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IRRIGATION AND DRAINAGE IMPROVEMENT PROJECT 2 (IDIP-2) MISSION FOR EVALUATION OF DAM SAFETY

KAZAKHSTAN

(January 28th to February 6th, 2007)

1. INTRODUCTION

This note describes observations that were collected during the mission carried out in Kazakhstan by F. Pelli from January 28th to February 6th, 2007. Scope of the mission was to inspect dams related to the irrigation schemes currently being assessed for the IDIP-2 Project, and to provide a first level evaluation on dam safety. Scope of the mission was also to estimate, wherever needed, the costs required to fulfil satisfactory safety criteria based on international standards. In addition some of the headworks closest to the dam sites could also be inspected.

The following dams were selected for inspection, based on information obtained at the Design Institute in Shimkent:

- Bugun dams - Arys-Turkestan irrigation scheme
- Tasotkel dam – GMC irrigation scheme
- Bartogai dam – Big Almaty Canal irrigation scheme
- Kapchagay dam – Akdalà irrigation scheme

Kapchagay dam, however, could not be inspected as the permits required for security reasons could not be obtained in time during the mission. Please note that the discussion and figures presented in this report refer exclusively to the dams that could be inspected, and therefore Kapchagay dam is not included. The main characteristics of the inspected dams are summarized in Table 1.

TABLE 1: MAIN CHARACTERISTICS OF INSPECTED DAMS

Dam	Reservoir volume(1) [Mm^3]	Dam height [m]	Construction	Dam Type	Catchment area [km^2]	ICOLD risk category
Bugun Karazhantak	370	21.5 10.5	1954-1962	earthfill- homogeneous	NA(4)	III-IV
Tasotkel	620 (250) (2)	32.0	1968-1974	earthfill- homogeneous with upstream blanket	4,300	IV
Bartogai	320 (230) (3)	60.0	1983	earth-rockfill with impervious core	NA(4)	IV

Notes: (1) Total volume including dead volume.
(2) Reduced reservoir volume which is currently allowed.
(3) Reduced reservoir volume proposed by Designer.
(4) Not Available.

Note that Bugun dam and the diversion weir on the Arys river (upstream of Bugun dam) were visited a first time by other engineers during the IDIP-2 preparation mission in October 2006, whereas no previous inspections to Karazhantak, Tasotkel and Bartogai dams are reported.

During the mission the following key officials and engineers were met:

Bugun and Karazhantak dams

- Akhmedzhan Madaliyev – "YugVodKhoz" (Water Management Enterprise) - Operation Department Head.
- Bekborda Zhumabay – Head of Arys Turkestan Canal and Bugun reservoir Administrator.

Tasotkel dam

- Baglan Karasholakov – Shu Rayon Akim (Governor) – Local Council.
- Daulet Assanbekov – Natural Resources Management and Protection Department under the Jurisdiction of Zhambyl Oblast Akim (Local Council) - Deputy Director.
- Nurakhan Ibraimov – "Tasotkel Reservoir" CSE (Communal State Enterprise) – in charge of Water distribution.
- Adilkhan Omarov – Tasotkel Reservoir Operation Administration - Shu Branch Director.

Bartogai dam

- Taufik Bashirov – Bartogay Reservoir sub-divisions (7 sub-divisions) Head.
- Abderim Abdurssulov – "Bartogay Reservoir and Big Almaty Canal named after D. Kunayev Operation Administration" CSE Komunal'noye Gosudarstvennoye Predpriyatiye-KGP (Communal State Enterprise) Deputy Director – Operation Manager (Head Engineer)

KazGyprovodKhoz JSC in Almaty

- Maydan Murtazin - Technical Manager
- Yuriy Shalom - Project Senior Engineer
- Vladimir Gorbachev - Project Senior Engineer

It should be emphasized that during the mission only limited information on dam design could be obtained, and therefore some of the aspects presented in the following are affected by significant uncertainty. In spite of this uncertainty, however, key issues relevant for the safety of the inspected dams could be identified.

In Section 2 the main conclusions and recommendations are summarized, and the estimated costs of the maintenance/upgrading works recommended to improve the current level of dam safety are presented. Sections 3, 4 and 5 describe Bugun dam, Tasotkel dam and Bartogai dam, respectively, and present currently available information on the state of each dam.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Main safety issues

The most relevant safety issues which were identified for each dam are the following:

- Bugun main dam and Karazhantak saddle dam:

1) The gates and the actuators of the main dam outlet works need be replaced.
2) No emergency spillway is available.
3) The toe drain system of the main dam is obstructed due to silting and does not work properly.
4) Nearly no piezometers are available to monitor seepage through the embankments and through the dam foundations.
5) The dams appear vulnerable to wave action and subject to wave overtopping, and both upstream facing and downstream slopes are affected.
6) The gates of the Arys river diversion weir, upstream of the Bugun reservoir, need maintenance and repair. The gates immediately downstream of the dam also need repair.

- Tasotkel dam:

1) The gates and the actuators of the dam outlet works need be refurbished or replaced.
2) No emergency spillway is available.
3) The dam is affected by abnormal seepage conditions around the outlet works which led to an incident several years ago, and since then the allowed reservoir level was lowered considerably.
4) The upstream dam facing needs repair.
5) The dam is said to require upgrade in order to provide sufficient seismic stability according to the Kazakh code.

- Bartogai dam:

1) Based on some information on dam design that could be collected during the mission, it appears that the minimum allowed freeboard need be increased. If this is the case the elevation of the reservoir water surface shall be reduced, and modification of the spillway inlet will be required.
2) The dam abutments are affected by relevant seepage with considerable water infiltration into the diversion and bottom outlet tunnels.

