



Taming the Monster - Attabad Landslide Dam

Fiaz Hussain Shah, Arshad Ali*, Muhammad Naseem Baig

National University of Sciences and Technology, Islamabad, Pakistan

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Abstract

Hindukash - Karakoram - Himalayan (HKH) is a hazard prone region where triggering of landslides due to seismic, geological, hydrological or anthropogenic reasons is a common phenomenon. On 4th January 2010, a massive landslide at Attabad swept the low lying Surat village and blocked Hunza River thereby creating a dam resulting into a huge lake upstream. As a result of preliminary planning, emergency response was launched by Frontier Works Organization (FWO), a civil engineering component of Pakistan Army Engineers on instruction of the Federal Government and a 24 meters deep spillway cut was made through which the water started flowing on 29th May 2010 resulting into lowering of water in the lake. A detailed planning ensued and different proposals including those of Chinese, Americans and FWO were considered and finally based on cost-benefit analysis, the indigenous effort for execution was approved. FWO planned the operation in five stages whereby 675 meters long spillway was to be deepened by 30 meters having a width of approximately 60 meters resulting into lowering of water in the lake by over 50 percent. The working and weather conditions were extreme. The work was only possible in winter season when the water inflow reduced to minimum. FWO with dynamic leadership, meticulous planning, determined execution and methodical working achieved the assigned target within three working seasons and reduced the spillway bed level from 2398 meters to 2368 meters. Following the examples of other landslide dams in the world, Attabad Lake can be sustained after partial draining out through spillway and this natural hazard can be transformed into an opportunity. Announcement regarding establishing Kashgar - Gawadar Corridor made by Prime Minister of Pakistan during his recent visit to China in June 2013, by developing road and rail link between the two countries has given a new dimension and importance to Northern Areas in general and Hunza Valley in particular where the transforming of Attabad lake into an opportunity has promising prospects and enlightened future.

Keywords: - Landslide Dam, Monster, Taming, Hazard, Mitigation, Vulnerability, Risk, Spillway, Coffor Dam, Slip mass, Inundated area, Reclaimed area, Blasting, Earth moving machinery, Morale and Silver Lining.

Introduction

Hindukash - Karakoram - Himalayan (HKH) region is considered third pole of the World [1]. From north and south poles, it differs on two accounts. Firstly, it comprises mountain ranges which have their own geological, geomorphological, seismological and hydro-meteorological settings and secondly, this region is shared by large number of countries who plan land use in their respective areas according to their peculiar design and interest. This is the reason; the region is prone to multifarious natural as well as anthropogenic hazards. Risk related to these hazards, is characterized by the possibilities and consequences [2]. Possibilities range from the intensity, magnitude, frequency, time of onset to duration of occurrence etcetera whereas the consequences range from direct to indirect and impacts in all spheres of life including physical, social,

political, economic and environmental domains. The most important factor in disaster risk is the vulnerability. If vulnerability exists, the hazard upon interaction with it, depending upon the level, will result into disaster. More the vulnerability more will be the disaster risk and vice versa. The disaster risk therefore can be effectively reduced or mitigated by reducing the vulnerability [3].

On 4 January 2010, a massive landslide occurred at Attabad, a village about 109 Kilometers from Gilgit in Hunza Valley [4]. Landslide washing away low lying Surat Village, swung across Hunza River blocking it completely, hit opposite valley wall and in a pendulum movement reversed its flow falling back on initial deposit and doubled its thickness. In the process, it initiated many other small slides. The slip mass measuring approximately 600 meters in length, 400 meters in width and 60 meters in depth, composed of 60 - 70 % huge rock boulders and 30 - 40 % clay and silt contents detached from the base and flowed in three directions. Firstly, the debris pushed across the river in a forward direction and reversed after pushing up and against the ridge. Secondly, mud flow travelled upstream of Hunza River for over a kilometer and thirdly, the downstream movement of the mudflow completely covering the River and its banks [5].

Coresponding authors: Arshad Ali, National University of Sciences and Technology, Islamabad, Pakistan, e-mail: aliarshad08@yahoo.com

