Concept Paper for a Dam-related Hazard Warning System in Sri Lanka

A Participatory Study on Actions Required to Avoid and Mitigate Dam Disasters

Rohan Samarajiva
Divakar Goswami
Rebecca Ennen
asia@lirne.net
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# Table of Contents

**Background** 111

Acknowledgements 11111

Vanguard Foundation 111111

LIRNEasia 1111111

Comments 11111111

**Executive Summary** 11111111

Introduction and Rationale 1

Parameters of an Early Warning System 4

Institutional Governance 19

*Status quo* 19

Financial issues 21

*Regulation and multi-party decision-making* 22

References 27

## List of Annexes:

- **Annex 1** Consultation Process Input
- **Annex 2** Expert Consultation Agenda
- **Annex 3** Pilot Study Proposal
Background

This is an interim concept paper for discussion purposes prepared by LIRNEasia on the basis of information gathered from multiple sources, including the Expert Consultation conducted on 20 May 2005. It has been written for a general audience unfamiliar with the specialized knowledge of dam management and safety by persons who are not experts on dams. While the enormous assistance offered by the Sri Lanka Committee on Large Dams and other government entities and the experts is greatly appreciated, they are not in any way responsible for the content. The authors emphasize the fact that this is a draft document which is bound to contain some errors and ambiguities given the time constraints it was prepared under. It is LIRNEasia practice to present all arguments as fairly as possible; to obtain the broadest range of views on them; and to make all the necessary revisions. Examination of the final and draft versions of the NEWS:SL concept paper at www.lirneasia.net will show that that all comments are taken seriously. The authors hope that the readers will accept this interim draft in the spirit that it is presented in and that, where there are differences in opinion or on the veracity of facts, they will state their positions clearly, supported by evidence. LIRNEasia commits to take such comments very seriously.

Based on the research and consultation conducted so far, this paper finds that Sri Lanka requires an empowered and efficient dam hazards unit to serve as the focal point of a comprehensive, multi-stakeholder safety program for Sri Lanka’s dams and related structures. The paper includes information about dam-related risk assessment, critical elements of safety/disaster planning, areas of engineering and technical oversight successes and failures, the current status of dam management, the potential dam safety uses of information technology use, and other corollary topics. Following the consultations on this draft, recommendations on specific actions will also be added to the paper.

The need for this project arose in the course of disaster-management expert consultations carried out by LIRNEasia and The Vanguard Foundation in the preparation of “NEWS-SL: A Participatory Concept Paper for the Design of an Effective All-Hazard Public Warning System.” It is being developed in a participatory, consultative, and transparent process.

This interim draft has been compiled on the basis of research and an Expert Consultation held 20 May 2005 at the Distance Learning Center located on the campus of the Sri Lanka Institute of Development Administration, with participation from experts representing several decades’ worth of experience in several key Sri Lankan dam administration authorities.

This draft is posted for comment on the Internet. Relevant comments and suggestions will be incorporated in the final paper.
At the same time we will conduct town meetings in three Sri Lankan cities that lie significantly in the flood path of the Mahaweli dam system, Kandy, Gampola, and Polonnaruwa. The purpose of these meetings is to raise awareness of the information herein contained and to receive input from this most important set of stakeholders. We hope to educate the public and motivate them to support dam safety initiatives. The received input will be incorporated in the final paper.

We have also produced a short video about the experiences of survivors of the Kantale breach of 1986, to illustrate the critical need for the type of reform that we are proposing.

**Acknowledgements**

The authors would like to thank: Badra Kamaladasa for her valuable input and contributions to this interim paper; Ayesha Zainudeen for her graphic and editorial assistance; and all the participants at the Expert Consultation.

**Vanguard Foundation**

http://www.vanguardfoundationlanka.org/

Vanguard Management Services (Pvt) Limited, floated Vanguard Foundation, to conceptualize and implement its corporate efforts in the areas of disaster relief, rehabilitation and preparedness. The Vanguard Foundation promotes activities, polices, and market based initiatives that would improve national disaster preparedness, mitigation strategies, and the flow of expertise to meet and deal with a wide variety of national disasters.

**LIRNEasia**

www.lirneasia.net

LIRNEasia, a regional ICT [information and communication technologies] policy and regulation capacity building organization, incorporated as a non-profit organization under section 21 of the Companies Act, No. 17 of 1982 of Sri Lanka in 2004 and funded at present by the IDRC and infoDev, a unit of the World Bank. The organization is physically located in Colombo but works throughout the Asian region. Its primary functions are research, training and informed intervention in policy and regulatory processes. Its current projects include research in India, Nepal, Bangladesh and Indonesia that deal with different approaches to network expansion and research on the telecom strategies of the poor.

LIRNEasia aims to improve the lives the people of Asia – by making it easier to make use of the information and communication technologies by facilitating the changing of laws, policies and regulations to enable those uses; by building Asia-based human capacity through research, training, consulting and advocacy.
Comments

Comments on this Interim Concept Paper can be submitted until **Wednesday 20 July 2005**, by email, post or fax, or you may enter your comments directly onto the LIRNEasia website. Relevant comments and suggestions will be incorporated in the final paper.

*email:* asia@lirne.net  
*post:* LIRNEasia  
Sri Lanka Institute of Development Administration  
28/10 Malalasekera Mavatha  
Colombo 07  
(Sri Lanka)  
*fax:* (94) 11 452 7648
Executive Summary

2.1 The dam network in Sri Lanka comprises over 350 medium and large dams, and over 12,000 small dams. Today, dams and their complementary structures shape Sri Lanka much as they did thousands of years ago. Maintenance, safety oversight, and usage rights are shared among several Ministries, Authorities, organizations, and informally stake holding nearby populations. This is natural given the multiple usages and demands placed on the dam system. However, there is a great need for better oversight of the dam system and the proper coordination of functions, especially related to safety.

2.2 Among the resultant negative outcomes are non-updating of and non-adherence to Standing Orders for maintenance and safety, minimal education of vulnerable populations on the risks and responsibilities of those living in the shadow of dams, and poor disaster response plans. Most seriously, it appears that inadequate priority is being given to the proper maintenance and periodic overhaul of dam structures, and that the existing financial arrangements are quite unsatisfactory. Given the number and widespread distribution of dams in Sri Lanka, it is clear that the affected populations and sectors are many, and that the effects of dam-related hazards can be very serious. In the opinion of the experts the current financial, operational and regulatory arrangements are unlikely to prevent the occurrence of dam-related disasters and may even contribute to them.

2.3 The key to effective dam safety is the formulation of Standing Orders that cover all aspects of dam hazard monitoring, risk assessment, remedial action, safe operation and emergency management; the keeping of the Standing Orders up to date; and strict adherence to their provisions.

2.4 Risk assessment and vulnerability mapping must be conducted for all dams. This is the basis for effective disaster preparedness.

2.5 Early detection of signs of a breach is critical to effective dam safety. If the weakening of the structure is detected very early, remedial measures may be taken to repair it and avoid it from becoming a hazard. Even if the detection of structural problems occurs relatively later, action may be taken to mitigate its effects, for example by lowering water levels. Even if it is detected a few hours prior to a breach, that would still allow for action to save lives and property.

2.6 At present, sophisticated dam hazard detection and monitoring devices are not in wide use in Sri Lanka, the most common methods being visual inspections, for the most part, by lower-level staff. The Kantale dam was visually inspected several months its breach to no avail. The actual breach was detected by a villager. The most advanced equipment was installed at Lunugamvehera, one of the most recent large dams, but they have not been maintained in optimal condition subsequently. Even this equipment required periodic visits to their locations by the technical staff.
2.7 While recognizing the costs and maintenance implications of state-of-the-art dam hazard detection and monitoring equipment, this Paper suggests that it may be worthwhile to conduct at least one pilot project using advanced dam hazard detection and monitoring equipment coupled with advanced information and communication technologies that would enable the data to be monitored in multiple locations including the dam’s own control facility.

2.8 Even if advanced detection and monitoring systems are adopted, it is essential that the staff, the villagers and others who live by and frequent the dam area be trained to look for signs of impending hazards.

2.9 Hazard detection and monitoring information must be interpreted by skilled professionals in order to generate disaster alerts and warnings. Given the short time periods that may be available and the importance of site-specific knowledge, the responsibility for issuing alerts and warnings must reside within the dam operator, preferably with the engineer responsible for the dam. ICTs may be used to provide the decision maker with back up expertise.

2.10 It is critically important that engineers in charge of major dams and their technical staff be provided with modern communication equipment and that they are exempted from government regulations inimical to use of fixed telephones above a threshold. Mobile telephone use should be encouraged with cost reimbursements.

2.11 Last mile dissemination of disaster alerts and warnings should be well planned, with multiple redundant media and channels, ranging from cell broadcasts that will be limited to coverage areas of specific base stations to use of mosque loudspeakers and temple bells. Training, drills and community participation is crucial to the success of last mile dissemination.

2.12 It has been found that unsatisfactory financial arrangements, wherein dam operators supply valuable services but cannot recover their costs, contribute to the systemic problems of neglecting or postponing major and ongoing maintenance work. It is essential that some mechanism for reliable, predictable cost recovery that can be used for maintenance be devised and implemented.

2.13 The government should establish a regulatory body with dam safety as its primary objective, separate from and superior to, each of the entities currently owning, operating, or using dams. It should give priority to expertise and stakeholder consultation and be insulated from day-to-day political interference. In other words, it should be independent. The current difficulty of a lack of power over peer government agencies can only be resolved by placing the dam safety functions within an organization that is accountable to Parliament and is not under a specific Minister.