In addition the following issues shall also be investigated for all dams:

1) Seismic stability according to international standards.
2) Ability of all dams to pass the probable maximum flood or the 1/10,000 years flood.
3) Safety procedures and emergency plans.

2.2 Recommended works

The works considered to be required for each dam are summarized in Table 2. The works are subdivided between 1st stage and 2nd stage, where:

- 1st stage activities include maintenance and works relevant to dam safety to be carried out immediately as well as site investigation and monitoring instrumentation. The proposed investigation is required to collect data on soil properties and dam configuration, and to plan the activities to be performed during the 2nd stage;

- 2nd stage activities include major repair or upgrade of the dams which may be required in order to fulfil minimum safety requirements and which need site investigation, preliminary studies and design.

TABLE 2: RECOMMENDED WORKS

		STAGE 1	STAGE 2
Arys river diversion weir	Replace screws, repair gates, fix/replace mechanical and electrical control equipment, fix concrete works	■	
Bugun dam	Geotechnical investigation	■	
	Install piezometers, settlement stations and accelerometers	■	
	Replace gates and fix/replace mechanical and electrical control equipment	■	
	Clean toe drainage system	■	
	Repair drainage system (if required)		■
	Repair downstream slope	■	
	Repair concrete facing	■	
	Repair gates located immediately downstream of the outlet works	■	
	Improve dam seismic stability (if required)		■
Karazhantak dam	Geotechnical investigation	■	
	Install piezometers, settlement stations and accelerometers	■	
	Complete and repair the concrete channel on dam crest	■	
	Provide road with asphalt paving	■	
	Repair concrete lined canal on downstream slope		■
	Improve dam seismic stability (if required)		■
Tasotkel dam	Geotechnical investigation	■	
	Install a few additional piezometers, settlement stations and accelerometers	■	
	Inspect and refurbish or replace gates and mechanical and electrical control equipment	■	
	Replace electric cabling	■	
	Prevent abnormal seepage around outlet and regrade dam crest		■
	Improve dam seismic stability		■
Bartogai dam	Modify spillway and lower maximum water level in the reservoir		■
	Provide upstream rockfill protection near crest and in other areas (if needed)	■	
	Reinforce rock face adjacent to spillway (if required based on seismic stability analyses)		■
	Provide remedial measures for seepage control in the abutments (if required)		■
	Improve dam seismic stability (if required)		■

The geotechnical investigations shall be carried out according to international standards.

The gates at Bugun and Tasotkel dams should be inspected and refurbished/replaced with no delay, as the safety of these two dams, which have no emergency spillway, and of the population living downstream, depend of the possibility of releasing water from the bottom outlet in case of emergency.

Note that for Tasotkel dam the need of improving seismic stability was reported by the KazGyprovodKhoz JSC in Almaty, based on specific studies.

The Arys river diversion weir was also included in the evaluation as it controls part of the inflow into the Bugun reservoir, thereby affecting the hydraulic safety of Bugun and Karazhantak dams.

2.3 Recommended studies

In order to provide a satisfactory evaluation of dam safety the following studies will have to be carried out for all dams during the 1st stage:

- Collection of relevant design and construction documentation for each dam, to be obtained from designers, construction management agencies and other institutions.

- Topographic surveys to define the exact crest elevation of all dams, and the geometry of several embankment cross sections at Bugun and Karazhantak dam.

- Probabilistic Seismic Hazard Analysis (PSHA) of all dam sites. A preliminary desk study to assess the possible presence and the characteristics of seismically active faults near the site and in the dam foundations and abutments shall also be carried out.

- Evaluation of dam stability and settlements under the action of seismic loads for a return period of 10,000 years and recommendations to improve seismic stability, where needed.

- Review the available hydrological data to check the return period of the largest flood that can be passed at each dam, and provide recommendations to improve hydraulic safety with reference to current international standards, where needed..

- Evaluation of seepage in the dam embankments, foundations and abutments based on the information obtained from the existing and/or the new piezometers installed at each dam site and from observations from ground surface and tunnels. Recommendations for remedial measures and for additional instrumentation, where needed.

- Review of operation and maintenance instructions, of emergency preparedness plans and of institutional arrangements for periodic dam safety inspections. Provide relevant recommendations, where needed.

In addition, the following studies will be considered for the 2nd stage:

- Evaluation of slope stability issues throughout the reservoir areas.

- Seismic stability evaluation of the rock face adjacent to the spillway of Bartogai dam based on the PSHA.

Some of the studies mentioned above may be already available for some of the dams where recent design activities are known to have been carried out, and in this case they will be thoroughly reviewed. The 1st stage studies referred to as preliminary may indicate the need of proceeding with further, more detailed studies in the 2nd Stage.

The seismic stability analyses of the dams shall be carried out based on static and dynamic properties obtained from design and construction documents, from information collected during soil investigations carried out after dam construction (where available), and from the new soil tests. As a minimum the study should include static and dynamic analyses on typical cross sections for dam response evaluation, stability analyses based on calculated dam response, simplified calculation of sliding displacements, where necessary. The seismic input will be established based of the results of the PSHA. Further refinements will be recommended for the design stage where improvement of seismic stability is required.

The hydrology of all dams should be checked. It is understood that the outlet works of Bugun dam were not designed to pass the 1/10,000 years flood, and therefore the water level in the reservoir should be kept sufficiently low to accommodate such extreme event with an adequate wave freeboard. With reference to Tasotkel dam, the level of the reservoir shall be kept low enough to make sure that the extreme flood can be accommodated in the reservoir without triggering critical seepage conditions in the dam. These measures should be implemented with no delay (if not yet applied) based on the available figures, and re-evaluated once the studies recommended in this report will be finalized.

