Ghana Water Sector Restructuring Project
Dam Safety Assessment

Ghana Water Company Ltd. (PMU)

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This report has been prepared by Royal Haskoning, the trading name of Haskoning Nederland B.V., in cooperation with AY&A Consult Limited, with all reasonable skill, care and diligence within the terms of the Contract with GWCL (PMU), taking account of the resources devoted to it by agreement with GWCL (PMU) and the available background information.

We disclaim any responsibility to GWCL (PMU) and others in respect of any matters outside the scope of the above.

Drafted by: Harry Wassink

Checked by: Henk Blok

Date/initials check: ...................... ......................

Approved by: Martine Leman

Date/initials approval: ...................... ......................
SUMMARY

This report includes a reconnaissance level safety assessment of the Ghana Water Company Ltd. (GWCL) dams and weirs involved in the Water Sector Restructuring Project (WSRP). We carried out inspections on a sample of dams and weirs and studied existing inspection reports. We made cost estimates on a reconnaissance level of required rehabilitation works.

The upper 3m section of the Owabi Dam is seriously damaged, requiring urgent intervention. Required structural measures for the other dams and weirs are less urgent.

In order to assess the safety of a structure its designs basis must be reviewed to check whether the maximum design load is not exceeded in the as-built, present or future situation. For instance the Inchaban dam and the Owabi dams have been raised resulting in a higher water load. Deforestation of the catchments area may have resulted in a faster run-off of water to the reservoir and a higher spillway peak discharge resulting in higher water loads. The original design documents of the dams and weirs incorporated in this underlying reconnaissance level study were not available. We therefore recommend as follow-up activity for each dam and weir a “stability design check”.

Since the construction of dams and weirs the reservoirs have experienced sedimentation, reducing their storage capacity and reducing the water quality. The sediments should be removed by dredging. We therefore recommend as follow-up activity the preparation of a dredging design.

Furthermore we assessed the present dam management and made recommendations for future dam safety management of the GWCL dams, including the set-up of a National Dam Safety Unit (NDSU) and the preparation of Emergency Preparedness Plans (EPP) for dams. We recommend investigating as follow-up activity whether the NDSU would consider only GWCL dams or that also should be included the Volta River Authority Akosombo Dam and / or the Irrigation Development Authority dams and how stakeholders would be represented in the NDSU and participate in decision making processes.
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Appendix 3 Inspection report Hohoe Weir
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INTRODUCTION

Since 1993, the Government of Ghana (GOG) has been implementing a number of reforms aiming at improving the management of the water sector, both in the fields of sanitation and water supply. Provision of potable water is considered as a critical element in its policy for sustainable economic development and poverty reduction.

The Water Sector Restructuring Project (WSRP) concerns about 80 water systems in 10 regions of Ghana. It is designed to increase urban water availability, to extend distribution networks, to assist the sector to establish a sustainable financial foundation and to support the introduction of the private sector into management and operation of the systems.

This document comprises the dam safety assessment which is part of the design and appraisal of this WSRP. The purpose of the dam safety assessment is to prepare a reconnaissance level assessment of quality management of dams and weirs involved in the WSRP and of the reliability of the water sources retained by these dams and weirs.

In appreciation of the World Bank Operational Policy (OP 4.37) the assessment will:

a. Inspect and evaluate the safety status of the existing dams and weirs.

b. Review and evaluate the owner’s operation and maintenance procedures.

c. Provide a written report of findings and recommendations for any remedial work or safety related measures necessary to upgrade the dams and weirs to an acceptable standard of safety.

GWCL has advised (see the minutes of meeting in Appendix 4) to include the following dams and weirs in our assessment. The Damongo Dam and the Yendi weir were not included in the original list of dams and weirs for this study, agreed upon with GWCL on the 17th of March. Therefore, the sample of dams/weirs visited by the Dam Specialist may not reflect those installations. During the meeting of 20th of April it is decided to incorporate those installations in the study. However, no information about these two facilities has been delivered (as discussed) by PMU/GWCL to the Consultant. Therefore, these installations are not assessed in detail.

Table 1.1 List of dams/weirs and their characteristics

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Height above river bed</th>
<th>Reservoir volume Approximate [m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Barikese Dam</td>
<td>15 (spillway) and 18.5 (embankment)</td>
<td>35,300,000</td>
</tr>
<tr>
<td>2</td>
<td>Owabi Dam</td>
<td>7.4m (spillway) and 11.5 (embankment)</td>
<td>2,600,000</td>
</tr>
<tr>
<td>3</td>
<td>Koforidua Weir</td>
<td>2.7 (top of stop-logs)</td>
<td>Not significant</td>
</tr>
<tr>
<td>4</td>
<td>Weija Dam</td>
<td>15.85</td>
<td>115,000,000</td>
</tr>
<tr>
<td>5</td>
<td>Winneba Weir</td>
<td>2.2</td>
<td>Not significant</td>
</tr>
<tr>
<td>6</td>
<td>Kwanjiku Dam</td>
<td>12.8 (to access bridge / scour blocks)</td>
<td>1,960,000</td>
</tr>
<tr>
<td>7</td>
<td>Brimsu Dam</td>
<td>7.2 (spillway) and 10.4 (access bridge)</td>
<td>2,300,000</td>
</tr>
<tr>
<td>8</td>
<td>Inchaban Dam</td>
<td>12.35 (spillway)</td>
<td>1,730,000</td>
</tr>
<tr>
<td>9</td>
<td>Axim Dam</td>
<td>3.7 (spillway) and 4.7 (flanks)</td>
<td>50,000</td>
</tr>
<tr>
<td>10</td>
<td>Mampong Weir</td>
<td>3m</td>
<td>6,000</td>
</tr>
<tr>
<td>11</td>
<td>Hohee Weir</td>
<td>2m</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

The locations of these dams and weirs are presented in the Figure 1.1 on the following page.
Chapter 2 and Appendix 9 present details of the dams and weirs. This chapter further includes the classification of rehabilitation measures into a) emergency - human life at immediate risk, b) urgent - likely to pose a risk to human life and c) significant - any needed rehabilitation beyond meaningful maintenance. Cost estimates of rehabilitation works on a reconnaissance level are included in chapter 3. Chapter 4 describes the existing dam (safety) management and its regulatory framework and recommends on future safety management, when chapter 5 and 6 include recommendations for a National Dam Safety Unit and Emergency Preparedness Planning. And finally chapter 7 includes recommended Terms of Reference for follow-up activities.
2 INSPECTION OF THE DAMS AND WEIRS

2.1 Barikese Dam

A staff member of GWCL and the dam expert of the consultant visited the Barikese Dam on Saturday morning 20 March 2004. The following photographs give an impression of the site visit.

| Photo 2.1.1 | Front view of the Dam |
| Photo 2.1.2 | Front view zoomed-in |
| Photo 2.1.3 | View on the upstream (right looking upstream) embankment slope |
| Photo 2.1.4 | Upstream (left looking upstream) embankment overgrown with (small) trees |
| Photo 2.1.5 | Subsidence of the upstream embankment |
| Photo 2.2.6 | Gauge house on downstream slope of embankment |
GWCL regional office made available the following documents:
- Barikese Dam, Operating Instructions, Howard Humphries and Sons, December 1970.
- Barikese Dam, Installation of piezometers, Howard Humphries and Sons, December 1989.

These documents do not include information to analyse the dam capacity to resist loading.

Our recommendations on the dam condition following our inspection include:
1. The embankment upstream (see photo 2.5.1.4) shows subsidence and damaged erosion protection and needs rehabilitation.
2. Although facilities are provided (ref.6 and photo 2.5.1.6), no monitoring is reported (ref.1). GWCL reported that three people who entered the gauge house did not survive probably because of lack of oxygen or poisonous gasses in the gauge house. We recommend installing new monitoring equipment.
3. We confirm the rehabilitation recommendations of Reference 1 as summarised in the table below.

<table>
<thead>
<tr>
<th>Dame / Weir name</th>
<th>Rehabilitation description</th>
<th>Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barikese Dam</td>
<td>Scour valve passing water needs repair. Due to lack of detailed drawings it is not clear whether we need to carry our repair works under water (with divers) or whether we will be able to isolate the scour facility from the reservoir and carry out the work</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Maintenance of all mechanical equipment</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Maintenance on instrumentation for settlement/movement monitoring housed in building on d/s of LHS embankment</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Operating downstream toe drains (discharge measurement)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Monitoring drainage gallery discharge</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Embankment overgrown – needs clearance u/s &amp; d/s.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Installation of new piezometers</td>
<td>X</td>
</tr>
</tbody>
</table>

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2.2 Owabi Dam

A staff member of GWLC and the dam expert of the consultant visited the Owabi Dam on Saturday afternoon 20 March 2004.

<table>
<thead>
<tr>
<th>Photo 2.2.1 Front view of the Owabi Dam</th>
<th>Photo 2.2.2. (Probable) differential settlement of the concrete elements (see arrows)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo 2.3.3 View on the extent of the masonry &quot;pushed out&quot; of the face</td>
<td>Photo 2.3.4. Details of the blocks pushed out of the dam on the downstream face</td>
</tr>
<tr>
<td>Photo 2.2.5 Weeds on the spillway</td>
<td>Photo 2.2.6 Downstream discharge measuring weir</td>
</tr>
</tbody>
</table>

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GWCL regional office made available the report on Inspection of Owabi Dam (Howard Humphries and Sons, March 1992). This report comprises a very limited design check in section 5.3: Dam Stability, addressing only the failure mechanisms overturning and sliding and not overstressing.

Our recommendations on the dam condition following our inspection include:

1. We confirm the rehabilitation recommendations of Reference 1 as summarised in the table below.

<table>
<thead>
<tr>
<th>Dam / Weir name</th>
<th>Rehabilitation description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owabi Dam</td>
<td>Remedial work required to mechanical equipment to bring to operational standard</td>
</tr>
<tr>
<td></td>
<td>Right hand embankment extensively overgrown – needs clearance</td>
</tr>
<tr>
<td></td>
<td>Left hand embankment: remove one large tree growing u/s and several d/s.</td>
</tr>
<tr>
<td></td>
<td>Spillway crest raising in poor condition – to be repaired</td>
</tr>
<tr>
<td></td>
<td>Access bridge in reasonable condition but needs repainting</td>
</tr>
<tr>
<td></td>
<td>Downstream training walls and apron side wall needs repair (LH side)</td>
</tr>
<tr>
<td></td>
<td>Scour facility needs to be reinstated. Due to lack of detailed drawings it is not clear whether we need to carry out repair works under water (with divers) which is extremely expensive or whether we will be able to isolate the scour facility from the reservoir</td>
</tr>
<tr>
<td></td>
<td>Replacement of gate valves bottom outlets</td>
</tr>
<tr>
<td></td>
<td>Replacement of penstocks bottom outlets</td>
</tr>
<tr>
<td></td>
<td>Under water installation of penstocks bottom outlets</td>
</tr>
<tr>
<td></td>
<td>The masonry blocks have been &quot;pushed out&quot; of the downstream face of the dam. Divers, who went down for inspection, reported (January 2004) a 20m long horizontal crack along the upstream face of the dam. This requires further investigation and remedial work</td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing</td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam</td>
</tr>
<tr>
<td></td>
<td>Piezometers installation</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing</td>
</tr>
</tbody>
</table>

2. We are very concerned about the masonry blocks pushed out of the downstream face of the dam (see photos 2.5.2.3 and 4). Appendix 7 presents the report of the inspection carried out by divers on the dam upstream face. The divers reported a 20m long crack 1m below the water surface. The diver report states that the water was “overflowing the banks of the dam” (we understand that the dam was spilling). We recommend lowering the water level of the reservoir to below this crack and the level of the "pushed-out masonry blocks" for safety and inspection reasons. Part of the masonry blocks should be removed for investigation. The water level could be lowered by using the water intake system, the bottom outlets (probably only after rehabilitation) and possibly by siphoning.

It seems that typically overstressing is the cause of the dam cracking (see the following figure with a very preliminary schematisation of the dam weak area or crack).
Figure 2.2.1
Schematisation of probable damage

Approx. location of "pushed-out" blocks

Approximate 8.5m

Figure 2.2.2
Schematisation of possible repair

Area to be replaced [approx. 6.5m²]
2.3 Mampong Weir

A staff member of GWLC and the dam expert of the consultant visited the Mampong Weir on Sunday afternoon 21 March 2004.

GWCL regional office made available the Design Report Mampong, Sir Alexander Gibb & Partners in association with Associated Consultants, August 1995. This report does not include (design) documentation on the dam capacity to resist loading.

The concrete downstream spillway face is eroded in several places (see photo 2.4.3) and is in need of remedial work (to be classified as "significant"). We do not consider dam safety an important issue here because the reservoir volume is only 6000m$^3$ and GWCL reported that no people live within 1km downstream of the dam.
2.4 Kwanyaku Dam

A staff member of GWLC and the dam expert of the consultant visited the Kwanyaku Dam on Monday afternoon 22 March 2004.

Photo 2.4.1 View on upstream side

Photo 2.4.2 View on right (looking upstream)
downstream side

Photo 2.4.3 View on left (looking upstream)
downstream side

Photo 2.4.4 View on downstream central
tower

No design documents could be made available by GWCL.

Following our inspection we confirm the rehabilitation recommendations of Reference 1 as presented in the table below.
<table>
<thead>
<tr>
<th>Dam / Weir name</th>
<th>Rehabilitation description</th>
<th>Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kwanyaku Dam</td>
<td>Refurbishment of penstocks and gate valves at intake tower required.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Refurbishment of penstocks in the bottom outlets</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Weed growth to be cleared from u/s of spillway.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Vegetation clearance and minor remedial work required downstream.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>D/S training wall undermined on RHS to be repaired</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>In addition we recommend taking off the concrete &quot;facing&quot;. This facing prevents proper visual inspection of the concrete condition.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>The concrete is eroded and cracked in place and in need of repair.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Piezometers installation</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing</td>
<td>X</td>
</tr>
</tbody>
</table>

### 2.5 Inchaban dam

The following photos present an impression of the dam.

- **Photo 2.5.1** Downstream view of the dam
- **Photo 2.5.2** Spillway cross-section
- **Photo 2.5.3** (left) Upstream view on the scour gates (closed with masonry) and the bottom outlets (pipes, valves and spindles)
Royal Haskoning is the Engineer for the Sekondi-Takoradi Water Supply System Rehabilitation Project which is being executed at the moment. Several drawings but no design reports were made available. In 2003, 450,000 m$^3$ of sediment has been dredged from the Inchaban reservoir.

We confirm the rehabilitation recommendations of Reference 1 as presented in the table below.

<table>
<thead>
<tr>
<th>Dam / Weir name</th>
<th>Rehabilitation description</th>
<th>Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Emergency</td>
</tr>
<tr>
<td>Inchaban Dam</td>
<td>Replacement of gate valves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Replacement of penstocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Under water installation of penstocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vegetation clearance and remedial work needed in d/s apron area.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intake dry well chamber to be pumped out and valve operation checked.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leakage at d/s toe and scour blocks to be investigated and monitored.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cracks in access walkway and landing to be repaired.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handrailing in reasonable condition but needs repainting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metal flooring around scour vertical lift gate operating mechanism needs replacement urgently – rusted badly with holes and dangerous.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tree growing in RH side scour vertical lift gate slot to be removed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vegetation growing on d/s face of dam to be removed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remedial work to masonry facing around intake (u/s) to be carried out – clearance and repainting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Piezometers installation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling (until the rock)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing</td>
<td></td>
</tr>
</tbody>
</table>

2.6 Brimsu Dam

The following pictures give an impression of the Brimsu dam.

Photo 2.6.1 Upstream view of the dam  Photo 2.6.2 Typical cross-section
We confirm the rehabilitation recommendations of Reference 1 as presented in the table below.

<table>
<thead>
<tr>
<th>Dame / Weir name</th>
<th>Rehabilitation description</th>
<th>Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Emergency</td>
</tr>
<tr>
<td>Brimsu Dam</td>
<td>Minor remedial work needed on dam and spillway structure</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Remedial work required to d/s sidewalls and apron concrete</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Operation of intakes difficult to access and unsafe</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Replacement of gate valves bottom outlets</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Replacement of penstocks bottom outlets</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Under water installation of penstocks bottom outlets</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>D/s gate valve extension spindles need replacement</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>General maintenance of mechanical equipment needed</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Original intake mechanical equipment to be reinstated for emergency use</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Minor vegetation growth in bridge joints to be cleared</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Piezometers installation</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling (until the rock)</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing</td>
<td>X</td>
</tr>
</tbody>
</table>

2.7 Weija Dam

The following photo gives an impression of the Weija dam.