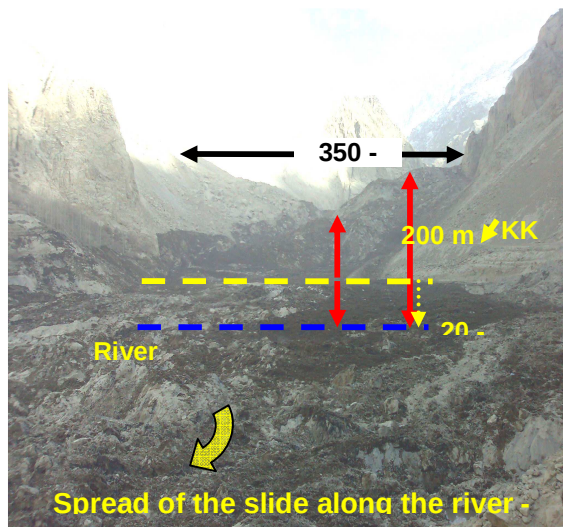


Figure 1: Attabad landslide dam profile

This way the Attabad landslide measured about 350 - 400 meters across the River, 1.5 to 2 kilometers along the River with thickness ranging from 130 to 200 meters, making the volume of slide mass over 50 million cubic meters (1.8 billion cubic feet) (Figure 1). This huge size slip mass completely sealed downward flow of Hunza River resulting into landslide dam. Due to winter being non-melting and non precipitating season, the inflow of Hunza River in that point of time was approximately 300 cusecs which started piling up behind the dam and the process of formation of a lake upstream started.

Attabad landslide was the primary hazard which interacted with the vulnerable elements like built up area, agricultural farms, orchards, Hunza River and KKH resulting into direct impact whereas newly formed lake was a secondary hazard which had potential to cause direct as well as indirect impact when unleashed. Challenge for the policy makers and planners was to respond to Attabad disaster in totality both in realm of primary as well as secondary hazards. Attabad landslide dam and the resultant lake were a reality and a hazard of enormous magnitude [6]. If not properly managed it had the potential to result into huge losses and damages to life, property, infrastructure, assets and environment. Government of Pakistan effectively responded to the disastrous situation and brought the threat level down through an innovative, imaginative and ingenious solution. Although Attabad dam has been quite successfully managed yet it poses threat of gigantic magnitude having the potential to cause massive damage in case it over flows or overtops. This paper is designed to provide an overview of planning, implementing and executing the strategy to reduce the risk by lowering the water level in the lake with special focus on the commitment level of those responsible to tame the monster thereon reflecting upon its future outlook.

Peculiarities of Attabad Landslide and Surrounding Areas

In 1858, a landslide had erupted at Salmanabad, 3 kilometers downstream of present site (Figure 2). The Salmanabad landslide had also moved in forward, upstream and downward directions. In the process, it had deposited the thick layer of river gravel overlaying silty-clayey bed. Settlement of Attabad and Surat Villages was developed on this floor [7]. Tectonically the area lies in between Main Karakoram Thrust (MKT) and Main Mantle Thrust (MMT) zones and keeps experiencing shocks due to plate's movement [8]. As a result of Astore Earthquake 2002 [9] (6.3 on Richter scale) and Kashmir Earthquake 2005 (7.6 on Richter scale), this area of Gilgit-Baltistan had received intense tremors which had resulted into fractures and fissures [10].



Figure 2: Land slide, lake and area around

Geo-morphologically the landslide area is a high barren mountain composed of fractured rocks underlying glacial moraine with fragmented material embedded in silty and clayey mixtures [11]. Topographically Hunza valley has a varying relief. Valley cuts Karakoram Range with extremely high horizontal to vertical ratio. From a height of approximately 1800-over 7000 meters, the valley attains a height of 6 kilometers which makes the slopes of valley walls very steep and instable. Porous and heterogeneous nature of rock and soil mass in the area makes it highly hazard prone [12].

To establish a strategic link between Pakistan and China, a road link by the name of Karakoram Highways was developed in 1960s. Developing of road infrastructure along the Hunza River entailed extensive rock cutting with blasting and earth moving machinery disturbing the slope and homogeneity equation of mountains resulting into destabilization of soil conditions. Sprawling settlements as a result of population growth, aggressive agricultural farming by creating terraces with the help of modern techniques and unplanned zigzag movement of irrigation water have aggravated the instability conditions of the area.

Accumulatively scar on the surface of earth in Attabad area had become sufficiently visible to be missed out by a conscious eye. Therefore in August 2009, on behest of National Disaster Management Authority (NDMA),

Geological Survey of Pakistan had carried out a study and predicted that the area was likely to experience a large scale landslide which could wipe away the settlements and block the Hunza River [13]. Based on the signs projected by the nature before the unleashing of a hazard, the area under immediate threat had been evacuated though some farmers continued working who paid the price in form of life. Finally the landslide was triggered at around 1130 hrs on 4th January 2010 with a complex sequence of catastrophic events.



Figure 3: Dust rising at time of the slide

Landslide comprised all possible grain sizes from clay to silt, sand, gravel, cobbles and large boulders. One of the most prominent peculiarities of Attabad landslide was the presence of dark, black colored clay in substantial quantity which indicated the presence of high organic contents. The highly plastic clay of grey-blackish color had complicated the dynamics of landslide whereby maneuverability and work by the plant and equipment had become difficult. Another striking feature of the landslide was grayish dust indicating the dried nature of the slip mass. The dust took many days to settle finally accumulating a thick layer of about half a meter over the slip mass deposit creating unfavorable working conditions by humans and machines (Figure 3).