Operation and maintenance instructions and emergency preparedness plans are understood to be available, at least for some dams, but detailed information on this issue could not be collected during the mission.

It appears that some of the dams (e.g., Bartogai) are periodically inspected by institutions in charge of evaluating the current dam safety level and impose remedial measures as needed, whereas other dams are not. This picture should be clarified in order to provide proper recommendations, where needed. Emphasis should be placed also on post-earthquake controls to identify damages or changes in dam behaviour which may jeopardize safety of the population and property in the downstream region.

2.4 Estimated costs of the proposed activities

The costs of the activities proposed for the **1st stage** were estimated (see Table 3 at the end of text for details) and can be summarized as follows (rounded figures):

- Arys River Headworks: $ 104,000
- Bugun dam: $ 594,000
- Karazhantak dam: $ 316,000
- Tasotkel dam: $ 583,000
- Bartogai dam: $ 45,000
- Studies: $ 350,000
- **TOTAL 1st stage: $ 1,992,000**

The costs of the above mentioned works are assumed to be inclusive of overheads, profit, 15% VAT and 15% contingency. The estimated cost of the studies includes 15% VAT. Note that in some instances (e.g., damage concrete facing at Bugun and Tasotkel dam) the extent of the repair work to be carried out is currently unknown, and therefore a crude estimate only could be made.

The costs of the activities proposed for the **2nd stage** are still uncertain as the need and the extent of some activities requires further insight. In any event, an attempt was made to provide at least a crude estimate of possible costs which may be expected based on the limited information at hand and on some assumptions:

- Bugun dam: $ 959,000-2,878,000
- Karazhantak dam: $ 448,000-1,285,000
- Tasotkel dam: $ 5,889,000
- Bartogai dam: $ 2,273,000-5,447,000
- Design, supervision and admin.: $ 1,100,000-1,782,000
- **TOTAL 2st stage: $ 10,669,000-17,281,000**

With reference to Bugun dam, note that whether or not repair of the drainage system will be required, and to what extent, depends on the effectiveness of the cleaning measures adopted during the 1st stage and on the evidence provided by the piezometers (to be installed). The estimate for Tasotkel dam and the upper bound cost associated with Bartogai dam are based on some assumptions and on overall cost figures provided by the KazGyprovodKhoz JSC in Almaty, where the latter are based on design of specific remedial measures for these two dams. The costs above are assumed to be inclusive of overheads, profit, 15% VAT and 15% contingency. The cost for design, supervision and administration is assumed as 11.5% of civil works (i.e., 5,5% design, 2,5% supervision, 3.5% administration).

3. BUGUN RESERVOIR

3.1 General

The Bugun reservoir is fed by the Bugun river, which normally only flows briefly in spring, and by the Arys river through the Arys main diversion canal. It is part of the Arys-Turkestan irrigation scheme. The reservoir has a total volume of 370Mm^3 with a dead volume of 17.0Mm^3 and an area of 6350*ha*. It was created by building two dams which will be referred to as *Bugun dam* and *Karazhantak dam*, respectively. The resevoir feeds the Turkestan main canal (45m^3/s) and the Bugun river (90m^3/s), and serves five different Rayons irrigating approximately 70,000*ha* of land on the right bank of the Syrdarya river valley.

It was reported that construction of the dams started in 1954 and the reservoir was gradually filled between 1962 and 1967. It is also understood that the seismic intensity VII of the MSK scale applies to the Bugun dam site. The latter seismic intensity implies roughly a peak ground acceleration of the order of 0.1-0.3g (e.g., Kramer, 1996[1]).

It is estimated that a few thousand people live downstream of the dam.

The risk category (according to ICOLD Bullettin #72[2]) can be estimated as follows:

1) Reservoir volume>120Mm^3	6	
2) Dam height: *<15* / *15-30m*	0-2	
3) People downstream: *100-1000* / *>1000*	8-12	
4) Potential damage downstream: *moderate* / *high*	8-12	
Total:	**22-32**	**(Risk Cat. III-IV)**

3.2 Diversion weir on Arys river

Most water feeding the Bugun reservoir is derived from the Arys river through the Arys main canal (Photo A6), with a rated capacity of 45m^3/s, located to the East of the dam site. The diversion weir on the Arys river (Photos A1 and A2), which supplies water to the Arys main canal, was visited briefly during the mission (note that a previous inspection was made by others during the IDIP-2 preparation mission in October 2006). These headworks are relevant to the safety of the Bugun and Karazhantak dams as they control a considerable amount of reservoir inflow.

The 7 gates on the Arys river have been recently (2004-2005) maintained and painted, whereas the 2 gates on the intake of the Arys main canal (Photo A3) need painting, seal replacement and a close inspection for cracks, although no major damage could be observed from the deck, during the visit. The screws of most gates are bent and need be replaced (Figure A4), and all components of the mechanical and electrical equipment should be inspected and repaired/replaced, where needed. Some cracks in the massive concrete were also observed (Photo A4), and although they are not such to endanger the stability of the structure they should be monitored. Some concrete repair works are also required around the gates (Photo A7).

An electric generator is said to be available at the site although at the time of the visit was reported not to be on site because it was to be repaired. The operators can communicate to Bugun dam using cellular phones.

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[1] Kramer S.L., 1996, *Geotechnical Earthquake Engineering*, Prentice Hall.

[2] ICOLD, 1989, Bullettin 72 - *Selecting seismic parameters for large dams – Guidelines*.

