3. Communicate all occurrences of environmental and emergency situations and incidents to the Managing Director.
4. Contact numbers of all key stakeholders including the Police, Fire Service, NADMO, Ambulance and District Health Management Team shall be posted prominently for quick reference.

<table>
<thead>
<tr>
<th>No.</th>
<th>Institution</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Information Service Department - Navrongo</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Information Service Department - Sandema</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ghana National Fire Service – Navrongo</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Upper East Regional NADMO - Bolgatanga</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Kassena Nankana Municipal Assembly - Navrongo</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Builsa North District Assembly – Sandema</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ambulance Service – Navrongo</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>The Police Service – Navrongo</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Municipal Health Directorate – Navrongo</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>District Health Directorate - Sandema</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Emergency Drills
It will be necessary for ICOUR to liaise with NADMO and the Ghana National Fire Service at Bolgatanga and Navrongo, respectively to conduct periodic drill sessions for its staff and farmers who are primary users of the Tono facility.

The following considerations should guide the performance of emergency drills:
1. Conduct company-wide emergency drills at least once in every 6 months within the first 3 years of implementation and extended to once a year.
2. Emergency drills shall cover all but not limited to different requirements for emergencies such as:
   - Evacuation
   - First Aid administration
   - Fire fighting
3. Use designated areas for evacuation such as exits and assembly points and should be made clear to all personnel.
4. Post the site layout/map, indicating strategic locations of ICOUR’s premises. The map should indicate access routes, recovery routes and whatever is applicable. It is important that employees are familiar with the evacuation map.
5. Review actions for continuous improvement in the procedures.
6. Maintain records of all emergency drills, duly signed by the appropriate authority.

3.4 Emergency Equipment Inspection and Maintenance

1. The Operations Manager shall ensure that the appropriate emergency equipment is provided and easily accessible at locations where potential emergency and associated risks could occur.
2. Emergency equipment shall cover but not limited to the following:
   - Fire extinguishers
   - Fire alarm system
   - Emergency lights
   - First aid kit
3. The Operations Manager and/or the assigned staff shall check and monitor periodically emergency equipment and keep records in an equipment logbook while specifying the frequency and maintenance in the list.
4. The assigned staff shall ensure that all the equipment are in good condition for use in the event of any emergency situation.

3.5 Some emergency cases and procedures

3.5.1 Accident/Injury/ill health of personnel on site
An accident may result in injury of persons on site and will require their proper handling in order not to aggravate the condition. As a result, the procedure below is suggested to be followed:

1. Recover the injured person and administer first Aid per the injury treatment.
2. Do not make any attempt to move the injured person where the capacity or knowledge to handle back or neck related injury is limited.
3. Report the accident to the Coordinator or the deputy.
4. Where the injured person can walk, use Office vehicle to transport him/her to seek medical attention at Navrongo Government Hospital.
5. Where the injured person is unconscious, call for Ambulance service at Navrongo and wait for the arrival of the rescue team.
6. Where a personnel reports of ill health, report the incident to the Coordinator.
7. Administer first aid to the person who is ill and transfer the sick person to the hospital for medical attention.
8. If Office vehicle is unavailable to transport staff who is ill, call the Navrongo Ambulance service.

3.5.2 Flooding
In the event of flooding where the spillway’s function will be activated, the following procedures should be considered:

1. Proceed to the nearest designated evacuation area.
2. Do not go back and get personal effects.
3. Move any chemicals to a safe place to avoid any contamination or spillage.
4. Switch off any electrical appliance likely to be affected by the flood event.
5. Use sandbags to prevent flood waters from entering critical areas.
6. Administer first aid to any victim of the flooding.
7. Transport the victim for medical attention at Navrongo Government Hospital.

3.5.3 Drowning
Recreational activities at the Tono dam should be sanctioned by management. The procedure suggested is as follows:

1. Assign divers on site to direct and guide use of the reservoir for recreational activities.
2. In the event of drowning, remove the victim from the water at the earliest possible time.
3. Remove wet clothing of victim and wrap with warming blanket.
4. Perform rescue breathing and chest compression on the victim.
5. Check the airway of the victim for any foreign material or debris and remove with a finger-sweep maneuver.
6. Transport the victim to the Navrongo Government Hospital for medical attention.
3.5.4 Dam failure

1. Use radio announcements and/or Kassena Nankana Municipal and Builsa North District Information Service dissemination mechanisms to alert communities of the dam failure.
2. Call relevant institutions such as NADMO and the Ghana Police Service at Navrongo for assistance.
3. Employees, visitors and communities likely to be affected should move to the designated evacuation areas.
4. Affected persons should not go back to get personal effects.
5. Deploy evacuation team members to the dam site to assist persons who may be trapped by the event.
6. Ensure that the team in charge of First Aid is on site to administer to victims.
7. Suspend all work downstream of the dam.
8. Transport all victims of the event to Navrongo Government Hospital for medical attention.

