IFAS AGENCY for the GEF PROJECT

ARAL SEA BASIN PROGRAM
WATER & ENVIRONMENTAL MANAGEMENT PROJECT

COMPONENT C:
DAM SAFETY AND RESERVOIR MANAGEMENT

UCHKURGAN DAM

SAFETY ASSESSMENT REPORT

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GIBB
LAWGIBB Group Member

In association with

SMEC

UCHKURGAN DAM
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CONTENTS

UNITS AND ABBREVIATIONS

ASBP	Aral Sea Basin Program
CA	Central Asia
CMU	Component Management Unit
EA/EIA	Environmental Assessment/Environmental Impact Assessment
EC-IFAS	Executive Committee of IFAS
FSL	Full Storage Level
FSU	Former Soviet Union
FAO/CP	Food and Agriculture Organisation/World Bank Co-operative Programme
GDP	Gross Domestic Product
GEF	Global Environment Facility
ICB	International Competitive Bidding
ICOLD	International Commission on Large Dams
ICWC	Interstate Commission on Water Coordination
IDA	International Development Association of the World Bank
IFAS	International Fund to Save the Aral Sea
JSC	Joint Stock Company
LDL	Lowest Drawdown Level
M & E	Monitoring and Evaluation
NCB	National Competitive Bidding
NGO	Non-governmental Organisation
O & M	Operation and Maintenance
PIP	Project Implementation Plan
PIU	Project Implementation Unit
PMCU	Project Management and Coordination Unit
PMF	Probable Maximum Flood
RE	Resident Engineer
TA	Technical Assistance
TOR	Terms of Reference
SIC	Scientific Information Centre (of the ICWC)
SU	Soviet Union
SW	Small Works
VAT	Value Added Tax
WARMAP	Water Resource Management and Agricultural Production in CA Republics

masl	metres above sea level
Mm^3	million cubic metres
km^3	cubic kilometres = 1000 Mm^3
m^3/s	cubic metres per second
ha	hectare
hr	hour

1 INTRODUCTION

This report is one of ten reports prepared under Component C: Dam and Reservoir Management, of the Water and Environmental Management Project (WAEMP). The WAEMP is supported by a variety of donors, such as the Global Environment Facility (GEF) via the World Bank, the Dutch and Swedish Governments and the European Union, and is being implemented by the IFAS Agency for the GEF Project under the Aral Sea Basin Program.

1.1 Background to Project

In general, the WAEMP aims at addressing the root causes of overuse and degradation of the international waters of the Aral Sea Basin, and to start reducing water consumption, particularly in irrigation. The project also aims to pave the way for increased investment in the water sector by the public and private sectors as well as donors. The project addresses this aim in several components. Dam and Reservoir Management, the assignment with which this report is concerned, is one of them. The other components are: Water and Salt Management, the leading component, to prepare common policy, strategy and action programs; Public Awareness to educate the public to conserve water; Transboundary Water Monitoring to create the capacity to monitor transboundary water flows and quality; Wetlands Restoration to rehabilitate a wetland near the Amu Darya delta; and Project Management. The components have close links with each other.

The Dam and Reservoir Management Component focuses on four activities as follows:

a) Continuing an independent dam safety assessment in the region, improve dam safety, address sedimentation and prepare investment plans;
b) Upgrading of monitoring and warning systems at selected dam sites on a pilot basis;
c) Preparing detailed design studies for priority dam rehabilitation measures; and
d) Gathering priority data and preparation of a program for Lake Sarez.

The activities are grouped for work process purposes into two packages and will be executed simultaneously, according to an agreed schedule of works:

- Dam safety and reservoir management (including activities "a", "b" and "c");
- Lake Sarez safety assessment (covering activity "d").

The Dam Safety and Reservoir Management package covers the following areas: dam safety, natural obstructions, silting of reservoirs, control of river channels etc.

The activity covers the following 10 dams, two in each country:

Kazakhstan: Chardara and Bugun dams;
Kyrgyzstan: Uchkurgan and Toktogul dams;
Tajikistan: Kayrakkum and Nurek dams;
Turkmenistan: Kopetdag and Khauzkhan dams; and

Uzbekistan: Akhangaran and Chimkurgan dams.
Because of the need to safeguard human life, early priority is being given to safety reviews at each of the dams, which is the subject of this report.

1.2 Safety Assessment Procedures

The dam safety assessments are the first stage in the evaluation (including costing and economic justification), analysis, design and implementation of measures aimed at ensuring safe operation of the selected dams. They have been prepared based on a brief reconnaissance visit to each dam, discussions with the operating staff and a perusal of such information and data as was found to be readily available. No attempt has been made at this stage to analyse any of the data. A data collection and cataloguing procedure was initiated before commencement of the assignment but this process (to be carried out by National Teams) is still at an early stage in implementation.

The field visits were made and the reports prepared by a team of international experts specialising in dam engineering and dam safety procedures. The team comprises experts from GIBB Ltd (United Kingdom) and its associate for this assignment, Snowy Mountains Engineering Corporation (SMEC) from Australia, together with members of a team of regional experts who have been contracted as individuals to work with the Consultants for this project. This team is referred to here as the International Consultants (IC). The International Consultants have been supported during the field visits by members of National Teams appointed for this project from each of the five Central Asian republics.

The principal members of the international team, who are the authors of this report, are the following: -

- Jim Halcro-Johnston (GIBB Ltd) – Team Leader
- Gennady Sergeyevich Tsurikov (Uzbekistan) – deputy Team Leader
- Edward Jackson (GIBB Ltd) – Dam Engineering Specialist
- Ljiljana Spasic-Gril (GIBB Ltd) – Geotechnical Engineer/Dam Structures Specialist
- Pavel Kozarovski (SMEC) – Hydrologist/Hydraulic Engineer
- E.V. Gysyn – Dams Specialist (Kazakhstan)
- E.A . Arapov – Hydraulic Structures Specialist (Turkmenistan)
- G.T . Kasymova – Energy Expert (Kyrgyz Republic)
- R. Kayumov – Hydrostructures Specialist (Tajikistan)
- R.G. Vafin – Hydrologist, specialising in reservoir silting (Uzbekistan)
- V.N. Pulyavin – Dam Instrumentation Specialist (Uzbekistan)
- N.A. Buslov – Dam Specialist (Turkmenistan)
- Y.P. Mityulov – Cost and Procurement Expert (Uzbekistan)
- N. Dubonosov – Mechanical Equipment Expert (Kyrgyz Republic)

Most of the above team members have contributed in the preparation of this report.