Royal Haskoning reported the “Rehabilitation & expansion of the Adam Clark Water Treatment Plant and improvement of the distribution network of the Western Accra area in March 2000. Currently Ballast Nedam International is carrying out rehabilitation works with Royal Haskoning as the Engineer. The following table presents “outstanding" rehabilitation works.
The largest part of the rehabilitation costs comprises the construction of a 25m berm on the downstream side of the Weija embankment. The following figure presents the geometry of this berm together with its cross-sectional area.

![Figure 2.7.1 Typical geometry of the berm to be constructed on the downstream side of the Weija Dam to ensure its stability during earthquake.](image)

The length along the embankment requiring a berm is estimated to be 200m.
2.8 Hohe Weir

Staff of GWCL together with an expert of the consultant visited the Hohe weir on 22 March 2004. The following photos give an impression of the weir and small reservoir.

![Photo 2.8.1 Impression of the Hohe weir](image1)

![Photo 2.8.2 Impression of the reservoir upstream of the Hohe weir.](image2)

The rehabilitation recommendations are presented in the table below.

<table>
<thead>
<tr>
<th>Dam / Weir name</th>
<th>Rehabilitation description</th>
<th>Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hohe Weir</td>
<td>Provision of new chain block for the gantry crane</td>
<td></td>
</tr>
</tbody>
</table>

GWCL has filled-out the inspection report as presented in Appendix 3.

2.9 Axim dam

The consultant did not visit the Axim dam. We copy the rehabilitation recommendations of Reference 1 as presented in the table below and present their reconnaissance level cost estimate.
<table>
<thead>
<tr>
<th>Character / Weir name</th>
<th>Rehabilitation description</th>
<th>Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axim Dam</td>
<td>Downstream apron overgrown and should be cleared</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spillway penstock spindles need replacing.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Dam concrete work required to spillway, d/s apron and sidewalls.</td>
<td>X</td>
</tr>
</tbody>
</table>

2.10 **Koforidua Weir**

The consultant did not visit the Koforidua dam. GWCL reported that rehabilitation recommendations of reference 1 have been implemented.

2.11 **Winneba Weir**

The consultant did not visit the Winneba Weir. GWCL reported that a new weir has been constructed recently which does not require rehabilitation works.
## RECONNAISSANCE LEVEL COST ESTIMATES

### 3.1 Dams and weirs

The following table presents a reconnaissance level cost estimate for rehabilitation works on the dams and weirs.

<table>
<thead>
<tr>
<th>Dame / Weir name</th>
<th>Rehabilitation description</th>
<th>Unit cost [USD]</th>
<th>Quantity</th>
<th>Estimated cost [USD]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bankissa Dam</strong></td>
<td>Removal of sediment in the vicinity of the scour valve.</td>
<td>7 USD/m³</td>
<td>10,000</td>
<td>70,000</td>
</tr>
<tr>
<td></td>
<td>Surch valve passing water needs repair. Due to lack of detailed drawings it is not clear whether we need to carry our repair works under water (with divers) or whether we will be able to isolate the scour facility from the reservoir and carry out the work &quot;in the dry&quot;.</td>
<td>Provisional sum</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Removal of sediment in the vicinity of the scour valve.</td>
<td>7 USD/m³</td>
<td>10,000</td>
<td>70,000</td>
</tr>
<tr>
<td></td>
<td>Maintenance of all mechanical equipment</td>
<td>Provisional sum</td>
<td>1</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>Maintenance on instrumentation for settlement/movement monitoring housed in building on d/s of LHS embankment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operating downstream toe drains (discharge measurement)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitoring drainage gallery discharge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Embankment overgrown – needs clearance u/s &amp; d/s.</td>
<td>0.5 USD/m²</td>
<td>3,840</td>
<td>1,920</td>
</tr>
<tr>
<td></td>
<td>Installation of new piezometers</td>
<td>100 USD/piece</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Sub Total</strong></td>
<td></td>
<td></td>
<td>101,920</td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies</td>
<td>50%</td>
<td></td>
<td>50,960</td>
</tr>
<tr>
<td></td>
<td><strong>Total cost estimate</strong></td>
<td></td>
<td></td>
<td>152,880</td>
</tr>
<tr>
<td><strong>Owabi Dam</strong></td>
<td>Remedial work required to bring to operational standard</td>
<td>Provisional sum</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Right hand embankment extensively overgrown – needs clearance</td>
<td>0.5 USD/m²</td>
<td>330</td>
<td>165</td>
</tr>
<tr>
<td></td>
<td>Left hand embankment: remove one large tree growing u/s and several d/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Siltation in downstream condition – to be repaired</td>
<td>250 USD/m³</td>
<td>30</td>
<td>7,500</td>
</tr>
<tr>
<td></td>
<td>Siltation in downstream condition but needs repainting</td>
<td>Provisional sum</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Downstream training walls and apron side wall needs repair (LH side)</td>
<td>50 USD/m²</td>
<td>16</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>Removal of sediment in the vicinity of the scour valve.</td>
<td>7 USD/m³</td>
<td>10,000</td>
<td>70,000</td>
</tr>
<tr>
<td></td>
<td>Scour facility needs to be reinstated. Due to lack of detailed drawings it is not clear whether we need to carry our repair works under water (with divers) which is extremely expensive or whether we will be able to isolate the scour facility from the reservoir and carry out the work &quot;in the dry&quot;.</td>
<td>Provisional sum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Replacement of gate valves</td>
<td>10,000 USD/piece</td>
<td>2</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Replacement of penstocks</td>
<td>10,000 USD/piece</td>
<td>2</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Under water installation of penstocks</td>
<td>12,500 USD/piece</td>
<td>2</td>
<td>25,000</td>
</tr>
<tr>
<td></td>
<td>Replacement of spillway top. This requires further investigation.</td>
<td>750 USD/m³</td>
<td>300</td>
<td>225,000</td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing</td>
<td>Provisional sum</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chainage markers, bench marks, staff gauges dam</td>
<td>Provisional sum</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Piezometers installation</td>
<td>50 USD/piece</td>
<td>100</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling</td>
<td>50 USD/piece</td>
<td>100</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing</td>
<td>Provisional sum</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Sub Total</strong></td>
<td></td>
<td></td>
<td>397,460</td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies</td>
<td>50%</td>
<td></td>
<td>193,730</td>
</tr>
<tr>
<td></td>
<td><strong>Total cost estimate</strong></td>
<td></td>
<td></td>
<td>591,190</td>
</tr>
<tr>
<td><strong>Koforidua Weir</strong></td>
<td>Gantry structures need replacing</td>
<td>GWCL reported the works to be completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Siltation u/s needs cleaning</td>
<td>GWCL reported the works to be completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RH protection embankment needs to be reinstated to protect RH side of structure</td>
<td>GWCL reported the works to be completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intake screens need replacing</td>
<td>GWCL reported the works to be completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dame / Weir name</td>
<td>Rehabilitation description</td>
<td>Unit cost (USD)</td>
<td>Quantity</td>
<td>Estimated cost (USD)</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>----------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Weija Dam</strong></td>
<td>Install on the crest of the dam and on the spillway markers for monitoring of horizontal and vertical displacements of the dam body, including benchmarks in the rock on both abutments of the dam. Remove the accelerometers in the dam body or at least the parts constructed on the dam body instrument box and solar panel. The existing Type 1 and 2 relief wells including the collector pit and the outfall to the Densu River have to be cleaned, which includes cleaning of the well chambers and flushing of the pipe drains between well chambers and collector pit and between the collector pit and the outfall. Clear the toe area of the dam and the area downstream of it of any trees, bushes and high vegetation. Provision and installation of 3 replacement flap valves for Type 1 relief valves. Construction of berm on the downstream side of the dam. The toe drain has to be incorporated in this berm which should include proper drainage facilities for the downstream area. Construction of the berm involves also the extension of the chambers of the relief wells. Drainage markers, benchmarks, staff gauges dam. Provisional sum.</td>
<td>Provisional sum</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>Kwanyaku Dam</td>
<td>Refurbishment of penstocks and gate valves at intake tower required.</td>
<td>Provisional sum</td>
<td>1</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>Refurbishment of penstocks in the bottom outlets</td>
<td>Provisional sum</td>
<td>5</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>Removal of sediment in the vicinity of the scour valve.</td>
<td>7 USD/m³</td>
<td>10,000</td>
<td>70,000</td>
</tr>
<tr>
<td></td>
<td>Weed growth to be cleared from u/s of spillway.</td>
<td></td>
<td></td>
<td>No significant costs</td>
</tr>
<tr>
<td></td>
<td>Vegetation clearance and minor remedial work required downstream.</td>
<td></td>
<td></td>
<td>No significant costs</td>
</tr>
<tr>
<td></td>
<td>Dis training wall undermined on RHS to be repaired.</td>
<td></td>
<td></td>
<td>Extent of damage and repair unknown</td>
</tr>
<tr>
<td></td>
<td>In addition we recommend taking off the concrete &quot;facing&quot;. This facing prevents proper visual inspection of the concrete condition.</td>
<td>Provisional sum</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The concrete is eroded and cracked in place and in need of repair.</td>
<td>2 USD/m³</td>
<td>1,150</td>
<td>2,300</td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing.</td>
<td>Provisional sum</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam.</td>
<td>Provisional sum</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peizometers installation.</td>
<td>50 USD/m³</td>
<td>50</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling.</td>
<td>50 USD/m³</td>
<td>50</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing.</td>
<td>Provisional sum</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sub Total</td>
<td></td>
<td>154,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies.</td>
<td>50%</td>
<td>77,750</td>
<td>333,000</td>
</tr>
<tr>
<td></td>
<td>Total cost estimate</td>
<td></td>
<td>999,000</td>
<td></td>
</tr>
<tr>
<td><strong>Brimsu Dam</strong></td>
<td>Minor remedial work needed on dam and spillway structure.</td>
<td>2 USD/m³</td>
<td>600</td>
<td>6,000</td>
</tr>
<tr>
<td></td>
<td>Remedial work required to its sidewalks and apron concrete.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operation of intakes difficult to access and unsafe.</td>
<td>Provisional sum</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Removal of sediment in the vicinity of the bottom outlet.</td>
<td>7 USD/m³</td>
<td>10,000</td>
<td>70,000</td>
</tr>
<tr>
<td></td>
<td>Replacement of gate valves.</td>
<td>10,000 USD/piece</td>
<td>2</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Replacement of penstocks.</td>
<td>5000 USD/piece</td>
<td>2</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>Under water installation of penstocks.</td>
<td>12,500 USD/week</td>
<td>2</td>
<td>25,000</td>
</tr>
<tr>
<td></td>
<td>Dis gate valve extension spindles need replacement.</td>
<td>Provisional sum</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>General maintenance of mechanical equipment needed.</td>
<td>Provisional sum</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Original intake equipment to be reinstated for emergency use.</td>
<td>Provisional sum</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minor vegetation growth in bridge joints to be cleaned.</td>
<td>Provisional sum</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concrete coring and testing.</td>
<td>Provisional sum</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam.</td>
<td>Provisional sum</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peizometers installation.</td>
<td>50 USD/m³</td>
<td>50</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling (until the rock)</td>
<td>50 USD/m³</td>
<td>50</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing.</td>
<td>Provisional sum</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sub Total</td>
<td></td>
<td>154,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies.</td>
<td>50%</td>
<td>77,750</td>
<td>231,750</td>
</tr>
<tr>
<td></td>
<td>Total cost estimate</td>
<td></td>
<td>231,750</td>
<td></td>
</tr>
<tr>
<td>Dame / Weir name</td>
<td>Rehabilitation description</td>
<td>Unit cost</td>
<td>Quantity</td>
<td>Estimated cost</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Winneba weir</td>
<td>A new weir has been constructed which is assumed not to need rehabilitation</td>
<td>USD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inchaban Dam</td>
<td>Replacement of gate valves</td>
<td>10,000 USD/piece</td>
<td>2</td>
<td>20,000 USD</td>
</tr>
<tr>
<td></td>
<td>Replacement of penstocks</td>
<td>5000 USD/piece</td>
<td>2</td>
<td>10,000 USD</td>
</tr>
<tr>
<td></td>
<td>Under water installation of penstocks</td>
<td>12,500 USD/week</td>
<td>2</td>
<td>25,000 USD</td>
</tr>
<tr>
<td></td>
<td>Removal of silt at the vicinity of the bottom outlet (Dredging close to the penstocks has not been carried out in 2003)</td>
<td>7 USD/m3</td>
<td>10,000</td>
<td>70,000 USD</td>
</tr>
<tr>
<td></td>
<td>Vegetation clearance and remedial work needed in d/s apron area.</td>
<td>0.5 USD/m2</td>
<td>7,000</td>
<td>3,500 USD</td>
</tr>
<tr>
<td></td>
<td>Intake dry well chamber to be pumped out and valve operation checked</td>
<td>Provisional sum</td>
<td>1</td>
<td>1,000 USD</td>
</tr>
<tr>
<td></td>
<td>Leakage at d/s toe and scour blocks to be investigated and monitored</td>
<td>No significant costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concrete in access walkway and landing to be repaired</td>
<td>Provisional sum</td>
<td>5</td>
<td>2,500 USD</td>
</tr>
<tr>
<td></td>
<td>Handrails in reasonable condition but needs repainting</td>
<td>Provisional sum</td>
<td>1</td>
<td>1,000 USD</td>
</tr>
<tr>
<td></td>
<td>Metal flooring around penstock vertical lift gate operating mechanism needs replacement</td>
<td>5 USD/kg</td>
<td>200</td>
<td>1,000 USD</td>
</tr>
<tr>
<td></td>
<td>Tree growing on RH side scour vertical lift gate slot to be removed</td>
<td>No significant costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vegetation growing on d/s face of dam to be removed</td>
<td>No significant costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remedial work to main penstock surrounding intake (u.s) to be carried out</td>
<td>Provisional sum</td>
<td>2</td>
<td>2,000 USD</td>
</tr>
<tr>
<td></td>
<td>Concrete cores and testing</td>
<td>Provisional sum</td>
<td>2</td>
<td>2,500 USD</td>
</tr>
<tr>
<td></td>
<td>Chainage markers, benchmarks, staff gauges dam</td>
<td>Provisional sum</td>
<td>1</td>
<td>1,000 USD</td>
</tr>
<tr>
<td></td>
<td>Piezometers installation</td>
<td>50 USD/m</td>
<td>50</td>
<td>2,500 USD</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: drilling (until the rock)</td>
<td>50 USD/m</td>
<td>50</td>
<td>2,500 USD</td>
</tr>
<tr>
<td></td>
<td>Geotechnical investigations: field and laboratory testing</td>
<td>Provisional sum</td>
<td>2</td>
<td>1,200 USD</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td></td>
<td></td>
<td>149,000 USD</td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies</td>
<td>50%</td>
<td></td>
<td>74,500 USD</td>
</tr>
<tr>
<td>Total cost estimate</td>
<td></td>
<td></td>
<td></td>
<td>223,500 USD</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Axim Dam</td>
<td>Downstream apron overgrown and should be cleared</td>
<td>0.5 USD/m2</td>
<td>200</td>
<td>100 USD</td>
</tr>
<tr>
<td></td>
<td>Spillway penstock spindles need replacing</td>
<td>Provisional sum</td>
<td>2</td>
<td>2,000 USD</td>
</tr>
<tr>
<td></td>
<td>Dam concrete work required to spillway, d/s apron and sidewalls</td>
<td>2 USD/m2</td>
<td>200</td>
<td>400 USD</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td></td>
<td></td>
<td>2,500 USD</td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies</td>
<td>50%</td>
<td></td>
<td>1,250 USD</td>
</tr>
<tr>
<td>Total cost estimate</td>
<td></td>
<td></td>
<td></td>
<td>3,750 USD</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Mampong weir</td>
<td>Concrete downstream spillway eroded in places and in need of remediation work</td>
<td>2 USD/m2</td>
<td>100</td>
<td>200 USD</td>
</tr>
<tr>
<td></td>
<td>Miscellaneous incl.. mobilisation / demobil for remedial work</td>
<td>Provisional sum</td>
<td>1</td>
<td>1,000 USD</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td></td>
<td></td>
<td>1,200 USD</td>
</tr>
<tr>
<td></td>
<td>Design, management and contingencies</td>
<td>50%</td>
<td></td>
<td>600 USD</td>
</tr>
<tr>
<td>Total cost estimate</td>
<td></td>
<td></td>
<td></td>
<td>1,800 USD</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>Hohoe weir</td>
<td>Provision of new chain block for the gantry crane</td>
<td>Provisional sum</td>
<td>1</td>
<td>2,000 USD</td>
</tr>
</tbody>
</table>
3.2 Operation and maintenance

Annual budget allocations will be required for the following activities:

- Maintenance of the dams and weirs, including transport, tools, equipment, materials;
- Operation and maintenance of the spillway structures, including transport, tools, equipment, materials;
- Periodic inspections by specialists;
- Scheduled replacement of equipment and components;
- Cost of staff training.