3.6 Reporting and Meeting

The coordination team shall consider the procedure as follows:

1. Convene a meeting of the relevant personnel to review and discuss any incident and shall plan corrective measures to avoid recurrence.
2. Review the emergency procedure and propose revision as necessary to reflect continual improvement.
3. Disseminate outcome of meetings to all staff. Contractors and other visitors shall be informed of new decisions regarding emergency and security procedure whenever they visit the facility.
References


[4]. Image Credit: The_Alloy_Valve_Stockist


## Appendix 1: TONO DAM AREA-VOLUME DATA

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>Area (Mm^2)</th>
<th>Elevation (m)</th>
<th>Volume (Mm^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>166.16</td>
<td>0.0</td>
<td>163.97</td>
<td>0.000</td>
</tr>
<tr>
<td>167.75</td>
<td>0.5</td>
<td>166.15</td>
<td>0.239</td>
</tr>
<tr>
<td>169.25</td>
<td>2.0</td>
<td>167.60</td>
<td>1.420</td>
</tr>
<tr>
<td>170.75</td>
<td>3.5</td>
<td>169.20</td>
<td>3.500</td>
</tr>
<tr>
<td>172.25</td>
<td>5.5</td>
<td>171.00</td>
<td>7.900</td>
</tr>
<tr>
<td>173.75</td>
<td>7.5</td>
<td>172.25</td>
<td>13.000</td>
</tr>
<tr>
<td>176.75</td>
<td>13.5</td>
<td>173.75</td>
<td>22.500</td>
</tr>
<tr>
<td>178.25</td>
<td>16.5</td>
<td>175.25</td>
<td>37.000</td>
</tr>
<tr>
<td>179.22</td>
<td>18.6</td>
<td>176.75</td>
<td>54.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>178.25</td>
<td>77.500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>179.22</td>
<td>92.600</td>
</tr>
</tbody>
</table>
APPENDIX 2A DIFFERENT FLOOD WAVE SHAPES

Figure 16 Four Basic Hydrographs (Ergish, 2010)
APPENDIX 2B ESTIMATION OF OUTFLOW DISCHARGE

For Triangular wave, hydrograph 1, the change in discharge storage due to the flood wave is expected outflow discharge is given as follows:

\[
\Delta q_p = Q_{p,\text{in}} - Q_{p,\text{out}}
\]

\[
Q_{p,\text{out}} = Q_{p,\text{in}} - \Delta q_p
\]  \hspace{1cm} -(1)

Where

\[ Q_{p,\text{in}} = \text{Peak inflow discharge of the flood wave reaching reservoir} \]
\[ Q_{p,\text{out}} = \text{Peak outflow discharge from reservoir to ensure safety of dam} \]
\[ \Delta q_p = \text{Peak discharge storage}; \text{ and} \]
\[ d_p = \text{Duration of peak flow} \]

Also, the volume, \( V \) is given by

\[
V = \frac{\Delta q_p^2}{2r_1} + \frac{\Delta q_p^2}{2r_2}
\]

Where \( V \) is the expected volume of flow of the hydrograph, and \( r_1 \) and \( r_2 \) are the rising and receding limbs of the hydrograph

From equation above,

\[
\Delta q_p = \frac{2Vr_1r_2}{\sqrt{r_1 + r_2}}
\]  \hspace{1cm} -(2)

Substitute equation (2) into equation (1) to determine the expected peak outflow

\[
Q_{p,\text{out}} = Q_{p,\text{in}} - \frac{2Vr_1r_2}{\sqrt{r_1 + r_2}}
\]  \hspace{1cm} -(3)

For Abrupt Wave, Hydrograph 2

\[
\Delta q_p = Q_{p,\text{in}} - Q_{p,\text{out}}
\]

\[
Q_{p,\text{out}} = Q_{p,\text{in}} - \Delta q_p
\]

\[
V = \frac{\Delta q_p^2}{2r}
\]  \hspace{1cm} -(4)

Where \( r \) is the receding limb of the hydrograph

\[
\Delta q_p = \sqrt{2Vr}
\]  \hspace{1cm} -(5)
Now substitute equation (5) into equation (3) for an abrupt wave

\[ Q_{p,\text{out}} = Q_{p,\text{in}} - \sqrt{2Vr} \]  