1.3 Scope of Safety Assessment

The safety assessments are made based on superficial evidence observed during the site visits, discussions with operating staff and subsequent discussions with members of the National Teams and an examination of supporting design and construction documents as has been made available to the IC for review. (A full list of the documents reviewed is included as Appendix A)

The safety evaluation of the dam has required an assessment of the following factors:

(1) The **characteristics of the reservoir and dam site**, which includes the flood regime
for the river, and the geological conditions at the site;
(2) The **characteristics of the dam,** covering its design and present condition;
(3) The expected **standards of operation and maintenance** of the dams, its performance, and the implications for safety;
(4) The **effects on the downstream** area resulting from a failure of the dam or an excessive release of water.

The structure of this report reflects the scope of safety assessment. Chapter 2 presents a general description of the dam, including location, purpose, principal dimensions and assessment of its hazard rating in relation to the impact that a safety incident would have on the adjacent community. Chapter 3 discusses the design factors that principally affect the safety of the dam.

Comments on the condition and performance of the dam are given in Chapter 4 and in Chapter 5 an assessment of its safety is given.

Chapter 6 gives recommendations for studies, works and supplies to be undertaken in the interests of ensuring the safety of the dam and the downstream community. Conclusions and recommendations are summarised in Chapter 7.

The recommendations for safety measures given in this report must be regarded as tentative as their precise scope will depend on the outcome of further studies which are outside the scope of the present assignment. No attempts has therefore been made at this stage to evaluate the cost of the required remedial works or to carry out an economic justification for the works proposed, which will be necessary to support an application for funding. This will be carried out when the necessary studies and detail designs have been completed.

2 PRINCIPAL FEATURES AND DIMENSIONS OF THE DAM

2.1 Location, Purpose, and date of Construction

Uchkurgan reservoir is located in Djalabad oblast of Kyrgyz Republic on the Naryn river near Shamaldy-Say village. Toktogul hydropower station is located further upstream at a distance of 92.5 km (Figure 1).

The dam can be accessed by asphalt road Bishkek-Osh turning at the village Shamaldy Say.

The purpose of the hydrosystem is

- Electric power generation;
- Water withdrawal to supply Big Namangan canal (BNC) and the left bank Uch-Kurgan canal.

Design of the dam was prepared by the Central Asian institute “Gidroproekt”, Tashkent. The hydrosystem was put into operation in 1960.

2.2 Description of the Dam

Uch-Kurgan hydropower station is a channel type structure with combined bed spillways at low level, and with high level water intake supplying water into the turbine outlets.

The major structures of the Uchkurgan hydro-system consist of (Figures 2 and 3):

- Hydropower station building
- Overflow dam
- Left bank embankment
- Head regulators of BNC and Uchkurgan canal

The hydropower station building is of the retaining type, which is combined with eight low-level sluices and located at the left bank of the river (Figures 4 and 5). The hydropower station building is situated on a conglomerate-pebble base with cut in deep anti-seepage profile. There are four hydropower units with a rated capacity 45 MW installed in the building of the hydropower station. Water is delivered to the units through pressure penstocks (two penstocks for each unit). The inlets of the sluices are located beneath the inlets of turbine penstocks.

An overflow dam (with one bay) is located at the right side of the hydropower station building and adjoins to the left bank adjacent wall (Figure 6). There is a baffle wall with littoral and separating walls located in the tailrace of the building and overflow dam. The total length of the building together with overflow dam and unloading platform is 100 m; the height is 56m.

The left bank embankment (Figure 7) is made of gravel-pebble bed fill with a density brought up to 2.2 - 2.25 t/m^3. A single layer and double layer of reinforced concrete facing which is brought up to the top of the conglomerate is installed at the upper slope from PK 0 to PK 15+80. A facing and fore apron made of sandy loam with gravel-pebble bed overload are installed at the upper slope of the remaining part of the embankment. Stone fill with fractions of diameter more than 150 mm is in place to protect the structure from wave's impact.

The right bank outlet of the BNC canal enters the body of the left bank adjacent wall. It is an open regulator with three openings 2 x 2 m in section. The left bank pipe outlet of Uchkurgan canal has two openings of section 2 x 2 m.

The hydromechanical equipment installed on the dam includes:

- At the spillway area of the dam: double-section vertical lift slide type maintenance gate (12 x 12 m) and double-section vertical lift slide type control gate (12 x 12 m);
- At the power section of the dam - low-level sluice gates: vertical lift slide type maintenance gates (8 x 5.5 m - 8 units) and vertical lift slide type control gates (5 x 5 m - 8 units);
- Gates of turbine water inlets: vertical lift slide type maintenance gates (8 x 10m - 8 units) and vertical lift slide type control gates (8 x 8m - 8 units).

The principal dimensions of the reservoir and the various components of the dam are given in Table 2.1.

2.3 Hazard Assessment

In many countries a formal classification system is used to define the risk a dam represents in terms of the potential for loss of life and/or damage to property which could result in the event of flooding caused by failure of the dam or an extensive release of water. The magnitude of the risk depends partly on the characteristics of the dam and reservoir and partly on the conditions downstream of the dam. Risk factors based on the procedure set out in ICOLD Bulletin 72 (Reference 1) are shown in Tables B1 and B2 in Appendix B.

Based on the tables in Appendix B, the total risk factor of 32 points (Table 2.2) puts the Uchkurgan dam in Risk Class IV, that is the highest risk category.