The GWCL staff will be involved in the water supply as well as in the dam component. The schedules and related cost for the above activities will have to be tuned with the activities related to the annual water supply and seasonal rainfall. A proportional share of the manpower and material inputs should be allocated to the dam safety component.

The following table presents provisional sums for Operation and Maintenance costs per year, assuming them to amount to 1% of the asset replacement value (ref. 1):

<table>
<thead>
<tr>
<th>Dam name</th>
<th>Dam replacement value [USD]</th>
<th>Operation and Maintenance [USD/y]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weija Dam</td>
<td>26,906,840</td>
<td>269,068</td>
</tr>
<tr>
<td>Axim Dam</td>
<td>489,870</td>
<td>4,899</td>
</tr>
<tr>
<td>Barikese Dam</td>
<td>12,480,960</td>
<td>124,810</td>
</tr>
<tr>
<td>Brimsu Dam</td>
<td>1,776,050</td>
<td>17,761</td>
</tr>
<tr>
<td>Inchaban Dam</td>
<td>4,791,990</td>
<td>47,920</td>
</tr>
<tr>
<td>Kwanyaku Dam</td>
<td>5,084,030</td>
<td>50,840</td>
</tr>
<tr>
<td>Owabi Dam</td>
<td>4,217,360</td>
<td>42,174</td>
</tr>
<tr>
<td>Hohoe Weir</td>
<td>906,580</td>
<td>9,066</td>
</tr>
<tr>
<td>Winneba Weir</td>
<td>201,735</td>
<td>2,017</td>
</tr>
<tr>
<td>Korofidua Weir</td>
<td>906,580</td>
<td>9,066</td>
</tr>
</tbody>
</table>
4 DAM SAFETY MANAGEMENT

4.1 Present management of the GWCL dams

GWCL owns, operates and maintains the dams and weirs (listed in the introduction of this report) and takes care of their safety. GWCL is a nation-wide operating water supply company under the Ministry of Works and Housing.

In daily practice GWCL operates as a rather traditional water supply company with a head office and regional offices. The regional offices are responsible for both technical and commercial affairs in that district. The following figure presents (as an illustration) the typical organisation of the GWCL Central region (GWCL CR).

![Organisation Chart of GWCL CR]

Figure 4.1.1 Organisation chart of GWCL CR. This organisation chart is derived from an organisation chart dated 1989 which was reported to be still valid.

In general the engineers and technicians charged with operation and maintenance of the structures are aware of deficiencies and potential risks. The present dam safety management procedures can be summarized as follows:

- Replacements, overhaul of equipment and preventive maintenance are not accepted as routine practices;
- Inspection of the civil engineering and the electro-mechanical works are taking place in case of malfunctioning equipment;
- Records about surveillance and maintenance are not systematically filed but data on major repairs and replacements are usually recorded. Long term records of topographic surveys of the dam profiles in general are not available, neither are results of measurements of settlement benchmarks, piezometers readings, leakage discharge records;
- Data on the general dimensions of the headworks usually are available, but not in great detail and limited to major parts of the works;
- Water levels in the reservoir are recorded on a daily basis;
- A comprehensive database does not exist.
4.2 Overview of other dams and authorities in Ghana

Further dam owners are the Volta River Authority (VRA) and the Irrigation Development Authority (IDA). The Water Resources Commission (Act 522, see Appendix 6) is responsible for the regulation and management of the utilisation of water resources and for the co-ordination of any policy in relation to them. The activities of the WRC relate for instance to the reservoir water inflow. A change of inflow results in a change of reservoir water level and related dam loading.

The National Disaster Management Organisation (Act 517, see Appendix 5) is responsible for the management of areas affected by disasters and similar emergencies, for the rehabilitation of persons affected by disasters and to provide for related matters. Act 517 does not specifically mentions "dam safety", but a dam break certainly relates to the National Disaster Management Organisation.

The following figure presents the existing authorities with respect to all dams in Ghana.

Figure 4.2.1 Dams and authorities in Ghana
4.3 Future dam safety management

Dam safety should primarily be the responsibility of GWCL, on technical matters guided and supervised by the Ministry of Works and Housing. GWCL is discharging these responsibilities to a certain degree within the constraints of a limited budget. At present the systematic planning of major overhaul of equipment and repair of observed deficiencies appears to be not a priority and is only carried out if the available funds are allowing this. Not before GWCL or the Ministry are getting concerned and decide that a deficiency is turning into a safety risk, action seems to be initiated.

It is recommended that future dam safety plans are prepared including the following subjects:

- GWCL management structure to be elaborated in more detail with sections for management of the head-works and technical support
- O&M activities more detailed and specified: planning of the monitoring and operation of structures, monitoring and surveillance guidelines and reporting, maintenance, scheduled replacements
- Recruitment and dedicated training of qualified staff
- Regular inspections by independent dam specialists (trained by the National Dam Safety Unit (NDSU) (reference to the relevant report sections)
- Preparation and annual updating of an EPP, including practising, communication with beneficiaries and authorities (reference to the relevant report sections)
- Annual budget preparation and allocation by GWCL, including safety issues
- Annual reporting by GWCL (including safety issues)

4.4 Features of future dam safety management

Dam safety management should be focussing on the prevention of any accident that could trigger the release of the reservoir volume in a catastrophic event. Management tools that are facilitating reaching the above objective should include the following.

a) Asset registers.

Setting up of a spreadsheet or database type of asset register is indispensable for a comprehensive dam safety management. In outline such register would comprise information about each main component of the head-works and will be developed step by step into more detail. The approach requires a systematic set-up, with clearly identifiable components and sub-components. This requires the installation of chainage markers on dam crests and berms as applicable. Further requirements are the indication of sequence or other identification numbers or chainages on objects like light poles, gate bays, gates, hoists, inspection manholes, piezometers, settlement beacons, benchmarks, triangulation points, water level gauges, pavement sections, drainage system components, and other relevant objects. All these items would be listed in the asset register. The register would also show information on design, construction (including material classification, type, cost of construction and replacement), repairs, upgrading, maintenance, records of observations, survey results, slope gradients, trends, visible erosion, leakage discharges, measurements of structures, seepage points, location and widths of cracks, etc.

The register should include information on actual maintenance works and inspections carried out, overhaul of components and possible other relevant data. The above set-up
would enable assessment of the current condition of the head works, but also the
previous conditions. The information collected and retrievable through the asset register
would facilitate focussing on a case history of suspect components or sub-components.

Digital photographs of relevant components and situations would provide additional
information that would be difficult to retrieve from written statements.

b) Plan of Operations

Guidelines for operation of spillway gates and valves in relation with rule curves for
reservoir operation and flood relieve purposes and with hydrological parameters (Water
Levels, pace of increase of WL, incremental rainfall during a storm period).

c) Plan for Maintenance and Replacements

For each component or group of components in the asset register a maintenance
schedule shall be prepared. This would be compiled in a summary table to clearly show
the successive results of the maintenance works, including observations and the cost of
maintaining the items. Where the approximate live time of certain dam and other head
works component is known, the plan should also make provisions for replacement of
certain components. The expected cost of replacement is to be shown as well.

d) Plan of Inspections

Inspections of all relevant head work components shall be carried out and shall be
recorded in sufficient detail to enable future inspectors to assess possible relevant
changes in the observed conditions. A Plan of Inspections shall be prepared and
maintained for each of the head works components. The Plan would distinguish:
- Daily surveillance and inspections;
- Periodic inspections of specific items by specialised staff;
- Safety inspections by independent inspectors.

The Plan would briefly describe all items to be inspected in each inspection with
particulars about these items as needed.

Table 4.4.1 Provisional Schedule of Inspections

<table>
<thead>
<tr>
<th>Subject</th>
<th>Embankment</th>
<th>Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry season</td>
<td>Daily</td>
<td>Weekly</td>
</tr>
<tr>
<td>Flood conditions</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>Settlement crest</td>
<td>2x/yr</td>
<td>1x/yr</td>
</tr>
<tr>
<td>Piezometers</td>
<td>1x/m</td>
<td>n.a.</td>
</tr>
<tr>
<td>Leakage</td>
<td>1x/wk</td>
<td>1x/m</td>
</tr>
<tr>
<td>Internal Inspection</td>
<td>1x/yr</td>
<td>1x/yr</td>
</tr>
<tr>
<td>External Inspection</td>
<td>1x/2yr</td>
<td>1x/2yr</td>
</tr>
</tbody>
</table>

e) Financial Plan

The Financial Plan could make use of the asset register with cost of works components.
Also the Maintenance Plan and the Inspection Plan could be used in estimating the
annual cost of these activities. The financial planning should cover a period of the next
five years, in order to be able to get a good idea of the moving average of the expenses
to be expected.
5 NATIONAL DAM SAFETY UNIT

5.1 Regulatory framework

There is to our knowledge no regulatory framework for dam safety in Ghana. In order to harmonise the various approaches in respect of dam safety and to ensure independent and high quality dam safety inspections, it is necessary to establish a national body to promote the implementation of this plan. This national body should harmonise dam safety guidelines and inspection practices and ensure a high quality of inspection, the preparation and enforcement of Ghana dam safety guidelines.

The above objectives may be achieved by establishing a National Dam Safety Unit (NDSU) in which the main present stakeholders participate, contributing their knowledge and experience and looking into these matters from another perspective. In this way the national interest may be best served.

The intention of the NDSU would not be to interfere with the daily affairs of the organisations responsible for the operation and maintenance of the dams. Through the NDSU these organisations would be supported in establishing, maintaining and enforcing harmonised national standards and it would assist these organisations in capacity building and enhancing the skills needed to ensure the safety of dams in Ghana.

The mandate of the NDSU would include inspection of all GWCL dams in Ghana, enforcement of prescribed measures, training of NDSU Dam Inspectors, Dam Operators and other professionals involved in dam and reservoir planning, construction and management. The NDSU would also be the organisation to accommodate a national Standards and Regulations Committee in respect of dam related issues. A Data Management Unit would be established to collect, manage and disseminate relevant information about the dams.

It is proposed that the NDSU would resort as a commission of the National Disaster Management Organisation of the Ministry of the Interior. The NDSU would be guided and supervised by a Board of the NDSU with representatives of various ministries, including the Ministry of Works and Housing, the Ministry of Energy and the Ministry of Food and Agriculture participate.

The legal base of the functioning of the NDSU will have to be defined and established within the framework of the current Ghana legislation. Care should be taken that the legal basis will provide the NDSU with sufficient mandate to be able to execute powers needed for enforcement of current and future legislation. The institutional arrangements of the NDSU will have to include its powers and responsibilities, its human and financial resources, norms, standards and guidelines, permits and licences and reporting requirements.

The day to day management of the NDSU is proposed to be carried out by a Director, supported by a Secretariat. The Director will communicate with the Board and with the organisations at present in charge of dam design, dam construction, dam operation and maintenance and dam inspections. He would initiate and co-ordinate activities needed to
enhance the development of the sector. For example he would co-ordinate and formulates the application for membership of Ghana of the International Commission of Large Dams (ICOLD). In order to be able to share and improve knowledge about large dams the International Commission on Large Dams (ICOLD) has been established. ICOLD is issuing technical bulletins of high standard as well as other publications in which the state of the art in respect of dam design, construction, maintenance and inspection can be found.

The NDSU would initially comprise 4 Sub-Units as presented in the following list

- Inspection Unit, headed by a (permanent) Head of the Inspection Unit;
- Training Unit, headed by a Co-ordinator;
- Standards and Regulation Unit, headed by a co-ordinator;
- Data Management Unit, with a Head of Data Management.

These sub-units would be staffed with qualified and skilled personnel. The Head Office of the NDSU would be in Accra and in time regional offices would be established.

5.2 Inspection Unit

The Inspection Unit of the NDSU would be headed by a permanent Head of the Unit who would organise, guide and supervise a core team of Dam Inspectors. These Dam Inspectors should be qualified professionals, trained to inspect and evaluate dams in Ghana in accordance with present guidelines and additional ones yet to be identified and established.

In order to be flexible in respect of manpower, the Inspection Unit would also be able to draw from expertise available in other organisations on Ghana and occasionally abroad in case specialist input would be needed that is not readily available in Ghana. These agencies may include Ministries, GWCL and VRA, scientific institutes, universities and consulting engineers from public and private companies.

After establishing and initial training of a core of Dam Inspectors, also in the regional offices of the NDSU Dam Inspectors would be appointed and trained. It will be necessary to provide training to the Dam Inspectors in order to keep them familiar with recent developments, methods, equipment, standards and dam safety focus points. They would be appointed for a certain period after which it will have to be decided if their appointment would be extended. This would depend on their performance and up to date knowledge of dam inspection.

5.3 Training Unit

Where the NDSU would have to start from scratch on, the establishment of a Training Unit will be essential for the future performance of the NDSU. Initial training most likely will have to draw heavily from foreign expertise to assist the development of a curriculum for training, adapted to the requirements and conditions in Ghana. In particular in the first years of the NDSU it will be necessary to make assessments of the need of additional training of already skilled professional staff, for which experienced specialists in various disciplines will be needed.

Part of the training could possibly be done by selected university teachers or specialists drawn from public or private consulting companies. For a limited number of Dam
Inspectors dedicated training courses or overseas training tours may be selected to enable to acquire special skills.

The training programme would also require some special facilities in the offices of the NDSU.

After developing suitable curricula, training courses and training material in the NDSU head office in Accra, training would also be decentralised towards regional offices of the NDSU.

5.4 Standards and Regulations Committee

One of the tasks of the NDSU, together with other organisations, will be to develop and upgrade national standards, regulations and guidelines in the field of dam design, dam construction, dam operation, maintenance and inspection. Where expertise, data and capacity in the field of storage dams will be largely concentrated in the NDSU, it is logical to make use of this expertise in a (permanent or not permanent) Committee that would convene whenever required. It would make use of the Secretariat and other facilities of the NDSU.

The Committee would contribute to the formulation of national standards and regulations but also to the preparation of guidelines in respect of dam safety, including assistance to the dam sector (e.g. in the regions) in the preparation of standards for Emergency Preparedness Plans, standard maintenance guidelines, river basin management plans and other more or less standardised dam related water management guidelines.

The NDSU Committee would be involved in:
- A review of current dam design standards;
- The formulation of upgraded dam safety standards.
- The preparation of a program for dam safety assessment by the National Dam Safety Unit;
- Guidelines and standards for periodic dam inspection, reporting and follow-up
- Guidelines for the preparation of Environmental Impact Assessments for dams;
- Preparation of a manual for the establishment of Emergency Preparedness Plans;

In order to be able to draw from sufficient expertise in Ghana, a Panel of Experts would be established to support the Committee in complicated matters or in exceptional projects where diverse skills will be needed.

5.5 Data management

The NDSU would require data and documentation that at present is scattered over various institutes and government agencies or that may be not available in Ghana altogether. It is proposed that the Data Management Unit (DMU) unit be stationed in the head office of the NDSU in Accra.

It is envisaged that the DMU will develop and maintain databases and other tools that are needed for the work of Dam Inspectors but also for training purposes, for dam statistics and for preparing budgets for dam rehabilitation planning. In particular
establishing and maintaining a national register on dams and reservoirs (including current condition and rehabilitation needs) would be a task for the DMU in the NDSU.

The specialised staff of the DMU would collect, compile, elaborate and analyse data and prepare outputs that can be used by the Government. Techniques would include the application of a Graphical Information System (GIS).
6  EMERGENCY PREPAREDNESS PLAN

6.1 Introduction to the EPP

An Emergency Preparedness Plan (EPP) aims to assist the authorities responsible for public security in taking adequate measures needed to prevent casualties and to limit physical damage arising from disastrous events anticipated in the case of possible dam failures. Each dam, reservoir and area at risk has its own characteristics and as such each EPP will have to be prepared taking into consideration the specific conditions of that project.