(6)

For a Flood Pulse, Hydrograph 3,

\[ \Delta q_p = Q_{p,\text{in}} - Q_{p,\text{out}} \]

\[ Q_{p,\text{out}} = Q_{p,\text{in}} - \Delta q_p \]

\[ V = d_p \Delta q_p \]

\[ \Delta q_p = \frac{V}{d_p} \]  

(7)

Now substitute equation (7) into equation (3) for a Flood Pulse wave

\[ Q_{p,\text{out}} = Q_{p,\text{in}} - \frac{V}{d_p} \]  

(8)

For Broad Peak, Hydrograph 4,

\[ \Delta q_p = Q_{p,\text{in}} - Q_{p,\text{out}} \]

\[ Q_{p,\text{out}} = Q_{p,\text{in}} - \Delta q_p \]

\[ V = \frac{\Delta q_p^2}{2r_1} + \frac{\Delta q_p^2}{2r_2} + d_p \Delta q_p \]

\[ V = \frac{r_1 + r_2}{2r_1r_2} \Delta q_p^2 + d_p \Delta q_p \]

\[ \Delta q_p = \frac{-d \pm \sqrt{d^2 - 2(r_1 + r_2)(-V)}}{r_1 + r_2} \]  

(9)

Now substitute equation (9) into equation (3) for a Broad Peak wave

\[ Q_{p,\text{out}} = Q_{p,\text{in}} - \frac{-d \pm \sqrt{d^2 - 2(r_1 + r_2)(-V)}}{r_1 + r_2} \]  

(10)

If the duration time \( d=0 \), the volume, \( V \) reduces to that of triangular hydrographs.
If the slope \( r_1 \) and \( r_2 \) are very steep, the volume, \( V \) approximates a pulse flow, and the formula approaches or is the same for rectangle shape hydrograph.
Therefore, the trapezoidal hydrographs formula becomes the general solution of the four types of hydrographs deduced by Ergish (2010) in Dong (2012).
APPENDIX 3: DATA COLLECTION FORM FOR SEEPAGE OR LEAKAGE

TONO DAM

SEEPAGE WEIR DATA COLLECTION FORM

Date:  
Time:  
Personnel:  

Weather:  
Recent Rainfall recorded:  

Headwater Elevation:  
Tailwater Elevation:  

Visual Observation (unusual or abnormal conditions):  

READINGS

INSTRUCTIONS: Measure depth of water upstream of weir from invert of weir notch. Record depth to nearest decimal. Under COMMENTS, reader should take note of the difficulties in taking the measurements, and make recommendations for repair and maintenance. Compare readings with threshold limits and previous readings. Retake reading to confirm them where threshold limit is exceeded or more than 5cm different than previous readings.

<table>
<thead>
<tr>
<th>WEIR ID</th>
<th>THRESHOLD READINGS, CM (MIN/MAX)</th>
<th>DEPTH OF WATER, CM</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Source: Adapted from Chapter IX: Instrumentation and Monitoring
## APPENDIX 4: DATA COLLECTION FORM FOR PORE WATER PRESSURE

### TONO DAM

**OBSERVATION WELL AND PIEZOMETER DATA COLLECTION FORM**

<table>
<thead>
<tr>
<th>Date:</th>
<th>Time:</th>
<th>Personnel:</th>
</tr>
</thead>
</table>

**Weather:**

**Recent Rainfall recorded:**

<table>
<thead>
<tr>
<th>Headwater Elevation:</th>
<th>Tailwater Elevation:</th>
</tr>
</thead>
</table>

**Visual Observation (unusual or abnormal conditions):**

### READINGS

**INSTRUCTIONS:** Measure depth of water from standpipe with water level meter. Record depth to nearest decimal. Under COMMENTS, reader should take note of the difficulties in taking the measurements, and make recommendations for repair and maintenance. Compare readings with threshold limits and previous readings. Retake reading to confirm them where threshold limit is exceeded or more than 1m different than previous readings.

<table>
<thead>
<tr>
<th>PIEZOMETER/ OBSERVATION WELL</th>
<th>THRESHOLD READINGS, M (MIN/MAX)</th>
<th>DEPTH TO WATER, M</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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*Source: Adapted from Chapter IX: Instrumentation and Monitoring*
# APPENDIX 5: TONO DAM INSPECTION CHECKLIST

**TONO DAM INSPECTION CHECKLIST**

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Source: Adapted from Chapter IX: Instrumentation and Monitoring