3.3 Bugun dam

Bugun dam was designed by the KazGyprovodKhoz JSC in Almaty, and constructed in the bed of the Bugun river. A previous inspection was carried out by others during the IDIP-2 preparation mission in October 2006. It is an homogeneous earthfill dam with a concrete facing (Photo B1) and a toe drain, 21*m* high and about 5.2*km* long. The width of the dam crest (Photo B2) is about 8*m*; the design upstream and downstream (Photo B3) slopes are said to be 2.5-3.5 and 2.0-3.0 (horizontal/vertical), respectively. In 1988 an approximately 1.5*m* high wavewall (Photo B2) was installed on top of the dam upstream slope, replacing the original 0.9*m* high parapet. The freeboard is reported to be 2.0*m* relative to dam crest, and about 3.5*m* including the wavewall.

The bottom outlet of the dam (Photo B7) is said to have a maximum capacity of 135m^3/s. It includes 2 pairs of gates (dimensions: about 2.5x2.0*m* - weight: about 2.0*t* each) which need be replaced (Photo B6). No emergency spillway is available.

The radial gates of the Turkestan main canal (Photos B8 and B9), with a combined capacity of 45m^3/s, are located immediately downstream of the dam, and two further gates, with a combined capacity of 90m^3/s, release excess water back to the bed of the Bugun river. They all need repair or renewal.

The drainage system is composed of a toe drain with cement-asbestos drainage pipes discharging water in 7-8*m* deep reinforced concrete wells (Photo B5), and then through collector pipes into an open drainage channel. The drain was not cleaned for a long time, it is currently clogged and abnormal seepage in the downstream shell of the dam was reported. Concrete is affected by weathering, but whether the concrete pipes are damaged or are still in working conditions is currently not known.

Six piezometers are said to be installed at the dam, but only three of them are reported to be in working conditions.

3.4 Karazhantak dam

Karazhantak saddle dam, which is about 10-10.5*m* high and 3.2*km* long, was also designed by the KazGyprovodKhoz JSC in Almaty and was constructed on one side of the reservoir. It is an homogeneous earthfill dam with a concrete facing which was protected by random rockfill (Photo C1) in 1987 and 2000 along about 2.2*km*. The downstream shell of the embakment, next to the toe, hosts a concrete lined canal (Photo C5) about 2.2*m* wide which is said to be not related to the drainage system of the dam (whose characteristics are currently unknown). The width of the dam crest (Photo C2) is about 8*m*; the design upstream and downstream slopes are said to be 2.5-3.5 and 2.0-3.0 (horizontal/vertical), respectively, although some different figures (2.0 and 1.5) were reported on site by the dam personnel. In any event, the downstream slope is quite uneven (Photo C3) and at least in some areas it looks definitively steeper than designed. There is a concrete channel for runoff-water collection running along the dam crest (Photos C2 and C4); it is badly placed within a loose trench with open-unsealed joints, and is completely missing along part of the dam. It is understood that placement of the channel had to be interrupted, probably because lack of funds. In 1988 an approximately 1.5*m* high wavewall was installed on top of the dam upstream slope, replacing the original 0.9*m* high parapet.

There is no outlet in the Karazhantak dam, and no emergency spillway is available. No or very few piezometers are understood to be available.

3.5 Foundation and construction material

The embankments are composed of compacted loam extracted from borrow areas located in the reservoir. The foundation material is said to be loess-like loam (18-22*m* thick) overlying a sandy gravel deposit. No drawings of the dams could be examined during the mission, and at present it is unclear whether the dams were constructed in strict compliance with the design, and if proper filters were placed between the loam and the drain material.

It was reported that in May-June 2000 an engineering-geological investigation was conducted to confirm the properties of the materials adopted for embankment construction.

3.6 Waves, freeboard and hydrology

It is understood that the design wind speeds were derived from records obtained at three different weather stations (Turkestan, Chimkent and Aryss) over a period of 10-18 years. Subsequently wind speed records were collected from 1960 to 1999 on two weather stations, Chayan and Bugun, and wind speeds up to about 28-32*m*/*s* were estimated depending on direction for probabilities of exceedance of 2 and 1%.

It was also reported that since the first reservoir infill in 1963 problems related to wave action on the upper slope protection occurred:

- In 1969 large sections of the concrete lining were damaged and subsequently restored.

- Storms took place in 1978 and 1979 (wind speeds as high as 30*m*/*s* were recorded) and as a consequence parapet overtopping occurred at Bugun dam and both the crest and the downstream slope were damaged. Following such incident the parapet was replaced with a more effective wavewall, the crest was paved with asphalt and the downstream slope was repaired.

- In 1988 a storm damaged the upstream slope facing on the left section of Bugun dam, and part of Karazhantak dam was also damaged.

At present the joints of part of the concrete facing of Bugun dam, on the left bank, are reported to be damaged, and the filter bedding is said to be eroded with presence of voids up to 30*cm* deep.

In order to provide an acceptable level of safety the dam should be able to pass the Probable Maximum Flood or at least a flood with a return period of 10,000 years, which is reported to imply a 689 m^3/s flood (source: KazGyprovodKhoz JSC), maintaining an acceptable freeboard. An adequate decrease of the normal reservoir level or construction of an emergency spillway shall be considered.

3.7 Main safety issues

The main aspects relevant to dam safety are the following:

- Design and construction documentation is currently not available, and whether the dams were actually constructed in full compliance with the original design is also uncertain. A soil investigation is required to evaluate the characteristics of the embankments and of the dam foundations, and to explore the configuration of the drainage systems.

- The dam monitoring system is insufficient and installation of instrumentation, including piezometers, monuments for settlements (where missing) and accelerometers is required.

Investigating seepage by regular piezometer readings is essential to dam safety, and apparently this has not been done for a number of years.