2.14 The Dam Hazard Unit (DHU), which contains specialized expertise on dam hazard detection and monitoring, can be placed within either the Public Utilities Commission, which already has some safety regulation functions, or the
The larger organization will give the necessary stature, authority and independence; the focused unit structure will allow the experts to conduct their business in a professional manner.

2.15 The removal of immediate dam safety responsibilities from the persons and organizations currently in charge of the reservoirs is not proposed in any way. Those who are closest to the potential hazard-generating structure and who have the best knowledge of it must continue to perform those functions. The mandate of the DHU will be explicitly limited to regulation, alternative dispute resolution and related practices to minimize and promptly resolve inter-agency disputes, and standard setting.

2.16 In order to enforce its directions and orders, the DHU and its parent should have the power to shut down structures that are judged to be dangerous, using carefully circumscribed procedures that allow for optimum publicity and which adhere to the principles of natural justice.

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Introduction and Rationale

3.1 In the horrific, destructive, and costly aftermath of the Indian Ocean tsunami of 26 December 2004, the realization of Sri Lanka’s need for a disaster-warning system has never been greater. However, the current preoccupation with tsunami fears has overshadowed other hazards, resulting in popular and political demands for ‘tsunami warnings.’ In light of Sri Lanka’s history of other natural disasters, it is critical to move away from popular fixation with tsunami threats, examine other existing and probable risks, and plan for the effective mitigation of possible disasters in these neglected areas.

3.2 Natural hazards come in various forms; an important distinction is the scale and origins of these hazards. Large hazards, such as major regional tsunamis, which originate in locations far removed from potentially threatened populations, will be sensed and reported in different ways than local hazards, like flash floods. Varied types of hazards are tracked differently, and present different scales of danger, in terms of both geographic area and numbers of people affected. Warnings for the various hazards must of necessity be targeted to the relevant areas and peoples for dissemination. It is of no use for Dry Zone farmers to receive warnings of landslides in Ratnapura. Calls for a Sri Lankan tsunami detection system are misguided in the light of the existing and emerging regional warnings centers. Sri Lankan resources should instead be directed towards effective all-hazard warning systems and preventing and mitigating locally-occurring as well as remotely-originated disasters.

3.3 This paper provides recommendations for comprehensive programs to increase dam safety in Sri Lanka. The urgent need for such programs was made clear during the development of a concept paper on an all-hazards warning system carried out by LIRNEasia and the Vanguard Foundation. Experts in the area of disaster prevention identified critical weaknesses in Sri Lanka’s dam safety protocols; it was learned that community activists in Gampola were taking action to raise awareness of potential disasters. In the recommendations of the NEWS:SL concept paper, LIRNEasia and Vanguard Foundation committed to develop a participatory concept paper on dam safety. The following paper is a key component of that process, presenting a basic analysis of the existing dam safety status in Sri Lanka, and making recommendations on interventions to improve these systems. It will form the basis of the town meetings to be conducted in Gampola, Kandy and Polonnaruwa.

3.4 The dam network in Sri Lanka comprises over 350 medium and large dams, and over 12,000 small dams. These structures vary in design, age, and construction. The earliest dam constructions in Sri Lanka are over 3000 years old. The renowned ancient civilizations were made possible by these constructions, which stood as testament to the ingenuity of engineers, the skill of builders, and the wealth and power of rulers.

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2 Presentation: “An overview of present dam safety management,” Ms Badra Kamaladasa, Deputy Director for Dam Safety, Department of Irrigation, 20 May 2005 Expert Consultation
3.5 Today, dams and their complementary structures shape Sri Lanka much as they did thousands of years ago. Most crucially, our dams supply irrigation water, electricity, and in some cases drinking water. The extensive irrigation systems fed by the dam network ensure water supplies for successful year-round paddy and other cultivation. Approximately 60% of CEB electricity is generated by hydroelectric dams.

3.6 Additionally, dam bunds are in use as roads and railways. The multiuse nature of dam structures highlights their importance as elements of the Sri Lankan economic, cultural, and physical landscape. However, the multiple demands on the system have resulted in a bureaucratic tangle of ownership, management, and authority.

3.7 The primary recommendations of this paper deal with institutional reforms. The current chain of institutional responsibility for Sri Lanka’s dams is complicated and ultimately ineffectual, which has in the past resulted in less than optimal functioning of the relevant agencies and the dams themselves. Maintenance, safety oversight, and proper usage rights are usually shared among several Ministries, Authorities, organizations, and informally stake holding nearby populations. This is natural given the multiple usages and demands placed on the dam system. However, there is a great need for better oversight of the dam system and the proper coordination of functions, especially related to safety.

3.8 The currently overcomplicated vestment and delegation of authority has resulted in several negative outcomes, notably, non-updating of and non-adherence to Standing Orders for maintenance and safety, minimal education for vulnerable populations on the risks and responsibilities of those living in the shadow of dams, and poor disaster management plans. Given the number and widespread distribution of dams in Sri Lanka, it is clear that the affected populations and sectors are many, and the effects of dam-related hazards far-reaching.

3.9 The tragic and costly Kantale tank bund breach of April 20th 1986 illustrates the far-reaching consequences of a recent massive dam disaster. 127 people were killed. Over ten thousand area residents were affected, with over a thousand homes destroyed or substantially damaged. Millions of rupees were spent to rebuild and rehabilitate the area. The breach was caused by the crumbling and collapse of one of the bund’s two sluices. The ancient masonry had experienced natural deterioration, probably accelerated by pile-driving associated with a water-supply pump house project. The disaster might have been prevented or mitigated had there been a unit in a position to carry out appropriate monitoring and warning procedures.

3.10 The creation of such an entity, called hereafter the dam hazards unit, is the central recommendation of this document. The institutional snarl around dam

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responsibilities and authority in Sri Lanka must be untangled in order to guard the safety and wellbeing of affected peoples, and to protect valuable public and private assets such as the dams themselves. In addition to proposing institutional reforms, this paper will suggest ways in which the current owner-operators may better manage and maintain the dams. A critical responsibility for the dam hazard unit will be the development of hazard-detection and warning systems.

3.11 The dam hazard unit can be aided in this dual role, dam safety monitoring and hazard planning oversight, by the use of information communications technologies (ICTs). These technologies, this paper proposes, can be employed to detect, predict, and avert dam hazards, to facilitate judicious decision-making by authorities, and to disseminate hazard warnings to threatened populations if necessary. Also, ICTs will be used by NEWS:SL and its designees to provide vectors for basic dam safety education for downstream stakeholders.

3.12 While this paper discusses advanced and emerging technologies relevant to the project herein outlined, the authors also wish to stress the importance of low-tech interventions in preserving the integrity of the dam system and the lives and assets of people living in dam watershed areas. All the stakeholders living near or using a dam system are variously responsible for their safety vis-à-vis the dam. Government authorities are of course the primary managers and decision-makers for the dams themselves, but the job of everyday custodianship extends to ordinary and casual users of the dams and tanks, from farmers who draw irrigation waters to tourism-oriented boat safari operators. The importance of dam and watershed education for the public cannot be overstressed.
Parameters of an Early Warning System

4.1 Warning systems typically include the installation of a range of instruments and technologies to ensure early detection and monitoring of hazards. They also include scientific and organizational capacity for analyzing the collected data to determine the extent of associated risk exposure, probable impacts, and processes for notifying those at risk in a timely fashion. For dam related hazards, these arrangements include the installation of sensors to measure seepage, movement, pore-pressure, moisture and temperature that provide around-the-clock, real-time data for detecting potential dam failures. The data from these sensors are the first components of an early warning system. By analyzing the sensor-data, dam engineers can predict the possibility of a dam breach and can set in motion relevant sequence of actions in the early warning system. If sensor data or visual detection warrant, alerts and warnings need to be issued on possible dam breach and flooding to those communities at risk. Warnings will trigger pre-determined sequence of actions at the local level that will lead to the safe evacuation of vulnerable downstream communities.

4.2 The objective of an early warning system is to prevent hazards (dam breach, overtopping) from becoming disasters (destruction of life and property). However, in order to achieve this objective various components of the warning system must work seamlessly. There are five inter-related components to a warning system:

- Hazard identification, risk assessment and vulnerability analysis
- Detection and monitoring
- Emergency management structure
- Local dissemination
- Public education

4.3 Unlike most hazards occurring in nature, dam related hazards can be prevented to an extent by proper maintenance and timely remedial action. It is imperative that dam operators in Sri Lanka implement the policies and procedures for effective dam safety management issued by the Dam Hazard Unit (DHU), a dam safety regulatory body.

4.4 Hazard Prevention-Dam Safety

4.4.1 A comprehensive program for dam safety will necessarily incorporate both hazard-prevention and hazard-mitigation procedures. These functions may be bundled together under a set of Standing Orders for monitoring, maintenance, notifications and warnings.

4.4.2 Monitoring: continuous surveillance of the dam structure and seepage by visual inspection, monitoring of sensor data, chemical analysis of seepage, seismic monitoring, and other.
4.4.3 **Risk assessment**: Periodic reviews of flood studies and inundation mapping.

4.4.4 **Remedial action**: Remedial work on dam so that it is in compliance with dam safety criteria and implementation of any statutory changes required by the DHU.

4.4.5 **Safe operation**: Keeping spillway channels free of debris, keeping bund free of trees & brushes, undertaking periodic maintenance of dam structure, keeping up-to-date manuals and procedures.

