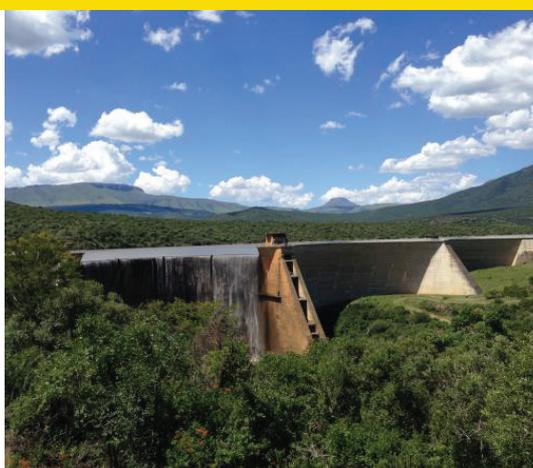
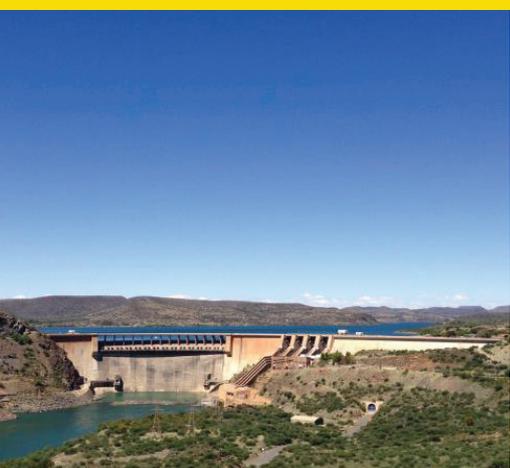




84th ICOLD ANNUAL MEETING



Proceedings of the
International Symposium on
***“Appropriate technology to ensure
proper Development, Operation
and Maintenance of Dams
in Developing Countries”***



18 May 2016
Johannesburg, South Africa



Proceedings of the
International Symposium on
***“Appropriate technology to ensure
proper Development, Operation and
Maintenance of Dams in Developing
Countries”***

Johannesburg, South Africa, 18 May 2016

Organised as part of the 84th ICOLD Annual Meeting,
Johannesburg, South Africa, 15 to 20 May 2016.

The information contained in this publication regarding commercial projects or firms may not be used for advertising or promotional purposes and may not be construed as an endorsement of any product or firm by the South African National Committee on Large Dams (SANCOLD). SANCOLD accepts no responsibility for the statements made or the opinions expressed in this publication.

Copyright © 2016 South African National Committee on Large Dams (SANCOLD)

ISBN 978-0-620-71042-8

South African National Committee on Large Dams (SANCOLD)
PostNet Suite, #498
Private Bag X025
Lynnwood Ridge
Pretoria, 0040, South Africa
secretary@sancold.org.za
www.sancold.org.za

Symposium organisation

Editor

Louis Hattingh

Secretariat

Louis Hattingh

Paul Roberts

Paul Vinagre

Review panel

Mr Michael Abebe (Ethiopia)
Prof Mark Alexander (South Africa)
Ms Henriette Anderson (South Africa)
Dr George Annandale (USA)
Ms Ilse Aucamp (South Africa)
Mr Christian Auel (Japan)
Dr Markus Aufleger (Germany)
Mr Danie Badenhorst (South Africa)
Dr Gerrit Basson (South Africa)
Mr Andrea Baumer (Switzerland)
Mr Johan Beukes (South Africa)
Ms Michelle Blaeser (South Africa)
Ms Terry Calmeyer (South Africa)
Mr David Cameron-Ellis (South Africa)
Dr Robin Charlwood (USA)
Dr Pierre Choquet (Canada)
Dr Ahmed Chraibi (Morocco)
Mr Bertrand Collet (South Africa)
Mr Ross Cooper (South Africa)
Mr Andrew Copeland (South Africa)
Mr Gerald de Jager (South Africa)
Dr Manuel Gomez de Membrillera Ortuño (Spain)
Dr Michael Detering (Germany)
Prof Ignacio Escuder Bueno (Spain)
Mr Jurgen Fleitz (Spain)
Mr Leon Furstenburg (South Africa)
Prof André Gorgens (South Africa)
Mr Duncan Grant-Stuart (South Africa)
Mr Thierry Guilloteau (France)
Mr DJ Hagen (South Africa)
Mr Louis Hattingh (South Africa)
Mr Dieter Heinsohn (South Africa)
Dr Andy Hughes (UK)
Dr Sam Johansson (Sweden)
Dr Andrzej Kijko (South Africa)
Mr Helmut Knoblauch (Austria)
Mr Johan Koekemoer (South Africa)
Mr Ian Landon-Jones (Australia)
Dr Aldu le Grange (South Africa)
Mr Stephen Mallory (South Africa)
Dr Peter Mason (UK)
Dr Ronnie McKenzie (South Africa)
Mr Andre Mostert (Namibia)
Mr Dawid Mouton (South Africa)
Dr Laurent Mouvet (Switzerland)
Prof Pilate Moyo (South Africa)
Mr Chris Muir (Namibia)
Ms Kogi Naidoo (South Africa)
Mr Jan Nortje (South Africa)
Dr Chris Oosthuizen (South Africa)
Dr George Papageorgiou (South Africa)
Dr Alan Parrock (South Africa)
Dr Alejandro Pujol (Argentina)
Mr Peter Pyke (South Africa)
Dr Paul Roberts (South Africa)
Dr Tendai Sawunyana (South Africa)
Mr Ivor Segers (South Africa)
Dr Mike Shand (South Africa)
Dr Quentin Shaw (South Africa)
Mr Frezer Shiferaw (Ethiopia)
Mr Jay Stateler (USA)
Mr Gawie Steyn (South Africa)
Mr T Sumi (Japan)
Mr Martin Teal (USA)
Mr Tente Tente (Lesotho)
Dr Michel Tremblay (Canada)
Ms Mari Trumpelmann (South Africa)
Mr Leo van den Berg (South Africa)
Mr Danie van der Spuy (South Africa)
Mr Walther van der Westhuizen (South Africa)
Mr Marco van Dijk (South Africa)
Mr Pieter van Rooyen (South Africa)
Dr Martin van Veelen (South Africa)
Mr Dawid van Wyk (South Africa)
Mr John Wates (South Africa)
Dr Pieter Wessels (South Africa)
Mr Henry-John Wright (South Africa)

Foreword

From the Chairperson of the Local Organising Committee of ICOLD 2016 and Chairperson of the South African National Committee on Large Dams (SANCOLD)

We are extremely happy that this ICOLD Symposium was staged in South Africa as part of the 84th ICOLD Annual Meeting held in Johannesburg in May 2016.

Sunny South Africa is known:

- for its friendly “rainbow” nation as demonstrated during the highly successful 2010 Soccer World Cup event;
- for its beautiful scenery with the Big Five animals in our National and Private Game Parks, the Drakensberg Mountains with its Lesotho Highlands dams and Cape Town with its world heritage site Table Mountain;
- to have 5 030 registered dams of which more than 1 114 are large dams;
- for contributing significantly since 1965 to ICOLD and Africa regarding development of the art and science of dam engineering.

Our SANCOLD Local Organising Committee worked very hard to ensure that this event was well organised, had a high technical content and could provide a forum to experience Africa.

This Symposium reflects much of local, regional and international experience with dams with an emphasis on the developing Africa. The keen interest we received from authors reflects that the subject matter is apt and we hope that these Proceedings together with the delivered Symposium Presentations will form a valuable resource for the future of dams throughout the world.

DBBadenhorst

Danie Badenhorst
Chairperson of the Local Organising Committee of ICOLD 2016
Chairperson of SANCOLD



Preface

Not only do many countries in Africa and other developing countries still require major water resources and dam engineering development for both water and energy supply but these countries also experience problems with proper long term operation and maintenance of their existing infrastructure. These problems in many cases lead to unsafe and unsustainable conditions that negatively impacts on the surrounding communities as well as the environment.