Table 2.2 Uchkurgan Dam – Risk Factor

		Points
Reservoir Capacity (Mm^3)	370	6
Dam Height (m)	21	2
Downstream Evacuation Requirements	>1000	12
Potential Damage Downstream	High	12
	TOTAL	32

Table 2.1 Uchkurgan Dam – Princial Dimensions

Reservoir main parameters		
1. Full capacity	Designed	56.4 Мм^3
	Actual	21.1 М м^3
2. Active capacity	Designed	16.4 Мм^3
	Actual	13.4 Мм^3
3. Dead storage capacity	Designed	40 Мм^3
	Actual	7.7 Мм^3
4. Full storage level	(FSL)	539.5 мasl
5. Maximum storage level	(MSL)	540.8 мasl
6. Dead storage level	(DSL)	536.5 мasl
7. Water surface with FSL	FSL	4 км^2
	(MSL)	4.4 км^2
8. Length of dam along the crest	Concrete	27 м
	Earth	2882м
9. Height of dam	Concrete	37 м
	Earth	30 м
10. Earth dam side slope	Upper	1:3
	Lower	1:2,5
11. Crest width		10 м
Maximum discharge capacity of structures during fresh flood at the level of 0.01% of available water supply		
12. All structures including:		4271м^3/s
- hydropower station spillways		760 м^3/s
- surface spillway		1000м^3/s
- bed spillways		2400м^3/s
- BFC water intake	with FSL	81м^3/s
	with DSL	27м^3/s
- Uchkurgan canal water intake	with FSL	30м^3/s
	with DSL	18 м^3/s

3 DESIGN CONSIDERATIONS

3.1 Hydrology

Uchkurgan hydrosystem is located on the lower reaches of the Naryn river. The river is fed by glaciers, melting snow and rainfall. The river basin area down to the hydrosystem gauge line is 58,200 km^2.

Designed reference gauge: Uchkurgan. Naryn River basin area in the gauging station section is F =58,400 km^2; there are no lateral inflows.

The river flow of many years period:

- Run-off norm - 429 m^3/s;
- Rate of run-off M = 7.35 l/s km^2 ;
- Depth of run-off - 232 mm.

Presently the run-off record is distorted by regulation provided by Toktogul, Kurpsay, Tashkumyr and Shamaldysay hydrosystems.

The fresh flood period is observed in April-August when there is up to 70% of annual run-off volume. The observed maximum discharge equal to 2,970 m^3/s occurred on 20 August 1966. The discharge at 0.1% of available water supply according to the project is 3,300 m^3/s. If the observed discharge is assumed as 1 % of available water supply, the discharge at 0.01% would be 4,385 m^3/s, and at 0.1% of available water supply - 3,570 m^3/s.

The discharge capacity of Uchkurgan hydrosystem is 3,300 m^3/s. The channel discharge capacity allows the release of 2,400 m^3/s. Summer monthly minimum water discharge was at the level of 190 m^3/s. Winter monthly minimum water discharge is 100 m^3/s. Standard observed minimum is - 0 m^3/s.

Sediments run-off in natural conditions is 250 kg/s, and annual suspended load run-off is 7.9 Mt. With volumetric weight equal to 1.3 t/m^3 the annual run-off is 6.07 Mm^3.

The volume of daily regulation of the reservoir was 30 Mm^3. At present the reservoir is silted to 70% of its volume. However, the construction of Toktogul reservoir and other hydrosystems reduced sharply the sediment load. The average annual amount of suspended load at this stage does not exceed 20 kg/s, which creates the suspended load in the amount 0.63 Mt or 0.485 Mm^3.

Due to the reduction of the regulating volume of the reservoir basin, a considerable proportion of the suspended load is presently transferred to the tailrace.

In emergency situations downstream from the Toktogul hydropower station the increase of the designed discharges amounts to:

- 0.01% of available water supply with guaranteed error - 675 m^3/s;
- 0.1% of available water supply - 470 m^3/s
- 1% of available water supply - 376 m^3/s.

3.2 Geology and Seismicity

The hydrosystem is located in flat and undulating land. The left bank of the valley descends smoothly to the river, the right bank is steep and cut with gullies and small rivers. The hydrosystem area is composed of four main types of strata: quaternary fine earth (melkozem) with thickness - from 0.3 to 2 m, pebble beds with a thickness up to 5 m, conglomerate/pebble thickness as deep as 30 m (underlying pebble beds within the limits of all hydrosystem structures) and lower deposited marlaceous clay.

The structure is located in seismic zone 9.

3.3 Construction Materials and Properties

Taking into account the fact that the earth dam and its foundations are built of gravel-pebble material of a high density, there seems to be no liquefaction risk.

3.4 Seepage Control Measures

In order to reduce seepage a cement grout curtain is installed in the foundation of the hydropower station located on conglomerate - pebble beds and in the base of the overflow dam.

A double layer (at the higher section of the dam) and single layer of reinforced concrete facing, brought up to the top of the conglomerate, was placed on the upstream face of the earth dam in order to avoid seepage. A facing and fore apron made of sandy loam (adding gravel-pebble material) were constructed on other sections of the dam.

3.5 Reservoir Draw-off Works

The schedule of operation of the reservoir is targeted to electric power generation and to maintenance of the water level required for water withdrawals into the BNC and Uchkurgan canals in accordance with the water consumption schedule. The volume of the reservoir daily regulation is approximately 30 Mm^3 with head range from 35.7 to 18.5 m (presently 70% of the reservoir volume is silted).

In accordance with the data of the exploitation office, the actual average annual run-off is 12.8 billion m^3, and actual average annual inflow - 13.5 billion m^3.

3.6 Performance Monitoring Instrumentation

Control and measuring instrumentation was installed for the purpose of monitoring seepage in the body and foundation of the dam, settlement and horizontal displacements in the dam and in the hydropower station building, temperature schedule and fixtures stress, head water and tail race levels:

- Piezometric network (deep drainage wells, pressure and free piezometers, piezo-dynamometers) - 135 pieces (81 units are operating);
- Instrumentation to control settlement and horizontal displacement: reference points, elevation marks, triangulation points, control points, spatial slot measuring tools, traversing points, earth dam marks) - 185 units (127 units are operational);
- Instrumentation to control fixtures stress - fixtures dynamometers - 24 pieces (13 operational);
- Instruments to control temperature schedule - thermoresistance thermometers - 29 pieces. (1 operational);
- Instrumentation to control head and tail race levels (water level gauges) - 7 pieces. (2 operational)

3.7 Hydropower Facilities

Uchkurgan hydropower station has a substantial power capability. The key function of the hydropower station is to generate electric power for consumers within the republic.