4.4.6 **Emergency management**: Planning for dam related hazards, maintaining hazard-management protocols, conducting emergency drills and ongoing personnel training.

4.5 The aim of any dam safety authority, like the DHU, will be to ensure that dam operators and owners have dam management procedures in place to minimize the possibility of dam-related hazards. However this body is additionally responsible for assuring that contingency plans and disaster-mitigation procedures are in place, in case a hazard does occur. The National Early Warning System provides the vector for warning dissemination and emergency plan implementation, as well

4.6 **Hazard identification**

4.6.1 People are not only recipients of warning messages from experts, they are also valuable sources of hazard detection information. Many hazard warnings, in fact, are triggered by affected local residents alerting families, neighbors and local officials. In the most recent major dam breach that occurred in Sri Lanka in 1986, villagers were the first to notice the breach in the bund and alerted the dam engineers, the military and downstream villages.

4.6.2 But in order to identify a dam related hazard in a timely manner, villagers living close to dams as well as dam inspection staff must be trained to look for early signs of a dam failure and identify it as a hazard. For example, unusually high water levels in the canals or muddy discharge from seepage may be indications of a potential hazard. The villagers must be informed on how to speedily get in touch with the relevant authorities when they identify a potential hazard.
4.7 Risk assessment and vulnerability analysis

4.7.1 In analyzing the risk levels around a possible dam hazard, two potentially opposing areas must be considered. In the event of even a minor dam failure, the initial and obvious threats are to the residents and property immediately downstream of the breached structure. The people, industry, and public infrastructure in the dam’s flood path are at the greatest risk of sustaining damage. Care should be taken to adequately educate these stakeholders on potential dangers and warn them in the event of a hazard.

4.7.2 In addition to the risks posed to the downstream environment by a potential dam hazard, there is also the risk that hazards can dramatically and expensively damage the breaching dam itself. Dams are costly and crucial public assets that require appropriate management and protection.

4.7.3 In the 1986 Kantale breach, the cost to the Government of rebuilding the breached section (LKR 186 million) was approximately three times the cost of all the Government’s relief,
rehabilitation, and re-housing expenditures for the affected downstream residents (LKR 65 million)\(^4\). These figures do not include the cost of rebuilding public properties and infrastructure, including schools, roads, railway lines, hospitals, government offices, and so forth.

4.7.4 From these figures it is concluded that the dam structure itself is expensively threatened by any kind of hazard related to its integrity. In other words, the consequences and costs of a breach multiply when the dam itself is at risk of major structural failure.

4.7.5 Risk assessment should thus weigh the costs and benefits of down-stream flooding versus the integrity of the dam structure itself. A minor, planned release of dammed waters may be better than a major inundation.

4.7.6 For example, it may be advisable in some cases to allow or create downstream flood conditions by opening dam sluices when a tank is overly full. The potential damage of minor flooding would in such a case be less than the risks of forcing the bund to hold more pressure than its designers intended. `Over-topping,' a type of breach resulting from a tank overflowing and/or washing away its dam, is an especially dangerous hazard for earth-bund embankment tanks of all sizes\(^5\).

4.7.7 In assessing the risks associated with a potential dam breach, the entire downstream network must be considered. The dam networks in Sri Lanka are sequentially situated along major watersheds. Because the flow from one dam fills the next, flooding waters from a higher dam may cause adverse consequences further down the cascade.

4.7.8 In a worst-case scenario, a major breach at one dam would cause a chain reaction cascading down the network. For this reason, detailed inundation plans and breach/flood scenarios should be part of any risk-reduction and disaster-management plan.

4.7.9 Professionally drawn and analyzed inundation plans are available for some of Sri Lanka’s larger dams. For most dams, no inundation plan or dam-break projection scenario is available. This


\(^5\) D W R Weerakoon, Former Director General of Irrigation and Secretary, Presidential Commission on the Kantale Dam Breach, 20 May 2005 Expert Consultation
represents a serious lack of disaster preparedness. Accurate disaster projections must be prepared\textsuperscript{6}.

4.7.10 A dam safety program should minimize the risk of dam failure. Risk is comprised of two elements, the likelihood (probability) of an event as compounded against the magnitude of the event's damages (consequences)\textsuperscript{7}. Risk is calculated with appropriate recognition of the various probability and consequences of different types of hazard.

4.7.11 Prevention strategies, like attentive operation and maintenance, reduce the probability of a dam failure. Mitigation strategies, like public warnings systems, reduce the consequences of a dam failure.

4.8 Detection and monitoring

4.8.1 The central element in a comprehensive public safety program is an accurate and reliable way of detecting hazards. In the realm of dam safety, hazard detection begins with comprehensive monitoring of the dam's physical integrity. Without this information there is no way to maintain or remediate potential flaws and failures in the structure.

4.8.2 An effective inspection/monitoring system must include the gathering of relevant data, to assure monitors of accurate safety status indications, and timely data gathering/sensing systems, to ensure that authorities have time to analyze data and issue warnings if necessary\textsuperscript{8}.

4.8.3 The Kantale tank bund had been "inspected" and found sound just six months previous to the catastrophic sluice failure\textsuperscript{9}. Though it is possible that all the deterioration leading up to the breach took

\textsuperscript{6} Comment, Mr. Dharmasena, Irrigation Department former Director, 20 May Expert Consultation

\textsuperscript{7} Presentation: "What are international best practices in dam safety?" Nimal Wickramaratne, Director, Headworks of the Mahaweli Authority, 20 May 2004 Expert Consultation

\textsuperscript{8} Presentation: "What are some innovative technologies for hazard detection in dams?" Tissa Illangasekare, AMAX Distinguished Chair of Environmental Science & Engineering & Professor of Civil Engineering; Director, Center for Experimental Study of Subsurface Environmental Processes (CESEP) Colorado School of Mines, USA &Anura Jayasumana, Professor of Electrical and Computer Engineering & Computer Science, Colorado State University, USA; 20 May Expert Consultation

\textsuperscript{9} p. 21, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987
place in the intervening six months, the Commission of Inquiry argues that the ancient sluice masonry had most likely deteriorated over the decades since the British restoration projects in the 1870s. The design of the sluice did not permit visual inspection of its interior and no mechanical means were used.

4.8.4 The November 1985 inspection noted the existence of potentially dangerous runnels on the downstream slope of the bund but failed to identify an existing weakness in the sluices. The sluice failure breach proved the inspection tragically insufficient as a safety protocol. An adequate inspection protocol must include appropriate, extensive, and accurate observations.

4.8.5 Routine inspections can and should include different types of observations. Observations are made via different sensing systems. At the high-tech extreme, one may use sophisticated systems to measure complex environmental factors and pressures within and around a dam structure. At the low-tech extreme, one may rely on the observation of potential dam related hazards by casual passersby.

4.8.6 Due to institutional failures, the monitoring of many dam structures has been left solely to visual inspection by dam engineers and untrained observers. The sluice disintegration at Kantale was first noted by a villager, who notified the resident Irrigation Engineer of unusually heavy flow from a sluice barrel. This villager was not a government employee but his action in warning the Irrigation Engineer is an excellent example of a successful low-tech hazard sensing system.

4.8.7 However, in the above case, the dam breach was a fait accompli when it was observed by the villager and the time frame between when the hazard was detected and developed into a disaster was

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11 Videoed interview of Mr Senawatta, Engineer in charge of the Kantale reservoir at the time of the breach, June 17th, 2005.

12 Presentation: “Nineteen years later, what lessons have been learnt from the Kantale breach (and what changes have been implemented)” D W R Weerakoon, Former Director General of Irrigation and Secretary, Presidential Commission on the Kantale Dam Breach, 20 May Expert Consultation

a small one. This increased the number of casualties and possibly property damage. Increasing the time lapse between hazard detection and the hazard event provides sufficient time to warn and evacuate vulnerable communities and to take mitigating actions (like opening spillways) to minimize property damage. Early detection of a potential dam hazard may result in remedial action that may even prevent the hazard event from occurring in the first place.

4.8.8 There are a number of different kinds of sensors that can be embedded in a dam that may provide information about a potential hazard long before it develops into a catastrophic event. Sensors that measure seepage, movement, pore-pressure, moisture and temperature, tiltometers etc. can provide around-the-clock, real-time data for detecting potential dam failures. These sensors can be networked and data sent remotely to computers. Computer-aided monitoring allows for continuous data collection, analysis, and archiving. These types of systems offer a great deal of flexibility in the proportion of human intervention necessary. It is possible to design a fully automatic integrated sensing and warning system.

4.8.9 Distributed sensing using optical fiber has been used in a number of dams in Sweden to measure seepage and pore pressure at frequent intervals along the dam structure. Since the reflection characteristics of laser light, traveling down an optical fiber, vary with temperature and strain, it is possible to discern changes in the reflection of the light and thereby variations in pressure and seepage.

4.8.10 Remotely installed sensors allow monitoring of difficult-to-access data (such as in areas that are underwater or underground). ‘Mote’ devices, tiny wireless network-forming sensor/transmitters, have been employed to monitor seismic activity and water quality. Motes can be embedded throughout the dam structure to measure relevant data and communicate the data between themselves and through a network to the local dam operators and to the DHU. Currently, these devices are relatively expensive for the sheer numbers required for an effective array, but in the coming years, they are expected to become so cheap as to be disposable.