To try and mitigate this and share the some of the collective wisdom and knowledge available in the larger ICOLD family it was decided have organise an International Symposium titled “Appropriate technology to ensure proper Development, Operation and Maintenance of Dams in Developing Countries” to address some of these issues, in conjunction with the 84st Annual Meeting of the International Commission on Large Dams (ICOLD). The ICOLD Meeting host, the South African National Committee on Large Dams (SANCOLD), organized the Symposium.

These Proceedings contain papers on 9 different themes. Before the Symposium call for papers, 8 different themes were identified as appropriate. A number of relevant abstracts that satisfied the main theme but that did not necessarily satisfied any of the 8 chosen themes were received and subsequently categorised under a theme called “Other”. The 9 themes for the Symposium therefore are:

- 1) Social and environmental impacts and mitigation measures;
- 2) Advances in the rehabilitation of dams and appurtenant works to extend their service life including the following:
 - a) Improving spillway capacity and flood hydrology determination;
 - b) Structural improvements to mitigate the effects of Alkali aggregate reaction, internal erosion potential, foundation failure;
- 3) Innovative river basin management including the optimisation of the operation of dams;
- 4) Reservoir sedimentation and management;
- 5) The state of the art of the tailings dams for their complete lifespan;
- 6) Strategies for proper surveillance of dams;
- 7) Sustainable hydropower development in developing countries; and
- 8) Other

We have received a total number of 333 papers for the Symposium. After the review process 245 papers from 42 different countries were chosen for publication in the proceedings. Of these 245 papers, 96 papers from 34 different countries were chosen for oral presentation in 4 parallel sessions and another 68 papers from 26 different countries were chosen for poster presentation.

All papers submitted for the Symposium were subjected to a full process of peer review and the proceedings contain only those papers that were accepted following this process. The review of the papers was undertaken by the members of the review panel acting independently on one or more assigned papers. This invaluable assistance, which has greatly enhanced the quality of the Proceedings, is gratefully acknowledged.

Finally, the editor wishes to thank the authors for their efforts at producing and delivering quality papers of appropriate quality and relevance. We trust that the Proceedings will be a valued reference for those working in the various fields covered and that it will form a suitable basis for discussion and future development and research.



Louis C. Haltingh
Editor

Table of contents

<i>Symposium organisation</i>	<i>ii</i>
<i>Foreword</i>	<i>iii</i>
<i>Preface</i>	<i>iv</i>
 <i>Theme 1. Social and environmental impacts and mitigation measures</i>	
Public Safety and Security of Dams are not Mutually Exclusive <i>WF Foos, F Calcagno, & PG Schweiger (USA)</i>	1-1
Health and Development in Large Projects <i>SA Kaul, M Kumalo & E Barendse (Lesotho)</i>	1-9
Assessment of the Relationship between Dams Owners and the Host Territory: The Italian Experience <i>G Mazzà, & A Frigerio (Italy)</i>	1-17
Conflict Management for Existing Water Resource Projects and Dams <i>P Mulvihill (New Zealand)</i>	1-27
Improvement of the Procedure for Conflict Resolution of Dam Projects in Korea <i>Hye Jin Kim, Seong Won Jin & Bong Soo Kim (South Korea)</i>	1-33
Veľká Domaša Dam – Current State in Water Management as a Result of Socio-Economic Changes in the Catchment Area <i>D Mydla & R Ivančo (Slovakia)</i>	1-39
Social Issues and Land Acquisition Mitigation in Construction of Nipah Dam and Gongseng Dam – East Java Indonesia <i>NA Fady, A Rahmat & S Inasih (Indonesia)</i>	1-45
Resettlement and Livelihood Restoration in the Context of Large Dams: Phase II of the Lesotho Highlands Water Project <i>TA Sekhesa & EG Barendse (Lesotho)</i>	1-55
Implementation of the LHWP Phase II - Approach towards Social Matters <i>T Tente, M Thokoa, G Mokone & M Phakoe (Lesotho)</i>	1-65
Effectiveness and the Role of Social Studies in the Localization and Selectivity Normal Level of Dams (Case Study: Layleh Dam and Hydro Power Plant) <i>A Nourisani, RG Rad (Iran)</i>	1-75
Rehabilitation of Bell Springs as a Symbol of Corporate Social Responsibility- A Case Study of Daryan Dam and Power Plant <i>A Nourisani (Iran)</i>	1-83
Construction of Chitgar Dam's Artificial Lake - Social and Environmental Impact Assessment <i>A Emam, M Zolfagharian, Kh Binazadeh, H Alavi Deilami, A Eslaminia & J Bayat (Iran)</i>	1-91
Environmental and Social Aspects of the Lom Pangar Reservoir Filling Program <i>JP Grandjean, G Gwét & M Lino (France)</i>	1-101
Environment Management of Jinping-I Hydropower Project during Construction <i>W Shiyong, C Wei, W Hongmei (China)</i>	1-109
The Challenges of Implementing Mega Projects in Urban Areas – A Case Study of BWP And MMTS-2 <i>K Naidoo, J Nyakale & T Tente (South Africa/Lesotho)</i>	1-119
Hydropower Reservoirs as Ramsar Sites: Dams to Support the Protection of Wetland Conservation Areas <i>E Branche (France)</i>	1-127
Practical Solutions for Accommodating Ecological Water Requirements in the Design and Operation of Dams in South Africa <i>H Pieterse, P Scherman, M Shand, G de Jager & J Lombaard (South Africa)</i>	1-137
Managing Ecological Flow Releases from the Berg River Dam in South Africa <i>M Shand, B Abban, D Van Wyk & N Rossouw (South Africa)</i>	1-147

Adapting to Environmental Demands: High Capacity Coanda Intake <i>S Løvfall, HT Ose & T Bakken (Norway)</i>	1-157
Promoting Eco-Friendly River Basin Development Solutions <i>A Abdulmit & S Ionescu (Romania)</i>	1-165
De-Commissioning of Hammarsdale Dam by Transforming it from a Contaminated Problem Child into a Sustainable Wetland <i>S Reynolds & W van der Westhuizen (South Africa)</i>	1-175
Environmental Vulnerability Assessment of Basin Climate Change and its Effects on Adaptive Conservation Countermeasures for Key Fishes involved with Huge Hydropower Station Operation in Yangtze River <i>G Yong, Z Xu , C Yongbo & S Zhiyu (China)</i>	1-185
Change of Redoks Potential in Aquatic Ecosystem at Djuanda Dam <i>M Amron, H Idrus, R Mayasari & E Dwi P (Indonesia)</i>	1-191

Theme 2a. Advances in the rehabilitation of dams and appurtenant works to extend their service life including improving spillway capacity and flood hydrology determination