An EPP should be prepared for large dams containing reservoirs just upstream of populated areas. The International Commission on Large Dams (ICOLD) defines a large dam as a dam (i) with a height of 15m or more from the foundation, or (ii) with a height between 5m and 15m and a reservoir volume of more than three million cubic meters. The United Kingdom Reservoirs Act states that a "reservoir" has a storage capacity of more than 25,000 m$^3$.

To date we have not been able to identify Ghana guidelines in respect of the requirements for preparing an EPP or instructions as to where relevant responsibilities for preparation and implementation of EPP plans for dam and reservoir projects should be vested. But we recommend that EPP be prepared for all "dams" and not for the "weirs" (reference is made to the list in the introduction of this report).

6.2 General EPP Requirements

In order to make an EPP an effective instrument for disaster prevention and disaster mitigation it will be necessary that certain legal instruments are available, enabling the authorities responsible for preparation and implementation of EPPs to execute the necessary powers. Such powers shall be allocated and specified in legislation addressing emergency conditions. If the existing legislation would appear not to be adequate for this purpose, adjustment of the legal framework must be considered.

In principle the organisations responsible for management and for operation and maintenance of a specific dam should be made primarily responsible for the preparation of an EPP as well. These organisations can reasonably be expected to have the relevant knowledge of the risk associated with a dam and a reservoir of a particular project. In context of this project, the organisation primarily responsible for preparation and execution of the EPP should be GWCL. The Ministry of Works and housing would likely have a supervisory role in respect of dam safety. Also other agencies and authorities could have certain mandates for setting rules and regulations or for preparation, implementation, inspection and enforcement of an EPP.

Preparation of a detailed EPP for a dam and reservoir project requires suitable maps, data on the river, dam, topography, hydrology, rural and urban infrastructure, population and properties at risk etc. as well as particular skills and computer programmes to assess the potential impact for various risk scenarios. These tools are not readily available at GWCL and before GWCL will be able to prepare EPPs, extensive preparations and certain investments will be needed. Possible ways of solving this
problem may be to provide support to GWCL through the proposed NDSU or to involve specialised consultants or institutes for this purpose.

Where at present for most dams and reservoirs no (extensive) EPPs exists, the cost associated with the preparation and the implementation of EPPs have to be born from budgets yet to be allocated. Where the support for additional budget can not be expected to be popular, it is anticipated that the responsible authorities will, as much as possible, make use of existing resources such as personnel, equipment, means of communication etc. This would require a well-elaborated plan and well co-ordinated actions and communications.

It is recommended that the EPP be updated each year and be presented to the NDSU for approval.

6.3 Intensified Surveillance

The EPP should start with detailed instructions for monitoring of the dam and auxiliary works by GWCL staff, in particular for monitoring during periods of extreme rainfall in the catchment or high reservoir levels. The instructions shall specify points that require special attention, in particular in case the reservoir levels would start rising fast. Such monitoring should include regular observations of seepage along the toe of the dam and at any locations along the dam surface where it is known that seepage is emerging at high reservoir levels.

Depending on a number of parameters, e.g.:
- High intensity widespread rainfall in the catchment for elongated periods;
- The amount of rainfall in the catchment in a short period;
- The reservoir water level and pace of rise of the water level in the reservoir;
- Increase of seepage or
- Increase of turbidity of seepage water on the downstream slope or at the toe of the dam;
- Movements of the dam crest or the downstream face of the dam;

GWCL should formulate appropriate alarm phases in more detail, adapted to the actual situation.

6.4 Definition and announcement of alarm phases

Each alarm phase or particular situation should trigger measures that would become more extensive with a deterioration of the conditions and with a more serious situation. The measures would start with information within the GWCL and grow in intensity with an increase of the gravity of the situation, for example:
- GWCL management to be kept informed continuously,
- Suspension of leave of certain GWCL officials,
- Police and local relieve services to be alerted,
- Certain specialists and operators with equipment to be summoned to the dam or to other locations,
- Announcements through local radio and television stations,
- Regional officials, army, municipal officials, public works department and other services to be alerted and instructed,
- Mobilisation of support services (fire brigade, army, red cross) and equipment,
- Information of the public and ensuring that everybody is informed,
6.5 Data Collection

For preparation of an EPP, GWCL would first require detailed maps of the whole area possibly affected. Houses, roads, tracks, bridges, high areas, low areas, embankments, canal alignments etc. should be shown. In particular for the preparation of a dam break analysis, detailed information would be required, including river valley cross-sections, major obstructions for the propagation of a flood wave in the river channel or flood plain, depression areas that could act as temporary storage, dikes, ridges, levees, gullies, creeks and other topographic features that possibly could affect a flood wave. Topographic maps should extend beyond the direct project area to be able to assess approach routes and areas and facilities (like schools and community halls) that possibly could be used for evacuation and shelter of flood victims. Hospitals in the vicinity of the potential inundation area should be identified and be informed about their potential task in case of dam break casualties.

6.6 Dam break analysis

A dam break analysis should be carried out to delineate the areas likely to be affected by flooding, especially when people living downstream of the dam would be affected. First one would determine the areas affected and then the number of people living there. However, the dam break analysis and the subsequent inundation analysis are extensive analyses. The necessity of such analysis is recommended in the table below on a reconnaissance level (see appendix 10 with copies of the maps scale 1:50.000).

<table>
<thead>
<tr>
<th>No.</th>
<th>Dam name</th>
<th>Dwellings within 1km downstream of the dam</th>
<th>Dam break / inundation analysis necessary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Barikese Dam</td>
<td>Not on the map</td>
<td>To be checked</td>
</tr>
<tr>
<td>2</td>
<td>Owabi Dam</td>
<td>Compound and huts</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Weija Dam</td>
<td>Accra (outskirts)</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Kwanyaku Dam</td>
<td>Kwanyaku and Fawomanye</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Brimsau Dam</td>
<td>Not on the map</td>
<td>To be checked</td>
</tr>
<tr>
<td>6</td>
<td>Inchaban Dam</td>
<td>Inchaban</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Axim Dam</td>
<td>Compound and huts</td>
<td>Yes</td>
</tr>
</tbody>
</table>

It is recommended to carry out the analysis for various conditions, e.g. for normal reservoir level, for full reservoir with the maximum flood surcharge, for a fast developing breach in the dam body, for various initial conditions e.g. for an already inundated flood plain and for relatively dry conditions, concurrent high river runoff.

In addition the dam break computer runs could be performed for various roughness coefficients and for possible measures to alleviate or otherwise affect the flood conditions at certain locations, e.g. to reduce flow velocities near residential areas, or elevated roads to enable access to or escape from certain areas.
The impact of obstructions in the river channel or flood plain should also be assessed in view of regulations aiming to limit flood levels in the rivers, not only for catastrophic events but also for "normal" extreme floods. Implementation of most of the possible measures to alleviate the impact of extreme flood discharges will not be possible on the short term but should be used as a river basin policy and planning tools for future or gradual implementation.

6.7 Inundation maps

The dam break analysis should provide insight in the areas most at risk in case of a disaster. Results of the analysis should be presented on inundation maps, showing the probable depth of inundation, flow velocities (as an indicator of potentially dangerous conditions), propagation of the flood wave through the valley, indicating the time possibly available for rescue operations.

Where initial dam break analysis would probably only give a rough indication of the above flooding parameters, in time, the dam break analysis should be improved to better simulate relevant conditions. In particular, the effect of (slightly) elevated embankments used for roads, railways, irrigation canals, flood control, spoil dumps along drainage canals etc could be significant. At such locations critical flow velocities could develop, making these embankments or roads inaccessible for persons and causing erosion that could destroy part or whole of these embankments. A network of such elevated features in the flood plain could change flow directions and cause severe conditions at locations where such conditions would not be expected.

Inundation maps for selected conditions should be available to key organisations that are involved in physical planning of the region and to authorities that are involved in possible rescue operations (Province, municipalities, police, fire brigade, hospitals, army, etc.). Such maps should be updated and re-distributed in case drastic changes of conditions are identified. The number of organisations that would need to receive such maps (and other information) depends on the severe ness of the conditions and in general is a function of the storage volume of the reservoir, the height of the dam and the area directly affected.

6.8 Organisational aspects

Although GWCL would probably be responsible for preparation and maintaining an EPP, large part of the activities after a catastrophic event would be carried out by other agencies and authorities. It is the duty of GWCL responsible for the dam and reservoir to prevent any critical conditions. In case critical conditions would emerge, GWCL shall initially take all possible measures to avoid a disaster. Once conditions grow more serious GWCL should not wait with warning higher authorities and hand over part of their responsibilities. In case such conditions would happen it should be clear to everybody who is responsible for what. A thorough planning and extensive communication should not be postponed until a disaster looms.

GWCL should first prepare an EPP for internal purposes in case flood conditions or the behaviour of the dam would require extra attention. The GWCL internal organisation should cope with such first alarm phase and inform higher authorities about concerns and possible consequences. In a next higher alarm phase possibly the assistance of other organisations would be needed and part of the responsibilities may be handed
over to these authorities. For such conditions a thorough planning would be needed and information should be readily available for necessary action. It should be realised that under serious weather conditions there may not be electricity, roads may be inundated, telephone lines may already be out of order and making of prints or photocopies of maps and other planning documents and instructions may be impossible.

Once conditions are turning serious the Regional authorities should take over most of the responsibilities and would need to be provided with blueprints of all actions, planned in an earlier stage. Such plans would include the organisational set-up of emergency operations envisaged and should show clear lines of responsibilities and communication for the whole of the operations and for decentralised (but well co-ordinated) activities, depending on the prevailing conditions.

Authorities that, according to the EPP, will be responsible for certain activities and inputs during any alarm phase should be kept well informed about any changes in the EPP. The same applies to organisations assigned to provide support to the activities, e.g. transport means, equipment, material resources and other inputs required in case of a disaster.

The following schematically drafted alarm phases should be extended to more comprehensive and detailed ones during the preparation of the next version of the EPP.

**Alarm Phase 1**

Description of conditions:
- Widespread rain of high intensity over the whole basin, prediction of continuing rainfall conditions and fast rising reservoir levels water beyond Full Supply Level of the reservoir;
- Substantial increase in seepage at any location of the dam;
- Seepage emerging from the dam bodies or their foundations is turning turbid, indicating internal erosion of the foundation or the embankment;
- Substantial increase of leakage from inlet structures or dam abutments;
- Movement of the dam crest, the downstream or upstream face of the dam.

Actions to be taken:
- GWCL Director and management to be kept informed continuously by the operators and supervisors;
- Suspension of leave of certain GWCL managers (EPP Manager, his Deputy and other EPP staff) and the dam supervisors and operators;
- Investigation into the cause or seriousness of the situation and formulation of necessary measures.

**Alarm Phase 2**

Description of possible conditions:
- Reservoir level rising above a critical elevation;
- Extreme wind and wave action at reservoir level above a critical level;
- Increase of leakage or turbidity to the extent that internal erosion of the embankment is to be feared;

Additional actions to be taken:
- Specialists and operators with equipment to be summoned to the dam or to other locations as needed;
- Key persons in the EPP to be summoned to their base of emergency operation;
Alarm Phase 3
Description of possible conditions:
- Water of the reservoir flowing across the crest of embankments;
- Substantial instability of slope(s) of the embankment;
- Obvious internal erosion of the embankment;
- Additional actions to be taken:
  o Officials, army, municipal offices, public works department and other agencies to be mobilised and instructed;
  o Mobilisation of support services (fire brigade, army, red cross, etc) and equipment;
  o Announcements and instructions through local radio and television stations;
  o Information to the public and ensuring that everybody is informed;
  o Closure of certain roads, suspension or adaptation of train and bus services;
  o Preparation of refugee shelters and facilities.

Alarm Phase 4
Description of possible conditions:
- Water of the reservoir flowing across the crest of the embankment and causing serious erosion of the downstream slope;
- Breach of any of the reservoir embankments.
- Additional actions to be taken:
  o Mobilisation of helicopters, vessels and transport equipment;
  o Preparation for evacuation in areas potentially affected threatened;
  o Evacuation ordered of all areas most threatened;
  o State of Emergency declared in the Regions affected.

6.9 Procedures

During the lowest alert phase the relatively simple internal GWCL procedures will remain valid as the operational procedure for monitoring and management of the dam and ancillary works. Once the conditions grow worse and the next alarm phase is declared, the normal operational GWCL procedures will be complemented and partly be superseded by new procedures that are focussing on the execution of the EPP.

The management guidelines for the dam itself should remain valid and the management of the dam should be carried out by the GWCL specialists as to be established in the GWCL procedures for that year. Other authorities shall not be authorized to take ad hoc decisions as to whether or not spillway gates or other outlet facilities should be opened.

Procedures for the higher alarm phases should transfer the overall responsibilities for the EPP implementation to higher authorities. These procedures should clearly allocate responsibilities and mandates to certain authorities co-operating in or supporting the emergency operations.

The EPP shall comprise clear organisational schedules to be able to easily follow the hierarchy pursued in the emergency operations. These schedules should also include the main communication lines and procedures to be followed for certain actions, e.g.
request to the central government for assistance and requests for additional support from the armed forces.

In case conditions grow worse and evacuation appears to be the only option, the area evacuated will have to be protected by police and or other armed forces. The EPP propose some draft provisions for these conditions that shall be communicated with the law enforcement agencies responsible for maintaining law and order. The final provisions shall also include the arrangements for access of essential services (red cross and similar) to higher inhabited areas within the flood-affected area.

6.10 Communications

Communications are a vital part of any emergency plan. During extreme conditions most of the normal means of communication may be out of order. The EPP should pay attention to this fact and identify possible means of communication that could be used under emergency conditions. Normal telephone lines and mobile telephone may be out of order during extreme conditions. Communication by radio could solve part of the problem. In this respect it could be vital to involve the police and the armed forces in the planning of an EPP.

First of all the communication between the dam site(s) and the GWCL head quarter should be secured. At all times these lines of communication should be operable and preferably the reservoir water levels should be readable in the GWCL head office at all times. During regular dam inspections the Dam Safety Inspectors should pay ample attention to the means of communication and the communication procedures established for each dam.

Secondly, communication with the higher authorities should be well structured. Once the dam conditions grow worse and once the responsibilities are exceeding the competence of the GWCL, a higher authority should be able to smoothly take over (part of) the responsibilities and continue to co-ordinate the EPP implementation. Under these conditions it is essential that the capacity of the communication means will be sufficient to cope with many incoming calls at the same time.

The communication addresses and procedures should be clear and well documented. All authorities with essential tasks in the emergency planning should receive a copy of these procedures as well as supporting explanations and instructions.

6.11 EPP Training and Practising

The EPP shall include programmes for training and for practising of selected components of the EPP. Preferably a need analysis shall be the basis for the programme. The programmes for such practising shall be prepared together with the authorities of other organisations involved. Training and practising shall focus on components with which the participants are not familiar.

6.12 Public Participation and Information

The main beneficiaries of the EPP will be the general public that may be subject to the hazards of a possible dam breach. In order to get their full co-operation it will be necessary to raise public awareness and to get the support from the public. The EPP
should address public awareness as an important subject, because without public awareness and support and participation by the public any EPP would be in vain.

After preparation and approval of the draft EPP the public shall be informed about the characteristics of the dam facilities, its potential risk, the measures taken and the plans prepared to avoid any adverse conditions or alleviate its results. For this purpose information material shall be prepared to inform the people by means of posters, information to school children, TV spots, local newspaper announcements and other means of public information.

6.13 Legislation

After all plans have been formulated it will be necessary to analyse if the intended measures are supported by adequate legislation. In case legislation would be lacking, the competent authorities should be requested to initiate adjustments in the current legislation to allow essential measures to be implemented. The legislation should empower competent authorities to take the necessary measures to cope with emergency conditions.

6.14 Reporting

The EPP shall also include requirements about annual reporting on targets set, progress made and problems encountered. The Authorities and stakeholders need such information to be able to identify common problems that should be addressed and to learn from experience of GWCL. The lessons learned are aimed to be translated into an adjusted approach of preparing and implementing EPPs.