- The toe drain of Bugun dam is not working properly due to fine sediments occluding the concrete drainage pipes. It was reported that as a result of drain inefficiency wet spots and soil softening with slumping occurred on the downstream slope (they could not be observed during the inspection, probably also due to the presence of melting snow on the dam). It appears that cleaning of the drains was not carried out for many years due to unavailability of suitable equipment. In addition weathering of the concrete might have led to collapse of the drainage pipes at some locations. Thorough cleaning of the drainage system, in conjunction with installation of piezometers to investigate the seepage pattern in the embankment, is recommended and should be carried out soon. Based on the results of such activities repair works to restore the drain efficiency shall be considered.

- The gates of the dam were never replaced since construction. They should be lifted and inspected; given their long operational life it is espected that replacement of the gates will be necessary. Since the dam has no emergency spillway, the efficiency of the bottom outlet is essential for the safety of the dam, and therefore these works should be given priority. The gates of the headworks located immediately downstream of the dam also need to be refurbished or replaced. The mechanical and electrical equipment may also need be renewed.

- The dams are exposed to strong winds and several incidents due to wave action (such as overtopping and damage of dam facing) were reported. It is recommended to restore the road on the dam crests and to provide paving (e.g., asphalt) where missing. The surface drainage system at Karazhantak dam, including the concrete channel along the crest and the collector pipes on the downstream slope, should be fixed. The joints of part of the concrete facing of Bugun dam, on the left bank, are reported to be damaged, and the filter bedding is said to be eroded with presence of voids up to 30*cm* deep. This damaged components must be repaired.

- Localized slumping was observed on the downstram slope of Bugun dam, probably triggered by surface water runoff. Careful inspection of the downstream slope and repair are needed.

- The downstream slope of the dams is quite steep, and at Karazhantak dam it is also uneven and eroded by surface water runoff. Therefore the dams may not be sufficiently stable under the action of seismic loads. Improvement of seismic stability, for instance by adding berms at the dam toes or flattening the downstream slope, may be required.

- The hydrology of the reservoir should be checked, and the possibility of passing the 10,000 years flood by properly managing water inflow and storage, or by providing an emergency spillway shall be verified.

- Apparently the dam is not periodically inspected by external specialits in charge of evaluating the dam safety conditions.

4. TASOTKEL DAM

4.1 General

The Tasotkel reservoir is fed by the Shu, Ak-su and Karabalta rivers and is part of the GMC irrigation scheme. It is reported the presence of a large upstream reservoir on the Shu river (i.e., Orto Tokoi in Kyrgyzstan) and of a smaller reservoir on the Aksu river. The Tasotkel reservoir has a total design volume of 620Mm^3 with a dead volume of 69Mm^3.

The reservoir has a command area of 65,000*ha*. Construction of the dam started in 1968 and the dam is in operation since 1974. It is understood that a seismic intensity VI of the MSK scale was originally applied in design, but subsequently such intensity was increased to VII calling for an upgrade of the embankment safety level. The latter seismic intensity implies roughly a peak ground acceleration of the order of 0.1-0.3*g* (e.g., Kramer, 1996).

A population of 15,000 is reported to live downstream of the dam.

The risk category (according to ICOLD Bullettin #72) can be estimated as follows:

1) Reservoir volume>120Mm^3		6
2) Dam height: *30-45m*		4
3) People downstream: *>1000*		12
4) Potential damage downstream: *high*		12
	Total:	**34: Risk Cat. IV**

4.2 Main characteristics of the embankment

The dam, which was designed by the KazGyprovodKhoz in Almaty, is composed of an homogeneous embankment 32*m* high and 5.1*km* long, with a concrete facing (Photo D1), an impervious upstream blanket and a toe drain. The width of the dam crest is about 10*m* (Photo D2) and the upstream and downstream slopes (Photos D1 and D3) are 2.0-2.5 and 3.0 (horizontal/vertical), respectively. There is a 1*m* wavewall on top of the dam which is considerably distorted (Photo D2) in one area close to the outlet due to significant localized settlement of the dam crest. The construction material is said to be clay loam whereas the foundation soil is composed of gravel. No drawings of the dam cross section could be obtained during the mission. The seepage from the toe drain is reported to be typically 0.3-0.5m^3/s.

Twenty-five piezometers are installed on the dam and are reported to be in working conditions. The facing of the dam include a 20*cm* thick reinforced concrete slab on a 10*cm* thick plane concrete layer resting on a gravel bedding. The wooden joints between slabs are said to be in poor conditions and to require repair.

4.3 Bottom outlet and electrical equipment

The bottom outlet of the dam (Photos D4 and D5) is said to have a nominal maximum capacity of 320m^3/s and includes 5 pairs of gates (dimensions: 2*x*3*m*). The gates (Photo D6) were never replaced since construction; they were inspected recently and found to be in poor conditions, and therefore they should be refurbished or replaced. No emergency spillway is available.

The power cables are also very old and worn out, and need be replaced with new ones.

4.4 Rehabilitation design

The dam is considered by the designers in emergency conditions and since the year 2000 the actual maximum impounded water is limited to 250Mm^3. It is understood that at present the current limitations are compatible with water needs for irrigation purposes. The reasons of this limitation are to be found in abnormal seepage that developed around the downstream portion of the outlet works, and caused lifting of the concrete slabs and voids in the foundations. The voids were filled with gravel and probably with concrete at some locations. In addition the dam is thought to be unable to withstand the seismic design loads envisaged by the current Kazakh design code.

The KazGyprovodKhoz in Almaty prepared a rehabilitation design for Tasotkel dam which was briefly described during a meeting. The remedial measures include increasing the seismic stability by providing a berm to support the downstream slope, repair of a portion of the concrete facing, demolition and reconstruction of the reinforced concrete mat and reconstruction of the drainage system at the downstream outlet works.

The estimated cost of the remedial measures for Tasotkel dam is reported to be 700 Million KST.