14 http://www.sensornet.co.uk/industries/dams/DamMonitoringArticle.cfm

15 Presentation: “What are some innovative technologies for hazard detection in dams?” Tissa Illangasekare & Anura Jayasumana, 20 May Expert Consultation
4.8.11 Motes, optical fiber and other advanced technologies may prove to be key sensor infrastructure elements for monitoring dam safety by the DHU and the dam operators. In order to develop a better sense of the potential benefits of such systems and their comparative advantages, the deployment of a number of sensor technologies on an experimental basis on a few dams is proposed in Annex C.

4.9 Emergency management structure

4.9.1 Sophisticated hazard detection systems will come to naught in the absence of functioning institutions that can ensure that those technologies are kept operable, that can get warnings and alerts quickly to vulnerable communities and undertake necessary evacuations and mitigating actions. The governance and institutional features of an early warning system for dam related hazards are dealt with in greater detail in section 5.0. This section will focus primarily on the emergency management structure at the local level.

4.9.2 Currently, the status quo of under-prepared authorities has forced local populations to devise their own hazard-detection and safety strategies. Fearing a repetition of Kantale, for example, the villagers living immediately downstream of the Kotmale dam are apparently drawing up flood maps against the event of a breach. Because the appropriate authorities have given them little assurance that they are being looked after, the people are developing local safety protocols. In the presence of such active grassroots awareness, there is surely strong need to develop better official structures.

4.9.3 Sri Lanka has about 80 dams of significant size and thousands of smaller dams. The extent of inundation and the geographical impact of a dam breach will vary according to the size of the dam. In the case of dams with only local impact if breached, the dam sensor data will only need to go to the local dam engineer/dam operator. In the case of large dams, the sensor data will also need to go to the DHU that can coordinate a more region-wide response.

4.9.4 For the large number of dams that are of small size, the dissemination of alerts and warnings to the vulnerable communities is the responsibility of the local dam engineer/dam operator.

4.9.5 Established protocols must be in place to facilitate speedy and streamlined decision-making on the part of dam engineers and local authorities. If a dam related hazard has been detected, the dam operators should contact pre-designated emergency first
responders in the local government, community level organizations and the media.

4.9.6 The key first step in maintaining dam physical plants is monitoring and observation. Protocols for operation and maintenance must include updated standing orders designed to incorporate these functions.

4.9.7 Standing orders function as a contingency-based series of procedures to be followed normally if and when conditions and inspections warrant. That is, the orders will describe the normal operation and maintenance, inspection and monitoring practices, identification of problems, remedial steps to fix these problems, emergency actions, and disaster response practices.

4.9.8 Disaster management plans must be specifically drawn up according to the particular features of the dam and its watershed area. These plans must include orders as to what steps on-site personnel must take to notify superiors and warnings-disseminators.

4.9.9 Given that every dam is different and has varying surroundings, there can be no one-size-fits-all disaster plan. Still, the plans for different dams should be similar in their structure of authority and decision-making, such that the most qualified experts are able to assist in every situation.

4.9.10 Currently, each of Sri Lanka’s major dams has a Standing Orders protocol. Their presence has not prevented mismanagement and poor physical upkeep of the dams. The ongoing government de-prioritization of reservoir maintenance funding has resulted in shrinking Mahaweli Authority, Irrigation Department, and Ceylon Electricity Board budgets. Moreover, the funding actually received by these authorities is less than the promised allocations.

4.9.11 Adherence to strict maintenance schedules will prevent further deterioration requiring ultimately costlier work. Standing orders must be properly revised, updated, and followed. Without monitoring and maintaining the dam structures, one cannot reduce the risk of a disaster.

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16 Presentation: “An overview of present dam safety management,” Badra Kamaladasa, Deputy Director for Dam Safety, Department of Irrigation, 20 May 2005 Expert Consultation

17 boxed text p. 69-70, Central Bank of Sri Lanka Annual Report, 2004

18 Presentation: “What are international best practices in dam safety?” Nimal Wickramaratne, Director, Headworks of the Mahaweli Authority, 20 May 2004 Expert Consultation
4.9.12 The issuance of clear and unambiguous warning requires a dependable and known warning issuer. To create this public trust, the issuing agency must play a visibly dominant role in structuring safety programs and providing public information. For dam related hazards with only local impact the nodal warning agency will be physically located near the dam site. In the case of large dams with greater geographical impact, the warning function can be subsumed under the central early warning agency (NEWS:SL).

4.9.13 ICT infrastructure may need to be in place linking on-site dam staff, local authorities, the DHU, and the early-warning and disaster management agency.

4.10 Local dissemination

4.10.1 The “last mile” of an early warning system that takes the alerts and warnings to households in vulnerable towns and village is one of the most crucial links of the warning system. After a dam related hazard has been detected, warnings and alerts must be communicated to local authorities (police, fire services, municipality), to religious establishments (like temples and mosques), to community leaders (like grama sevakas, leadership of farmer organizations), to local, grass-roots organizations (like Sarvodaya) so that warning can be disseminated to every individual household at risk so that individuals can take necessary actions.

4.10.2 The local communication mechanisms used in the warning system may vary from village to town based on the level of economic development and socio-cultural factors. A combination of temple bells, mosque and church loud speakers, sirens, radios, TV sets, mobile phones maybe available. The warning system should take into account these variations and be tailored to the local conditions.

4.10.3 During the Kantale disaster, the Army and Police played a large role in warning and evacuating residents. Also, a mosque loudspeaker was used to broadcast warnings. These differing warning-dissemination vectors illustrate the effectiveness and necessity of redundant and varied strategies within a dissemination system.

4.10.4 The early responders of a hazard have to be equipped with basic communication capabilities, including some combination of fixed phones, mobile phones, and two-way radios. Internet access is

not available in most rural areas at this time, but as it becomes available it should be integrated into the communications plans. Additionally, there may be the possibility of utilizing communication channels used by the Ceylon Electricity Board for congestion-free emergency communications.  

4.10.5 Additional care must be taken in the structure of the emergency response communications network to protect it from congestion. It is most likely insufficient to use only the civilian/general communications networks because in the event of an emerging hazard the regular networks may be swamped with ordinary users trying to get information. Further, the physical communications infrastructure may be damaged by unfolding hazard conditions.

4.10.6 Though ideally there would be a dedicated, secure disaster communications network, this will take time to build. In the interim, it is essential that on-site monitors, dam authorities, and warning authorities have at least basic communications facilities. If there are at this date any outstation facilities with no phone or backup communications, they should be equipped immediately. Archaic and inappropriate government rules that penalize use of fixed telephones above a low threshold and do not allow for reimbursement of the costs of mobile service must be changed, at least with respect to persons with dam safety responsibilities. Given the wide availability and relative cheapness of mobile and fixed phone service, there is no excuse today for neglecting this aspect of disaster management.

4.10.7 The stark absence of communications facilities (and/or their poor functioning) has in the past resulted in severe failures to adequately contact and warn early responders and threatened populations. In 1986 the Kantale Irrigation Engineer had no telephone and thus was forced to physically drive to different locations to notify the Police, Army, and other affected authorities. It is impossible to know what deaths and damages could have been averted had better communications been in place. Today, the Kantale headworks engineering office is equipped with

\[\text{20} \text{ Comment 20 by Lakshitha Weerasinghe on 9 February 2005 at } \text{http://www.lirneasia.net/2005/02/tsunami-warning/} \]

\[\text{21} \text{ p. 35 NEWS:SL concept paper, Vanguard Foundation and LIRNEasia} \]

\[\text{22} \text{ the engineer in charge of the Kantale reservoir at the present time, stated that he and others on his staff use mobile telephones for dam safety related purposes, but have to pay for it out of their own pockets. He also stated that the fax machine at the Kantale office of the Irrigation Department is not operational because of problems in getting its repair authorized. Videoed interview, June 17th, 2005.} \]
telephones, but the phone lines are insufficiently manned especially during holidays.²³

4.10.8 Once a hazard is identified it is the responsibility of the dam owners and the local dam engineers to issue warnings and alerts. The warning must be communicated to the affected public. As a practical matter, the public warning-notifications system must be comprehensive and redundant such that vulnerable groups are assured of receiving clear messages.

4.10.9 Warnings and alerts, in addition to being clear, must be designed to elicit a proactive response among the threatened communities. The quality of a warning system is not only in its accuracy and timeliness but in its ability to provide the public with appropriate instructions on how to protect themselves.

4.10.10 These instructions will include specific information as to where the hazard is occurring, what threats the hazard includes (flood waters, landslides), what safe areas to evacuate to, when the dangerous period(s) are, and what steps will minimize threats to life and property. It is not sufficient to simply notify populations of existing or occurring threats. This final element of warning, instructions for protective measures, is necessary to give people the best chance of escaping serious harm. Information must also be provided when a warning or alert is lifted.

4.10.11 Though the use of television and radio broadcasting will be crucial to the warning-dissemination system, these warnings should be targeted specifically to areas affected. It is not efficient to have a general television broadcast of warnings. Resources would better be used in assuring that warnings reach threatened populations. For this reason it will be useful to investigate ways of targeting individual areas and/or districts with technologies like television, radio, and telephones.²⁴

4.10.12 According to 2004 survey data 74.9 per cent of Sri Lankan households have electricity; 78.3 per cent have a radio; 70.8 per cent have a TV set and 24.5 per cent have access to telecommunications in the home.²⁵ Thus in order to ensure that

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²³ video interviews Kantale residents, compiled by Divakar Goswami June 2005
²⁴ Para 2.25 of the NEWS:SL concept paper recommends action to enable remote access to specific retransmission towers so that localized warnings or alerts can be issued; or better still the licensing of low-power or community broadcasting stations. Para 2.28 recommends the use of cell broadcasts in mobile telephones, a congestion-free method of communicating to targeted areas.
²⁵ Central Bank of Sri Lanka, 2005, Special Statistical Appendix, Table 9, excluding three districts affected by the war.
warnings reach the maximum number of potentially affected people, there must be additional vectors for dissemination.