Design Flood Estimation in South Africa: Challenges and Developments <i>JC Smithers (South Africa)</i>	2a-1
New Methodology for a Robust Estimation of Large Return Period Floods for Design of Large Dam Spillways <i>E Cifres (Spain)</i>	2a-11
Risk Governance Implementation for a Cascade System on Drini River, Albania <i>I Escuder-Bueno, A Jovani, J Moralo-García & JM Alonso Muñoz (Spain/Albania)</i>	2a-21
The Advantages of Performing a Probabilistic Spillway Assessment in an Arid Environment – The Namibia Example <i>A Mostert & LC Hattingh (Namibia/South Africa)</i>	2a-29
Generation of Extreme Events for Flood Risk Assessment - Single Events and Continuous Discharge Time Series <i>H Lohr (Germany)</i>	2a-39
Devils Lake Flood Risk Management <i>SL McCaskie, PD Madison & BK Greenleaf (USA)</i>	2a-49
A Study of the Effective Hydrological Safety of Concrete Dam <i>S Cho, S Jang & D Cha (South Korea)</i>	2a-59
Flood Control Ability Improvement Project for the Peace Dam in Korea <i>HS Park, DH Kwon & HI Kim (South Korea)</i>	2a-69
A Comparative Study of Telemetric Rainfall Data in Three Gorges Project <i>Y Xu & L Zhiwu (China)</i>	2a-77
Hydraulic Scaled Model Tests for the Optimization of Approach Channel Excavation and Approach Flow Conditions of Haraz Morning Glory Spillway <i>S Emami & AJ Schleiss (Iran/Switzerland)</i>	2a-87
Existing Shaft Spillway Enhancement Based on Physical Modelling <i>M Broucek , L Satrapa, M Zukal & M Kralik (Czech Republic)</i>	2a-97
Investigation into the Fluid and Structural Behaviour of Piano Key Weirs <i>FJM Denys, GR Basson & JAvB Strasheim (South Africa)</i>	2a-107
Breach Formation in a Fuse Plug – Evaluation of Field and Laboratory Tests <i>J Lagerlund, A Vazquez, M Svensson, M Billstein & P Viklander (Sweden)</i>	2a-117
Dam Kjøljua, Efficient Spillway Design Reassessment using CFD <i>C Thomas-Lepine, (Norway)</i>	2a-127
The Development of the Vc-Ogee Relationship which Incorporates Upstream 3-Dimensional Flow Conditions <i>SJ van Vuuren & GL Coetzee (South Africa)</i>	2a-137
Rehabilitation of Dams owned by the Department of Water and Sanitation in South Africa <i>W Ramokopa & W van der Westhuizen (South Africa)</i>	2a-147

“Smaller” Dam Spillway Rehabilitation <i>H Anderson (South Africa)</i>	2a-157
Planning and Design of Additional Discharge Facilities in Japan <i>N Hakoishi, T Sakurai & T Ikeda (Japan)</i>	2a-161
Kariba Dam Rehabilitation Project – Improving Spillway Capacity through Reshaping of the Plunge Pool <i>MC Munodawafa, DZ Mazvidza & SZ Mhlanga (Zambia)</i>	2a-171
Hazelmere Dam Raising <i>AJ Botha, D Booyse & IP Fitz (South Africa)</i>	2a-181
Reconstruction of Emergency Spillway on the Vihorlat Dam <i>M Miščík & O Hrabovský (Slovakia)</i>	2a-191
Safety Improvement of Massingir Dam <i>LP Mandlate, P Anthinac & F Del Rey (Mozambique/France)</i>	2a-195
Decreasing of Nipah Spillway Crest Elevation due Social Issue, Sampang - Indonesia <i>CD Yuliningtyas, B Prasetyo, N Hidayat & AI Ambara (Indonesia)</i>	2a-205
Practical Lessons Learnt from the Rehabilitation of Spillway Gates at Cahora Bassa Dam <i>AJ Botha, A Campos De Carvalho, J Chipuazo, E Carvalho L Boulat, D Hensi & C Chatron (South Africa/Mozambique)</i>	2a-209
Re-Commissioning Storfinnforsen’s Bottom Outlet after over 60 years’ idling <i>J Yang, J Larsson & C-O Nilsson (Sweden)</i>	2a-219
Refurbishment of the Phalaborwa Barrage <i>A Chaminuka, AJ Botha, F Shabalala & M Motaung (South Africa)</i>	2a-229
Hydro-Mechanical Equipment Design for the Rehabilitation of the Corumana Dam <i>RSJ van Wyk, AM Hay, RJ Minnaar, M Perduh & H Barnard (South Africa)</i>	2a-239
Strategies for Improving the Safety of Spillway Gates <i>BW Leyland (New Zealand)</i>	2a-249
Automatic Self Actuating Spillway Gates to Improve Dam Safety and Storage in Dams <i>PD Townshend (South Africa)</i>	2a-259
Assessment and Surveillance of Erosion Risk in Unlined Spillways <i>SE Pells (Australia)</i>	2a-269
A Tale of Two Spillways <i>PJN Pells, S Pells & M van Schalkwyk (Australia)</i>	2a-279
Mechraa Homadi Dam Bottom Outlet Rehabilitation <i>A Kwayep, F Bouajaj & M El Alaoui (Morocco)</i>	2a-289
Computational Fluid Dynamic (CFD) Modelling of the Outlet Control Valve of Ncora Dam <i>O Sawadogo, P Townshend & GR Basson (South Africa)</i>	2a-297
Power Intake Structure Model Testing of Mica Project <i>W Yihong, Z Jinxiong, Y Fan, Z Wenyuan & Z Dong (China)</i>	2a-307

Theme 2b. Advances in the rehabilitation of dams and appurtenant works to extend their service life including structural improvements to mitigate the effects of alkali aggregate reaction, internal erosion potential, foundation failure

Natural Pozzolan Effects on Aggregate A.S.R. Delimitation in Sharyar Dam <i>H Khadiv (Iran)</i>	2b-1
Dam Rehabilitation in the presence of AAR – the Matala HEP <i>G Casagran, L Pradolin & J Victor (Canada)</i>	2b-11
Analysis of Inhibiting the Alkali Activity of Concrete Aggregate for Nierji Reservoir Project <i>Z Zhu, P Zheng & Z Wang (China)</i>	2b-21
A Unique Case: New Works at Chambon Dam <i>A Scuero, G Vaschetti, & J Machado do Vale (Switzerland)</i>	2b-27
Kariba Dam Rehabilitation Project – Structural Improvements to the Kariba Dam Spillway Upstream Control Facility to Mitigate the Effects of Alkali Aggregate Reaction <i>MC Munodawafa, DZ Mazvidza & SZ Mhlanga (Zambia)</i>	2b-37

The RCC Moula Dam: Reinforcement Work and Appropriate Instrumentation to Challenge a Weak Foundation <i>NeH Dhiab & M Belaid (Tunisia)</i>	2b-45
Safety Assessment of an Arch-Gravity Dam with a Horizontal Crack <i>A Hadrović, M Partovi & M Selimotić (Bosnia-Herzegovina)</i>	2b-55
Stability Analysis and Repair Measures Assessment of Concrete Dam Cracks in High Water Level Operation <i>S Guo, E Zhai, D Li & H Jin (China)</i>	2b-65
Performance Based Approach for Rehabilitation of Golestan Historical Masonry Gravity Dam <i>M Safi (Iran)</i>	2b-73
Reconstruction and Reinforcement New Techniques for Masonry Gravity Dams Upstream Anti-Seepage Panels <i>P Qi, G Dashui & W Min (China)</i>	2b-83
Application of Reliability Analysis to Slope Stability of an Embankment Dam: A Case Study <i>A Noorzad & H Alimoradi (Iran)</i>	2b-93
Rehabilitation of Downstream Slope of Cacaban Dam due to Wetting <i>D Djarwadi (Indonesia)</i>	2b-103
Improving Slope Protection of Nahand Dam <i>SH Partovi Azar, A Mihandoost, & M Akbarzad (Iran)</i>	2b-111
Engineering Characterization of Aging Cores of Earth-Cored Fill Dams <i>P DongSoon & S Dong-Hoon (South Korea)</i>	2b-119
Impact of Lime Treated Soils Performance on Design of Earthfill Dams and Dikes <i>N Nerincx, S Bonelli, D Puiatti, G Herrier, J-J Fry, R Tourment & S Nicaise (France)</i>	2b-129
Using ICOLD Bulletin 164 to Develop Good Practice Against Internal Erosion in Dams <i>R Bridle (United Kingdom)</i>	2b-139
Probability of Failure of an Embankment by Backward Erosion Using the Formulas of Sellmeijer and Hoffmans <i>T Mallet & J-J Fry (France)</i>	2b-149
A Theoretical Framework to Understand the Mechanical Consequences of Internal Erosion <i>CJ MacRobert (South Africa)</i>	2b-159
Investigation of Piping Phenomenon in Embankment Dams Utilizing Dams Risk Assessment <i>A Noorzad , F Bagheri , I Vaezi & M Gharavi (Iran)</i>	2b-169
The Filtration Stability Safety Assessment of the Dam Liptovská Mara after Grouting Curtain Reconstruction <i>E Bednárová, D Grambličková, M Minárik, J Škvarka & B Kopčáková (Slovakia)</i>	2b-179
Rehabilitation Works to Control the Foundation Internal Erosion and to Mitigate the Effects of Alkali - Aggregate Reaction at Dridu Dam <i>D Ștematiu, A Popovici, C Voinitchi & C Ilinca (Romania)</i>	2b-189
Quantification on the Probability of Dam Failure due to Internal Erosion Using Event Tree Anaysis <i>G Heo & C-K Chung (South Korea)</i>	2b-199
A 70m depth Cut-off Wall to Control Seepage on an Operating Clay Core Dam <i>AF Chraïbi, M Benyahia, & A Mhirech (Morocco)</i>	2b-207
Importance of Geological and Geotechnical Understanding for Mitigation of Reservoir Leakage and Slope Instability Problems: The Case of Tendaho Reservoir <i>DN Abraha (Ethiopia)</i>	2b-217
Foundation Failure of Gheisaragh Dam, Causes and Solutions <i>SP Azar (Iran)</i>	2b-227
Evaluation of Grout Curtain Efficiency Due to Instrumentation Data Analysing <i>MA Toosi (Iran)</i>	2b-235
Design for Rehabilitation of an Embankment Dam for Seismic Safety Improvement <i>E Yıldız & F Gürdil (Turkey)</i>	2b-245
The Seismic Analysis of an Earth-Fill Dam on Thick Liquefiable Ground and Countermeasures against a Large Earthquake <i>T Kato, T Honda & S Kawato (Japan)</i>	2b-253