4.5 Main safety issues

The main aspects relevant to dam safety are the following:

- The dam requires upgrading in order to become sufficiently stable under the action of the seismic loads. An increase of stability by adding berms at the dam toes may be required.

- Due to the abnormal seepage problems occurred around the outlet works downstream of the dam, installation of additional piezometers and soil investigation are required in the dam body and around the downstream section of the bottom outlet to evaluate possible remedial actions. The upstream blanket should be inspected and the mechanism that caused the settlement at the dam crest shall be investigated. Based on the outcome of such activities, remedial works to restore satisfactory safety levels shall be established. Within this framework a relevant aspect is whether a permanent limitation of the reservoir volume can be accepted.

- The gates of the dam were never replaced since construction. They should be pulled out and inspected; given their long operational life it is possible that replacement of at least some of the gates will result necessary. Since the dam has no spillway the efficiency of the bottom outlet is essential for dam safety, and therefore these works should be given priority.

- The electrical equipment of the dam is in poor conditions and need be repaired. An emergency generator is not available and should be provided.

- Some repair of the concrete facing may also be required.

- The hydrology of the reservoir should be checked, and the possibility of passing the 1/10,000 years flood by properly managing water storage shall be verified. Alternatively construction of an emergency spillway should be considered.

- Reportedly the dam is not periodically inspected by external specialists in charge of evaluating the dam safety conditions.

5. BARTOGAI DAM

5.1 General

The Bartogai reservoir is fed by the Chilik river and is part of the Big Almaty Canal irrigation scheme. The reservoir has a total design volume of 320Mm^3 with a dead volume of 70Mm^3**,** an area of about 1300*ha* and a length of 6.2*km*.

The reservoir feeds the Big Almaty Canal and the Chilik river, with a command area of 175,000*ha* and an actual irrigated area of 50,000*ha*. The dam was constructed in 1983. It is understood that the seismic intensity IX of the MSK scale applies to the Bartogai dam site according to the current Kazakh design code. Such seismic intensity may roughly imply a peak ground acceleration around 0.6*g* (e.g., Kramer, 1996).

It is estimated that a few tens of thousand people living downstream of the dam would be affected in case of dam failure.

The risk category (according to ICOLD Bullettin #72) can be estimated as follows:

1) Reservoir volume>120Mm^3	6
2) Dam height: *>45m*	6
3) People downstream: *>1000*	12
4) Potential damage downstream: *high*	12
Total:	**36: Risk Cat. IV**

5.2 Main characteristics of the embankment

The dam, which was designed by the KazGyprovodKhoz in Almaty, is composed of a zoned embankment 60*m* high and 325*m* long, with gravel filters and pebble to rockfill shells and a toe drain. The dam crest, which can be accessed through a tunnel driven in the right rock abutment (Photo E1), is 10*m* wide (Photo E3), whereas the upstream and the downstream slopes (Photos E2 and E4) are 2.5 to 4.0 and 2.5 (horizontal/vertical), respectively. There is a 1*m* high wavewall on top of the dam. The dam is mostly founded on rock although part of the upsteram shell is founded on gravel and pebble. Some indications on the design features of the dam could be obtained on site and from the KazGyprovodKhoz in Almaty. As mentioned above filters were placed between the loamy core and the shell material, but the grain size characteristics of the materials are not currently available. At the core base the foundation rock was grouted, and a grouting courtain about 40*m* deep was provided along the dam central axis. No drainage systems was provided in the rock foundation and in the abutments.

Eleven piezometers are installed on the dam (five upstream and six downstream), and are reported to be in working conditions.

5.3 Bottom outlet and spillway

The bottom outlet of the dam is said to have a maximum capacity 142m^3/s and include 2 gates and two cone valves. The gate size is 3.5x3.0*m*, and each gate weights about 4-5*t*. They are located in the left abutment and access is granted by a tunnel in the downstream slope. The gates were replaced in 1997 and are said to be periodically inspected, and periodic maintenance (painting and replacement of sealings) is also performed. Two cone valves (2.2*m* diameter, 2.5-3.0*t* weight) are located at the downstream end of the dam. They were never replaced since construction and are reported to work properly. The left valve (Photo E5), which is not in operation during the winter time, is covered by frost.

A shaft spillway is available (Photos E6 and E7), with a nominal maximum capacity of 282 m^3/s, which is said to be sufficient to pass the 1/10,000 year flood. Apparently the spillway was tested after construction, and since then it was never active. Based on the information collected during the mission, it appears that very little freeboard, if any, would be left in extreme flood conditions, and if this is the case a modification of the spillway to decrease by a few meters the intake elevation and/or alternative measures to increase the minimum freeboard will be mandatory. The spillway discharges into the diversion tunnel which was originally driven in the right abutment, during dam construction. A vertical rock face was noticed adjacent to the spillway (Photo E8); it appears sound and stable, but given the high seismicity of the area and the potential damage/clogging of the spillway that could result in case of rockfall, a detailed structural survey of the rock mass should be carried out and stability analyses accounting for seismic loads should be performed.

The diversion tunnel in the right abutment, and reportedly also the bottom outlet tunnels in the left abutment, are affected by rather severe seepage. Clear water (about half cubic meter per second) discharges at the downstream tunnel portal of the diversion tunnel (Photo E9). The tunnels are reported to be in good conditions and periodically inspected and maintained, and there is no evidence, from what could be ascertained during the mission, of significant erosion problems which could affect the embankment or the dam foundation.

5.4 Rehabilitation design

The KazGyprovodKhoz in Almaty prepared a rehabilitation design for Bartogai dam, which was briefly described during a meeting, where a reduction of the reservoir volume to 230Mm^3 is proposed. It is understood that this reduced volume is considered sufficient for the present irrigation needs. It was probably planned in order to increase the freeboard that at present appears insufficient, also in account of possible dam settlements associated with seismically induced deformation of the upstream slope.