4.10.13 Multiple-media strategies should be employed, including targeted broadcasts via television, radio, and all types of phones; activation of dedicated sirens or alarms; announcements over local loudspeakers (e.g. at mosques and temples); and parties dispatched to carry out notification and evacuation, for example, Army and/or Police personnel in loudspeaker-equipped vehicles.

**4.11 Public education**

4.11.1 The public must be educated about the nature of hazards and their effects, who and what is at risk, how people will be warned, what the warnings mean and what actions must be taken. Warning systems must be tested regularly, both to ensure that the system works and that the public understands their purpose and messages.

4.11.2 The success of the dam safety program will depend in large part on the abilities of the public to respond appropriately to the all-hazards warning authority’s warnings, alerts and instructions, both in the case of a dam hazard and in the general and everyday use of dams and reservoirs. Local people and organizations have by far the greatest stake in, and thus the deepest motivation for, preserving the safety and utility of the dam and reservoir system. The all-hazard management authority should carry out dam-safety training programs for the affected segments of the public.

4.11.3 As discussed earlier, the dams and their attending structures provide numerous resources to the public, including electricity, irrigation waters, roadways, railways, fishing waters, space for bathing and washing, and various recreational and tourism related functions. Because the dams have obvious and high value to the (resident and non-resident) population, educational programs on dam safety and usage should be designed to create a sense of custodianship in the people.

4.11.4 These programs must provide the public with information as to both the normal functioning of the dam systems, including proper and safe use, and hazard-related information, including disaster-response practices.

4.11.5 These programs should instill in the population a sense of urgency and importance of the public role in utilizing and maintaining the dams. Basic management and safety practices can be shared with the public.
4.11.6 For example, the growth of large trees or bushes on earth dams can be destructive to the integrity of the bund. Roots may disrupt the earthworks, and jungle cover may obscure developing runnels or seepage problems. Local people can be employed formally or informally to control plant growth on bunds.

4.11.7 Another potential problem area is the bund-top roads. There is no consensus as to what exactly the safety standards, like vehicle size and speed, should apply to roads atop dams. They agree, however, that there is currently insufficient oversight of the loading and speed of vehicles over dams.

4.11.8 Dam authorities are currently unable to exercise effective oversight of activities of the types described above. Unauthorized construction and forestry projects are particularly hard to control.

4.11.9 Similarly, oversight of reservoir boating activities is almost nil. The waves created by high-speed boating activities may threaten damage to the dam structures. The appropriate standards must be devised in consultation with all relevant parties and uniformly enforced. Local populations must be educated about these risks.

4.11.10 Care must be taken in training to highlight the safety issues around small as well as large dams. Large dam breaches are obviously more catastrophic thus more attention-grabbing, but small dams too pose risks.

4.11.11 There are thousands of small dams in Sri Lanka, most of which are constructed and maintained with a minimum of government oversight. Local custodianship of these small dams is particularly crucial because centralized management is impractical.

4.11.12 Finally, safety training should include information on the warning signs of a potential hazard (e.g. seepage or overtopping) and, critically, directions as to how a local resident can contact the local dam operator and the central dam hazards unit. Local people, as in the example of the Kantale breach, are a valuable and effective link in the hazard-detection system.

4.11.13 The dam operators will thus need to be receptive of information coming from area residents. With effective training, local people

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27 This subject was the point of much discussion at the 20 May Expert Consultation.

28 Amarasekera, Irrigation Department, comment, 20 May Expert Consultation
can be valuable contributors to the dams’ maintenance and safety oversight.

4.11.14 Local organizations, notably farmers’ groups, may prove valuable advocates for and allies in the protection of dams. They often play influential roles in communities, and thus can help the dam authorities deliver their dam-safety training programs effectively.

4.11.15 Further, reputable local organizations can be given responsibilities in the custodianship of the dams and reservoirs, as with the above suggestion that locals maintain bund plant growth. If the dam operators can make clear the manifest value of the dam structures, they stand to benefit from a great deal of public support in their safety programs.
Institutional Governance

Status quo

5.1 Currently, responsibility for building, operating, and maintaining the medium- and large-sized dams of Sri Lanka resides with several governmental authorities. All dams are owned by government entities, and operated with government funds. Small dams and other 'tertiary irrigation infrastructure' are planned and built, with local input, by different government authorities; their operation and maintenance are then handed over to local Farmer Organizations.

5.2 The Mahaweli Authority of Sri Lanka, the Ceylon Electricity Board, and the Irrigation Department (reservoirs with an irrigable area over 200 acres) are the main actors with regard to the large dams. Other players include the Highway and Railway authorities, and the National Water Supply and Drainage Board. The Sri Lanka Committee on Large Dams has coordinating responsibility. The Provincial Councils, local government authorities, local/informal advocacy groups and farmer organizations are among those with an interest.

5.3 The jurisdiction and powers of the different government authorities in not well demarcated and is confusing. The different agencies have different organizational structures and management mechanisms. At the regional and national level, responsible oversight authority is in many cases unclear or absent.

5.4 The Mahaweli Authority of Sri Lanka (MASL), created in 1979, was responsible for the development of the Mahaweli river basin as a site of several large dams caching water for irrigation and power generation. Additionally, the MASL provided resettlement services for the population displaced by dam construction. With the conclusion of large-scale construction projects, the agency restructured itself into a watershed/river basin management agency.

5.5 The restructuring was marked by a shift in orientation from construction to management, with a particular focus on integrated water and natural resources management planning. Among the many dams owned and operated by the MASL are the largest and most spectacular dams in Sri Lanka, the Mahaweli high dams.

5.6 The Ceylon Electricity Board (CEB) is tasked, under the statutes of its creation, with responsibility "to construct, maintain and operate the necessary works for the generation of electricity." The CEB also transmits and distributes electricity. Hydroelectric dams are the main source of electricity generation.

5.7 Hydro generation is dependent on rainfall. Recent drought years, and their consequential electricity shortages, have impressed CEB officials with the need to diversify generation strategies. Even with thermal generation capacities doubling between 1996 and 2002, 61% of Sri Lanka's electricity is generated by hydroelectric dams.

5.8 Though the CEB owns and operates its hydro stations, it does not always control the supplies of water for electricity generation. Water disbursement is decided twice yearly by a multilateral meeting between officials of various agencies and
representatives of local interests, including agricultural officers and farmers’ organization leaders. The MASL and its officials are organizationally and literally the gatekeepers of Mahaweli-cached waters, and in a position to supply the CEB with its needed hydropower input.

5.9 The CEB is the only revenue-generating component of the dam system. As a government-owned monopoly it does not recoup all its costs: “in 2001, the average tariff (Rs 5.53 per unit) was kept below the average cost (Rs 7.20 per unit) resulting in losses of about Rs 12 billion for the CEB.” The actual costing of hydro power should be examined to ensure that depreciation and contributions to maintenance are included.

5.10 The current political dispute over CEB restructuring stems from the 2002 Electricity Reforms Act, which called for electricity sector restructuring, towards the goal of more stable electricity supply with reduced government subsidies. The Central Bank Annual Report for 2004 argues for exploitation of the CEB’s revenue-generating capabilities to fund dam management, including safety.

5.11 The CEB and the MASL were jointly responsible for the creation in 1998 of a National Dam Safety & Water Conservation Inspectorate. This entity works through a concurrent World Bank project in the Mahaweli Basin to address dam safety and water resources management needs. The CEB outsources the safety and maintenance oversight of its properties, while the MASL has operational centers at each dam as well as a system of independent inspections.

5.12 The third major player in dam oversight is the Irrigation Department, which is part of the Ministry of Agriculture, Livestock, Land, and Irrigation. This agency’s authority covers the whole country, including dams of reservoirs above a specified size and other irrigation infrastructure like canals. Most ancient and restored large earth dams are owned and operated by the Irrigation Department.

5.13 The Irrigation Department is divided into specialized divisions, which deal with different aspects of irrigation oversight, including a National Dam Safety Committee. Water storage and appropriate disbursement is the focus of the Irrigation Department’s activities. Thus the Department places emphasis on water conservation, as opposed to the CEB, for whom water is an input and not a product in and of itself.

5.14 The other agencies and organizations holding a stake in the management and ownership of dams are numerous. They include agencies that use dam-related assets for other purposes, such as the Road Development Authority (RDA), which use dam-tops for roads. Other organizations are concerned mainly with regulating the products of the dams, like the National Water Supply and Drainage Board, which includes dam safety procedures under its maintenance statutes.

5.15 Yet another group of parties has (sometimes critically demanding) economic agendas related to dam products and usage. This group includes Provincial and Municipal Councils, the Department of Agrarian Development, environmental and other advocacy groups, and farmer organizations. These agents may have little
power to control the dams or their products, but naturally have strong stakes in how the dams are managed.

5.16 The media, which periodically highlight issues of dam maintenance and safety, are seen as performing the role of a pseudo-regulator. The inspection that occurred prior to the Kantale dam breach was triggered by media coverage.