The annual reports shall be brief and include:
- Previous year planning;
- Training and exercises carried out, results and suggestions for improvements;
- Adjustments required in the EPP of next year;
- Training programme for the next year;
- Changed information and data;
- Accounts of previous year and budget of next year.
7 TERMS OF REFERENCE FOR FOLLOW-UP ACTIVITIES

7.1 Dam stability design check

7.1.1 Introduction

In order to assess the safety of a structure its designs basis must be reviewed to check whether the maximum design load is not exceeded in the as-built, present or future situation. For instance the Inchaban dam and the Owabi dams have been raised resulting in higher water load. Deforestation of the catchments area may have resulted in a faster run-off of water to the reservoir and a higher spillway peak discharge resulting in higher water loads.

The original design documents of the dams and weirs incorporated in this underlying reconnaissance level study were not available. Some documents however presented fragments of design aspects. For instance reference 5 includes a check on the dam spillway "overturning" and "sliding" factors of safety, but it is not complete. The "stability design check" needs to be carried out for all dams and weirs in order to assess their safety.

7.1.2 Purpose of the stability design check

The purpose of the design check is:
1. Establishment of the structure design basis.
2. Calculation of the structure stability (factors of safety).
3. Recommendations on structure strengthening when required.
4. Definition of the detailed investigations program
5. Preparation of cost estimates to feasibility level

7.1.3 Scope of work

1. Establishment of the design basis including:
   • Description (preferably in drawings) of the existing situation:
   • Geometry of the structure (layout, cross-sections, detailed drawings of the mechanical equipment)
   • Characteristics of the building material (concrete and steel quality)
   • Characteristics of the foundation (soil layering and properties)
   • Design Codes and Standards
   • Operation and maintenance procedures and manuals
2. Determination of the structure loading including all forces which may be expected to affect the stability of the structures:
   • External water pressure
   • Internal water pressure (pore pressure or uplift) in the dam and foundation
   • Silt pressure
   • Earthquake (see Appendix 12)
   • Weight of the structure
   • Forces from gates or other appurtenant structures, traffic, accidental loading (such as floating debris)
3. Calculation of the (concrete) structure stability considering failure mechanisms such as:
   • Overturning
4. Calculation of the embankment stability considering:
   - Sliding ("slip circles")
   - Settlement
   - (Excess) pore pressures and liquefaction
   - Erosion due to for instance wave action and overtopping and "piping".
   - Slope protection.

5. Recommending the required structure strengthening in case the factor of safety is too low and recommendations on monitoring and investigations such as soil investigations, piezometer installation, inclinometers settlement beacons, water level gauges and discharge measurement weirs.

6. Preparation of cost estimates to feasibility level.

7. Preparation of the "Design Check Report" including the necessary drawings

7.2 Dredging design

7.2.1 Introduction

Since the construction of dams and weirs, the reservoirs have experienced sedimentation, reducing their storage capacity and reducing the water quality. The sediments should be removed by dredging. Reservoir sedimentation quantities have been estimated (ref. 1) as presented in the following table.

<table>
<thead>
<tr>
<th>Dam / weir name</th>
<th>Catchment area [km²]</th>
<th>Reservoir capacity [m³]</th>
<th>Estimated sedimentation [m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axim</td>
<td>0.35</td>
<td>50,000</td>
<td>1,300</td>
</tr>
<tr>
<td>Barikese</td>
<td>906</td>
<td>35,300,000</td>
<td>1,700,000</td>
</tr>
<tr>
<td>Brimsu</td>
<td>330</td>
<td>2,300,000</td>
<td>620,000</td>
</tr>
<tr>
<td>Kwanyaku</td>
<td>821</td>
<td>1,350,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Owabi</td>
<td>69</td>
<td>6,200,000</td>
<td>130,000</td>
</tr>
<tr>
<td>Weija</td>
<td>2460</td>
<td>115,000,000</td>
<td>9,200,000</td>
</tr>
</tbody>
</table>

7.2.2 Purpose of the dredging design

1. Definition of the suitable dredging method taking into account the environmental impacts.
2. Establishment of the dredge disposal location and facilities
3. Preparation of cost estimates to feasibility level

7.2.3 Scope of work

1. Design of dredging works including:
   - Definition of location to be dredged (depth, area, volume, tolerances)
   - Selection of suitable dredging plant and transportation of dredged material
2. Design of disposal area including the settlement pond, dikes, drainage systems...
3. Planning of dredging works including the performance and production of the equipment, the GWCL requirements for potable water production and the rainy and dry season
4. Definition of the required soil investigations and tests (of the sediments and also of the disposal site sub-soil) and the required bathymetric and topographic surveys.
5. Assessment of the Environmental impacts of the dredging operations.
6. Preparation of cost estimates to feasibility level.
7. Preparation of the "Dredging Design Report" including the necessary drawings

7.3 NDSU Implementation study

7.3.1 Introduction

See section 5.1 of this report.

7.3.2 Purpose of the Implementation study

The purpose of the implementation study is
1. To advise whether the NDSU would consider only GWCL dams or that also should be included the Volta River Authority Akosombo Dam and / or the Irrigation Development Authority dams.
2. Facilitation for consultation between stakeholders regarding representation in the NDSU and participation in decision making processes.

7.3.3 Scope of work

1. Consultation of the dam owners on their participation as stakeholders of the NDSU on the institutional set-up for the NDSU on the basis of the existing (legislation and) regulatory framework and the best practices based on national interests and international experience.
2. Inventory of the relevant regulatory framework (laws, acts, decrees) for implementation of the NDSU.
3. Preliminary recommendations on institutional set-up.
4. Meetings and interviews with the stakeholders with the aim to facilitate the creation of consensus on the NDSU scope of work, budget requirements, resources, office(s), organisation and (implementation) planning.
5. Reporting
REFERENCES


Appendix 1
Inspection aspects (ref. 3)
Inspection aspects (ref. 3)

Concrete dams and concrete structures
Monthly inspections should cover such items as:
1. Abnormal settlements, heaving, deflections or lateral movements of concrete structures.
2. Cracking or spalling of concrete and opening of contracting joints
3. Deterioration, erosion or cavitations of concrete
4. Abnormal leakage through foundation or formed drains or through concrete surfaces, construction joints or contraction joints
5. Possible undermining of the downstream toe or other foundation damage
6. Unusual or inadequate operational behaviour.

Earth fill dams and embankments
Monthly inspection should cover such items as:
1. Condition of the embankment slopes and the crest
2. During rapid filling of the reservoir, the downstream slope of the embankment and the foundation downstream from the embankment should be carefully inspected for indications of cracks, slides, sloughs, subsidence, impairment of slope protection, springs seeps, or boggy areas caused by seepage from the reservoir.
3. The upstream slope should also be carefully inspected after periods of sustained high velocity winds and as the reservoir water surface is being drawn down, for evidence of cracks, slides, sloughs, subsidence or damages to the slope protection such as displacement of riprap or other signs of serious erosion.
4. During periods of low reservoirs level, the exposed portions of the abutments and the reservoir floor should be carefully examined for sinks or seepage holes or cracking

Channels and surrounding areas
Monthly inspections should cover such items as:
1. Channel bank or bed erosion and silting
2. Condition of riprap areas
3. Presence and conditions of undergrowth in bottoms and on sides of channels and estimated effect on tail-water levels
4. River aggradations or degradations and possible effect on hydraulic operation of structures involved.
5. Abnormal subsidence of backfill of embankment areas.
6. Unusual or inadequate operational behaviour.

Reporting of abnormal events
The occurrence and characteristics of unusual conditions should be reported immediately in writing (preferably with photographs).

It is very important to record the development in time of the above mentioned mechanisms.
Appendix 2
Inspection report Mampong weir
### Inspection Report Mampong Weir

<table>
<thead>
<tr>
<th><strong>Name of Dam:</strong></th>
<th>Mampong Weir</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date of Inspection:</strong></td>
<td>21 March 2004</td>
</tr>
<tr>
<td><strong>Inspection by:</strong></td>
<td>Harry Wassink (RH), Daniel Bampoh (GWCL)</td>
</tr>
<tr>
<td><strong>Accompanied by:</strong></td>
<td>Mr. K. Ashemang (Station Manager)</td>
</tr>
<tr>
<td><strong>Region:</strong></td>
<td>Ashanti</td>
</tr>
<tr>
<td><strong>Location:</strong></td>
<td>Mampong</td>
</tr>
<tr>
<td><strong>Year of Commissioning:</strong></td>
<td>1961</td>
</tr>
<tr>
<td><strong>Year of Refurbishment:</strong></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Year of last Inspection:</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Name of Reservoir:</strong></td>
<td>No name</td>
</tr>
<tr>
<td><strong>Reservoir Description:</strong></td>
<td>Reservoir surrounded by rock</td>
</tr>
<tr>
<td><strong>Reservoir Water Level on Date of Inspection:</strong></td>
<td>Spilling (the weir is always spilling)</td>
</tr>
<tr>
<td><strong>Name of River:</strong></td>
<td>River Chiremfa</td>
</tr>
<tr>
<td><strong>Catchment Area (km²):</strong></td>
<td>Unknown but the river Chiremfa has an estimated discharge of 16,000 m³/day (ref.4)</td>
</tr>
<tr>
<td><strong>Catchment Description:</strong></td>
<td>Farmers</td>
</tr>
<tr>
<td><strong>Capacity of Reservoir (m³):</strong></td>
<td>Gross (G): 6000</td>
</tr>
<tr>
<td><strong>Dead Water (DW):</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Design Usable (DU = G-DW):</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Siltation Estimate (SE):</strong></td>
<td>The reservoir experiences serious siltation (ref.4). In 1995 &quot;desilting work&quot; has been undertaken.</td>
</tr>
<tr>
<td><strong>Actual Usable (AU = DU-SE):</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Extent of Weed Growth:</strong></td>
<td>Algae on the downstream weir face</td>
</tr>
<tr>
<td><strong>Type of Dam:</strong></td>
<td>Reinforced concrete</td>
</tr>
<tr>
<td><strong>Spillway Crest Level (m):</strong></td>
<td>280.35 feet in 1996</td>
</tr>
<tr>
<td><strong>Weir Length (m):</strong></td>
<td>90</td>
</tr>
<tr>
<td><strong>Spillway length (m):</strong></td>
<td>90</td>
</tr>
<tr>
<td><strong>U/S slope:</strong></td>
<td>Vertical</td>
</tr>
<tr>
<td><strong>D/S slope:</strong></td>
<td>See photos</td>
</tr>
<tr>
<td><strong>U/S protection:</strong></td>
<td>Concrete</td>
</tr>
<tr>
<td><strong>D/S protection:</strong></td>
<td>Concrete</td>
</tr>
<tr>
<td><strong>River bed level (D):</strong></td>
<td>3m below Spillway crest level</td>
</tr>
<tr>
<td><strong>Foundation level (mAD):</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Height of Dam (max above river bed level) (m):</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Height of Dam (max above foundation level) (m):</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Type of cut-off:</strong></td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Type of Spillway:</strong></td>
<td>Ogee (overflow) spillway</td>
</tr>
<tr>
<td><strong>Type of Stilling Basin:</strong></td>
<td>Concrete slab and downstream rock plateau</td>
</tr>
<tr>
<td><strong>Normal Retention Water Level (mAD):</strong></td>
<td>Spillway crest level</td>
</tr>
<tr>
<td><strong>Maximum Flood Water Level (mAD):</strong></td>
<td>Less than 1 m above crest</td>
</tr>
<tr>
<td><strong>Monitoring:</strong></td>
<td>Water level gauge in Sumampa approximately 500 m from the dam site</td>
</tr>
<tr>
<td><strong>Draw-off/Intake/Outlet Pipework Description:</strong></td>
<td>Two strainers piped to wet chamber discharging under gravity to 200mm buried AC pipe</td>
</tr>
<tr>
<td><strong>Scour Valves:</strong></td>
<td>Not existing</td>
</tr>
<tr>
<td><strong>Spillway Gates:</strong></td>
<td>Not existing</td>
</tr>
<tr>
<td><strong>Design documentation:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>As-built documentation:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Rehabilitation design:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>As-built rehabilitation:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Operation documentation:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Maintenance documentation:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Inspection documentation:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>Emergency Preparedness / Action Plans:</strong></td>
<td>Not available</td>
</tr>
<tr>
<td><strong>General Comments:</strong></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3
Inspection report Hohoe weir
Appendix 4
Letters and faxes
Appendix 5
Minutes of meetings
Comments from GWCL and the WB on the Inception Report

1. **PMU/GWCL comment 2.e): Damango Dam and Yendi Weir**
   These two facilities were not included in the list of dams and weirs agreed upon during the meeting on 17.03.04. Therefore the sample of dams/weirs visited by the Dam Specialist may not reflect those installations. However, it is agreed upon that those two will be included in the study. If available, information about these two facilities will be sent by PMU/GWCL to the Consultant by 23.04.04, so that he can include them in his analysis. If no information is provided, then these installations will still be mentioned for the record in the DSR, but without detailed analysis.

2. **PMU/GWCL comment 2.f): ToR for the Dam Safety Component**
   The comment on the level of detail of such ToR was included to emphasize the importance of these ToR for the project. No further action is required. A seminar to train Ghanaian project staff in preparation of such ToR would be a good idea but is not possible anymore considering the project planning and budget.

3. **PMU/GWCL comment 1.c): pipeline crossing of major highways**
   Pipeline crossing of major highways are not expected for the first year civil works, except maybe on the road between Obuasi and Kumasi. The consultant will make inquiries in order to report on the process in case of highway crossings.

4. **WB comment 1.**
   As requested by the WB, a copy of the Ghana Land Administration Project RPF was given to the Resettlement Specialists.

5. **WB comment 2.**
   The Consultant confirmed that the environmental aspects of the dredging of the Brimsu reservoir will be included in the EAMP report.
ROYAL HASKONING

Comments from the WB on the scoping report

6. **WB comment 1.**
   The two issues, a) the expanded flow through water treatment plants and the consequent need to safely dispose of additional sludge, and b) the potential water quality and health risks of additional water supply due to the WSRP causing overloading of municipal water drainage, treatment and disposal systems) will be addressed in the EAMP.
   However, PMU/GWCL mentioned that they do not expect significant increase in water consumption as a result of the first year civil works, except for the area supplied by the water from the Brimsu reservoir.

7. The Consultant has not received yet comments from the EPA on the scoping report. Comments are expected to be discussed during the meeting planned on 21.04.2004.

Questions and comments from the Consultant on the scope of work

8. **What is the status of the Public Consultation process, as required per WB guidelines?**
   A number of sessions have been planned starting on 23.04.04. The plan is to use the draft final reports for the consultation session planned in Accra on 30.04.2004.

9. **How is coordination organised between the various authorities when works start?**
   A Coordination Committee exists at the National and Regional level. PMU/GWCL will provide the name of the GWCL staff who participates in the National Coordination Committee.

10. **Organisation of the resettlement training:**
    **When?**
    According to the Consultant such a training should take place preferably:
    - after all comments on the RPF have been received,
    - when design is sufficiently advanced (e.g. on which side of the road the pipeline is going to be laid).
    It is expected that the training will take place during the first week of June.
    **Where?**
    One location: Accra. It is proposed that a field trip to the Accra works location be conducted as part of the training.
    **Participants?**
    PMU/GWCL will provide the list of participants by 23.04.04. The Consultant suggested that the Regional Project Engineers, as well as the land acquisition expert from the Estate Department, Mr. Dayour, participate in this training.
    The Resettlement Specialists will discuss this more into detail during the meeting planned with Mr. Nkrumah on 23.04.04, 10:00 AM.

11. **Field trips for Resettlement Component**
    The Resettlement Specialists conducted field trips in the Greater Accra Region, and will furthermore use the information collected during the field trips to all the other first years works done by Mr. Seth Larmie. Besides, some other projects where resettlement took place or is ongoing will be visited in order to gather information for the training.

12. **Information about costs for the Dam Safety component**
    PMU/GWCL will send this information to the Consultant by 23.04.04.

13. **Institutional arrangements in relation to the EMP implementation**
    PMU/GWCL explained how the WSRP is organised and will provide the Consultant with a copy of their Annual Report for more detailed information.

20/04/2004
14. Contracting in relation to the EMP implementation
PMU/GWCL explained their approach in this matter; packages will be formed, mostly on a geographical basis. Some packages can be done by local contractors and some packages will be combined with others. Drilling and dredging will be separated packages.

15. Water Quality Monitoring conducted by GWCL, in relation to the monitoring plan to be prepared for the EMP
A monitoring program is implemented by GWCL. For more details, PMU/GWCL advised the Consultant to take contact with Mrs. Peace from GWCL head office.