Another measure included in the design is grouting works to reduce seepage in the diversion and outlet tunnels. Grouting will be carried out both from the tunnels and from the ground surface on the rock abutments. The designers, however, appear not to have major safety concerns related to the high seepage rates in the abutments.

The estimated cost of the remedial works is reported to be 590 Million KST.

5.5 Main safety issues

The main aspects relevant to dam safety are the following:

- Apparently the current elevation of the spillway intake leaves very little freeboard for settlements and waves in extreme flood conditions. Lowering of the reservoir and modification of the spillway shall be considered in order to reach acceptable safety levels.

- The area is characterized by high seismicity, but according to the designers the dam is able to sustain the design seismic loads without major water release. This aspect, however, should be investigated further based on the findings of the above mentioned studies on site seismic hazard, dam response and dam seismic stability. The possible presence of active faults in the dam foundation should also be investigated.

- As mentioned above the diversion tunnel in the right abutment, and reportedly also the bottom outlet tunnels in the left abutment, are affected by rather severe seepage. The tunnels are reported to be in good conditions and periodically inspected and maintained, and there is no evidence, from what could be ascertained during the mission, of significant erosion problems which could affect the embankment or the dam foundation.

- The cone valves of the dam were never replaced since construction. They look in reasonable conditions but the components of the valves should be checked periodically in order to identify possible problems and, in case of need, they should be refurbished or replaced. The possibility of operating the left valve, which appeared clogged with frost during the inspection, in case of emergency should be checked. The valve house also needs some maintenance works.

- The presence of a sound rockfill protection of the upstream slope near the top of the dam (not visible at present due to a cover of fine grained materials) should be checked at several locations, and additional rockfill should be placed if and where needed.

- A vertical rock face was noticed adjacent to the spillway, and its height may increase if the spillway intake elevation is modified. It appears sound and stable, but given the high seismicity of the area and the potential damage to the spillway that could result in case of rockfall, a detailed structural survey of the rock mass should be carried out and stability analyses accounting for seismic loads should be performed.

- Reportedly the dam is periodically inspected by external specialists in charge of evaluating the dam safety conditions. In particular it is reported that inspections are carried out every 3 months by the Balkhash-Alakol Basin Water Management Administration (water management + safety), and every 6 months by the Rayon & Oblast Sub-divisions Emergency Situations Agencies (safety only).

Appendix: Cost Tables

TABLE 3 - COST ESTIMATE -STAGE 1

N.	DESCRIPTION	U.M.	QUANTITY	UNIT PRICE (USD)[1]	TOTAL COST INCLUDING 15% CONTINGENCY (USD)
1	ARYS RIVER DIVERSION STRUCTURE - STAGE 1				
	A) REPLACE 2 GATES (8.0 TONS EACH ASSUMED), 9 SKREWS AND 4 ACTUATORS[2]	**L.S.**	**1**	**86.052,83**	**98.960,75**
	B) PARTIAL DEMOLITION OF EXISTING REINFORCED CONCRETE WORKS INCLUDING DISPOSAL	**M^3**	**20**	**86,65**	**1.992,90**
	C) REINFORCED CONCRETE WORKS	**M^3**	**20**	**139,60**	**3.210,83**
	TOTAL:				104.164,49
2	BUGUN DAM - STAGE 1				
	A) GEOTECHNICAL INVESTIGATION: 18 BOREHOLES (CONTINUOUS CORE RECOVERY)	**M**	**540**	**149,50**	**92.839,50**
	B) GEOTECHNICAL INVESTIGATION: DOWN-HOLE TESTS, SAMPLE RECOVERY AND SOIL LABORATORY TESTS	**L.S.**	**1**	**42.490,89**	**48.864,52**
	C) INSTALLATION OF 18 PIEZOMETERS, 2 ACCELEROMETERS AND SETTLEMENT STATIONS	**L.S.**	**1**	**66.835,30**	**76.860,60**
	D) REPLACE 4 GATES (2.0 TONS EACH ASSUMED), SCREWS AND 2 ACTUATORS[3]	**L.S.**	**1**	**45.492,05**	**52.315,86**
	E) REFURBISH GATES DOWNSTREAM OF OUTLET WORKS	**L.S.**	**1**	**20.000,00**	**23.000,00**
	F) CLEAN DRAINAGE SYSTEM	**HR**	**146**	**189,12**	**31.752,83**
	G) REPAIR DOWNSTREAM AND UPSTREAM SLOPES (EARTHWORKS)	**M^3**	**5200**	**1,40**	**8.372,00**
	H) REPAIR CONCRETE FACING (PARTIAL DEMOLITION OF EXISTING FACING INCLUDING DISPOSAL)[4]	**M^3**	**1000**	**86,65**	**99.645,20**
	I) REPAIR CONCRETE FACING (CONCRETE WORKS)[4]	**M^3**	**1000**	**139,60**	**160.541,47**
	TOTAL:				594.191,98
3	KARAZHANTAK DAM STAGE 1				
	A) GEOTECHNICAL INVESTIGATION: 12 BOREHOLES (CONTINUOUS CORE RECOVERY)	**M**	**240**	**149,50**	**41.262,00**
	B) GEOTECHNICAL INVESTIGATION: DOWN-HOLE TESTS, REMOULDED AND INDISTURBED SAMPLE RECOVERY AND SOIL LABORATORY TESTS	**L.S.**	**1**	**21.345,84**	**24.547,72**
	C) INSTALLATION OF 12 PIEZOMETERS, 1 ACCELEROMETER AND SETTLEMENT	**L.S.**	**1**	**32.758,20**	**37.671,93**