Pull Out Tests of 50-years old Rock Bolts <i>R Hellgren, FR Bayona, R Malm & Fredrik Johansson (Sweden)</i>	2b-263
Rock Treatment around Morning Glory Spillway Shaft of Sefidrud Dam <i>A Faghimohaddess, H Abbasi & F Farhadi (Iran)</i>	2b-273
Baihetan Dam – China: Rock Mechanics Control of Columnar-Jointed Basalt <i>H Lianxing, Z Endi, F Yilin & L Shaojun (China)</i>	2b-283
Slope Stability Analysis of Jinping Dam using Limit Equilibrium Method and Finite Element Methods <i>WJ Herweynen & H Liu (Australia)</i>	2b-291
Condensed History and Samples of Water-stop's Development for CFRDs in China <i>F Minghui, L Yihui, L Chun, X Yao & H Jutao (China)</i>	2b-299
Brush-Coated Flexible Waterstop Structure of CFRD Joints <i>X Yao & S Zhiheng (China)</i>	2b-307
Mohale Dam Crack Stage 2 Rehabilitation <i>L Matete, S Mojela & T Maseatile (Lesotho)</i>	2b-313
Rehabilitation and Long Time Behaviour of Asphalt Concrete Faced Reservoirs and Dams <i>P Tschernutter (Austria)</i>	2b-323
Lessons from Geotextile Use in Embankment Dams <i>J-J Fry, GE Degoutte & D Poulain (France)</i>	2b-333
Selection of Liner Type for Raw Water Storage <i>DJ Hagen & AJ Botha (South Africa)</i>	2b-343
Adaptation of a Geosynthetic Clay Liner to a Cofferdam using a Decision Matrix <i>Ö Özen, H Küsmez, E Üzücek & T Dinçergök (Turkey)</i>	2b-353
Controlled Demolition Techniques during raising of the Hazelmere Dam Spillway in KwaZulu Natal, South Africa <i>JR Brinkmann, AJ Botha & A Olden (South Africa)</i>	2b-361
Blasting for a Large Pollution Control Dam Directly Beneath Overhead Powerlines <i>CVB Cunningham (South Africa)</i>	2b-371
Talybont Dam Tunnel Pipework Repair Following Damage Caused by a Pressure Shock Wave <i>TA Williamson & AL Warren (United Kingdom)</i>	2b-381
Mohale Tunnel Dewatering System: The System still to be Commissioned <i>L Matete & E Mathaba (Lesotho)</i>	2b-391
Renovation of Långed Hydro Power Plant, Sweden <i>A Engelmarm Hofgaard & R Ascila (Sweden)</i>	2b-397
Raising of Clanwilliam Dam Design and Construction Considerations <i>P Barnard, H Swart, H Durieux & A Thobejane (South Africa)</i>	2b-407

Theme 3. Innovative river basin management including the optimisation of the operation of dams

Orange Senqu Shared International Basin: Importance of a Common Understanding of Water Resource Modelling Capabilities and Results for Decision Makers involved in the Planning and Operation of the System <i>HG Maré, CJ Seago & C Talanda (South Africa)</i>	3-1
Drought Management: The Case of Hluhluwe Dam, Kwazulu-Natal, South Africa <i>AS Sikosana & C Ntuli (South Africa)</i>	3-11
Analysis of Multiple-Target Optimized Regulation of the Three Gorges Reservoir under Changed Operating Environment and its Integrated Benefits <i>X Tao, Z Man & L Changchun (China)</i>	3-21
Cause-Effect Analysis of River Basin Management Options - Case Study of a Small Dam in Thailand <i>H Lohr & R Treitler (Germany)</i>	3-29
The Practice and Discussion on the Joint Operation of Cascade Hydropower Plants on the Upstream Catchment of Yangtze River <i>B Zhengfeng, X Ge & W Yuhua (China)</i>	3-39
Reservoir Operation Rule Changing to Maintain Sustainability of Gajah Mungkur Life Time, Central Java - Indonesia <i>DAS Kubontubuh, CD Yuliningtyas & N Hidayat (Indonesia)</i>	3-47

Operation of Citarum Cascade Reservoirs to Optimize Water and Power Requirement and Flood Control <i>M Khan, I Samoon & D Pranowo (Pakistan)</i>	3-53
Role of the Dams in the Strategy for Prevention and Reduction of the Destructive Consequences of Floods <i>I Asman, S Randasu & C Ban (Romania)</i>	3-63
Using Topographic Dams to Increase the Energy Production Potential and Flood Management <i>AAN Pourkiaei & S Emami (Iran)</i>	3-73
Challenges of Water Management in Trans-Basin Diversion Systems <i>B Kamaladasa & J Meegastenna (Sri Lanka)</i>	3-81
Modernisation of the LHWP Royalties Computation using Water Evaluation and Planning (WEAP) Tool to Determine Benefits Sharing <i>K Lepholisa, R Molapo & F Tlhomola (Lesotho)</i>	3-89
The Use of Cultural Ecological Knowledge, the Pranata Mangsa as Comparative Tool for Shifted Seasonal Pattern in Sermo Dam Operation, Yogyakarta, Indonesia <i>V Ariyanti, Aa Wicaksono, Tb Adji & A Anung (Indonesia)</i>	3-97
The Dams Master Plan for Kurdistan Region – Iraq. Getting the Job Done <i>C Popescu, P Mazilu, I Dragan, A Mihai, N Sirbu, R Sarghiuta & M Segarceanu (Romania)</i>	3-107
Technical and Economical Assessment of Large Dams Design Flood Selection in Iran <i>M Fadaeifard & S Daneshvar (Iran)</i>	3-115
Low Submersible Dams <i>F Lemperiere, M Hotakhanh & N Nerincx (France)</i>	3-125