The power station consists of 4 units with a rated capacity of 45 MW. There are 3 hydraulic turbines (type ПЛ-577-БВГ) and one experimental hydraulic turbine (type ПЛ-707 ВБ-500) immediately connected with hydraulic generators (type СВ-840/150 –52). The main circuit diagram of the station is arranged on the basis of enlarged blocks. Two units are connected to one step-up double-winding transformer. The generated electric power is transmitted to the energy system of the Kyrgyz Republic by three high voltage lines (110 kW).

4 DAM CONDITION AND PERFORMANCE

4.1 Comments Arising out of Inspection

The IC, in company with representatives from the Kyrgyz National Team and Engineers from the site visited the dam on 5 October 1999. Areas inspected included the whole of the embankment and the draw-off works. The reservoir water level at the time was about 539 masl.

During the inspection it was found that:

- The reservoir basin is silted to 70% of its volume.
- The whole set of hydromechanical and electrotechnical equipment is generally in a satisfactory condition.
- The maintenance personnel are concerned with failures of the electrical equipment (power cables, switch gear, etc.) and the turbines regulating equipment. It is necessary to replace cables, repair switch gear and carry out major repairs or replace the hydraulic turbines automatic regulating equipment.
- Specialists of the maintenance department reported that three low level sluice outlets are blocked by sediments that make it impossible to lift the maintenance gates. This is a serious situation and requires urgent action to release the gates.

4.2 Assessment of Performance Monitoring Results

Monitoring of the instruments at Uchkurgan dam is carried out annually by the personnel of the laboratory of full-scale research of Toktogul hydropower station cascade, in accordance with full-scale measuring rules elaborated on Toktogul hydropower station.

During the visit to Uchkurgan hydropower station the experts studied the materials of annually prepared reports on full-scale research carried out on the reservoir. In this connection there are the following conclusions:

- Joint opening does not exceed 1-2 mm;
- Back pressure on the basement of the building of the hydropower station is absent;
- Ground water level increase is observed
- Increase of average annual seepage discharge is occurring
  (1995 -35 l/s, 1997 -10 l/s, 1998 -15 l/s) ;

The last round of geodetic study of settlement and displacements of the structures of Uchkurgan hydropower station was conducted in 1995 and revealed the following:

- Settlement of marks installed in the foundation of the hydropower station building was 1-2mm,
- The total settlement of the dam marks does not exceed 31 mm: up to 9 mm rise is observed on many marks on the left bank side; settling on the right side is 12 mm;
- In comparison with 1992, in 1995 the dam left bank side displacement toward the head race increased by 5.47 – 7.54 mm;

For the purpose of ensuring control of the performance of the hydraulic structures and on the request of the exploitation office it is necessary to carry out the following measures:

- To conduct inspection of all control and measuring equipment;
- To install geodesic marks - 18 pieces.
- To install slot measuring tools;
- To complete extension of piezometric and drainage network - 102 pieces
- To automate the process of measuring of piezometric pressures in the foundation of the building of the hydropower station and seepage discharge - 40 pieces.

4.3 Dam Safety Incidents

In 1995 there was an intensive earthquake (7 points on the Richter scale) 12 km from Uchkurgan city. During subsequent inspection of the dam no negative developments were observed by the experts. Only some cracks appeared in the building of the hydropower station. It means that the building built of reinforced concrete is earthquakeproof and stable. There were other numerous minor earthquakes, which caused no damage to the concrete dam.

It was reported that in 1997 the water level in the reservoir was allowed to rise to 541 masl, that is the same level as the crest of the embankment, because of problems in opening gates at the power station. The reservoir stayed at this level for a period of about half an hour. No damage was incurred.

4.4 Maintenance Procedures and Standards

Standard instructions on exploitation of Uchkurgan hydropower station are elaborated on the basis of “Standard instructions on exploitation of hydraulic structures of the dam hydropower stations”, Moscow 1979. “Soyuztechenergo”. The instructions are revised once in three years by the directorate of Uchkurgan hydropower station and approved by the chief engineer of the head office of Toktogul hydropower stations cascade.

4.5 Existing Early Warning & Emergency Procedures

A system of early warning for the population of the neighbouring regions in case of an emergency situation is in place but it does not meet international standards and rules.

In case of an emergency (accident) there is a loudspeaker communication, automatically controlled telephone communication with commutator, as well as external communication lines used to inform the population living downstream from the reservoir about the emergency situation in the region.

5 SAFETY ASSESSMENT

5.1 General

The safety assessment is based on the following general criteria:

(1) Structural safety
The dam, along with its foundations and abutments, shall have adequate stability to withstand extreme loads as well as normal design loads.

(2) Safety against floods
The reservoir level shall not rise above the critical level (maximum flood level) for the largest possible flood. Gate mechanism and power units must remain fully operational and accessible at all times.

The dam should have adequate facility for rapid lowering of the reservoir level in case of emergency.

(3) Safety against earthquakes
The dam shall be capable of withstanding ground movements associated with the maximum design earthquake (MDE) without release of the reservoir. The selection of the appropriate value of MDE is based on an assessment of the consequences of dam failure (Section 2.3).

(4) Surveillance
Arrangements for inspection, surveillance and performance monitoring of the dam should ensure that a danger arising from damage, defect in structural safety or an external threat to safety is recognized as soon as possible, so that all necessary measures can be taken to control the danger.

Adequate emergency planning, early warning and communications facilities shall be in place to ensure the safety of the downstream population in case of emergency.

The material made available for study in respect of the Urchkurgan dam has been very limited and no inspection reports were seen, but the following conclusions are drawn regarding its safety.

5.2 Structural Safety

The dam is a simple structure and not particularly high, comprising a concrete section incorporating the powerhouse, intakes, spillway and canal intakes in the original river bed, with a long (approx. 3 km) embankment section along the left side river bank. Design documents and drawings were inspected briefly by the IC, but there was no opportunity for a detailed study or to make copies of drawings. However, the structures are of robust construction, embankment slopes are conventional and there were no obvious signs of structural deterioration such as might prejudice safety.

Internal water levels in the embankment are not known (piezometers not functioning since 1992 or earlier) but with a watertight upstream face the embankment should be fully drained, which is a safe condition. Drainage flows are not measured.

It is reported that the last full inspection was carried out by Gidroproekt, Tashkent, in 1988, but no report was available for inspection. The dam is said to be inspected annually by Kyrgyz Energo but, again, no reports were available for examination on the site.