	STATIONS				
	D) REPAIR CONCRETE CHANNEL ON DAM CREST	**L.S.**	**1**	**20.000,00**	**23.000,00**
	E) REPAIR ACCESS ROAD ON DAM CREST (EARTHWORKS)	**M^3**	**7680**	**1,40**	**12.364,80**
	F) REPAIR ACCESS ROAD ON DAM CREST (ASPHALT PAVING)	**M^2**	**25600**	**6,00**	**176.640,00**
	TOTAL:				315.486,45

TABLE 3 –STAGE 1 – CONTINUES ON NEXT PAGE
TABLE 3 –STAGE 1 – CONTINUES FROM PREVIOUS PAGE

4	TASOTKEL DAM - STAGE 1				
	A) GEOTECHNICAL INVESTIGATION: 12 BOREHOLES (CONTINUOUS CORE RECOVERY)	**M**	**420**	**149,50**	**72.208,50**
	B) GEOTECHNICAL INVESTIGATION: DOWN-HOLE TESTS, INDISTURBED SAMPLE RECOVERY AND SOIL LABORATORY TESTS	**L.S.**	**1**	**31.403,97**	**36.114,57**
	C) INSTALLATION OF 12 PIEZOMETERS, 2 ACCELEROMETERS AND SETTLEMENT STATIONS	**L.S.**	**1**	**61.004,80**	**70.155,52**
	D) REPLACE 5 MAIN GATES (4.0 TONS EACH ASSUMED), REFURBISH 5 EMERGENCY GATES (20% OF REPLACEMENT COST ASSUMED) AND REPLACE 5 ACTUATORS[2]	**L.S.**	**1**	**105.500,00**	**121.325,00**
	E) REPAIR ELECTRICAL CABLING AND MINOR ELECTRICAL EQUIPMENT	**L.S.**	**1**	**20.000,00**	**23.000,00**
	F) REPAIR CONCRETE FACING (PARTIAL DEMOLITION OF EXISTING FACING INCLUDING DISPOSAL)[4]	**M^3**	**1000**	**86,65**	**99.645,20**
	G) REPAIR CONCRETE FACING (CONCRETE WORKS)[4]	**M^3**	**1000**	**139,60**	**160.541,47**
	TOTAL:				582.990,26
5	BARTOGAI DAM - STAGE 1				
	A) INSTALLATION OF 2 ACCELEROMETERS AND SETTLEMENT STATIONS	**L.S.**	**1**	**39.500,00**	**45.425,00**
	TOTAL:				45.425,00
6	TECHNICAL STUDIES				
	TOTAL:				350.002,50
	TOTAL STAGE 1				1.992.260,68

NOTES:

1) INCLUSIVE OF GENERAL EXPENSES, PROFIT AND 15% VAT.

2) A COST OF 2 USD/KG INCLUSIVE OF VAT WAS ASSUMED FOR GATES AND SKREWS (SEE WP1), AND A COST OF 10,000 USD + VAT WAS ASSUMED FOR ACTUATORS, BUT THE LATTER FIGURE MUST BE CHECKED BASED ON SPECIFIC GATE CHARACTERISTICS

3) A COST OF 2 USD/KG INCLUSIVE OF VAT WAS ASSUMED FOR GATES AND SKREWS (SEE WP1), AND A COST OF 8,000 USD + VAT WAS ASSUMED FOR ACTUATORS, BUT THE LATTER FIGURE MUST BE CHECKED BASED ON SPECIFIC GATE CHARACTERISTICS

4) QUANTITIES OF CONCRETE FACING TO BE FIXED ARE UNCERTAIN

TABLE 4 - COST ESTIMATE - STAGE 2

N.	Description	U.M.	Quantity	Unit price (USD)[1]	Total cost including 15% contingency (USD)[2]	Total cost including 15% contingency (USD)[3]
1a	**Bugun dam - Stage 2 - Option 1**					
	a) Partial repair of drainage system (if required - assumed 20% of total):					
	1) trench excavation (including temporary shoring)	m^3	11100	61,30	782.430,68	
	2) placement of draining material	m^3	11100	10,00	127.650,00	
	3) placement of new concrete pipe	m	500	84,50	48.587,50	
	Total:				**958.668,18**	
1b	**Bugun dam - Stage 2 - Option 2**					
	a) Repair drainage system and improve seismic stability (if required):					
	1) provide berm (selected granular material)	m^3	130000	6,00		897.000,00
	1) provide berm (selected granular material)	m^3	130000	10,00		1.495.000,00
	2) provide new concrete pipe	m	5000	84,50		485.875,00
	Total:					**2.877.875,00**
2a	**Karazhantak dam - Stage 2 - Option 1**					
	a) Repair concrete lined canal: demolish and dispose reinforced concrete lining	m^3	660	86,65	65.765,83	
	b) Repair concrete lined canal: new reinforced concrete lining	m^3	660	139,60	105.957,37	
	c) Repair downstream slope (earthworks)	m^3	40000	6,00	276.000,00	
	Total:				**447.723,20**	
2b	**Karazhantak dam - Stage 2 - Option 2**					
	a) Repair concrete lined canal: demolish and dispose reinforced concrete lining	m^3	1320	86,65		131.531,66
	b) Repair concrete lined canal: new reinforced concrete lining	m^3	1320	139,60		211.914,74
	c) Improve seismic stability (if required): (earth works - loam)	m^3	51200	6,00		353.280,00
	d) Improve seismic stability (if required): (earth works - gravel)	m^3	51200	10,00		588.800,00

	Total:					**1.285.526,41**

TABLE 4 –STAGE 2 – CONTINUES ON NEXT PAGE