Preliminary Planning

The planning at federal and Gilgit-Baltistan levels had started immediately after the disaster. Due to less inflow, the water level was rising gradually behind the dam forming a lake. Initially due to restricted valley, water was rising 1 meter a day but as the lake expanded upstream, the valley got opened and the rise in water level though reduced to 0.4 meters per day yet it continued engulfing more areas, turning into bigger and bigger monster day by day. All stakeholders like National Planning Commission, NDMA, Gilgit-Baltistan Disaster Management Authority and Pakistan Army had joined heads together to find an immediate solution to mitigate the impact by applying various means available to the public and private sectors [14].

To manage the situation, for removal of the river blockade and reduction of water in the lake, following options were considered:

Option-1. Allow the water to rise in the lake until it overtops the slided mass. Overtopping will erode the slided material blocking the river and clear the water way.

Option-2. Make a spillway cut as deep as possible in the direction of river flow, on top of slided mass, using heavy machinery. The spillway cut will allow the impounded water to pass through and erode the slided material and clear the waterway.

Option-3. Use of explosive to clear the blockade of river as accessibility to site for machinery is difficult.

Option-4. Lake Tap by constructing a tunnel through the slip mass.

Option-5. Siphoning the water from the lake across the blocked portion of the River [15].

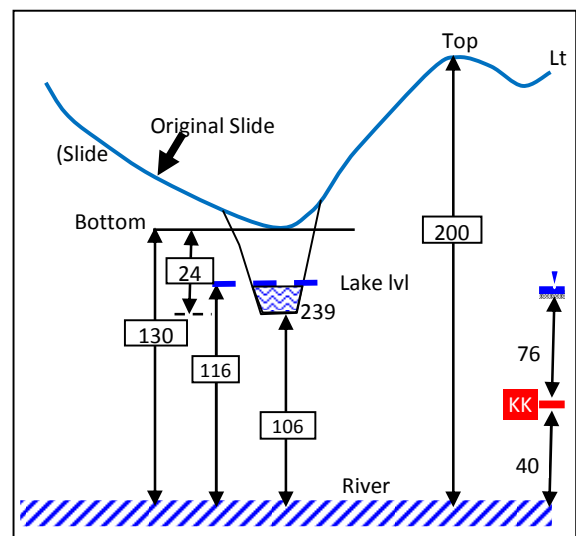


Figure 4: Cross Section of Attabad land slide

Based on observation, analysis, urgency and suitability, option of cutting a spillway as deep as possible was adopted for execution (Figure 4). Pakistan Army Engineers were tasked to design and construct the spillway. On two prongs, efforts started. On one side, Design Directorate of Engineer-in-Chief Branch prepared a design of spillway in which a cut of 261 meters length, average 37.5 meters wide and 24 meters deep was to be made in the slided mass along the river line while maintaining the width in relation to the depth. On the other hand, Frontiers Works Organization (FWO), a dynamic component of Pakistan Army Engineers configured and structured to undertake challenging and uphill tasks across the width and breadth of the country and abroad, mobilized to the site on 22nd January, 2010 to execute the work. The task at hand was extremely demanding as the site was inaccessible. The temperature was very low. The nature of slided mass comprised large boulders which were embedded in almost saturated cohesive and sticky soil with very low varying capacity. The social and public pressure was building up in view of the expanding lake [16].

Emergency Response

The first and foremost priority with Frontier Works Organization (FWO) was to mitigate the disastrous impact

of landslide dam and ever expanding lake. Under extreme low temperature and in-conductive soil conditions, FWO mobilized one company of its Road Maintenance Battalion fully equipped with blasting specialists and experienced operators to cut a spillway in the slip mass and established a camp on the site. Although the working environment was too challenging, risky, demanding and fatiguing yet valorous and committed soldiers of Pakistan Army commenced the spill way cutting operation on 24/7 basis (Figure 5).



Figure 5: Perils of deepening the spillway

In first phase, China Road and Bridge Corporation (CRBC) which was already working in the area for repair and maintenance of KKH had cleared 450 meters length of the road from 10-15 January 2010 for creating an ingress into the slip mass. In second phase, an excess track of 600 meters length from KKH to the site of spillway was constructed from 15-19 January 2010. In the third phase, on 29th January 2010, the excavation of spillway started and the desired cut of 261×37.5×20 meters was completed by 15th March 2010 reducing the storage potential of artificial reservoir by 36 percent. However the rise in lake was not as anticipated and on 15th March 2010 after excavating a 20 meters deep spill way, the difference between lake water and level of spillway water was still 41 meters. The plan was revised by Engineer-in-Chief Branch and new design of 415×60×24 meters was given to FWO for execution.