16. Reporting
The number of reports to be provided to PMU/GWCL has been agreed as follows:
- Inception report: 10
- Scoping report: 6
- Draft Final reports: 6
- Final reports: 10

Each report will include one original. A digital version of each report will be provided.
Minutes

Present: Mr. Nkrumah (PMU)
Mr. Blok (Royal Haskoning)
Mr. Scheren (Royal Haskoning)
Mr. Hulscher (Royal Haskoning)
Mr. Wassink (Royal Haskoning)
Mr. Addo (AY&A)
Mr. Larmie (AY&A)

Absent: --

Date: 15 March 2004 (Monday afternoon)
Copy: --
Our reference: 9P2503.A0/C00001/hwa/Nijm

Subject: Ghana Water Sector Restructuring Project,
Environmental, Resettlement and Dam Safety Studies,
Kick-off Meeting with PMU

Action

1. Opening
Mr. Nkrumah welcomes everyone present

2. Dam Safety
2.1 Mr. Nkrumah explains that the dams have been reviewed by the Consultant M.S. Atkins in 1999 and that this review is still. Mr. Nkrumah presents the dam review report “The Department for International Development, Ministry of Works and Housing – Water Sector Restructuring Project Secretariat, Ghana Water and Sewerage Corporation, Ghana Water Sector Improvement Project, Fixed Assets Revaluation Study, Final Report Volume 12 Technical Review (Dams) by WS Atkins International.” This report presents the review of 7 dams and 3 weirs.

2.2 Mr. Nkrumah states that the Akosombo Dam on the Volta River is not included in the project scope of work because it is the responsibility of the Volta River Authorities (VRA) and not of Ghana Water Company Ltd. (GWCL).

2.3 Mr. Nkrumah invites the project team to start their assessment in the PMU “Data Room” containing the “GWCL Asset Documentation” as collected by W.S. Atkins

2.4 Mr. Nkrumah states that the GWCL Engineer is available to assist with the Dam Safety Study.
Minutes

Present: Mr. Bampoh (GWCL / PMU)
       Mr. Wassink (Royal Haskoning, RH)
       Mr. Larmie (AY&A)

Absent: --

Date: 17 March 2004 (Wednesday, 11.00 hours)

Copy: --

Our reference: 9P2503.A0/C02/hwa/Nijm

Subject: Ghana Water Sector Restructuring Project,
         Meeting with the GWCL Dam Expert

1 Opening
   Mr. Larmie introduces Mr. Wassink to Mr. Bampoh

2. Scope of work: number of Dams
   2.1 Mr. Wassink presents to Mr. Bampoh letter 9P2503/L00001/hwa/nijm dated 17 March 2004 with the suggested topics to be discussed for the Sam Safety Assessment.
   2.2 Mr. Wassink states that the Dam Safety Study will not consider the weirs because they do not have storage reservoirs.
   2.3 Mr. Bampoh confirms the reasoning related to safety, storage and weirs but adds that we should assess within the project scope of work the sustainability of the water sources also for the weirs.
   2.4 Mr. Bampoh states that we should furthermore assess the Mempong weir and the Hohoe weir.
   2.5 Mr. Bampoh states that the construction of the Hohoe weir has just been completed and is of the “stop-log type”. Currently the gantry crane has difficulty operating the stop-logs because they “tilt” when lifted”. Furthermore the weir is reported to experience sedimentation.

3. Required documentation

Action by

15 March 2004

9P2503.A0/C00001 hwa Nijm
3.1 Mr. Wassink elaborates on the list of documents to be received from GWCL presented in the letter 9P2503/L00001/hwa/nijm:
1) Existing dam operations;
2) Maintenance logbooks (including the "Atkins" recommended rehabilitation works);
3) Instrumentation and monitoring;
4) Regulatory Framework for Dam Safety;
5) Emergency preparedness;
6) O&M resources (human and financial); and
7) Status of reservoir sedimentation and measures to prolong the life of storage (reservoir conservation).

3.2 Mr. Wassink adds the "design documentation and calculations" to the list presented above. The dam structural integrity (safety) would be assessed on the basis of these design documents.

3.3 Mr Bampoh states that that information requested should be available with the regional GWCL offices. Mr. Bampoh will send letters to the regional authorities of the 7 dams 5 weirs requesting for this information.

3.4 Mr. Bampoh introduces Mr. Kwame Odame-Abadio (Water Resources Commission, WRC)) in light of the Regulatory Framework for Dam Safety.

3.5 Mr. Wassink outlines the issues of the book "Regulatory Frameworks for Dam Safety - A Comparative Study" The World Bank Law, Justice, and Development Series by D. Bradlow, et al. (2002) and asks Mr. Kwame Odame-Abadio whether he has the documentation on:
- The existing form of the regulation, e.g. Reservoir Acts and Disaster Plan (Emergency Preparedness Plan).
- Institutional Arrangements and Regulatory Authority including powers and responsibilities, human and financial resources, norms, standards and guidelines, permits and licences.


3.7 Mr. Bampoh states that the Volta River Authority (VRA) co-ordinates the "National Commission on Large Dams". They should be able to provide us with the required documentation.

4 Site inspections
4.1 The following inspection program will be carried out by Mr. Bampoh and Mr. Wassink:
Friday 19 March: meetings with the Kumasi Regional GWCL station manager.
Friday and Saturday: inspection of Barkese Dam, Owabi Dam and Mempong weir.
Monday: meeting with the Cape Coast Regional GWCL station manager.
Monday and Tuesday: inspection of Kwanyaku Dam, Koforidua Weir and Winaba weir.

4.2 Mr Bampoh and Mr. Wassink have contacted the station managers to confirm their meetings.

15 March 2004
Estimated dams and weirs replacement costs

The database of the "Fixed Assets Revaluation Study" (ref.1) carried out in 1999 by WS Atkins International recommends the following replacement values for the dams and weirs:

<table>
<thead>
<tr>
<th>Dam name</th>
<th>USD</th>
<th>Cedi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weija</td>
<td>26,906,840</td>
<td>62,962,005,600</td>
</tr>
<tr>
<td>Axim</td>
<td>489,870</td>
<td>1,146,295,800</td>
</tr>
<tr>
<td>Barikese</td>
<td>12,480,960</td>
<td>29,205,446,400</td>
</tr>
<tr>
<td>Brimsu</td>
<td>1,776,050</td>
<td>4,155,957,000</td>
</tr>
<tr>
<td>Inchaban</td>
<td>4,791,990</td>
<td>11,213,256,600</td>
</tr>
<tr>
<td>Kwanyaku</td>
<td>5,084,030</td>
<td>11,896,630,200</td>
</tr>
<tr>
<td>Owabi</td>
<td>4,217,360</td>
<td>9,868,622,400</td>
</tr>
<tr>
<td>Hohoe</td>
<td>906,580</td>
<td>2,121,397,200</td>
</tr>
<tr>
<td>Winneba</td>
<td>201,735</td>
<td>472,059,900</td>
</tr>
<tr>
<td>Korofidua</td>
<td>906,580</td>
<td>2,121,397,200</td>
</tr>
</tbody>
</table>

Note that in the table above (dated 1999) a currency rate has been used of 1 USD=2340 Cedis.
Appendix 7
Appendix 8
Water Resources Commission, Act 522
of the Parliament of the Republic of Ghana,
published on 31 December 1996 in the Gazette
Appendix 9
Owabi Dam Dive Report, January 2004
Appendix 10
Copies of detailed maps areas
Appendix 11
Copies of Dam Inspection Reports (ref. 1)
**Date of Inspection:** 31.3.99  
**Inspection by:** M Hill - WS Atkins  
**Accompanied by:**  
1. Mr John Sackey (GWSC counterpart)  
2. Mr Bernard Missah (District Manager)  
3. Mr JSC Quagraine (Station Manager)  

**Name of Dam:** Alengasuri / Nsein  
**Region:** Western  
**Location:** 60 km West of Takoradi  
**Year of Commissioning:** 1965  
**Year of Refurbishment:** 1998 (new intake pumps & delivery pipeline to WTW)  
**Year of last Inspection:** 1994 30 Nov by: Mr JD Gosden (Howard Humphreys)  
**Name of Reservoir:** Axim  
**Reservoir Description:** Reservoir margins heavily wooded or cleared for cultivation. Water quality poor (iron). Weed growth.  
**Reservoir Water Level on Date of Inspection:** 8.7' (2.65m) read off gauge (actual level = 39.6mAD which is 0.4m below lowest spillway crest level.  
**Name of River:** Alengasuri  
**Catchment Area (km$^2$):** 0.35  
**Catchment Description:** Primarily plantation & forest  
**Capacity of Reservoir (m$^3$):**  
- Gross (G): Not known  
- Dead Water (DW): New intake suction (2.1m) off reservoir bottom (old suction 0.9m off bottom)  
- Design Useable (DU = G-DW): 50,000  
- Siltation Estimate (SE): 10% (5,000)  
- Actual Useable (AU = DU-SE): Reduced from design by siltation  

**Extent of Weed Growth:** Some weed around margins and lily pads in reservoir  
**Type of Dam:** Concrete gravity weir  
**Crest Level (mAD):** Bridge level ≈ 45.37  
**Crest Length (m):** 40m incl. extensions into abutments (10m LHS, 16m RHS)  
**Crest Width (m):** 0.8m (spillway bridge)  
**U/S slope** Vertical  
**U/S protection** N/A  
**D/S slope** 1V:0.7h  
**D/S protection** N/A
Level: 41.3m / 40.5m
Screens: None
Operation: Penstocks at bridge level
Condition: All valves operate but are hard to seal closed after opening. Spillway penstock spindles need replacing.

Spillway Gates: None

Maintenance: Minimal

Inspection Report availability:
Revaluation assessment

General Comments:
Dam concrete generally in reasonable condition with only minor work required to spillway, d/s apron and sidewalls.
Vegetation needs to be cleared from d/s apron area.
Intake in good condition as recently refurbished.
GHANA WATER AND SEWERAGE CORPORATION
FIXED ASSETS REVALUATION STUDY

BARIKESE DAM/INTAKE DATA

Date of Inspection: 6.4.99
Inspection by: M Hill – WS Atkins
Accompanied by:
1. Mr John Sackey (GWSC counterpart)
2. Mr Eric Bansah (Mechanical Engineer)
3. Mr JK Kwakye (Works Superintendent)
4. Mr RD Arhin (Quality Control)

Name of Dam: Barakese Dam (Barikese)
Region: Ashanti
Location: 19 km NW of Kumasi
Year of Commissioning: 1972
Year of last Inspection: 1991 31 Oct – 5 Nov
by: Mr JM Reid (Howard Humphreys)

Name of Reservoir: Barikese
Reservoir Description:
The reservoir margins are forested. Some growth of aquatic weeds. No reported siltation problems
Reservoir Water Level on Date of Inspection: 219.7mAD
(1.2m below spillway crest)

Name of River: Offin
Catchment Area (km²): 906 km²

Capacity of Reservoir (m³):
- Gross (G): 35.3 million
- Dead Water (DW): 1.55 million
- Design Useable (DU = G-DW): 33.75 million
  (7.5 billion gallons)
- Siltation Estimate (SE): Minimal
- Actual Useable (AU = DU-SE): 33.75 million

Extent of Weed Growth: Weed growth around reservoir margins.

Type of Dam: Composite. Central concrete spillway (14 siphons & free overflow) with earthfill embankments.

Earthfill Embankment Crest Level (mAD): 223.69m
Earthfill Embankment Crest Length (m): 526m (spillway length = 77m)
  Total length = 603m

Earthfill Embankment Crest Width (m): 6m (crest road width = 3.35m)

U/S protection:
- Rip rap
Earthfill Embankment D/S slope: 1v:2h & 1v:3h
D/S protection: Grass

Other comments:
Dam is generally in good condition. U/S floating boom provided. Embankment overgrown – especially RHS. Mechanical equipment not maintained. Although monitoring facilities have been provided, no records are kept. Condition of drainage gallery cannot be assessed as no access possible on safety grounds. Scour valve passing water. Iron staining on spillway. U/S intake tower and bridge in reasonable condition. Original instrumentation for settlement/movement monitoring housed in building on d/s of LHS embankment – no longer working.

River bed level (mAD): Not known
Foundation level (mAD): Not known
Height of Dam (max above river bed level) (m): Earthfill embankment = 18.5m
Spillway = 15m
Height of Dam (max above foundation level) (m): Earthfill Embankment = 21.5m
Spillway = 19m

Type of cut-off:
Central impervious core zone to earthfill embankment. Single line grout curtain.

Type of Spillway: Mass concrete gravity block incorporating 14 air regulated siphons (each 4.6m long) & central open spillway (6.1m long)

Type of Stilling Basin: Shilling pool

Spillway Crest Level (mAD): 220.9
Normal Retention Water Level (mAD): 220.9
Maximum Flood Water Level (mAD): 222.4

Monitoring: Although provision has been made no monitoring is carried out

Piezometric Levels: Piezometers located in d/s shoulders of earthfill embankments – not monitored

Seepage: Measuring points provided d/s of earthfill embankment – not monitored

Downstream Toe Drains: Provided but discharge not measured

Settlement/Deformation (earthfill): Surface monument located on d/s shoulders of earthfill embankment - not monitored

Movement (concrete): Tell-tales at joints

Drainage Gallery: Yes – drainage not monitored

Draw-off Tunnel Culvert: Yes
Type: Steel pipe in concrete culvert (80m long)
Size: 1200mm dia.
Length: 80m – 110m
**Draw-off/Intake/Outlet Pipework:**

**Type:** Draw-off tower on left abutment adjacent to spillway section.

**Outlet Offtakes:**
- **Number:** 3
- **Type:** Sluice gates + butterfly valves (1.2m dia. on outlet pipe)
- **Size:** 1.2m square
- **Level:** 214.0mAD/217.0mAD/218.8mAD
- **Lowest Draw-Off Level (mAD):** 214.0m (excluding scour @ 209.9m)
- **Screens:** Coarse screens external
- **Operation:** Manual (originally remote operated pneumatic)
- **Condition:** All valve & sluice gates reported to operate but in need of maintenance

**Scour Valves:**
- **Number:** 2 + 1
- **Type:** Butterfly & sluice valve
- **Size:** 1.5m dia. & 900mm dia.
- **Level:** 205.9mAD
- **Screens:** Bar screen intake structure
- **Operation:** Manual (butterfly valves originally remote operated pneumatic)
- **Condition:** All valves reported to operate but in need of maintenance. 900mm dia. outlet valve cannot be fully closed.

**Spillway Gates:** None (siphon details)
- **Number:** 14
- **Type:** Air regulated siphons
- **Size:** 4.6m wide
- **Level:** 220.9mAD
- **Screens:** 100mm dia. Steel pipe at 900mm c/c.
- **Operation:** Automatic (no mechanical parts)
- **Condition:** Siphon concrete in good condition

**Maintenance:** Minimal

**Inspection Report availability:**
- Dam Revaluation Report
- Dam Inspection Report – June 1992

Barakese.doc
General Comments:
Spillway in good condition.
Embankment overgrown – needs clearance u/s & d/s.
Mechanical equipment not maintained - operates but needs attention.
Although facilities provided no monitoring is carried out.
Intake (outlet works) concrete and metalwork in good condition.
# BRIMSU DAM/INTAKE DATA

**Date of Inspection:** 30.3.99  
**Inspection by:** M. Hill - WS Atkins  
**Accompanied by:**  
1. Mr John Sackey (GWSC counterpart)  
2. Mr CK Amoah (Station Manager)  
3. Mr EO Yeboah (Deputy Station Manager)

**Name of Dam:** Brimsu Dam (Kakum Dam)  
**Region:** Central  
**Location:** 13km North of Brimsu  
**Year of Commissioning:** 1928  
**Year of Refurbishment:** 1959 – raised by 4m  
1959 – New valves & pipework.  
1992 – Scour inlets modified as intakes.  
Scour adapted for supply  
**Year of last Inspection:** 1994 29 Nov by: Mr JD Gosden (Howard Humphreys)  
- previous inspection 1969

**Name of Reservoir:** Kakum Reservoir  
**Reservoir Description:** Reservoir has shallow margins and is surrounded by woodland. Siltation and weed growth are reported problems.  
**Reservoir Water Level on date of Inspection:** 29.9m AD  
(1.3m below spillway level)

**Name of River:** Kakum  
**Catchment Area (km²):** 330  
**Catchment Description:** Primarily dense woodland

**Capacity of Reservoir (m³):**  
- Gross (G): 2.3 million  
- Dead Water (DW): 0.2 million  
- Design Useable (DU = G-DW): 2.1 million  
- Siltation Estimate (SE): 0.17 million  
- Actual Useable (AU = DU-SE): 1.93 million

**Extent of Weed Growth:** Can be extreme but recently cleared  
**Type of Dam:** Mass concrete gravity  
**Crest Level (mAD):** 34.6m (access bridge level)  
Spillway level 31.2m/31.4m/31.5m/31.9m/32.3m  
**Crest Length (m):** 60m (access bridge) concrete cut-off wall extends between 12-25m into LH abutment from top of steps.  
1.8m (access bridge) 2.0m (spillway crest)
**U/S slope**: Vertical  
**D/S slope**: lv: 0.8h  
**U/S protection**: N/A  
**D/S protection**: N/A

**Other comments:**
Dam consists mainly of spillway. RH abutment is exposed rock. LH abutment does not have exposed rock and has extended concrete cut-off. Exposed rock in bed of river d/s of dam. Spillway concrete in reasonable condition with minor cracking, surface abrasion and one area of spalling on spillway crest. Some cracking to spillway bridge. Some undermining of facing concrete u/s of dam on LH side. Some cracking to d/s training walls and facing concrete. Some undermining of apron concrete at d/s end. Iron staining on spillway. SI was carried out in 1997 — three boreholes through dam body and evidence of one (or two) on LH abutment.