Financial issues

5.17 The Annual Report of the Central Bank of Sri Lanka (CBSL) (2004) states that a dam audit has identified numerous problems with the administration of Sri Lanka’s dams. The root cause of many of the problem areas—from poor maintenance schedules to human-resources mismanagement—was found to be a critical and ongoing shortage of funds. This finding was echoed by many of the participants at the 20 May Expert Consultation.

5.18 To implement a successful dam safety initiative, the agencies tasked with performing maintenance and safety functions must receive sufficient funding. The CBSL Annual Report suggests that additional and alternative sources of funding must be found because the government’s allocations for dam maintenance are insufficient.

5.19 The budgeted allocation for basic dam maintenance had been set at LKR 300m per year in 2004. This is deemed an appropriate baseline for routine maintenance; however, in this budget there is no provision for larger, longer-term repair projects such as must be undertaken every few years. Dam experts agree that modern dams are built for a period of 50 years. That means that the dam of the Senanayake Samudra, constructed on the early 1950s, is now due for major maintenance work that will cost multiple millions. There are no allocations in the current budget for these kinds of costs.

5.20 Amounts actually received fell short of the budgetary allocation, forcing the dam owners (primarily the MASL, CEB, and Irrigation Department) to prioritize more urgent maintenance projects and leave others pending. Postponement of needed maintenance may raise its eventual cost and unnecessarily increases the risk of structural failures.

5.21 The MASL is completely dependent on government funding. Water from the Mahaweli catchments is supplied free to the CEB for power generation and to farmers for irrigation purposes. Originally the Mahaweli scheme called for a graduated program of usage charges, whereby tariffs for irrigation waters would be phased in over a period of years. This system was oriented towards developing efficient irrigation practices among farmers, as well as sustainability. The tariff system was never devised or implemented, largely due to the political unpopularity of imposing irrigation charges on farmers.

5.22 The CEB likewise receives free water from Mahaweli sources. The MASL supplies the major input of the commodity’s production (dammed water), while the CEB draws revenues directly from the provision of a commodity (electricity). Because electricity-generating water is not monetized, the costs of MASL water storage
are thus not reflected in electricity pricing structures. The MASL is additionally unable to recoup its costs.

5.23 The dam owning-operating authorities are hamstrung by insufficient financial allocations and ever-diminishing budgets. The financial decision-making agents in the Government are not directly responsible for dam safety, and those responsible for dam safety are unable to secure needed funds. Thus the owner-operators are tasked with duties they cannot discharge.

5.24 In other countries dams may be privately or publicly owned, but usually the operating authority has the ability to generate revenues. It is highly desirable that the Sri Lankan dam authorities gain a measure of financial stability along these lines.

5.25 The Central Bank recommends several strategies by which the government could raise additional funds. A small increase in electricity tariffs (LKR 0.05 per unit) would pay for the annual LKR300m maintenance budget, thereby freeing up the current budgetary allocation for major repairs, employee and public trainings, safety sensing systems, and other critically needed items and programs.

5.26 The gradual introduction of irrigation tariffs, as initially planned under the Mahaweli scheme, would increase available funds as well as encouraging efficient resource usage. Other activities in and around the reservoirs, like commercial fishing and recreational/tourist usage, could be licensed under a safety program. Licensing these activities provides revenues as well as an opportunity to better regulate safe use of the dam/reservoir system.

5.27 It is highly doubtful that the dam authorities in Sri Lanka could function financially without government funding. It will be critical to assure that these agencies, and in particular a dam hazards unit, receive or generate sufficient funding to carry out needed maintenance and training programs. Money will additionally need to be spent on the development and implementation of a comprehensive warning system as outlined above.

5.28 Unless the government prioritizes dam safety and assures adequate funding, the dams will further deteriorate and their operating agencies will increasingly struggle to maintain them, provide services, and assure safety. A dam disaster will be inevitable.

Regulation and multi-party decision-making

5.29 The dam authorities in Sri Lanka are forced to compete with for priority in funding allocation and decision-making powers. There is no clear delegation of overarching authority by the government, making oversight only as effective as the leadership of the particular agency carrying it out.

5.30 The government must vest the powers of safety oversight with one unit. Powers and functions must be clearly demarcated. In the case of an interagency conflict, there must be clear procedures to resolve disputes and solve problems.
It is patently hazardous to neglect pressing maintenance, management, and usage issues as is the case now.

5.31 At present, dam safety functions are vested in agencies that are also operators. It is widely recognized that regulation and operation must be separate; and that regulation must be independent. The absence of a separate and independent regulatory body undermines the effectiveness of regulatory systems. When regulation is carried out by the owning-operating party, there is always a conflict of interest. The agency has no incentives to prioritize safety in its dams; it is treated as a peer by the other agencies is thus unable to perform its regulatory functions effectively.

5.32 In lieu of an effective and transparent regulatory system, the Sri Lankan media acts as a pseudo-regulator. Even this is ineffective; in November 1985, just six months before the disaster, the Dinarasa newspaper reported that the Kantale bund was in danger of breaching. The then-Director of Irrigation sent a Deputy Director to inspect the bund, who seems not to have inspected the upstream side of the bund, or the later-to-fail sluice barrel. In the same way, media have carried stories of a crack in the Kotmale dam, which appears to have resulted in slightly higher attention being paid to dam safety at this time.

5.33 In December 2003, the Ceylon Daily News warned that heavy vehicle traffic on the restored Kantale dam was endangering the integrity of the bund. The Secretary of the Ministry responsible for irrigation quickly responded with a letter stating that Irrigation Department and independent engineers had previously investigated the problem and declared such claims unfounded. Further, wrote the Ministry Secretary, the agency had instructed the Police to prevent high-speed traffic on the bund road.

5.34 Dam owner-operators are responsible for maintenance and safety procedures. They cannot however be relied upon to carry out extensive internal safety audits. A combination of internal and external monitoring is required. This would include frequent monitoring by operations staff, annual inspection by owner-employed qualified engineers, and periodic inspection by fully independent qualified engineers.

5.35 The logical conclusion is that government should establish a regulatory body with dam safety as its primary objective, separate from and superior to, each of the entities currently owning, operating, or using dams. It should give priority to expertise and stakeholder consultation and be insulated from day-to-day political interference. In other words, it should be independent. Independence requires that the constitution of its decision making board, the recruitment and discipline of its staff, and the overall conduct of its activities meet some minimum specified criteria. Independence also requires strict provisions for transparency and accountability. The current difficulty of a lack of power over peer government agencies can only be resolved by placing the dam safety functions within an organization that is accountable to Parliament and is not under a specific Minister.
5.36 The government need not create an entirely new agency to regulate dam safety. The DHU, which contains specialized expertise on dam hazard detection and monitoring, can be placed within either the Public Utilities Commission, which already has some safety regulation functions (for the electricity network), or the proposed NEWS:SL national early warning system. The larger organization will give the necessary stature, authority and independence; the focused unit structure will allow the experts to conduct their business in a professional manner.

5.37 The organizations described above contain several units already pursuing dam safety agendas. The DHU can be staffed by drawing from one or more of these entities.

5.38 It will be necessary to enact legislation to give effect to the proposals contained herein. The PUCSL Act envisages that Commission’s general powers will be supplemented by industry specific acts (e.g., the Electricity Reforms Act, No 28 of 2002). Since the NEWS:SL agency has not been created, it may be possible to include Dam Safety as a chapter in the main statute, or preferably, design that Act in the same modular form as the PUCSL Act, and link the Dam Safety Act to it.

5.39 It must be emphasized that the removal of immediate dam safety responsibilities from the persons and organizations currently in charge of the reservoirs is not proposed in any way. Those who are closest to the potential hazard-generating structure and who have the best knowledge of it must continue to perform those functions. What is proposed is not a central dam safety authority, but a central entity responsible for setting standards on dam safety and enforcing them without fear or favor. The DHU will contain the country's best expertise on dam safety and it will have a mandate to continually seek out and apply knowledge on international best practices in this field. This means that it will be the natural place to go when anyone, including the persons in charge of the dams, need advice and assistance. The mandate of the DHU will be explicitly limited to regulation. The relationship between the current dam operators and the DHU will be similar to that between a telecom or electricity operator and the relevant regulatory body. The regulatory body does not interfere in or usurp the everyday managerial functions of the dam operators. It gives directions on dam safety, leaving the details of implementation to the operators. It will specify, and enforce, periodic internal and external audits. It may conduct public hearings, investigations, or it may direct that investigations be conducted by the operators. It may provide expert advice and training.

5.40 In the same way that large operators with market power are treated differently from small operators in telecom and electricity regulation, it will be necessary to impose differential regulatory burden on the operators of large dams with major hazard potential (e.g., the Mahaweli high dams) and the thousands of minor irrigation works under the Department of Agrarian Services.

5.41 Given the multi-use characteristics of dams and reservoirs, disputes between different users and agencies will be unavoidable. The legislation should include
provisions for alternative dispute resolution by the DHU and its parent body so that these disputes can be resolved speedily. Ideally, the DHU will promote decision making procedures that will minimize the occurrence of disputes (known in the regulatory field as “alternative regulatory practices”).

5.42 It is well known that simply giving an agency the power to issue directions is not enough. It must have the ability to follow through in the event of non-compliance. In the case of infrastructure regulation, regulatory agencies are given carefully circumscribed powers to compel regulated entities to follow directions. The DHU and its parent organization should also be given such powers.