FWO regrouped and retrofitted itself to go deeper into the slip mass for cutting a spillway according to a new design given by Engineer-in- Chief Branch. Still the cutting was in dry soil without gushing water in the stream but the water was gradually rising in the lake. Hydrological, social, economic and political pressures were building up accumulatively on the command hierarchy of Pakistan Army as well as political government. The secondary hazard was getting intense in magnitude and volume day by day whereas time for those executing the new spillway plan was squeezing. With untiring and round the clock efforts by FWO it could manage to achieve a depth of 24 meters by 15th May 2010. With this depth, 50 percent reduction had been achieved in the storage potential of artificial reservoir. Excavating beyond 24 meters depth was not possible due to pronounced phenomena of caving in of side slopes of the cut spillway. It was on 29th May 2010 when the water started flowing downward through the spillway.

Initially the water through the spillway was very small as compared to the water inflow in the lake. Water level kept increasing in the lake and it was 11th June 2010 when the outflow balanced the inflow. Subsequently there has been a minor increase in lake level depending upon increase or decrease in the water inflow into the lake. On 29th May 2010, the out flowing water was few hundred cusecs but it increased to more than 30,000 cusecs by August 2010.

Deliberate Planning

Initially, the increase in water outflow through the cut spillway rapidly eroded its sides and bottom on the downstream and the erosion progressed upward towards its mouth touching the lake. Due to presence of very large boulders, deepening and widening at the mouth of the spillway, however, did not take place and the process of retrogressive corrosion stopped. Due to presence of cohesive nature of soil and large boulders in the slid mass, deepening of spillway did not proceed as expected. This phenomena, however, validated a fact that due to heavy armouring of bed and sides of spill way with large boulders, its deepening and widening are not likely to take place by normal process of erosion by water for years. The inference ensued that the lake was likely to remain at the same level unless the spillway bed was lowered by some other means.

This situation created unrest amongst displaced people of this area whose houses were submerged upstream. Taking notice of the situation, a high level meeting under the co-chairmanship of the President and the Prime minister, was held on 21st July 2010 at Awan - e - Sadar and the decision was taken to further lower the lake level and open the KKH. Subsequently a number of meetings were held at Planning Commission of Pakistan to work out the modalities for implementation of the decisions taken at the presidency. For this purpose, a proposal each by Chinese, Americans and FWO experts was presented to Planning Commission. Salient of each proposal are briefly discussed below:

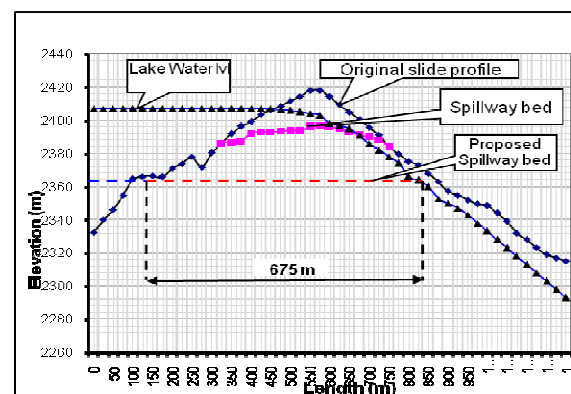


Figure 6: Proposed spillway for lowering lake by 30 meters

Chinese Proposal: In the spillway be blasted by using Trench Mortars according to the experience in tackling the dammed lake after Wenchuan Earthquake. The blasting should be stopped when boulders are reduced to less than 0.5 meter. When conditions permit, artificial blasting and obstacle- removing can be used as supporting approach.

The quantity of work for lowering the dam was estimated at 250-300 Trench Mortars for blasting boulders in the spillway. About 100 boulders on the left bank slope were to be blasted in advance; about 2 million cubic meter excavation; 1.8 million cubic meter with transport distance of 1500 meters and 10,000 cubic gabions for protection. The cost for lowering the bed by 30 meters was estimated at US \$ 28 million (Rs 2.4 billions) which did not include any other cost (Figure 6).

American Proposal: A delegation of American experts from US Bureau of Reclamation visited Attabad landslide from 22-23 August 2010 and recommended simultaneous deepening of spillway and construction of tunnel for lake tapping. NESPAK was already working on similar proposal on Lake Tap. It was expected that construction for tunnel of Lake Tap was likely to take more than 3 years with the cost effect of over US \$ 50 million (Rs 4.25 billion).