The drawings show about a 1 km length of the embankment as being constructed to a crest level that is 1 m below that of the rest of the dam (possibly originally to provide an overspill section), and this lower crest level is clearly apparent on site. The embankment is therefore highly vulnerable to overtopping, and the land below the embankment has now been fully developed. It was reported on the site visit that, on one occasion two years ago, the water level rose to the same level as the crest for a period of about half an hour after one or more of the sluice gates failed to open.

5.3 Safety against Floods

5.3.1 Introduction

Uchkurgan outlet structures were designed using 1% and checked against 0.1% annual exceedance probability (AEP) hydrograph. A cascade of four dams have been constructed upstream of Uchkurgan, with Toktogul being the largest. Toktogul dam has been designed using 0.1% and checked against 0.01% AEP hydrograph. Discharges from Toktogul dam combine with the streamflows from Left Karasu and Right Karasu. Toktogul discharges with 0.01% AEP (various combinations of outlet structures) were combined with 0.01% AEP discharges from the local catchment (between Toktogul and Uchkurgan) for the current assessment of the dam safety during extreme floods. As Uchkurgan flood storage is negligible when compared to the volume of the design flood hydrographs, no routing was necessary and the capacity of the outlet structures was assessed by comparing the peak inflow to the maximum capacity of the outlet structures. The 0.01% AEP peak values are given in Table 5.1.

Table 5.1 Uchkurgan 0.01% AEP peak discharge values (m^3/s)

Toktogul outlet scenario	Qtokt	Lateral inflow	Inflow to Uchkurgan
Qbottom+Qsurface+Qturbines	4140	675	4815
Qbottom+Qsurface	3520	675	4195
Qbottom+0.5*Qsurface Note: Max. Tok. Res. Level=904.3 m	3100	675	3775

The maximum capacity of the outlet structures is 4,260 m^3/s of which:
- Gated surface spillway, Qmax=1,000 m^3/s
- 8 bottom outlets with a combined Qmax=2,400 m^3/s
- Left and right irrigation offtakes, Qmax=110 m^3/s
- 4 turbines with a combined capacity of 760 m^3/s

5.3.2 Discussion on the exceedance probability of design hydrographs

The aim of this section is to discuss the conservatism involved during derivation of design hydrographs in accordance with SNIP and how do these hydrographs compare with PMF.

The design hydrographs are determined through a statistical analysis of historical records. A theoretical curve, based on a 3-parameter gamma distribution, is fitted to maximum annual peak discharge values and design peak discharges for various exceedance probabilities are determined. The 0.01% discharge value is subject to a correction, which is approximately 20% higher than the original value. The correction itself brings the exceedance probability of the obtained value to 0.005% or 1 in 20,000 years.

The volume of the hydrograph is also defined through frequency analysis of annual maxima. The coincidence of all historical peaks and maximum flood volumes would result in the two variables (peak discharge and flood volume) to be totally dependent, with the exceedance probability of the combined hydrograph equal to the exceedance probability of the peak discharge value. However, the historical peak discharge values do not necessarily coincide with the maximum volumes. In other words these two variables are partially dependent, resulting in a hydrograph with exceedance probability lower than the exceedance probability of the peak discharge.

During the practical fitting of the theoretical frequency curve, a coefficient of asymmetry Cs is calculated from the recorded series of annual maxima. This coefficient is then used to fit an appropriate curve. Higher the coefficient, more skewed is the theoretical curve, resulting in higher discharge values for low probabilities of exceedance. In practice, the obtained value of Cs was not used, but Cs equal to k*Cv was often adopted. The k value obtained from longer records of similar rivers was adopted instead. The adopted value usually exceeded the calculated value of Cs resulting in higher design peak discharges for lower probabilities of exceedance. This practice introduced an additional conservatism into the derivation of the design discharge values, which results in the overestimation of the design discharge value. For example change form Cs=3Cv to Cs=4Cv results in higher discharge or volume values of 10 to 15%.

The above three factors result in the design discharge hydrograph with exceedance probability significantly lower than 0.01% (1 in 10,000 years). It is expected that the resulting exceedance probability of the design hydrograph would be in the range of 0.001% or 1 in 100,000 years. Further investigations into this matter are required to support this statement. If the results confirm the above statement it can be concluded that the conservatism introduced during the design calculations results in the outlet structures of the dams to have been designed for a 1 in 100,000 years events instead of 1 in 10,000 years events, which in general approaches the range of a PMF event.

The local Bureau of Meteorology provides a forecast of expected streamflows at the beginning of the wet season (early spring). The forecast is based on the snow deposits in the catchments of particular rivers. Based on the forecast, the central authority, which regulates the dam operation, issues a request for the initial level in the reservoir prior to the beginning of the melting season. In the cases of wet years the requested initial level can be lower than the FSL. This mechanism introduces an additional storage available for flood routing, increasing the dam safety during extreme floods.

5.3.3 Factors which reduce the dam safety during floods

There are several factors that affect the performance of the Uchkurgan dam during large flood events. These are related to:

- Uncertainty in definition of extreme flood hydrographs based on statistical analysis of relatively short historical records of annual peaks and volumes.
- Existence of three dams other than Toktogul upstream of Uchkurgan. All these dams have a storage larger than Uchkurgan's storage and if there is a dam failure upstream it would result in Uchkurgan dam failure.
- Inadequate capacity of the outlet structures. The maximum possible inflow, assuming that 0.01% AEP flood is representative of PMF, exceeds the maximum outlet capacity by approximately 600 m^3/s. If turbines are not operational then the maximum outlet capacity is 3,500 m^3/s, which is approximately 1,300 m^3/s less than the maximum possible inflow. If Toktogul releases the minimum possible discharge of 3,100 m^3/s (remaining at or below the maximum reservoir level), then the total inflow is expected to be 3,775 m^3/s or 275 m^3/s more than the maximum outlet capacity. The releases from Toktogul affect the peak discharge values along the entire cascade. It is unknown at this stage what are the maximum outlet capacities of the dams between Toktogul and Uchkurgan, however, the operating manual for Toktogul states that the maximum release should not exceed 3,300 m^3/s due to the limited outlet capacities of the downstream dams. In this case the Uchkurgan outlet capacity has to be increased by 475 m^3/s.