5.43 The facts that most if not all operators do not directly earn revenues from the operation of the dams and that all the dams in Sri Lanka are owned and operated by government entities pose a special challenge with regard to enforcement of orders and directions. Conventional infrastructure regulation assumes that the regulated entities earn revenues and do not wish to be deprived of those revenues. Therefore, enforcement rests on penalties and levies. Conventional regulation further assumes that the payment penalties and levies will actually hurt the operator and the management. In the case of fully government owned operators this assumption does not hold. If the regulator takes away a portion of the revenue of the government-owned operator, its management can simply ask the government to replenish its funds or can engage in some form of investment or service-provision “strike,” postponing or reducing investments or service provision to make up for the lost revenues.

5.44 Additional creative solutions may be devised in the course of the consultation, but at this point the only feasible solution appears to be to give the DHU and its parent the power to shut down structures that are judged to be dangerous, again using carefully circumscribed procedures that allow for optimum publicity and which adhere to the principles of natural justice. Assume that it is found that a certain dam is found to be a potential hazard. Directions are given to prevent or mitigate the hazard. For whatever reason, possibly because of a lack of funds, the prescribed actions are not taken. Because it is pointless to fine a non-revenue generating entity that is in any case short of funds, the solution would be to order a gradual emptying of the reservoir to the level that it ceases to be a potential hazard. The question can be asked about getting this order enforced. If the first order was disobeyed, why will the second order be obeyed? The answer is publicity. It will be difficult for a government owned dam operator to justify the continuance of the public hazard. On the other hand, the publicity and the threat of closure will strengthen the hand of the dam operator against the government in obtaining the necessary resources. For example, the farmers who will be deprived of irrigation water may take to the streets seeking resources to prevent the closure of the reservoir. The objective, it must be recognized, is not to close dams or punish operators, but to ensure safety. Therefore, the closure powers must be used very sparingly and with as many opportunities as possible for remediation of the problem and the avoidance of the penalty.
5.45 As a regulatory body, the DHU and its parent are responsible only for safety oversight of the dam and watershed system. It is not responsible for dam management and thus will not directly implement the safety programs outlined above. The unit will have the technical expertise and funding to aid operators in proactively developing these programs; however, implementation is ultimately the responsibility of the operators. Because the unit’s primary responsibility is regulation, it will deal only with the heads of the operators or nominees on specific issues. It will keep scrupulously clear from second-guessing managers.
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Annexes:
Concept Paper for a Dam-related Hazard Warning System in Sri Lanka
A Participatory Study on Actions Required to Avoid and Mitigate Dam Disasters

Annex 1 Consultation Process Input* _________________________ 1
Annex 2 Expert Consultation Agenda__________________________ 6
Annex 3 Pilot Study Proposal_________________________________ 7
## Annex 1  Consultation Process Input*

<table>
<thead>
<tr>
<th>Comment/Suggestion and Source</th>
<th>Response</th>
<th>Explanation</th>
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<tbody>
<tr>
<td><strong>Governance</strong></td>
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<tr>
<td>One agency should be entrusted with dam oversight.</td>
<td>Accepted with caveat</td>
<td>The agency must not, for reasons of potential interference, be involved in owning/operating dams.</td>
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<tr>
<td>???, Irrigation Department</td>
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<td>Attempts in the past to create legislation have not progressed past legal drafts stage.</td>
<td>Acknowledged</td>
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<td>Mr de Silva?, speaker #2 in open forum</td>
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<tr>
<td>In the past steps have been taken by a Presidential Commission toward establishing a regulatory body.</td>
<td>Acknowledged</td>
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<tr>
<td>KSR de Silva, Director General of Irrigation &amp; President, Sri Lanka National Committee on Large Dams</td>
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<tr>
<td>We need to pass and implement a Dams and Reservoir Safety Act.</td>
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<td>???, 4th speaker, 2nd presentation</td>
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<tr>
<td>Though the owner and operator may be different entities (GoSL vs. Mahaweli Authority), the dam oversight is nil. There is no regulation therefore no best practices are implemented in Sri Lanka.</td>
<td>Accepted</td>
<td></td>
</tr>
<tr>
<td>Nimal Wickremaratne, Sri Lanka Committee on Large Dams</td>
<td></td>
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</tr>
<tr>
<td>We need a regulatory body under government, not with the owners. New dam plans, safety, and environmental clearances should be sought through this entity.</td>
<td>Accepted</td>
<td></td>
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<tr>
<td>???, speaker #9 open forum (lady!)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>There are many factors beyond the control of owner/operators. Several of these are political. These entities will have to work in collaboration with government institutions and law enforcers.</td>
<td>Accepted</td>
<td></td>
</tr>
<tr>
<td>Mr. Amarasekere, Irrigation Department</td>
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<td></td>
</tr>
<tr>
<td>In other countries, for advice/authority for technical matters in this area, Institution of Engineers and National Committees of Large Dams are the accepted widely. But I am not sure in Sri Lanka how matured they are to take up that role.</td>
<td>Acknowledged</td>
<td></td>
</tr>
<tr>
<td>Badra Kamaladasa, Deputy Director (Dam Safety), Department of Irrigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All roadways above or over major dams should</td>
<td>Not accepted; should be left</td>
<td>The concept of an oversight mechanism, the DHU, is</td>
</tr>
</tbody>
</table>

* This is a preliminary draft. We intend to insert the correct names and designations of the speakers, after having someone from the Irrigation Department go over the tapes. If any reader can assist, particularly with regard to their own comments, we shall be grateful.
Annexes: Concept Paper for a Dam-related Hazard Warning System in Sri Lanka

-INTERIM ONLY-

**be owned and operated by the Irrigation Dept.**

M. Amarasekere, Irrigation Department

**to proposed process**

larger than the specific issue of roads.

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### ICTs

New technology hasn’t come into this field of observation and safety monitoring as much as it should. There is a lot of potential in applications for warning communication, risk management, etc.

*Mr Jayatilake, former Irrigation Board Director*

**Accepted**

Laser scanning technology would be key in producing good inundation maps.

*Nimal Wickremaratne, Sri Lanka Committee on Large Dams*

**Acknowledged**

We must consider the cost of new technologies in the context of a developing country.

??, Sinhala, speaker #1 presentation #4

**Accepted**

Motes are not a very expensive technology and are going to get cheaper very quickly.

*Anura Jayasumana, Professor of Electrical and Computer Engineering & Computer Science, Colorado State University, USA*

**Acknowledged** Useful in long-term planning.

Must consider whether mote technology can be supported with existing ICT capacity, including internet coverage, bandwidth, and power.

*Divakar Goswami, LIRNesia*

**Acknowledged** Useful in long-term planning.

Several dams already have sensors, most of which are not working. Given that there are already problems with maintenance of sensing and other infrastructure, we should focus our resources on these already-costly problem areas.

*Mr Dharmasena, former director, Irrigation Board*

**Partially agree, but...** As technology progresses, costly maintenance of old technology becomes moot. With small cheap items like motes there is no need to maintain extant sensors, one replaces components.

**Acknowledged**

There are potential mote applications for landslides as well, as the sensors can monitor pressure and temperature.

*Anura Jayasumana, Professor of Electrical and Computer Engineering & Computer Science, Colorado State University, USA*

**Acknowledged**

Some notes on motes: the battery can use solar power or bridge vibration-charging in Sri Lanka; an advantage is that there is no required infrastructure, because they are wireless; they are capable of some data processing and so do not simply relate data back to centre.

*Anura Jayasumana, Professor of Electrical and Computer Engineering & Computer Science, Colorado State University, USA*

**Acknowledged**

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### Technical Problems

Roadways upon bunds, in particular the Kantale bund, are heavily loaded and speed limits not always observed. This needs to be further

*The DHU shall be responsible for making sure that these studies are*

**Acknowledged**
<table>
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<th>Annexes: Concept Paper for a Dam-related Hazard Warning System in Sri Lanka</th>
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<tr>
<th>studied.</th>
<th>carried out.</th>
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<tbody>
<tr>
<td>Mr Dharmasena, former director, Irrigation Department</td>
<td></td>
</tr>
<tr>
<td>Especially with masonry structures of old/ancient dams, the road-loading must be analyzed as mortar may lose strength over time due to vibrations. Mr Sabanda?, CCT? (2nd speaker open forum)</td>
<td>Unclear at this time; too detailed for present report</td>
</tr>
<tr>
<td>If the road surface is unaffected, the below-ground state of the dam should be safe. KSR de Silva, Director General of Irrigation &amp; President, Sri Lanka National Committee on Large Dams</td>
<td>Unclear at this time; too detailed for present report</td>
</tr>
<tr>
<td>The presence of snakes and other physical impediments makes it difficult to survey and monitor dam works especially with ancient and restored bunds ??, Irrigation Department</td>
<td>Accepted</td>
</tr>
<tr>
<td>Field staff of dam sites may inappropriately take holidays. The Kantale staff at the time of the breach may have been off celebrating Avurudhu. Adequate staff levels must be maintained. ??, Irrigation Department</td>
<td>Accepted</td>
</tr>
<tr>
<td>Necessary to update ancient dams with modern technology. DWR Weerakoon, former Director, Irrigation Board</td>
<td>Partially accepted</td>
</tr>
<tr>
<td>The tension of the cables on Kotmale dam was never checked until 3 years ago; not sure if it has now been checked. Mr. Harinanda, former CEB ??</td>
<td>Acknowledged</td>
</tr>
<tr>
<td>Automated systems dealing with water levels and sluice opening mechanisms are not set to proper automation guidelines. Nimal Wickremeratne, Director, Headworks of the Mahaweli Authority</td>
<td>Acknowledged</td>
</tr>
<tr>
<td>Dams may be hydraulically imbalanced, with spillways designed unrealistically with respect to flooding. There have been cases of flooding due to wrong operation of reservoir gates. Mr Dharmasena, former director, Irrigation Department</td>
<td>Acknowledged</td>
</tr>
<tr>
<td>Concrete aging is a major safety problem. At some dams it is possible to clearly see the deterioration that has taken place. ??, Irrigation Board (speaker #4, open forum)</td>
<td>Acknowledged</td>
</tr>
<tr>
<td>Because modern and ancient dams are structurally different (modern being from about 25 years ago), may need to use different systems to monitor them ??, speaker #7 open forum</td>
<td>Partially accepted, but…</td>
</tr>
<tr>
<td>As engineers we should be able to assess risk</td>
<td>Acknowledged</td>
</tr>
</tbody>
</table>
within calculable parameters, notably the bund-road loading problems.