FWO Proposal: Towing the Chinese line of lowering the lake by 30 meters from the level 2406 (lake level observed during August 2010) to level 2376 so that submerged under construction Sheeshkat Bridge could be utilized for realignment of KKH, FWO also proposed to lower the spillway by 30 meters from existing spillway bed level. Since the water had started flowing through the spill way so the work of its deepening was to be undertaken during low flow conditions from October 2010 to May 2011 in five stages as shown in the figure 7. During stage 1, spillway mouth was to be blocked and bed would be deepened by 6 meters. Large boulders in the spillway bed would be broken using controlled blasting and cleared using mechanical means like excavators, loaders and dumping trucks. The spillway mouth was to be accordingly widened maintaining a plausible slope with respect to the depth achieved. Similarly spillway bed was to be lowered further by 6 meters during each subsequent stage. In this proposal, 30 meters deep spillway cut was to be 675 meters long and 60 meters wide to be completed within 8 months with an estimated cost of Rs. 500 million (US\$ 5.9 million). Notwithstanding much lesser time, this cost was about one fifth of Chinese proposal and one eighth of American proposal. The lake would be finally lowered to level 2368 meters.

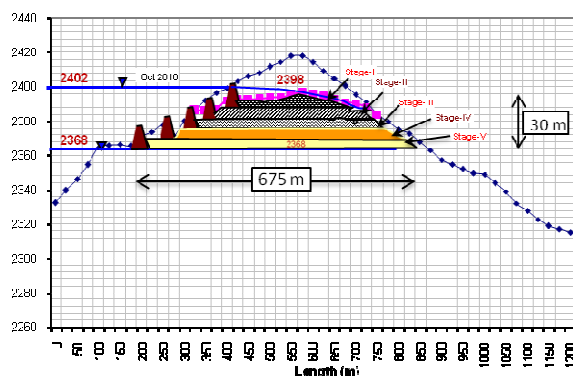


Figure 7: Spillway deepening methodology

About 22 kilometers of KKH was submerged due to landslide dam and formation of lake up stream. Chinese had proposed restoration of KKH along existing alignment by

lowering lake from 2406 to 2320 level i.e. 86 meters as shown in the figure -6, with the estimated cost of US\$ 250-300 million (Rs 21.5- 25.5 billion). FWO proposed for lowering of lake to 86 meters as recommended by Chinese within estimated cost of Rs 7.6 billion (US\$ 90 million) within 3-4 years time frame.

Deliberate Response

Excavating spillway deeper than the initial cut of 24 meters was a great challenge for Frontier Works Organization (FWO). The working limitations were enormous. The working season was restricted to winter only starting from October to May when the inflow reduced to the lowest level. The weather conditions were extreme and the temperature dipped from -10 to -28 degree Celsius. A temperature under which keeping the conventional plant and equipment functional was a nightmare. The technology available for the task was limited and conventional which suffered frequent breakdown due to extreme weather and working conditions. Discharge from the spillway was higher than average and against the expectations [17]. The boulders in slip mass were of hard rock with large sizes which posed unusual difficulties in drilling and blasting. Under these circumstances, the FWO, Pakistan Army Engineers had planned to proceed for execution of plan of deepening the spillway to 30 meters.

Deepening of spillway to 30 meters depth would accrue extraordinary benefits. The length of submerged KKH due to upstream formation of lake would further reduce by 50. Under construction Sheeskat Bridge would re-emerge and would be used for KKH realignment. Length of KKH realignment would be reduced from 32 kilometers to 22 thereby reducing the cost from US \$ 599 million (Rs 58 billion) to US\$ 275 million (Rs 26 billion), a difference of approximately Rs 32 billion. Submerged areas of Hussaini, Gulkin and Gulmit would be completely reclaimed whereas areas of Sheeskat and Ainabad will be partially reclaimed. As a nut shell, from any comparison the accumulative benefits of deepening the spillway to 30 meters were overwhelmingly greater than the nominal cost likely to be incurred on the project.

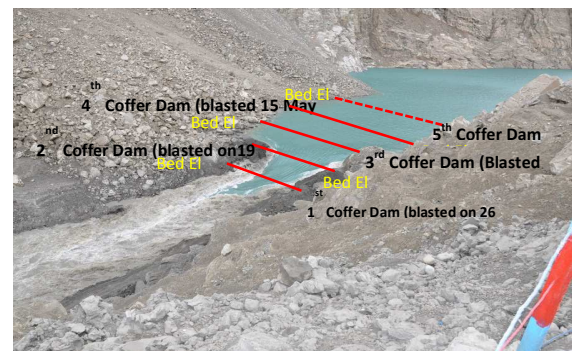


Figure 8: projected location of coffer dams

Besides physical and economic benefits, the project promised immense dividends in term of political, social, psychosocial and environmental returns. This inspiration led Frontier Works Organization (FWO) to start the operation with bottomless dedication and professional

commitment by mustering resources and employing in a concentrated form to achieve the target within stipulated time frame.