Theme 4. Reservoir sedimentation and management

Sediment Management at Reservoirs and Hydropower Plants: New World Bank Technical Note <i>Gw Annandale, GI Morris, & P Karki (USA)</i>	4-1
Positive Effects of Reservoir Sedimentation Management on Reservoir Life: Examples from Japan <i>C Auel, SA Kantoush & T Sumi (Japan)</i>	4-11
Comprehensive Basin-Wide Sediment Management in Brantas River Basin, Indonesia <i>R Erwando, MA Satria, H Fahmi, RR Valiant & Harianto (Indonesia)</i>	4-21
Run of River Hydro - Latest Innovations in Diversion Dams and Sediment Exclusion <i>S Mottram, K Ainsley & E Scherman (Canada)</i>	4-29
Design of Run-Of-River Hydropower Schemes to Limit Sediment Diversion <i>M Van Heerden, & GR Basson (South Africa)</i>	4-39
Development of a Bedload Transport Measuring System for Sediment Bypass Tunnels in Japan <i>T Koshiba, T Sumi, D Tsutsumi, Sa Kantoush & C Auel (Japan)</i>	4-49
Dredging with Riverine Disposal to the Channel below the Dam for Supporting Sustainable Sedimentation Management of the Selorejo Dam <i>A Yhadhianto, F Hidayat, A Santoso, S Bachri & Harianto (Indonesia)</i>	4-59
A Practical Example of Change of River Bed Environment Downstream from Dam Reservoir by Sediment Replenishment <i>Y Musashi, Y Nakata, T Suzuki, M Oshima & S Demizu (Japan)</i>	4-67
Study and Practice on Sedimentation Reduction of Three Gorges Reservoir under the New Water and Sand Inflow Condition <i>B Zhengfeng (China)</i>	4-77
Study of Sediment Excavation in the Tail of the Three Gorges Reservoir based on Unsteady Flow-Sediment Model <i>X Tao & G Xiao (China)</i>	4-87
Research on Flow and Sediment Flux into the Three Gorges Reservoir and the Sedimentation Change Trend <i>J Zhongwu & W Huali (China)</i>	4-95
Sediment Control Interventions in the LHWP Muela Catchment <i>G Mokone, P Monongoaha & R Nts'Ohl (Lesotho)</i>	4-105
2D Hydrodynamic Modelling of Sediment Deposition Processes and Flushing Operation of Boegoeberg Dam, South Africa <i>O Sawadogo & Gr Basson (South Africa)</i>	4-113

2D Reproduction Analysis of Reservoir Sedimentation Caused by Flood <i>N Sorimachi, K Hashimoto & T Sato (Japan)</i>	4-123
The Response Law of Fluid Mud to Density Current in the Xiaolangdi Reservoir in the Yellow River, China <i>L Kunpeng, M Huaibao & W Yuanjian (China)</i>	4-133
Rehabilitation of the Kat River Barrage, Fort Beaufort, Eastern Cape, South Africa <i>BJ Krieglner, O Sawadogo & GR Basson (South Africa)</i>	4-139
HPP Vrhovo Operation under Reservoir Sediment Management <i>L Javornik, M Mikoš & A Kryžanowski (Slovenia)</i>	4-149
Sedimentation Problem at TNB Ringlet Hydroelectric Power Stations <i>R Radzi, A Hasnul & S Akib (Malaysia)</i>	4-157
Automatic Scour Gates to Keep Small Dams Free of Sediment <i>JF von Holdt (South Africa)</i>	4-167

Theme 5. The state of the art of the tailings dams for their complete lifespan

Key Steps for Conducting Tailings Dam Breach Studies <i>AJ Strauss, V Martin, D Fontaine & J Cathcart (South Africa/Canada)</i>	5-1
Prediction of Potential Tailings Storage Facility Inundation Zones <i>M Rust & S Dressler (South Africa)</i>	5-9
Requirements for Stability Assessments of Tailings Dams <i>M Theron, M Rust & E Rust (South Africa)</i>	5-19
Common Practice and Innovations in Tailings Dams using Geosynthetic Tubes <i>MT Van Keßel, M Breytenbach & M Wilke (Germany/South Africa)</i>	5-29
Reliability of Tailings Dams with Possible Disturbance of the Impervious Elements and Seismic Impacts <i>V Glagovsky, S Golubev, S Sosnina, T Sinitsyna & N Yurova (Russia)</i>	5-39
Review of Finnish Tailings Dam Safety <i>JP Laasonen (Finland)</i>	5-47
Application of Rock-Filled Concrete on Tailings Reservoir Project <i>F Jin, Y Wang, H Zhou, M Huang & X Cui (China)</i>	5-53
Operation and Maintenance of Ash Dams in South Africa: Challenges and Shortcomings <i>PJ Gouws (South Africa)</i>	5-63

Theme 6. Strategies for proper surveillance of dams

Effect of Common Cracks on Structural Behaviour of Concrete Dams <i>M Westberg Wilde, M Hassanzadeh, M Janz & T Ekström (Sweden)</i>	6-1
The Behaviour of a RCC Dam Raised with RCC...10 Years on <i>CI Dankers & C Oosthuizen (South Africa)</i>	6-11
High Resolution Distributed Fiber Optic Temperature Measurement of Massive Concrete in Concrete Dams at an Early – Age <i>N Humar, S Milevski, D Zupan, A Vidmar & A Kryžanowski (Slovenia)</i>	6-21
Monitoring the Behavior Changes of an Unreinforced Multi Domed Buttress Dam during Rehabilitation <i>JL Schoeman & C Oosthuizen (South Africa)</i>	6-29
Long-Term Integrity Monitoring of a Concrete Arch Dam using Continuous Dynamic Measurements and a Multiple Linear Regression Model <i>P Bukonya, P Moyo & C Oosthuizen (South Africa)</i>	6-39
Identifying Behavioural Trends and the Development of Calibrated Finite Element Models for a Double Curvature Arch Dam <i>ZJ Prins, CN Mahlabela & P Moyo (South Africa)</i>	6-47
Notes on the Behaviour of a 65 Year Old Concrete Arch Dam affected by AAR (Based on Visual Observations only) <i>O Human & C Oosthuizen (South Africa)</i>	6-57
Safety Monitoring and Controlling System for Xiaowan Arch Dam <i>Z Lichun, Z Zhiyong & C Shenghong (China)</i>	6-67