5.3.4 The consequences of reservoir siltation

Nearly the entire reservoir is now filled with sediments and this has important repercussions on the operating regime for the reservoir and the safety of the dam against floods. Firstly, the filling of the reservoir with sediments removes the buffer storage that is important in providing a safeguard against sudden operating surges in the river flow; secondly, the sediment deposits in front of the power station are reported to be interfering with the safe operation of the sluice gates. Reports received subsequent to the site visit indicate that at least three of the sluice gates, and possibly more are actually blocked, and the sluice gates can not be opened. This is a serious situation and requires urgent action to release the gates.

5.3.5 Conclusions and recommendations

It can be concluded in general that:

- The design discharge hydrograph has a relatively low AEP, which approaches the range of a PMF event. The capacity of the outlet facilities is not sufficient to pass an extreme flood without using the turbines.
- A PMF must be determined for the entire cascade on Syrdarya, taking into account all dams. The adequacy of the capacities of the existing structures should be assessed and enlarged where necessary to provide a safe passage of the PMF along the cascade.
- The sediment regime in the reservoir, particularly in front of the power station, is a serious cause for concern and needs to be investigated further.

5.4 Provision for Emergency Draw-down

Draw-down of the reservoir in case of emergency could be achieved by the use of the spillway gates and low level sluices (total capacity about 2,400 m^3/s at normal reservoir level), without the use of the turbines, though releases in excess of about 1,200 m^3/s are said to cause flooding downstream.

Should such an emergency release of water be approved, however, the risk to the downstream population could be substantially mitigated if an effective emergency plan could be put into operation rapidly. The IC understand that an alarm siren is located in the dam, though whether the downstream population or civil defence authorities know what action to take on hearing the alarm should be clarified.

5.5 Safety against Earthquakes

5.5.1 Seismic design criteria

In the original design seismic input parameters and stability analysis in seismic condition are assumed to have been carried out in accordance with procedure given in the Russian Seismic Standards (Reference 2). According to the Russian Seismic Standard, a seismic design coefficient (k_g) is derived for a site based on MSK earthquake intensity scale. The coefficients are derived based on 1:500 year earthquake. The required minimum factor of safety in seismic condition is always greater than unity.

However, the current practice based on the guidelines given in ICOLD Bulletin 72 (Reference 1) is to assess dam safety against two representative design earthquakes that are as follows:

OBE - Operating Basis Earthquake
MDE - Maximum Design Earthquake

Where:

- OBE, or “no damage earthquake” is the earthquake which is liable to occur on average not more than once during the expected life of the structure (of not less than 100 years). During an OBE, the dam and its ancillary works should remain functional but may need repair. The required minimum factor of safety for the OBE earthquake should be greater than unity.

- MDE or “no failure earthquake” is the earthquake that will produce the most severe level of ground motion under which the safety of the dam against catastrophic failure should be ensured. For dams which are classified to be Risk Class IV a recommended return period of MDE is 30,000 years (Reference 3). For this earthquake displacements of the crest are assessed and compared with the allowable wave freeboard

The dam safety has not been assessed for OBE and MDE earthquakes and it is recommended to carry out additional engineering studies (see Section 6.2.4) to evaluate dam performance in those conditions.

As a part of safety assessment a check should be carried out to evaluate the height of seismic waves (seismic seiche) of the reservoir which may occur during a seismic event and which requires the additional height to be added to the standard “static” freeboard.

5.5.2 Dam Structures

The IC have not had opportunity to review the seismic design of the dam, but the general appearances of the structure does not give cause for concern. The concrete faced embankment should be fully drained, and is believed to be constructed of a compacted gravel material which is not expected to be susceptible to liquefaction or loss of strength on seismic shaking.

5.5.3 Ancillary Works

It is possible that the tall, massive, crane gantries would be more vulnerable to damage by an earthquake than the main dam structures. Any damage which impaired the function of the cranes would have important dam safety implications, and an assessment should be made of the likely impact of an earthquake on such items.

5.6 Other Safety Matters

A number of other matters will need further examination as part of more comprehensive safety assessment than has been possible during the present study, for instance:

5.6.1 Safety of access

The dam can be accessed from both sides of the river and the chances that extreme events (e.g. floods, earthquake) would completely sever both are remote, unless the roads are cut due to washouts, collapsed culverts etc.

5.6.2 Security of electricity supply

It is unlikely that 100% security of electricity supply can be assured in all circumstances, and a standby generator to operate the crane gantry in emergency is recommended.

5.7 Safety Assessment - Summary

5.7.1 Principal matters of concern

The IC considers the following to be the principal matters of concern:

1) The safety of the dam, in the absence of a surface spillway, depends wholly on the reliable operation of the draw-off works. The hydromechanical equipment appears to be in working order at present. It is ageing, however, and repairs and a high standard of maintenance are necessary if it is to remain in 100% reliable condition.

2) The sediment regime in the reservoir, in so far as this is interfering with the safe operation of the gated outlets, is a matter of considerable concern, particularly in view of some uncertainty concerning the adequacy of the capacity of the outlets to pass floods.

3) The reduced crest level (by 1.0m) of the main part of the long left embankment make this section of the embankment particularly vulnerable to overtopping by floods.

4) Deficiencies in the instrumentation systems mean that it is not possible to monitor the performance of the embankment adequately.

5) Absence of a coherent emergency plan and early warning system in case of emergency from natural causes (e.g. extreme floods), human error, equipment or structural malfunction or unauthorised actions. Guidance is needed to assist the supervision staff in recognising when a dangerous situation is developing.

5.7.2 Safety Statement

From examination of the dam and such data as was available on the site, and a brief discussion with the site manager, the IC conclude that structurally the Urchkurgan dam is in a satisfactory condition. Continued vigilance and a high level of maintenance of all components, in particular the hydromechanical equipment, is, however, essential if the dam is to remain safe.

The dam is particularly exposed to danger from floods in that siltation of the reservoir has resulted in the available flood storage being drastically reduced. A rapid change in the flow through the turbines and/or spillway must be achieved in response to unexpected changes in river flows if large fluctuations in the reservoir level (or in the extreme, overtopping of the dam) are to be avoided. Furthermore, sediment deposits are reported to be interfering with gate operation which could have serious repercussions if it were found to be not possible to open the gates in response to a major flood inflow.

Overtopping of the embankment, if it should lead to a breach, would flood large and important industrial and residential areas, for which at present there appears to be no coherent emergency plan or warning system.