The methodology followed by FWO was customized according to the situation on ground. The deepening of spillway was planned in five stages, starting the work in October 2010. The total length of approximately 675 meters was to be cut by achieving a depth of 30 meters reducing the spillway bed level from 2398 to 2368 meters. In each stage, 6 meters depth was to be achieved. Since certain level of water was flowing in the spillway therefore first and foremost task was to reduce that flow to minimum possible by making temporary dykes in the form of coffer dams so as to allow work in dry environment (Figure 8). For each stage, a coffer dam was constructed which reduced the water level to minimum and allowed the earth moving machines and boulders blasting parties in an unrestricted manner.

When the water flow was reduced by constructing coffer dam, the boulders and rocks in the bottom of the spillway were exposed and in a relatively dry working environment, machines and manpower were extensively employed across the complete width of the spillway and progressed downward in a systematic manner. Meanwhile, when the water flow was blocked after constructing the coffer dam, the water level in the lake kept rising in those days which was minutely observed against the overtopping. As the water level in the lake reached a critical stage, the bund was lifted and increased flow of water would be experienced for 4-5 days. During this high flow period, the already excavated material from the spillway was transported on dump trucks at a suitable place away from the site. The water level and the bed level determined after 48 hours of lifting the bund indicated the progress achieved. Whole cycle of constructing the bund, lifting the bund and again constructing the bund used to be averagely completed in 10-15 days. Depending upon the flow, excavation work and material disposal varied on daily basis.

As a deliberate response, when the work had started in second phase of spillway deepening by FWO, the lake level at that time precisely was 2402.5 meters whereas the spillway bed level was at 2398 meters. On 25th January 2011, when the first coffer dam was blasted, the lake level was reduced to 2401 meters whereas spill way bed level was down to 2396.5 meters with a progress of only 1.5 meters. This was the first experience and the progress was much less than planned. On 19th March 2011, when the second coffer dam was blasted, the lake level had come down to 2399.5 meters and spill way bed level to 2394 meters giving a progress of 2.5 meters. So in this winter season, a total of 4 meters depth could be achieved. Now the water inflow had increased and became extremely difficult to undertake further excavation in this season.

In the next working season, from October 2011 to May 2012, the spillway deepening operation was resumed with the construction of third coffer dam and the work started on the same lines and methodology, as was done in the previous season. On 27th February 2012, third coffer dam was blasted and the lake level achieved as a result of this effort was 2392.5 meters whereas spillway bed level went down to 2388 meters giving a progress of 6 meters. This

time extremely low temperature and freezing of the lake was optimally exploited to extend the excavation period and achieve deeper progress. In that season, when fourth coffer dam was constructed, the water inflow had started increasing though at a gradual level, therefore, on 15th May 2010 when the fourth coffer dam was blasted, the lake level was brought down to 2390.5 meters and the spillway bed level to 2386 meters achieving a depth of two meters. This way by end of second working season, a total of 12 meters lowering of lake level was achieved against 30 meters which made just the 40% in two working seasons. The progress was less than expected and some innovation and imagination was needed to expedite the process of deepening the lake. The working season of 2011/2012 had also gone with progress still below 50% than the target to be achieved. All hopes were pinned on next working season for the completion of the work and the achievement of the target.

Next season starting from October 2012 to May 2013 was very crucial. Based on the experience of previous two seasons, FWO had developed plans, practices and procedures. Organizational structures and earth moving plants and equipment were well configured. A revised work plan was prepared wherein the work was to start in October 2012 with extension of track for construction of 5th coffer dam which was completed by 15th December 2012, followed by deepening of the spill way to the depth of 2378 meters which was completed by 1 February 2013, an excavation of approximately 10 meters in less than three months. Before continuing further excavation, construction of the coffer dam was undertaken which was successfully completed within less than one and a half month. Complete management, technical and logistic machinery of FWO was in state of fast but stable motion which was moving in top gear. The operational dynamics had changed. After construction of 5th coffer dam in first week of March 2013, the deepening of spillway to the depth of 2371 meters resumed and got successfully completed before mid April 2013. FWO had neared the target very successfully and still had more than a month to complete remaining three meters of the depth. Now there was no hold bar to the highly dynamic machinery to continue seeking excellence. Before close of the winter season, FWO had achieved a remarkable progress of deepening the spill way to 2368 meters, the depth designed to complete the matrix of new dimensions of 675 meters long spillway [18].

The Silver Lining to Excellence

FWO is mainly a civil engineering dynamic organization of Pakistan Army Engineers which remains committed on host of national level priority projects. Importance of each project in itself exceeds other.

Attabad landslide project was no less than any other project being undertaken by the organization. By default, during second half of 2012, key appointments at top (FWO level), middle (group level) and lower (unit level) tiers changed. New team took this project as a great challenge, joined heads together, revised the plans, reorganized the manpower, retrofitted the machinery and equipment and reinvigorated the morale of human resource so as to achieve the desired level of spillway excavation by close of

impending winter season in which they remarkably succeeded.