Geodetic Deformation Monitoring System of the 185 m High Katse Dam in Lesotho <i>CJ Pretorius, S Mojela & T Maseatile (South Africa)</i>	6-77
Monitoring System of Cahora Bassa Dam....The Past, Present and Way Forward <i>EF Carvalho, BT Matsinhe & C Oosthuizen (Mozambique)</i>	6-87
The Application of Fuzzy Comprehensive Evaluation Method on Large Concrete Dam Safety Monitoring System Evaluation <i>C Wenbo, T Yuanyuan & Y Jin (China)</i>	6-95
Analysis of Potential Failure Modes and Re-Instrumentation of a Concrete Dam <i>R Malm, E Nordström, C-O Nilsson, R Tornberg & J Blomdahl (Sweden)</i>	6-101
Improving Longevity of High Embankment Dam Instrumentation <i>D Salehi (Iran)</i>	6-111
Behaviour Monitoring of Driekoppies Dam – 18 Years on <i>L Hattingh, C Zwane, L Nkozi, E Khoza & C Oosthuizen (South Africa)</i>	6-119
Surveillance of Lom Pangar Dam during First Filling of the Reservoir <i>T Guillemot, A Towa, M Lino, C Daux, L Vauloup & E Remy (France)</i>	6-129
Evaluation and Monitoring Response to Upstream Slope Failure at an Embankment Dam <i>JN Stateler & J Wormer (USA)</i>	6-139
Analysis Method for the Monitoring of Pore Water Pressure in Embankment Dams <i>AG Simon & T Guilloteau (France)</i>	6-149
Development of Emergent Monitoring System for Leakage from the Dam <i>T Higuchi, T Sugai, T Sato, & T Kayukawa (Japan)</i>	6-159
Seepage Control and Monitoring of Zirdan Dam <i>A Bagherzadehkhalhali & M Karimi (Iran)</i>	6-165
Application of Response Surface Method in Analysis of Hydraulic Structures <i>M Klun, A Kryžanowski & S Schnabl (Slovenia)</i>	6-175
Thermal-Hydraulic-Mechanical Coupled Analysis to Diagnose Condition of Earthen Dams and Reservoirs <i>B-H Choi & KT Chang (South Korea)</i>	6-185
External Deformation Monitoring of Five Rockfill Dams in the same Radar Satellite Data <i>H Sato, T Sasaki, T Kobori, Y Enomura, Y Yamaguchi, W Sato, N Mushiake, K Honda & N Shimizu (Japan)</i>	6-193
Surveillance of CFRD Built on Deep Alluvium Foundation <i>Z Xu (China)</i>	6-203
Performance Analysis and Safety Monitoring Key Points for Concrete Face Rockfill Dams <i>L Nenghui, Z Ganwu & L Denghua (China)</i>	6-213
Rehabilitaion of Seepage Monitoring System of Rockfill Dam for Dam Safety <i>L Jongwook (South Korea)</i>	6-221
Behaviour of the Spring Grove Dam During and After Construction <i>M Trümpelmann, D Badenhorst & J Nyakale (South Africa)</i>	6-231
Surveillance of Bedford and Bramhoek Dams <i>E Lillie (South Africa)</i>	6-241
Improving Seismic Monitoring in the Active East African Rift System for Detailed Seismic Hazard Assessments: A Case Study in Malawi <i>VA Dimas, PRN Chindandali & B Kendaragama (Australia)</i>	6-249
Outcomes of the Devastating Mw 7.8 April 2015 Nepal-Gorkha Earthquake and Establishing a Seismology Research and Monitoring Centre in the Kingdom Of Bhutan <i>VA Dimas, B Kendaragama & N Arora (Australia)</i>	6-259
Use of Hydrogeological Parameters in the Performance Monitoring of Dams and Their Foundations <i>W Riemer (Germany)</i>	6-269
Hydrologic Information Measuring Application based on Redundant System Framework <i>L Yu & Y Xiao (China)</i>	6-277
Inspection of Submerged Area with the use of an Underwater-Camera Surveying Vehicle <i>Y Sakamoto, S Akimoto, & K Kera (Japan)</i>	6-285
Monitoring of the Submerged Structures of Dams <i>E Isomäki & K Hänninen (Finland)</i>	6-295

Organization of Surveillance of Dams in Russia <i>EN Bellendir, EA Filippova & OA Buriakov (Russia)</i>	6-305
Implementation of a Dam Monitoring Management System in the Tagus River Basin Authority <i>S Hoppe & E Moreno Calle (Spain)</i>	6-311
Aloha: An Innovative System for Proper Surveillance of Hydraulic Structures <i>P-H Faure, F Zenss, V Gbiorczyk, V Degezelle & V Morisseau (France)</i>	6-319
New Ideas for Dam Safety Monitoring System Establishment in the Smart Basin <i>S Hui, Z Lan & L Qi (China)</i>	6-329
The Thinking about Dam's Safety Monitoring Based on the Full Life Cycle <i>C Gang & G Fawang (China)</i>	6-335
Implementation of Failure Mode-based Monitoring of Dams <i>A Isander, U Kuoljok, P Wilén & J Oestberg (Sweden)</i>	6-345
A Study on the Development of Performance Evaluation Method on Existing Dams in South Korea <i>KJ Hye, KY Soo, P Jiyeon, SC Shik & KH Ki (South Korea)</i>	6-347
Dam Safety Management in the Brantas and Bengawan Solo River Basins, Indonesia <i>Hariato, RV Ruritan, F Hidayat, F Sarifudin, K Windianita & MTB Raharjo (Indonesia)</i>	6-353
Suggestions for Dam Crisis Management Learned through the 2011 off the Pacific Coast of Tohoku Earthquake <i>H Okumura, T Matsumoto & K Koyama (Japan)</i>	6-361
Telemetry System as a New Approach for Dam Surveillance in Indonesia <i>M Anissa & DK Nofyar (Indonesia)</i>	6-371
The Use of Bio-Location in the Safety Evaluation of Dams <i>LC Hattingh & C Oosthuizen (South Africa)</i>	6-381

Theme 7. Sustainable hydropower development in developing countries

Important Policy Considerations for Hydropower Development in Developing Countries in an Era of Climate Change <i>GW Annandale (USA)</i>	7-1
Challenges in Development of Small Hydropower in Africa: A Technical and Financial Perspective <i>H-J Wright, BR Collet & H Hawarden (South Africa)</i>	7-11
The Rehabilitation of the Mt Coffee Hydropower Project in Liberia <i>WD Hakin, QHW Shaw, R Guimond & B Taraldsten-Brunes (Canada)</i>	7-21
Analysis of Future Hydropower Development and Operational Scenarios on the Zambezi River Basin <i>JP Matos, T Cohen Liechti & AJ Schleiss (Switzerland)</i>	7-31
Study Approach into the Hydropower Development along the Luapula River <i>SG Renecke (South Africa)</i>	7-41
LHWP Phase II Hydropower Feasibility, Further Studies <i>JR Sawyer & T Mochaba (Lesotho)</i>	7-51
Monont'sa Pumped Storage Scheme – Sustainable Hydroelectric Development In Africa <i>CF Logan (South Africa)</i>	7-61
Study on Hydro Power Potentials in Existing Major Reservoirs in Sri Lanka <i>WB Palugaswewa (Sri Lanka)</i>	7-71
Sustainable Hydropower Development in I.R. of Iran <i>S Salavitarab & A Salavitarab (Iran)</i>	7-81
Oiești Development Scheme Conversion <i>ID Iacob & C Abdulamit (Romania)</i>	7-91
Development of a Novel System for Improvement of Operation and Maintenance Works in Dams and Hydropower Plants in Iran <i>K Nasser, E Hassan & Yousefi Saied (Iran)</i>	7-99

Theme 8. Other

Ambarau Hardfill Dam - Appropriate Dam Technology for Central Africa <i>D Cameron-Ellis (South Africa)</i>	8-1
---	-----