6 RECOMMENDED STUDIES, WORKS AND SUPPLIES

6.1 General

The review of the design of the dam, information obtained during the site inspections, and discussions with the site manager has enabled the IC to arrive at certain conclusions regarding the safety of the dam, which are discussed in Section 5. These conclusions, along with considerations of requirements for emergency management have provided the basis for an assessment of the need for additional studies, investigations, construction works and supplies necessary to bring it to an acceptable and sustainable standard of safety. However, it must be recognized that the need for further work might still become evident as an outcome of this work, as the preliminary conclusions are refined.

A more detailed specification and methodology for the work described in this Section is presented in the accompanying report `Methodology for Detailed Design of Priority Rehabilitation Measures'.

6.2 Additional Surveys, Investigations, Inspections and Studies

6.2.1 General

To provide the basic data for designing the works described below and for refining the conclusions of the safety assessment, additional information is required which is outside the scope of the present study. This work is described under the following headings:

- surveys
- ground investigations and inspections
- engineering studies

In addition, it is recommended that a dossier of 'as constructed' record drawings and other essential information relating to the design, construction and performance of the dam be assembled, and regularly updated.

Where original drawings have deteriorated they should be retraced or preferably re-drawn using a computer system. The dossier would comprise the basic source of information to be referred to when carrying out inspections or undertaking modifications in the future.

6.2.2 Surveys

(1) Topographic Surveys

The following ground surveys are recommended:

- embankment longitudinal crest profile;
- typical cross sections of the embankment to verify the `as-constructed' profile;

(2) Reservoir Bed Survey

To provide firm data for an updated review of reservoir sedimentation and its effect on reservoir management it is recommended that a new reservoir bed (bathymetric) survey be carried out at an early date.

6.2.3 Ground Investigations, Inspections and Studies

The following investigations and inspections are recommended:

(1) Reinstatement of the embankment piezometers will involve a considerable amount of drilling in the embankment. It is recommended that during the course of this work in-situ testing should be carried out to verify the properties of the embankment and foundation material, and samples taken for laboratory testing.

(2) Inspections

To provide information on which to base a full assessment of required repairs and equipment, it is recommended that a detailed inspection should be carried out and an inventory of defects, materials and repairs required prepared, covering:

- repairs to embankment upstream concrete face (inspect when reservoir is at a low level);
- improvements to embankment drainage (inspect for seepages when reservoir is at high level);
- repairs to embankment downstream face protection and surface water drainage works;
- electrical wiring etc., and lighting;
- gates and operating equipment;
- steelwork (e.g. stairways and landings);

6.2.4 Engineering Studies

1) Review the estimates of extreme flood inflows to the reservoir, taking into account the effect of possible actions (intentional or unauthorised) at upstream dams;

2) Review reservoir management procedures giving first priority to ensuring the safety of the dam.

3) Investigate, possibly by model studies, the sediment regime in the reservoir, particularly in the area in front of the power station and sluice outlets.

4) Study design and cost of raising left flank embankment to reduce risk of overtopping in the event of a severe flood.

6.3 Construction Works

A preliminary assessment of the required construction works is made on the basis of the safety assessment and available data. Final details will depend on the outcome of the studies described above.

1) Embankment - instrumentation

Although the embankment appears to be generally in good condition it is essential that its performance is properly monitored. The performance monitoring installation should be reinstated where necessary. The following is proposed:

- install new standpipe piezometers where the existing tubes are blocked;
- install surface settlement measurement markers and fixed beacons, for precise measurement of vertical displacements.

2) Embankment - crest level

Raise crest level of all or part of the left flank embankment.

3) Sediments

It is necessary to reinstate reservoir storage capacity and clean the blocked sluice gates.

4) Hydromechanical and Electromechanical Equipment

The safety of the dam relies wholly on the proper operation of the electromechanical equipment. Any necessary repairs and renewals should be undertaken immediately, and adequate standby electricity generating plant provided.

5) Miscellaneous

Other matters requiring attention would be discovered during the detailed inspections described above and should be rectified.

6.4 Equipment and Supplies

A preliminary assessment of supplies needed, based on the Consultants' inspection and discussions with site managers, is as follows:

(1) Piezometers

(2) Surface settlement markers and measuring equipment.

(3) Provide equipment (water jets, dredge pumps, etc.) to release gates obstructed by sediments.

(4) Provide standby generator and associated housing and wiring.

(5) Provide early warning and communications equipment.

6.5 Emergency Planning Studies

Given the potentially damaging consequences of an emergency which results in the release of a large volume of stored water, it is essential that plans for dealing with such a situation are well prepared, and supported by an efficient organization, communications and alarm system. Inundation and flood hazard maps showing dambreak wave arrival time and duration of inundation should be prepared, based on dambreak modelling and simulation of dambreak wave propagation in the downstream areas. Flood damage estimates and potential loss of life should be developed on the basis of the above results.

A detailed emergency plan and instruction document should be prepared setting out the procedures to be followed, and the responsibilities of the site managers, regional engineers and civil authorities.

6.6 Safety Measures - Priorities

The safety measures identified above are listed in Table 6.1 and assigned to one of three priority levels (I, II, III).

The proposed Priority levels are:

I - high priority; work to be carried out immediately
II - intermediate; work to be carried out within three years
III - low priority; the need to be kept under review.

Table 6.1 Uchkurgan Dam - Dam Safety
Priorities for Studies, Works and Supplies

Item	Studies etc	Construction Works and Supplies		
		Priority I	Priority II	Priority III
1. Surveys (6.2.2)	☐			
2. Investigations and Inspections (6.2.3)	☐			
3. Engineering Studies (6.2.4)	☐			
4. Construction Works (6.3)				
• Instrumentation		☐		
• Raise Embankment Crest Level			☐	
• Reinstate reservoir storage capacity and clean blocked sluices		☐		
• Hydromechanical Equipment		☐		
• Power supply			☐	
• Miscellaneous Repairs			☐	
5. Supplies (6.4)				
• Piezometers and deformation monitoring equipment		☐		
• Dredge pumps, etc. to release gates trapped by sediments		☐		
• Standby Generator(s)		☐		
• Early warning and communications equipment		☐		
6. Emergency Planning Studies (6.5)	☐			

7 CONCLUSIONS

On the basis of the information received and brief inspection of the dam the IC conclude that structurally, the Uchkurgan dam is in a generally satisfactory state. However, the dam appears to be at risk from floods since flood routing through the Naryn dams indicate that the Uchkurgan flood outlets are of inadequate size, and sediment deposition in the reservoir appears to be obstructing the outlet gates. The long left embankment, which has a crest level one metre below that of the rest of the dam, is particular5ly vulnerable to overtopping. The reservoir may continue to be impounded to the normal full storage level of 538.50 masl but a continuing high level of operational efficiency is required, particularly in respect of the gates and operating equipment. Reservoir management procedures should give priority to dam safety.