**River bed level (mAD):** 24.2m  
**Foundation level (mAD):** 21.8m  
**Height of Dam (max above river bed level) (m):** 10.4m (access bridge level)  
7.2m (spillway level)  
**Height of Dam (max above foundation level) (m):** 12.8m (access bridge level)  
9.6m (spillway level)  
**Type of cut-off:** Concrete cut-off trench  
**Type of Spillway:** Free overflow (8 openings under access bridge with total length = 60m - effective length = 50m)  
**Type of Stilling Basin:** Concrete apron  
**Spillway Crest Level (mAD):** Varies from 31.2m to 32.3m in steps from centre to abutments  
**Normal Retention Water Level (mAD):** 31.2m  
**Maximum Flood Water Level (mAD):** 34.2m estimated (1955 flood level marked on steps)  
**Monitoring:** None except reservoir WL from stilling tube in low lift pumping station basement.

**Draw-off Tunnel Culvert:**
- **Type:** Original cast iron pipe  
- **Size:** 375mm dia.  
- **Length:** 100m (estimate)  
- **1992 steel pipe from scour outlets**  
- **900mm dia.**  
- **100m (estimate)**

**Draw-off/Intake/Outlet Pipework:**
- **Type:** Upstream modified scour inlets. Original 1.5m x 1.8m intake chamber on u/s face of dam to RH side
- **Outlet Offtakes:** 2 chambers modified from scour inlets
Number: 3 + 2
Type: Penstocks on steel plate installed in original screen slots
Size: 0.3m x 0.3m
Level (mAD): 28.8m/26.3m/23.9m (in 3 intake chamber – other chamber levels unknown)
Lowest Draw-Off Level (mAD): 23.9m
Screens: Fixed external reported. Screens on ropes external to original intakes
Operation: Manual from landing at spillway crest level – access difficult and dangerous
Condition: All valves are reported to be operative. Only top valve in three valve inlet chamber normally used. Upstream gates at scour inlet permanently open – cannot be closed.

Scour Valves:
Number: 2 (original) 2 (new)
Type: Circular Penstocks Knife gate valves
Size: 36" dia. (900mm) 600mm dia.
Level: 23.5mAD 23.65m
Screens: Replaced by new intake -
Operation: u/s & d/s high level handwheels 600mm dia. u/s valves connected to high level handwheels
Condition: u/s penstocks stuck open and inoperable. All valves reported to operate. RH outlet only being used
d/s penstocks removed when new d/s pipework installed

Spillway Gates: None
Stoplog Provision: Not possible
Maintenance: Minimal

Inspection Report availability: Revaluation Assessment

General Comments:
Dam and spillway structure in reasonable condition for age – minor remedial work needed. Remedial work required to d/s sidewalls and apron concrete. Operation of intakes difficult to access and unsafe. U/s scour gates in need of refurbishment including extension spindles to handwheels. D/s gate valve extension spindles need replacement. General maintenance of mechanical equipment needed. Original intake mechanical equipment to be reinstated for emergency use. Scour valves to be operated to clear silt. Minor vegetation growth in bridge joints to be cleared.
GHANA WATER AND SEWERAGE CORPORATION
FIXED ASSETS REVALUATION STUDY

INCHABAN DAM/INTAKE DATA

Date of Inspection: 31.3.99
Inspection by: M. Hill – WS Atkins
Accompanied by:
1. Mr John Sackey (GWSC counterpart)
2. Mr Kwaw (Assistant Station Manager)

Name of Dam: Inchaban
Region: Western
Location: 16km East of Tokoradi
Year of Commissioning: 1918
Year of Refurbishment: Raised 1955 Intake screens replaced 1998
Year of last Inspection: 1994 30 Nov
by: Mr JD Gosden (Howard Humphreys)

Name of Reservoir: Anakwari
Reservoir Description:
Reservoir margins are relatively steep and wooded. Little reed growth but siltation is a problem.

Reservoir Water Level on Date of Inspection: 13.9mAD
(5.2m below spillway level)

Name of River: Anakwari
Catchment Area (km²): 65
Catchment Description: Primarily forest
Capacity of Reservoir (m³):
Gross (G): 1.73 million
Dead Water (DW): 45,000
Design Useable (DU = G-DW): 1.6 million
Siltation Estimate (SE): 20,000 – 400,000
Actual Useable (AU = DU-SE): 1.6 million – 1.28 million

Extent of Weed Growth: Not excessive
Type of Dam: Mass concrete gravity
Crest Level (mAD): Spillway 19.15m (raised from 18.3m in 1955)
Access bridge level not known.
Crest Length (m): 140m
Crest Width (m): 1.5m (access bridge)
U/S slope Vertical U/S protection N/A
D/S slope 1v:0.75h D/S protection N/A

Inchaban.doc
Other comments:
Dam consists mainly of spillway with central scour block and non-overflow sections at each abutment. Spillway concrete is in good condition with exposed aggregate finish – possibly due to flow abrasion. Spillway & u/s face is formed with large precast blocks filled in between with mass concrete. Siltation reported to be 0.9m in depth at u/s face. Downstream concrete apron and training walls overgrown and in need of clearance. Dam raised in 1955 by addition of 700mm high block on top of original spillway crest. Masonry facing u/s of intake has growth in cracks and needs re-pointing in places. Concrete apron only in central section otherwise rock. Evidence of leakage from base of dam at block / insitu concrete junction – on both sides.

River bed level (mAD): 6.7m
Foundation level (mAD): Not known
Height of Dam (max above river bed level) (m): 12.35m
Height of Dam (max above foundation level) (m): Not known
Type of cut-off: Not known – assumed concrete core trench.
Type of Spillway: Free overflow. RH section 40.5m long, LH section 47.1m long – 8 openings.
Type of Stilling Basin: Concrete/rock apron with training walls
Spillway Crest Level (mAD): 19.05m
Normal Retention Water Level (mAD): 19.05m
Maximum Flood Water Level (mAD): Reported to have risen to u/s of bridge arches in 1997 flood (19.75m)

Monitoring: None except reservoir WL from gauge board which needs replacing as it is difficult to read.

Draw-off Tunnel Culvert:
Type: CI pipe
Size: 15" (375mm dia.) this bifurcates d/s of dam into 12" & 15"
      then joins again near WTW into 400mm pipe
Length: 200m

Draw-off/Intake/Outlet Pipework: 3.3m x 2.8m chamber 9.5m deep just u/s of dam on LH side
Type: Dry well – but full of water to a level above reservoir WL. Vertical pipe connected to draw-offs
Outlet Offtakes:
Number: 4
Type: 2 gate valves for each offtake
Size: 300mm dia
Level (mAD): 16.76m/15.24m/13.72m/12.34m
Lowest Draw-Off Level (mAD): 12.34m
Screens: New coarse and fine screens fitted in 1998 with fixing for lifting tackle
Operation: All draw-off valves are operated from surface with key (manual) and are reported to be open and have not been closed for at least 5 years
Condition: Most of draw-off pipework under water - appears reasonable condition

Scour Valves:
Number: 2 + 2
Type: Vertical lift (inoperable) and gate valves
Size: Vertical lift gates ≈ 4m wide (height not known)
600mm dia. gate valves
Level (mAD): 6.7m (vertical lift gates)
Gate valve IL ≈ 7.0m
Screens: None
Operation: Counterbalance and manual winding gear at high level for vertical lift gates. Headstocks at intermediate level for gate valves
Condition: Vertical lift gates and operating mechanism badly rusted and inoperable. Gate valves rusted and inoperable. RH valve closed LH valve partly open

Spillway Gates: None

Stoplog Provision: Stoplog grooves u/s of scour gates - no stoplogs evident
Seal Condition: Not known
Leakage: Slight leakage from both scour gate valves
Maintenance: Minimal
Inspection Report availability:
WRSP Planning and Design Reports 1993/94
Revaluation Assessment

General Comments:
Dam and intake generally in reasonable condition.
Refurbishment of scour vertical lift & gate valves required – including lifting mechanism.
Vegetation clearance and remedial work needed in d/s apron area. Intake dry well chamber to be pumped out and valve operation checked. Leakage at d/s toe and scour blocks to be investigated and monitored. Cracks in access walkway and landing to be repaired. Handrailing in reasonable condition but needs repainting. Metal flooring around scour vertical lift gate operating mechanism needs replacement urgently – rusted badly with holes and dangerous.
Tree growing in RH side scour vertical lift gate slot to be removed.
Vegetation growing on d/s face of dam to be removed.
Remedial work to masonry facing around intake (u/s) to be carried out – clearance and repointing.
KOFORIDUA WEIR/INTAKE DATA

Date of Inspection: 7.4.99
Inspection by: M. Hill – WS Atkins
Accompanied by:
1. Mr John Sackey (GWSC counterpart)
2. Mr Manu (Station Manager)

Name of Dam: Koforidua
Region: Eastern
Location: Bebianiha, 6km SW of Koforidua
Year of Commissioning: 1954
Year of Refurbishment: New pump installed 1987
Year of last Inspection: 1994 26 Nov by: Mr JD Gosden (Howard Humphreys)

Name of Reservoir: Densu-Anu Weir
Reservoir Description:

Reservoir Water Level on Date of Inspection: 6.9’ below pier level (457.25’) : 139.4 – 2.1=137.3m

Name of River: Densu
Catchment Area (km²): 587
Catchment Description: Rural farmland/forest
Capacity of Reservoir (m³): Regulating weir : no significant storage
Extent of Weed Growth: Some around edges
Type of Dam: Concrete weir structure with concrete piers. 5 No 3m wide openings with stoplogs
Crest Level (mAD): Lowest stoplog weir section 137.2m
Crest Length (m): 20.1m = length of weir openings. Wingwalls extend 7m LHS & 15m RHS
Crest Width (m): Bridge over weir 2.4m wide
U/S slope Stoplogs U/S protection Stoplogs

Other comments:
Two sets of stoplogs infilled with clay form weir. Significant leakage through weir structure – washes out infill material. Siltation of river upstream of weir.
Weir concrete generally in good condition with few signs of cracking or crazing.
Some horizontal cracks in LH sidewall beneath access bridge.
Original bank protection raising on RHS has been breached and attempts made at repair.
Water can flow around back of RHS wingwall and has caused erosion and settlement up to 1m deep. Weir cannot be raised above present level without water flowing around.
structure.
Stoplog lifting gantry and hoist not operational.

River bed level (mAD): 134.6m (441.75’)
Foundation level (mAD): 133.3m (437.25’)
Height of Dam (max above river bed level) (m): 2.6m (to top of stoplogs)
Height of Dam (max above foundation level) (m): 3.9m (to top of stoplogs)
Type of cut-off: 0.9m wide concrete cut off to rock level
Type of Spillway: Stoplog weir
Type of Stilling Basin: Concrete apron with side walls and d/s upstand beam
Spillway Crest Level (mAD): 137.2m (to top of stoplogs)
Normal Retention Water Level (mAD): 137.3m
Maximum Flood Water Level (mAD): Not known

Monitoring: None

Draw-off Tunnel Culvert: N/A

Draw-off/Intake/Outlet Pipework:
Type: Chamber just u/s of weir on LH side

Outlet Offtakes:
  Number: 2
  Type: Suction pipework with foot valves
  Size: 225mm & 300mm
  Level: 135.6mAD (225 dia.) – 300 dia. at higher unknown level
  Lowest Draw-Off Level (mAD): 135.6m
  Screens: 2 sets coarse bar screens + 1 fine mesh screen
  Operation: Satisfactory provided water level high enough
  Condition: In need of some rehabilitation. Lifting gantry needs refurbishment/replacement. 300 dia. delivery pipeline exposed in two places in steep LH u/s bank which shows signs of slippage.

Scour Valves: None

Spillway Gates: None

  Stoplog Provision: Used as weir
  Seal Condition: Stoplogs do not seal well – wrong size of stoplogs
  Leakage: Significant

Maintenance: Minimal
**Inspection Report availability:**
Revaluation Assessment

**General Comments:**
Concrete weir structure in reasonable condition. Stoplog weir is not efficient but works. Gantry structures need replacing. Siltation u/s needs clearing. RH protection embankment needs to be reinstated to protect RH side of structure. Intake screens need replacing.
# KWANYAKU DAM/INTAKE DATA

**Date of Inspection:** 30.3.99  
**Inspection by:** M.Hill – WS Atkins  
**Accompanied by:**  
1. Mr John Sackey (GWSC counterpart)  
2. Mr William Aggrey (District & Station manager)  
3. Mr Kojo Arthur (Electrical Maintenance)  
4. Mr Anthony Arhinfu (Laboratory Technician)

**Name of Dam:** Kwanyaku Dam  
**Region:** Central  
**Location:** Kwanyaku, 12m NE of Swedru  
**Year of Commissioning:** 1965  
**Year of Refurbishment:** Scour gates, intake screens, gantry crane. Low lift pumping station refurbished in 1998  
**Year of last Inspection:** 1994 29 Nov  
**by:** Mr JD Gosden (Howard Hunhreys)

**Name of Reservoir:** Ayensu Reservoir  
**Reservoir Description:** Surrounded by wooded areas or cultivation. Weed growth around margins and at dam. Siltation

**Reservoir Water Level on Date of Inspection:** 42.37m (approx 150mm below spillway level)

**Name of River:** Ayensu  
**Catchment Area (km²):** 821  
**Catchment Description:** Largely deforested and covered with low scrub.

**Capacity of Reservoir (m³):**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross (G)</td>
<td>Not known</td>
</tr>
<tr>
<td>Dead Water (DW)</td>
<td>Not known</td>
</tr>
<tr>
<td>Design Useable (DU = G-DW)</td>
<td>1.36 million</td>
</tr>
<tr>
<td>Siltation Estimate (SE)</td>
<td>0.26 million</td>
</tr>
<tr>
<td>Actual Useable (AU = DU-SE)</td>
<td>1.1 million</td>
</tr>
</tbody>
</table>

**Extent of Weed Growth:** Around margins and at dam flanks  
**Type of Dam:** Concrete gravity with short flank embankments  
**Crest Level (mAD):** 46.32m – access bridge over RH side spillway  
**Crest Length (m):** 152m  
**Crest Width (m):** 1.8m footbridge  
**Spillway U/S slope:** Vertical  
**Spillway D/S slope:** 1v:0.85h  
**U/S protection:** N/A  
**D/S protection:** N/A
Other comments:
LH embankment cannot be accessed across spillway. Probably earthfill with u/s and d/s slopes in the range 1v:2h to 1v:3h. Masonry facing to embankment u/s slope on both flanks.

River bed level (mAD): 33.5m
Foundation level (mAD): 30.8m
Height of Dam (max above river bed level) (m): 12.8m (to access bridge/central scour block top level)
Height of Dam (max above foundation level) (m): 15.5m
Type of cut-off: Concrete cut-off trench and twin curtain grouting.

Type of Spillway: Free overflow (2 sections 57.3m RHS & 57.6m LHS ≈ 115m total length)
Type of Stilling Basin: Concrete apron
Spillway Crest Level (mAD): 42.67m/42.52m (lower central section)
Normal Retention Water Level (mAD): 42.67m
Maximum Flood Water Level (mAD): Maximum overtopping reported to be 0.6m.