*Mr Amaresekera, Irrigation Board*

Kantale heavy traffic diversion project is underway, including the installation of vibration-measuring sensors on the current road.

*KSR de Silva, Director General of Irrigation & President, Sri Lanka National Committee on Large Dams*

<table>
<thead>
<tr>
<th><strong>Disaster Preparedness</strong></th>
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<tbody>
<tr>
<td>Confidential analysis of the dam break possibilities a must. With publicity, the area residents will needlessly scare population.</td>
</tr>
<tr>
<td><em>Mr Dharmasena, Irrigation Board</em></td>
</tr>
<tr>
<td><strong>Partially agree, but...</strong></td>
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</tbody>
</table>

Confidentiality is questionable; the public has the right to know answers to these queries and locals are also already preparing their own inundation plans, e.g.

The owner of each dam should prepare built drawings as part of their standard operations documentation (standing orders).

??, consultation; responder # 5 in presentation #2

**Accepted**

Need to make provisional councils aware of their dam safety obligations. Dam owners are supposed to supply local councils with safety reports.

*Mr Harinanda (?), former CEB*

**Accepted**

Minimum forces dam-break analysis should be done especially for small dams, given that earthquakes were not considered a threat at the time many of them were designed.

??, speaker #9 open forum (lady)

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<th><strong>Acknowledged</strong></th>
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The DHU shall be responsible for making sure these studies are carried out.

It is necessary to carry out dam break analysis, especially for Kotmale and Victoria dams. Wide publicity will create panic in people, but it needs to be done.

*Mr. Dharmasena, Irrigation Board*

**Accepted**

1:10000 map analysis has been done on Mahaweli areas. If we have the maps, then we can prepare better inundation projections. We need detailed topographic info to do this. Currently no capacity to carry out flood damage parameters map.

*Nimal Wickremeratne, Director, Headworks of the Mahaweli Authority*

**Acknowledged**

Flood protection should not be left out of the hazard-management scheme.

**Accepted**
### Annexes: Concept Paper for a Dam-related Hazard Warning System in Sri Lanka

- **DWR Weerakoon, former director, Irrigation Board**

  The World Bank funded a dam safety project 1 year ago in which preliminary dam break analysis has been done. But *detailed* dam break analysis has to be done.

  **Acknowledged**

  The DHU shall be responsible for making sure these studies are carried out.

- **Mr de Silva, Director General, Irrigation Board**

  Safety is essentially a question of dam structure preservation but ultimately is for the benefit of people.

  **Accepted**

  We must also identify other disasters that would affect dams, e.g. earthquakes.

  **Accepted**

- **??, 4th speaker, 2nd presentation**

  Prevention is better than cure. Serious damage had been caused by paddy cultivators’ usages, which government could be quicker to control.

  **Accepted**

- **Mr Amaresekera, Irrigation Board**

  Tsunami not the only type of disaster to be worried over; there is greater chance of earthquakes from now on. Floods and landslides remain a threat.

  **Accepted**

- **Mr Dharmasena, former director, Irrigation Department**

  Acknowledged

  The DHU shall be responsible for making sure these studies are carried out.
## Annex 2  Expert Consultation Agenda

Expert Consultation on Early Warning System for Dam Related Hazards  
Distance Learning Centre, SLIDA Premises, May 20th, 2005

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Moderator/Speaker</th>
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<tbody>
<tr>
<td>9.00-9.30</td>
<td>Arrival of participants and tea</td>
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<tr>
<td>9.30-9.45</td>
<td>Welcome and introduction</td>
<td>Rohan Samarajiva, Executive Director, LIRNEasia and Director, Vanguard Foundation</td>
</tr>
<tr>
<td>9.45-10.00</td>
<td>Presentation: Nineteen years later, what lessons have been learnt from the Kantale breach (and what changes have been implemented)? Discussion</td>
<td>D W R Weerakoon, Former Director General of Irrigation and Secretary, Presidential Commission on the Kantale Dam Breach</td>
</tr>
<tr>
<td>10.00-10.30</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>10.30-10.45</td>
<td>Presentation: What are international best practices in dam safety?</td>
<td>Nimal Wickramaratne, Director, Headworks of the Mahaweli Authority</td>
</tr>
<tr>
<td>10.45-11.15</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15-11.30</td>
<td>Presentation: Current situation of dam management in Sri Lanka</td>
<td>Badra Kamaladasa, Deputy Director (Dam Safety), Department of Irrigation</td>
</tr>
<tr>
<td>11:30-11:45</td>
<td>Presentation: What are some innovative technologies for hazard detection in dams?</td>
<td>Tissa Illangasekare, AMAX Distinguished Chair of Environmental Science &amp; Engineering &amp; Professor of Civil Engineering; Director, Center for Experimental Study of Subsurface Environmental Processes (CESEP) Colorado School of Mines, USA &amp; Anura Jayasumana, Professor of Electrical and Computer Engineering &amp; Computer Science, Colorado State University, USA</td>
</tr>
<tr>
<td>11:45-12:15</td>
<td>Discussion</td>
<td></td>
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<tr>
<td>12:15-12:35</td>
<td>Open Forum</td>
<td>Chaired by: K.S.R. De Silva, Director General of Irrigation &amp; President, Sri Lanka National Committee on Large Dams</td>
</tr>
<tr>
<td>12:35-12:45</td>
<td>Summary and conclusion</td>
<td>Rohan Samarajiva, Executive Director, LIRNEasia &amp; Director, Vanguard Foundation</td>
</tr>
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</table>
Annex 3  

Pilot Study Proposal

Deployment of sensor technologies for detection of dam related hazards-Pilot Study

Goal: Investigate feasibility and effectiveness of various sensor technologies for hazard detection on two Sri Lankan dams.

Rationale: The primary, and in the case of Sri Lanka, the sole mechanism for monitoring and detecting potential dam related hazards is by visual inspection\(^29\). Although regular, visual examination by dam inspectors is necessary, structural deterioration of a dam may not be visible to human eyes until it is too late. For example, the Southern California St Francis dam, which catastrophically failed in 1928, was inspected and found safe only twelve hours before breaching. Closer to home, the Kantale dam failed six months after a complete and satisfactory safety inspection.

Sensor technologies increase the time lapse between hazard detection and the hazard event and make hazard prevention and mitigation more likely. It may provide sufficient time to not only warn and evacuate vulnerable communities but also in some cases allow for remedial action to be undertaken that may prevent the hazard event from occurring in the first place. ICTs enable the sensor data to be communicated to the dam operator and to various relevant bodies creating redundancies and safeguards. It is possible to design a fully integrated sensing and warning system linked to computers that can automate routine monitoring tasks.

While recognizing the costs and maintenance implications of state-of-the-art dam hazard detection and monitoring equipment, it is suggested that it may be worthwhile to conduct at least one pilot project using advanced dam hazard detection and monitoring equipment coupled with advanced information and communication technologies. This study would be carried out using external funding, and shall include implementation on one earth dam and one modern concrete dam.

Methodology: Sensors have at least two components—the “sensing” component that measures changes in the physical environment and the communication component that transforms sensory information into data and transmits it to other sensors and/or to a communication network. “Motes” are an example of such a device that can bear tiny sensing equipment and

\(^{29}\) One exception is the dam at Lunugamvehera, one of the most recent large dams, where pressure gauges have been installed, but these have not been maintained in optimal condition subsequently.
transmit various types of information among spontaneously aggregated wireless networks. That is, motes can “talk amongst themselves” when placed within broadcast range of other motes. Sensors can measure moisture, pressure and temperature among other environmental data. Sri Lankan dam engineers are in the best position to select the kinds of sensors that would be required for deploying an effective hazard detection system suited to the local conditions. It is proposed that the selected sensors be deployed in two kinds of dams that have different physical characteristics. Sri Lanka has a number of large concrete dams and thousands of earthen dams. For this project, sensors can be deployed on both types of dam structures to assess their effectiveness.

The data from the sensors can be transmitted using appropriate ICT networks to a central records station and to the dam control room located physically at the dam site. Data sent to a central station can be analyzed by computers and only flagged for attention of human dam safety experts when sensor data indicate potential hazards or anomalies. The data sent to the dam control room can be analyzed by a dam engineer.

**Outcomes:** Besides providing valuable information about the real status of the studied dams, this project will substantiate and elaborate on the various benefits of this cutting-edge technology of sensor networks. The pilot project will enable the evaluation of different kinds of sensor technologies and their effectiveness as one component of the early warning system. Potentially the pilot study may provide the template for an exportable technology/system, marketable to other dam safety oversight agencies.