High priority should be given to the following activities:

- Reinstating the embankment piezometers and settlement monitoring systems;
- Removing sediments from the immediate vicinity of the sluice gates and clean blocked sluices;
- Inspecting and carrying out such repairs as may be necessary on the hydromechanical plant, electric wiring and lighting, and crane gantry and providing a standby generator;
- Instituting a programme of formal inspections and reporting on the safety of the dam;
- Preparing a comprehensive emergency plan.

Consideration should be given to increasing the crest/parapet level of the left flank embankment to reduce the risk of overtopping by unexpected floods.

APPENDIX A

LIST OF DATA EXAMINED

APPENDIX B

HAZARD ASSESSMENT PROCEDURE

UCHKURGAN DAM
APPENDIX B – HAZARD ASSESSMENT

Table B1 Classification Factors

	Classification Factor			
Capacity (10^6m^3)	>120 (6)	120-1 (4)	1-0.1 (2)	<0.1 (0)
Height (m)	>45 (6)	45-30 (4)	30-15 (2)	<15 (0)
Evacuation requirements (No of persons)	>1000 (12)	1000-100 (8)	100-1 (4)	None (0)
Potential downstream Damage	High (12)	Moderate (8)	Low (4)	None (0)

Table B2 Dam Category

Total Classification factor	**Dam Category**
(0-6)	I
(7-18)	II
(19-30)	III
(31-36)	IV

Ref: ICOLD Bulletin 72, (Reference 2)

APPENDIX C

UCHKURGAN DAM INSTRUMENTATION

REPORT BY SPECIALIST MR V. N. PULYAVIN

October 1999

Inspection of instrumentation condition and dam structures observations
Uchkurgan water reservoir

It should be carried out the observations for the dam seepage regime at head wall and through foundation of the power house and abutments, of settlement and offset of the power station house and of the dam, also of condition of the structure and temperature regime at the process of Uchkurgan dam safety control.
Number of instrumentation, either it was provided by design or for actual situation is given below in the table.

Observations	Instrumentation	Designed number of the instrumentation	Constructed number of the instrumen-tation	Actual number of the instrumentation
Seepage regime observations	Drainage wells head piezometer pressure free piezometer piezodynamometer	63 27 47 15	58 17 47 13	39 13 16 13
Settlement and horizontal offset observation	bench marks reference marks triangulation station control section points slotmeters polygonometry stations benchmarks at the earth dam	4 81 4 5 17 6 46	4 81 4 5 3 6 46	4 74 4 5 3 6 31
tensile reiforcement observations	Reinforcement dynamometers	24	24	13
temperature regime observations	Bolometers	29	29	1

As it is on opinion of chief of hydraulic structures service of Joint-Stock company "Kirgizenergo" Mr.Zirianov, to perform control of Uch-kurgan power house hydraulic structures safety at a required level it is necessary to establish additionally:

- geodetic marks - 18
- triangulation station-3
- slotmeters- 14
- piezometers and drainage wells - 102
- remote instrumentation - 40

Acquaintance with the reports on full-scale observations executed in 1995 and 1998 showed, that the following items of information in the reports are presented:

- joints disclosure in three measuring points;
- water levels in drainage wells in the footing of the power station house;
- uplift to footing of the power station house and seepage discharge;

It is shown in the report for 1998 :

- the joints disclosing does not exceed 1-2mm;
- uplift to footing of the power station house is absent;
- ground water level arising is observed (presumably owing to scour of silted reservoir bottom caused by clarification after putting Toctogul reservoir into operation,) without connection with upstream and downstream level of water
- there is an increase of the seepage discharge (1995 -3.5 l /sec, 1997 -10 l/sec, 1998 – 15.15 l/sec);
- for observations for seepage regime at the footing of power station house it was used 11 piezometers and 38 drainage wells. The observation for offset and seepage regime of the earth dam was not conducted because of piezometers failure.

Last cycle of geodetic survey of settlement and of Uchkurgan power station structures offset was executed in 1995 and it showed following:

- the settlement of the marks established in the footing of the power station house was 1-2 mm
- the grand total value of marks settlement was not exceeded 31 mm, it was observed their rising (9 mm) for many of them at the left bank , and the settlement of the right bank is 1-2 mm
- in comparison with 1992г. in 1995г the increase of offset (5.47-7.54мм) of the left side bank of the dam in the upstream direction was marked;

RELATIVELY TO A BEGINNING OF OBSERVATION, AS THE DATA GIVEN IN THE REPORT TESTIFY, THE CREST OF THE DAM WAS OFFSET IN THE DOWNSTREAM DIRECTION FOR 17-23MM.

At inspection of the dam the geodetic marks on upstream slope and concrete kerb were found. There is no reliance that settlement of the concrete kerb corresponds to the dam settlement value. Where are the triangulation station , used for measurement of horizontal offsets?

Thus, being based on the submitted materials, it is possible to conclude, that the instrumentation, available at Uchkurgan power station house allow in the certain degree to observe seepage regime at the power station house footing , a settlement and an offset of the building and the dam. At the same time it is necessary to note, first of all, absence of the dam seepage regime observation, that testifies about carrying out unsatisfactory safety control over the structures

For implementation of full-scale observation for a condition of the hydroelectric station structures at necessary level and maintenance of the control them safety, it is necessary to fulfil:

1. Revision and technical servicing of instrumentation
2. Establishment of the geodetic marks - 22
3. Slotmeters installation - 14
4. Piezometers establishment in the building of the hydroelectric station - 14
5. Construction of drainage wells – 24
6. Installation of piezometers at the embankment - 31

DRAWINGS