The Cemented Soil Dam (CSD): A New Concept of Cemented Dam <i>M Lino, F Delorme, D Puiatti, P Agresti & F Lempérière (France)</i>	8-9
Simple RCC Dams for Developing Countries <i>F Ortega (Spain)</i>	8-19
RCC Mixtures Study for the Design of a Large Dam in Mexico <i>A Garduno-Gallo & M Montero (Mexico)</i>	8-29
Global Stability of High Gate Dam Based on Deep Overburden Layers by Geomechanical Model Test <i>D Bin, H Zhonghui & Z Lin (China)</i>	8-39
Design Features of Koyunbaba Concrete Faced Sandy Gravel Dam founded on Deep Alluvium <i>MH Askeroglu, H Kusmez & N Pelen (Turkey)</i>	8-49
Analysis of Factors Affecting the Stability of the Mosul Dam <i>ZA Aladwani, N Younis & AA Mahmood (Iraq)</i>	8-57
Research on Structural Safety Design of High Embankment Dams <i>B Li (China)</i>	8-67
Application of Monte-Carlo Simulation for Slope Optimization of CSG Dams using Fuzzy Uncertainty Set <i>A Noorzad, E Badakhshan, I Vaezi & M Gharavi (Iran)</i>	8-73
Geological Studies for Increasing the Operating Level of Karun1 (Shahid Abbaspour) Dam, Iran <i>A Barjasteh (Iran)</i>	8-83
Partial Factor Calibration Based on Non-Numerical Method of Gravity Dam Foundation Material <i>B Li (China)</i>	8-93
Criteria for the Selection of Dam Types in Areas of High Seismicity <i>M Wieland (Switzerland)</i>	8-101
Seismotectonic Modelling for Seismic Hazard Assessments in Low-Seismicity Regions of Africa: Western Africa <i>VA Dimas, UA Kadiri & B Kendaragama (Australia)</i>	8-111
Seismic Vulnerability Analysis of Tendaho Dam in Ethiopia <i>A Aman, T Mammo & M Wieland (Ethiopia)</i>	8-121
Seismic Safety Evaluation of a RCC Gravity Dam under Maximum Credible Earthquake <i>D Li, J Tu, S Guo, H Wang & W Wang (China)</i>	8-131
Seismic Responses of Conventional Concrete Gravity Dams on Weak Foundations <i>K Tayyebi, MS Gilani & M Ghaemian (Iran)</i>	8-141
Modeling of Earthquake-Induced Settlement in Embankment Dam by new Approach <i>D Behnia, A Noorzad, M Behnia & K Ahangari (Iran)</i>	8-151
Case Studies of Reservoir-Induced Geo-Hazards for the Jiansha River Hydropower Projects in China <i>E Zhai, Q Fan & H Jin (China)</i>	8-159
Some Lessons Learnt from the Failure of Earthfill Dams in Burkina Faso: Case Stories <i>A Nombre, E Somda & M Kabore (Burkina Faso)</i>	8-169
Regulatory Dam Safety Inspections and Evaluations in South Africa <i>CL van den Berg (South Africa)</i>	8-179
Eastern Nile Transboundary Cooperation on Dam Safety: Challenges and Opportunities <i>M Abebe (Ethiopia)</i>	8-185
Dam Safety Assessment of FAN Dams in Ethiopia <i>F Shiferaw (Ethiopia)</i>	8-193
Dam Construction Key in Future Dream of Water in Africa <i>Ei Ekpo (Nigeria)</i>	8-201
Dam Safety Regulations in Norway; Relationship between Rehabilitation Project Cost and Resulting Added Dam Safety <i>H Kjærås, L Basberg & Ø Lier (Norway)</i>	8-207
Evaluation of Dam Safety Using Limit States <i>J Riha & M Spano (Czech Republic)</i>	8-217
Risk-Informed Decision-Making in Dam Safety - Federal Agency Perspectives Based on 20 Years of Experience <i>N Snorteland, D Osmun, & BC Muller (USA)</i>	8-227

Application of Risk Analysis in Membrío Dam (Spain) to Inform Safety Investments <i>M Setrakian, I Escuder-Bueno, A Morales-Torres & D Simarro (Spain)</i>	8-237
A Description of the Application of a New Quantitative Dam Safety Risk Screening Tool to assist a Remote Northern Community in Making Risk Informed Decisions on the Dam Safety Risks and Remedial Actions <i>CR Donnelly, K Jamieson, CDSS Perkins & M Orton (Canada)</i>	8-245
Risk Issues and Mitigations for Very High Concrete Arch Dams <i>M Safi & M Gharavi (Iran)</i>	8-255
Dam Hazard Analysis using GIS and Nationally Coordinated Emergency Preparedness Plans <i>M Jewert, G Sjödin, M Hautakoski & M Björk (Sweden)</i>	8-265
Evaluation of Life Safety Criteria for South African Dams <i>S Reynolds & C Viljoen (South Africa)</i>	8-275
Is the S-Shaped Curve a General Law? An Application to Evaluate the Damage Resulting from Water-Induced Disasters <i>M Chen, J Ma, F Zhou, Y Hu, J Li & L Yan (China)</i>	8-285
The Main Technological Innovative Practice in Construction of Jinping I hydroelectric Project <i>W Jimin, D Shaohui, Z Jiang, H Shuhong & J Xuelin (China)</i>	8-295
Use of a Cushion Layer to Reduce the Cost and Installation Time of a Vibrating Generator Foundation and Spiral Case: A 3D Nonlinear Study <i>SM Yousefi & T Dell (Canada)</i>	8-305
Application of Data Driven Models in River Flow Forecasting <i>A Khazaiepour & M Shourian (Iran)</i>	8-315
The Ntabelanga and Lalini Dams Conjunctive Scheme – A Water Food Energy Nexus <i>SV Johnson, M Mugumo, AJ Pepperell & T Moore (South Africa)</i>	8-323
Feasibility Study for Foxwood Dam, Eastern Cape, South Africa <i>J Hampton, L Spasic-Gril, J Bristow & R Gilbert (United Kingdom)</i>	8-333
Analysis of Vulnerability to Climate Change in terms of Water Supply for San Jose Hydroelectric Project (Bolivia) <i>MF Villazón, D Inturias , P Pardo, O Zarate & G Rodríguez (Bolivia)</i>	8-343
Value Add of Remote Sensing in the Planning of Dams in Africa <i>DR De Witt & R Nel (South Africa)</i>	8-353
Gate Operation of Small Dams for Flushing the Pollutants Accidentally Released into the Nakdong River <i>MJ Kim & KS Jun (South Korea)</i>	8-361
A Quantitative Approach to Optimizing the Fuel Consumption of Dump Trucks in Earthmoving Projects to Decreasing Emission <i>D Bahadorbeygi, NH Alaei & ER Azar (Iran)</i>	8-371

Theme 6. Strategies for proper surveillance of dams

SURVEILLANCE OF BEDFORD AND BRAMHOEK DAMS

Edwin Lillie¹

1. Knight Piesold Consulting, Rivonia, South Africa

ABSTRACT

Bramhoek and Bedford Dams are the two reservoirs for the Ingula Pumped Storage Scheme. Bedford Dam is the upper storage dam which is a 41m concrete faced rockfill dam. Bramhoek Dam is the lower storage dam which is a 32m high roller compacted concrete dam. Both Bedford and Bramhoek Dams have been provided with a wide range of instrumentation to measure their performance. Bedford Dam is currently below the minimum operating level. Bramhoek dam starting impounding water in November 2010 before the end of the construction period. Bramhoek dam filled very quickly during January 2011 and was at the full supply level by the end of April 2011.

The instruments in Bramhoek Dam have provided useful information of its performance. Some of the main findings were; not all the induced joints in the RCC dam opened, the RCC left bank rotated after first filling more than the right bank, the piezometers all showed a rapid increase in uplift pressure during first filling which stabilised quickly, the strain gauges indicated a maximum negative 200 micro strain in the core of the dam, the temperature rise in the RCC after placement was about 10 degrees Celsius and post construction the temperature in the core of the dam ranges by 2 degrees between summer and winter. The measured leakage from the dam was about 4.5l/s immediately after construction but is now less than 1l/s.

1. INTRODUCTION

This paper presents the dam safety surveillance approach for Bedford and Bramhoek dams. At the time of writing this paper, Bramhoek Dam has been full since April 2011, Bedford Dam water level remains below the minimum operating level. Bramhoek Dam forms the lower storage reservoir and Bedford Dam forms the upper storage reservoir for the 1332MW Ingula Pumped Storage Scheme (IPSS). The hydropower scheme will make use of an active water storage capacity of 19 million m³. Although neither Bedford nor Bramhoek Dams are very large dams, they are very important structures as the IPSS depends on their reliability. There are also complex environmental release requirements that must be adhered to in terms of the Water Use Licence issued by the Department of Water Affairs and Sanitation. These releases must also be effectively measured for auditing purposes.