Monitoring: None except reservoir WL from gauge board

Draw-off Tunnel Culvert:
Type: CI pipe laid on bed of reservoir
Size: 600mm dia.
Length: 75m

Draw-off/Intake/Outlet Pipework:
Type: 13m high 3.7m internal diameter intake tower located centrally u/s of dam

Outlet Offtakes:
Number: 3 + 3
Type: Penstock gate (external) and gate valve (internal)
Size: 450mm
Level (mAD): 39.95m, 37.49m, 35.10m
Lowest Draw-Off Level (mAD): 35.10m
Screens: Coarse screens (external) – new 1998
Operation: Only top intake used
Condition: External Penstock gates – top operative (& open), middle stuck open (partially), bottom closed . Three internal valves reported to operate, one leaking.

Scour Valves:
Number: 2
Type: Vertical lift gates
Size: 3.6m wide x 1.8m high
Level (mAD): 34.4m
Screens: No
Operation: Hydraulic operation

Spillway Gates: None
Stoplog Provision: u/s bulkhead gate for scour outlets
Seal Condition: RH scour gate leaking – possible RH seal problem
Leakage: RH scour gate

Maintenance: Minimal

Inspection Report availability:
WRSP Planning & Design Reports 1993
Revaluation Assessment

General Comments:
Dam and intake generally in good condition. Refurbishment of penstocks and gate valves at intake tower required. Weed growth to be cleared from u/s of spillway. Scour gates to be operated to attempt to flush silt. Vegetation clearance and minor remedial work required downstream. Condition of LH embankment to be checked. D/s training wall undermined on RHS.
GHANA WATER AND SEWERAGE CORPORATION
FIXED ASSETS REVALUATION STUDY

OWABI DAM/INTAKE DATA

Date of Inspection: 6.4.99
Inspection by: M.Hill – WS Atkins
Accompanied by:
1. Mr John Sackey (GWSC counterpart)
2. Mr Baafour Ofusu-Addai (Station Manager)

Name of Dam: Owabi Dam
Region: Ashanti
Location: 10km NW of Kumasi
Year of Commissioning: 1928
Year of Refurbishment: 1960 spillway crest raised by 0.56m
1990 new valves on RW pipeline and new lifting wires

Year of last Inspection: 1991 30 Oct – 5 Nov
by: Mr JM Reid (Howard Humphreys)

Name of Reservoir: Owabi Reservoir
Reservoir Description:
The reservoir margins are forested, with weed growth causing intake problems
Reservoir Water Level on Date of Inspection: 227.3mAD
Name of River: Owabi
Catchment Area (km²): 69
Catchment Description: Primarily forest. Problems with encroachment within catchment area

Capacity of Reservoir (m³):
Gross (G): Not known
Dead Water (DW): Not known
Design Useable (DU = G-DW): 6.2 million
Siltation Estimate (SE): Not known but present
Actual Useable (AU = DU-SE): Not known

Extent of Weed Growth: Weed growth around reservoir margins
Type of Dam: Composite. Central concrete gravity spillway with earthfill embankments
Earthfill Embankment Crest Level (mAD): 229.2m
Earthfill Embankment Crest Length (m): 135m LH bank 50m, RH bank 85m
Earthfill Embankment Crest Width (m): 3.05m
Earthfill Embankment U/S slope: 1v:3h
U/S protection: Concrete slab pitching & wave wall
Earthfill Embankment D/S slope: 1v:2.5h
D/S protection: Grass
Other comments:
Concrete spillway – u/s vertical d/s 1:0.67 Mass concrete with external blockwork (precast) facing. Downstream earthfill embankment shoulder has longitudinal and transverse drainage but outlets not found. Central scour block - width 6m (in spillway section). Access bridge over LH section of spillway. Metalwork reasonable but needs repainting. Seepage evident through d/s face of spillway and at junction of raising and original crest. Vegetation growing on d/s face of spillway. LH embankment well maintained with some trees. RH embankment extensively overgrown. Area of training wall d/s LH side damaged in spillway apron area. Scour facility not operational (u/s bulkhead gates no longer connected to lifting chains and silted up). Wave wall damaged in places. Dam appears to curve slightly u/s.

River bed level (mAD): 219.5m
Foundation level (mAD): 218.7m
Height of Dam (max above river bed level) (m): Spillway = 7.4m (before raising) Embankment = 11.5m
Height of Dam (max above foundation level) (m): Spillway = 8.1m (before raising) Embankment 12.5m
Type of cut-off: Concrete core walls to earthfill embankments
Type of Spillway: Mass concrete free overflow RH length – 48.5m LH length = 32.5m
Type of Stilling Basin: Concrete lined channel to central stilling basin
Spillway Crest Level (mAD): 226.8m + 0.710m = 227.5m
Normal Retention Water Level (mAD): 227.5m
Maximum Flood Water Level (mAD): 228.3m
Monitoring: None except reservoir water level

Draw-off Tunnel Culvert:
Type: CI pipe/AC pipe
Size: 18” dia. (450mm)/15” dia. (375mm)/ 24” dia. (600mm) - varies
Length: 15m

Draw-off/Intake/Outlet Pipework:
Type: 7.3m deep 1.2m x 2.4m wet well with 3 draw-offs into 2.9m x 2.4m dry well valve shaft

Outlet Offtakes:
Number: 3
Type: 2 gate valves for each offtake
Size: 150mm dia.
Level (mAD): 220.3m/223.9m/225.7m
Lowest Draw-Off Level (mAD): 220.3m
Screens: Coarse and fine screens – poor condition
Operation: All valves reported to operate – manual by handwheel (removable)

Condition: Valves/pipework/spindles show signs of corrosion. Blank flange missing from top of draw-off pipe. Dry well shaft has water in it. Periodically pumped out. Intake screens need replacing.

Scour Valves:
Number: 2 Scour outlets
Type: u/s flap valves and sluice weir on each outlet
Size: 900mm dia.
Level: 219.5m
Screens: None
Operation: u/s flap valves lifted by chains.
Sluice weir operated by handwheel
Condition: U/s flap valves are inoperable as chains parted from gates.
Sluice valves are reported to operate but are not used due to fear of not being able to close again with u/s flap valves inoperable.
Sluice valves/spindles are corroded and need attention.

Spillway Gates: None
Stoplog Provision: Slots for stoplogs at intake chamber

Maintenance: Minimal

Inspection Report availability:
Revaluation Report
Dam Inspection Report March 1992
Underwater Inspection Report on Sluice Gates Feb 1999

General Comments:
Dam generally in good condition.
Remedial work required to mechanical equipment to bring to operational standard.
Right hand embankment extensively overgrown – needs clearance. Left hand embankment well maintained but one large tree growing u/s and several d/s.
Spillway crest raising in poor condition – leakage under.
Access bridge in reasonable condition but needs repainting.
Downstream training walls and apron side wall needs repair (LH side)
Scour facility needs to be reinstated.
WEIJA DAM/INTAKE DATA

Date of Inspection: 29.3.99
Inspection by: M.Hill – WS Atkins
Accompanied by:
1. Mr John Sackey (GWSC counterpart)
2. Mr Evans Balaara (Station Manager)
3. Mr James Oteng Mensa (Electnical Maintenance)

Name of Dam: Weija Dam
Region: Atma
Location: 13km West of Accra
Year of Commissioning: 1978
Year of Refurbishment: N/A
Year of last Inspection: 1993 24-29 Oct by: Howard Humphreys

Name of Reservoir: Weija Reservoir
Reservoir Description: Surrounded by low scrub near dam
Reservoir Water Level on Date of Inspection: 13.66m (0.67m below normal TWL)
Name of River: Densu
Catchment Area (km²): 2460
Catchment Description: Cultivated land or low scrub
Capacity of Reservoir (m³):
- Gross (G): Not known
- Dead Water (DW): Not known
- Design Useable (DU = G-DW): 115million to normal WL
- Siltation Estimate (SE): No evidence of major problem
- Actual Useable (AU = DU-SE): 115million

Extent of Weed Growth: Minimal. Seasonal algal problems Oct-Feb
Type of Dam: Earthfill embankment with rock fill protection u/s and d/s. wide impermeable core
Crest Level (mAD): 17.07m – 18.29m
Crest Length (m): 375m incl. spillway
Crest Width (m): 6.1m
U/S slope: 1v:3h above 10.97m, 1v:5h below
U/S protection: Rockfill
D/S slope: 1v:3h above 10.97m, 1v:5h below
D/S protection: Rockfill

Other comments:
Horizontal blankets u/s and d/s of embankment to control seepage. Relief wells at d/s toe
at embankment section. Drainage collection channels at d/s toe. Drainage gallery in spillway weir.

River bed level (mAD): 1.22m
Foundation level (mAD): -0.61m
Height of Dam (max above river bed level) (m): 15.85m
Height of Dam (max above foundation level) (m): 18.90m
Type of cut-off: Cut-off trench and grout curtain – spillway section. No positive cut off for remainder of embankment

Type of Spillway: 8m high concrete weir block with 5 radial gates
Type of Stilling Basin: Hydraulic jump with dentated sill
Spillway Crest Level (mAD): 8.84m
Normal Retention Water Level (mAD): 14.33m
Maximum Flood Water Level (mAD): 15.24m
Capacity 52,000 cusecs (1473 m³/s)

Monitoring: Reservoir water level from spillway gauge – WL recorder at intake tower not working
Downstream Toe Drains: Drainage collected in chamber but not monitored
Movement (concrete): Gaps in bridge over spillway measured after seismic events.
Drainage Gallery: Water pumped out but not measured.

Draw-off Tunnel Culvert:
Type: Concrete culvert from intake tower to intake chamber
Size: 1.6m dia.
Length: 46m

Draw-off/Intake/Outlet Pipework:
Type: 13m high 3m internal dia. intake tower with intake channel located u/s of dam on LH side

Outlet Offtakes:
Number: 3
Type: Vertical sluice gates
Size: 1m wide x 1.8m high
Level: Not known
Lowest Draw-Off Level (mAD): Not known
Screens: External trash racks on chains
Operation: Bottom intake not used. Vary use of top and middle intake. Top being used at present
Condition: All intake gates reported to work. Headstock handles need replacing. Trash screen removal ability not known. Previous report indicated bottom two jammed. General refurbishment required.

Scour Valves: None

Spillway Gates: Yes
Number: 5
Type: Radial
Size: 9.14m wide 6.1m high
Level: Weir crest level 8.84m – gates open over range 0-6.674m
Screens: No
Operation: Hydraulic rams each side. Manual operation (hand pump) possible
Condition: One hydraulic pump does not operate but whole system can be pressurised using other pumps. Side seal leakage on all gates. Some deterioration of ram/gate connection. Some plant growth in d/s spillway area.

Stoplog Provision: Yes, 9m x 6m single bulkhead stored in chamber LH side of spillway. Stoplog cannot be used due to damage to guide rails (vertical) in u/s slots.
Seal Condition: Side seals need attention. Bottom seals mostly ok.
Leakage: Side seal leakage, minor bottom seal leakage at one gate

Maintenance: Minimal

Inspection Report availability: Revaluation Assessment

General Comments:
Dam generally in good condition. No apparent slope movement. Some seepage d/s. Toe drain and relief well collection system needs to be restored to operation. Undergrowth at d/s toe on LH embankment needs clearing. Toe ditches need to be repaired on both side embankments. Some cracking to spillway concrete, but not major, no spalling of concrete or exposed reinforcement/staining. Side seals to radial gates need attention. Radial gates need a closer inspection of condition – minor work may be needed structurally. Gate operating mechanism needs overhaul/rehabilitation. Stoplog guide rails need remedial works to allow installation. Water inflow to drainage gallery needs to be measured and monitored. Wooden decking access to intake tower unsafe (termites) and needs replacement. Intake gates require overhaul incl. new handles. Trash rack screens operation to be reinstated. Intake tower concrete and hand railing/metalwork in reasonable condition – painting needed.
GHANA WATER AND SEWERAGE CORPORATION
FIXED ASSETS REVALUATION STUDY

WINNEBA WEIR/INTAKE DATA

Date of Inspection: 29.3.99
Inspection by: M.Hill – WS Atkins
Accompanied by:
1. Mr John Sackey (GWSC counterpart)
2. Mr Elliot LK Kwangbedzie (District Manager)
3. Mr Christian Numanyovor (Deputy District Manager)

Name of Dam: Winneba Weir
Region: Central
Location: Gyahadze Village – 6.4km NE of Winneba
Year of Commissioning: 1921
Year of Refurbishment: N/A
Year of last Inspection: 1994 (29 Nov)
by: Mr JD Gosden (Howard Humphreys)

Name of Reservoir: Ayensu Weir
Reservoir Description:
Impounded area u/s of small weir. Constantly overtopping. Cultivation adjacent. Siltation not a major problem.
Reservoir Water Level on Date of Inspection: Just spilling
Name of River: Ayensu
Catchment Area (km²): 384 d/s of Kwanyaku
Catchment Description: Rural & urban (incl. Sewdru)
Capacity of Reservoir (m³): Not impounding storage as regulating weir

Extent of Weed Growth: Weed growth apparent but managed
Type of Dam: Concrete weir
Crest Level (mAD): 2.2m high
Crest Length (m): 42m (incl 6m long wingwalls each side)
Crest Width (m): No access across weir crest
Weir U/S slope: Vertical U/S protection N/A
Weir D/S slope: Not known D/S protection N/A

Other comments:
No access across weir

River bed level (mAD): Not known
Foundation level (mAD): Not known
Height of Dam (max above river bed level) (m): 2.2m
Height of Dam (max above foundation level) (m): 2.2m
<table>
<thead>
<tr>
<th><strong>Type of cut-off:</strong></th>
<th>Not known – assumed no cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Spillway:</strong></td>
<td>Weir</td>
</tr>
<tr>
<td><strong>Type of Stilling Basin:</strong></td>
<td>Natural rock river bed with training walls 18m long</td>
</tr>
<tr>
<td><strong>Spillway Crest Level (mAD):</strong></td>
<td>Not known (2.2m above d/s river bed level)</td>
</tr>
<tr>
<td><strong>Normal Retention Water Level (mAD):</strong></td>
<td>Weir level or above</td>
</tr>
<tr>
<td><strong>Maximum Flood Water Level (mAD):</strong></td>
<td>Reported to be 6’ but flood levels marked in pumping station indicate higher levels (+3-4m)</td>
</tr>
<tr>
<td><strong>Monitoring:</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Draw-off Tunnel Culvert:</strong></td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Draw-off/Intake/Outlet Pipework:</strong></td>
<td>Chamber u/s of weir on RH side</td>
</tr>
<tr>
<td><strong>Outlet Offtakes:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Number:</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Type:</strong></td>
<td>Suction pipework with foot valves</td>
</tr>
<tr>
<td><strong>Size:</strong></td>
<td>150 mm dia. and 200 mm dia.</td>
</tr>
<tr>
<td><strong>Level:</strong></td>
<td>1m below weir crest level (estimated)</td>
</tr>
<tr>
<td><strong>Lowest Draw-Off Level (mAD):</strong></td>
<td>Both intakes about same level</td>
</tr>
<tr>
<td><strong>Screens:</strong></td>
<td>Reported to be a screen on inlet to offtake chamber – but chamber below WL</td>
</tr>
<tr>
<td><strong>Operation:</strong></td>
<td>Pumps abstract water directly from river</td>
</tr>
<tr>
<td><strong>Condition:</strong></td>
<td>Suction pipework, pumps and pumping station in poor condition. Pumping station prone to flooding. Two pumps – one pump not working.</td>
</tr>
<tr>
<td><strong>Scour Valves:</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Spillway Gates:</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Maintenance:</strong></td>
<td>Minimal</td>
</tr>
<tr>
<td><strong>Inspection Report availability:</strong></td>
<td>Revaluation Assessment</td>
</tr>
<tr>
<td><strong>General Comments:</strong></td>
<td>Winneba.doc</td>
</tr>
</tbody>
</table>
Weir in serviceable condition but d/s toe could not be seen to assess any undermining or erosion. LH wingwall and training wall appears to be in reasonable condition. RH wingwall undermined and cracked. Concrete/masonry facing to bank above RH training wall eroded in places, overgrown and in need of remedial work. Suction pipe supports cracked. All mechanical & electrical plant needs replacement. Pumping Station prone to flooding – needs replacement at higher level. Access problems to site in rainy season due to flooding.
Appendix 12
Seismic Risk Map of Ghana