Figure 9: The intensity of work

The silver lining in achieving this excellence is visible from following measures which the organization took to achieve the desired deepening target within planned timelines.

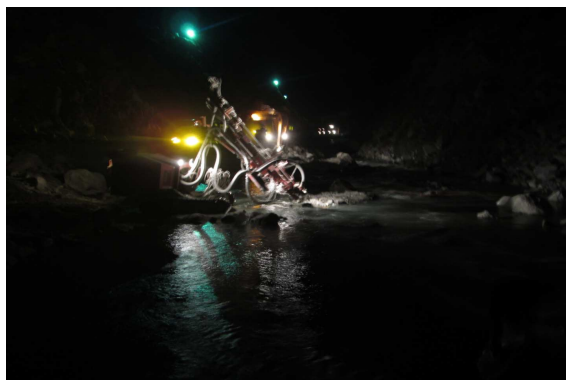


Figure 10: Night work

A clear direction from top to bottom realigned and synergized the effort (Figure 9). The command was decentralized and the executive on site was allowed to maximum initiative in execution of plan. Resources were promised, funds allocated, technical needs fulfilled and logistic chain established, gave a fillip and boost to the organizer on ground for judicious use of available resources to produce optimum results within the projected timeframe. To this end, officer in charge on site instituted innovative measures to maintain the momentum of the work in achieving planned progress.

An operational command centre was established on the site which had all requisite communication required to maintain a contact with working parties and monitor their progress. Three dedicated shifts of an average of 10 hours each were organized on daily basis particularly during those days when spillway used to be closed for water. This was an extremely innovative way of enhancing a normal day of 24 hours into a working day of 30 hours. In this way each shift will have an overlapping period of at least 2 hours. Day and night for these determined and valorous workers

had become immaterial (Figure 10 & 11). The organizational mission was in front and every member of the team was working and living with the thought of achieving the target laid down by local commanders for every day. Timing of the shifts was systematically rotated so as to provide every individual a chance to work in the morning, evening and at night. Technical repair and maintenance chain was efficiently configured to make the earth moving plant and machinery available for each shift [19].



Figure 11: Night operation

In the process of visiting the site and interacting with the executives who participated in last winter season in June 2013, it was revealed to the author that the silver lining in achieving the excellence rested in the leadership. Their resolve, will power, commitment level, technical prowess and professional acme played a pivotal role in mobilizing the human, technical and logistic resources in a focused manner for the accomplishment of the mission. The personal examples of sacrifice, dedication and valour by the immediate commanders on site in form of laying their lives in pursuit of achieving the objective of keeping the working force integrated and harmonized proved catalyst in meeting the dictates of challenging environment. The progress and performance by the organization and manpower was extraordinary, with rare parallels and precedences and will go a long way in projecting the professional acumen of FWO and its under command formations and units in the realm of disaster risk management at national, regional and international levels [20].

Historic Overview of Landslide Dams

Landslide dam is a common phenomenon which occurs in different parts of the world. Each incident varies in its parameters, dimensions, triggering mechanism, environment and consequences. Mostly the landslide dams occur due to seismic activities. Earthquakes measuring 7 or more on Richter scale usually trigger the landslides in mountainous areas. However examples of soil failure due to geological, hydrological or anthropogenic reasons are also not very uncommon. In the world we have examples like Usoy Dam which resulted in Lake Suarez in 1911 as a result of massive earthquake triggered landslide in Tajikistan and is still being sustained [21]. A landslide dam

created by an earthquake measuring 8 on Richter scale on 12th May 2008 in Tangjiashan, China overtopped the landslide when volume of water in lake immensely increased [22]. Kangding - Louding landslide dam developed on 1st June 1786 due to earthquake measuring 7.75 on Richter Scale in Sichuan Area of South Western China got breached when the slip mass could not sustain the water pressure in the lake [23].

Examples of lakes systematically and deliberately drained out can also be traced in world history for comparison. Thistle dam in USA developed on 13th April 2003 on Spanish Fork River was successfully drained by end of the same year. Hegbin Lake developed due to blocking of the Madison River on 17th August 1959 due to an earthquake measuring 7.5 on Richter scale in south-western part of Montana USA was completely drained through deliberate efforts [24]. The example of Haitian Bala Dam in Azad Kashmir, Pakistan which developed as a result of landslide creating two lakes on River Jhelum was triggered by an earthquake measuring 7.6 on Richter scale on 8th October 2005 [25]. First the Karli Lake breached on 9th February 2010 due to intense precipitation and the second Tang Lake breached from 27th July to 1st August 2010 due to intensive monsoon rains [26]. From the examples cited above, it will become a little easier for the readers to comprehend future outlook projected in succeeding paragraphs.

Future Outlook of Attabad Landslide dam

After completion of 30 meters deep excavation of 675 meters long and about 60 meters wide spillway in Attabad landslide dam, the hazard radiating potential danger has been sufficiently mitigated. In other words, a monster has been appropriately caged.



Figure12: New Sheshkat Bridge

But like the monster in cage, the latent danger in form of a huge lake behind the dam still exists. Now the question arises that how the monster will be tamed as are tamed wild animals like a lion, a bear, a leopard or gorillas who dance on the tune of their masters. Likewise taming the monster of Attabad landslide dam would mean transforming the disaster into an opportunity. This will only be possible when all possible adverse effects of the landslide dam and lake are adequately addressed like reclamation of areas of Sheeshkat and Ainabad villages and making a controlled

spillway to regulate the water according to own requirement.

As for as the first outlook of the plan is concerned which relates to further lowering of the lake level or draining of the water, further excavation of the spillway at least by another 10 meters would have to be made to reclaim the areas of Sheeshkat and Ainabad. Going by the corollary that after deepening the spillway by 30 meters, more than half of the area engulfed by the lake has been reclaimed (Figure 13) and if another 10 meters deepening of spillway is done, more than one third inundated area would be further reclaimed leaving remaining two third which would be approximately 7-8 kilometers of upstream dam which can be effectively used even if lake stays with no more excavation of the spillway or lowering of the water level. Going beyond 40 meters deepening of spillway presumably will be cost prohibitive as the dividends subsequently will be rather minimal.



Figure 13: Reclaimed area

For transforming the disaster into opportunity, a plan then needs to be formulated for utilizing the minimum level of lake water after the controlled spillway has been put in place. The examples of Lake Waikaremoana in New Zealand, believed to be 2200 years old is a classic example of landslide Dam Lake transformed into a hydroelectric power generation source after the landslide was tunneled and sealed to stabilize between 1935 and 1950 [27]. The Government of Gilgit-Baltistan can plan hydroelectric power generation from Attabad Lake and provide the electricity to people of their own area and supply the same to down country in Pakistan where power crisis already haunts.

The second area from which benefits can be accrued from the Attabad Lake relates to tourism. Hunza valley has immense tourist attraction. Provide a high number of tourists visit the valley during summer as well as winter seasons. During summer season the temperature is moderate and weather extremely pleasant which can inspire the tourists to come and stay around the lake if through public or private investment, tourist resorts are developed along both banks of the lake. Freezing of the lake during winter season had added yet another dimension which can be a source of attraction in low temperature as well (Figure 14). Presence of Nanga Parbat and Raka Poshi in the near

vicinity of Attabad Lake provides a readymade platform from where even the international tourists and mountain climbers can be easily attracted towards Attabad lake resort.



Figure 14: Frozen Lake

Third area which has the promising prospect and opportunity relates to developing trout fishery industry around the lake. Trout lives in environmentally clean and low temperature water which is the peculiarity of Northern Areas of Pakistan. By developing proper trout hatchery in the area of Gulkin or Gulmit, a profitable trout fishery can be developed from which the product can be supplied at national and international levels. The possibility of enticing private investors through an attractive package does exist which the Government of Gilgit-Baltistan should earnestly explore to reap the benefit from this natural resource.

Finally it will be worthwhile, if a logical linkage is established between the projected outlook of Attabad Lake as enunciated above and the announcement made by Prime Minister of Pakistan during his recent visit to China in June 2013 for establishing Kashgar-Gawadar Corridor by developing road and rail link between two countries [28]. On face of it, announcement by the Prime Minister Nawaz Sharif may appear to be a dream but if realized, may be in a little delayed timeframe, developed Attabad Lake with all its three aspects of hydroelectric power generation, tourism and fishery industry as discussed in the above paragraphs will, as a whole, attain a central position in development of Gilgit-Baltistan in general and Hunza Valley in particular [29].

Conclusion

Like many hazards present in the country, Attabad landslide dam is also a secondary hazard developed as a result of eruption of a landslide due to multiple reasons. Disaster risk is a function of hazard and vulnerability. If hazard is mitigated and vulnerability is either reduced or eliminated, the disasters risk is proportionally reduced. In case of Attabad landslide dam, concerted efforts by Government of Pakistan have been put in by employing Pakistan Army Engineers for mitigating the impact of disaster through deepening the spillway by a depth of 30 meters and lowering the water level in the lake thereby reclaiming the inundated land effectively. An economical solution still needs to be sought by the policy makers and

planners to further mitigating the hazard and reducing the vulnerability and at the same time conceiving an innovative plan of transforming this disaster into an opportunity. Management of Attabad landslide dam and lake till now is a success story which needs to be further capitalized for drawing optimum benefits from this natural resource.

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