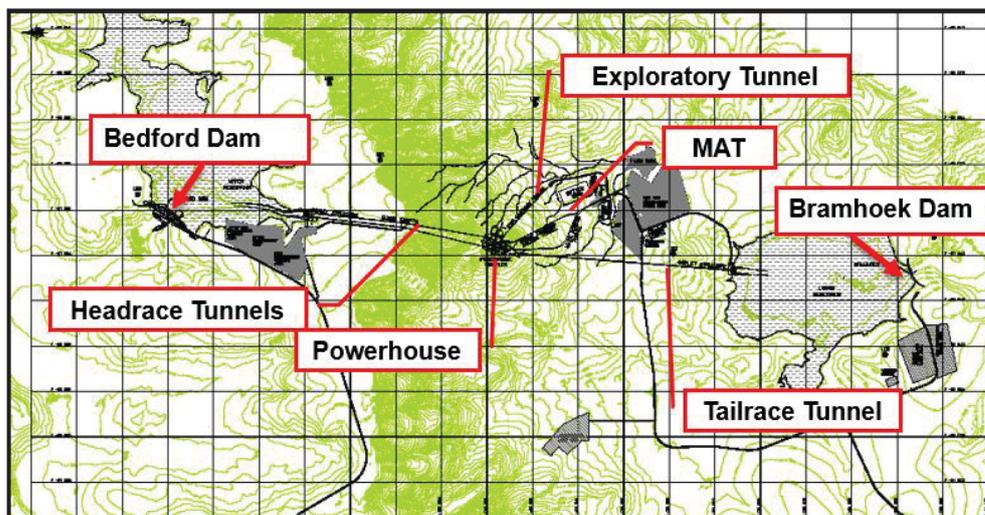


Figure 1. Ingula Pumped Storage Scheme Layout

2. BEDFORD DAM INSTRUMENTATION

Bedford Dam was classified by the Dam Safety Office as a Category III dam with a high hazard potential. Bedford dam is a 41m high Concrete Faced Rockfill Dam (CFRD) with a storage capacity of 22.6 million m³. The crest length is 774m and the fill volume is just over 1 million m³.

Instruments are included to monitor the performance and behaviour of the CFRD embankment, the concrete face, the plinth, the perimetric joint and the outlet conduit during the construction and operation of the dam. Magnetic Flow meters were installed on the outlets pipework to measure flow releases to the downstream wetland.

The instrumentation included the following:

- Joint meters for opening, settlement and shear monitoring at 5 locations on the perimetric joint.
- Joint meters to monitor openings in the face slab where opening is anticipated.
- Tilt meters are located on the CFRD face.
- Survey and settlement pins are installed at strategic positions on the dam embankment.
- Internal embankment settlement cells are installed on a specific cross section.
- Piezometers are installed in the foundation and in the dam embankment to monitor pressure.
- A seepage gauging weir is strategically located to allow the monitoring of seepage from the CFRD dam.
- Strain gauges and pressure cells monitor imposed loading and deformation of the outlet conduit.
- A water level meter is installed on the inlet/outlet tower.

3. BRAMHOEK DAM INSTRUMENTATION

Bramhoek Dam was also classified by the Dam Safety Office as a Category III dam with a high hazard potential. Bramhoek dam is a 32m high Roller Compacted Concrete Dam (RCC) with a storage capacity of 24.9 million m³. The crest length is 337m and the concrete volume is just over 80 000m³.

Instruments are included to monitor the performance and behaviour of the RCC dam. Measurements are taken of the micro strains in the concrete, movement of the dam, relative movement between blocks, induced joint openings and the pore water pressure in the foundation. A crump weir has been constructed downstream to measure flow releases.

The instrumentation included the following:

- Eight Long-base-strain-gauge-temperature meters at strategic locations across induced joints in the body of the RCC.
- Three dimensional joint meters on eight joints on the dam crest.
- Tilt meters on eight joints on the dam crest.
- Fifteen piezometers in four rows to measure foundation pressures.
- An array of five strain gauges was installed to measure temperature related strain across the dam structure in an upstream to downstream direction.
- Three air, three water and five concrete temperature gauges in and on the dam wall.
- Four V-notch weirs for measuring seepage in the gallery and at the toe of the dam.
- A crump weir downstream to measure releases from the dam.
- Survey and settlement pins was installed at strategic positions on the dam crest.
- A water level meter was installed at the inlet/outlet works.

Most instruments are of the vibrating wire type, capable of remote reading and fully waterproof.

Trigger limits were set for each instrument with instructions on actions required should these limits be reached.

4. BRAMHOEK DAM INSTRUMENTATION RESULTS

4.1. Long-Base-Strain-Gauge-Temperature-Meters

Long-base-strain-gauge-temperature-meters (LBSG) are very effective and reliable for the measurement of induced joint openings and temperature in RCC dams. A row of these instruments are installed across three joints in the dam wall at gallery level.

The joints that are instrumented with LBSGs are at 180m on the right bank, the central joint on the spillway section at chainage 220m and the joint above the lowest point on the foundation at chainage 260m as shown on figure 2.

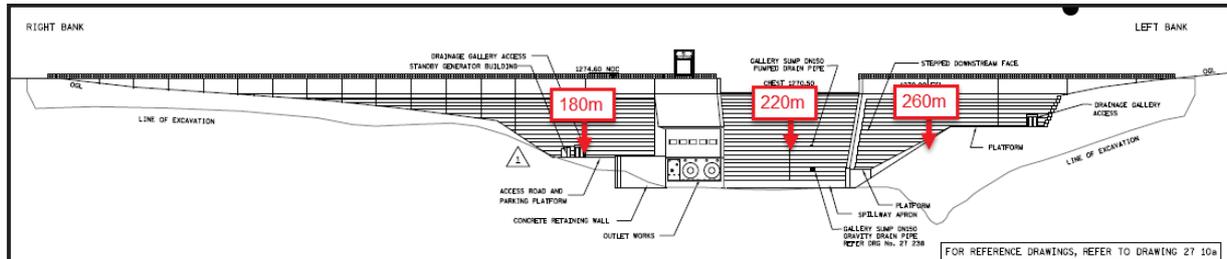


Figure 2. Position of LBSG

The LBSGs at chainage 260m indicated a maximum joint opening of 1.5mm. The joint on the downstream side at chainage 260m opens and closes with the seasonal change in temperature over a range of approximately 0.4mm. The gauge on the upstream side remains open at 0.6mm and only changes marginally with the seasons in line with the small fluctuation in temperature of the upstream face. The temperature does not vary much as the upstream face of the dam is sealed with a clay plug on the left bank.

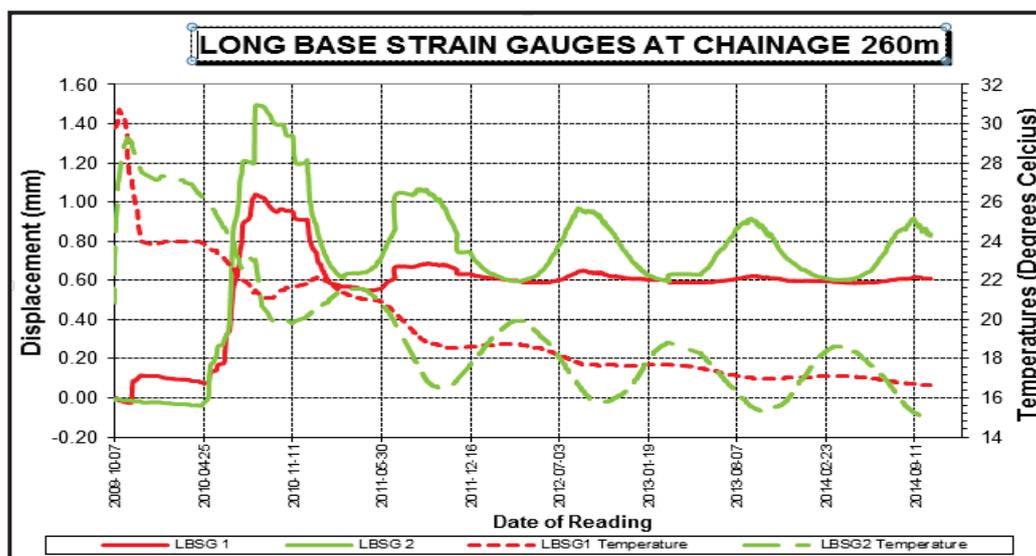


Figure 3. Braamhoek Dam LBSG at chainage 260m

The LBSGs at chainage 220m indicates that this induced joint in the centre of the dam has not opened.

The LBSGs at chainage 160m indicated a maximum opening of 1.6mm. This joint also opens and closes with the seasons over a range of approximately 0.4 mm. For a seasonal change in temperature of about 3 degrees, it is expected that the joint will open and close by 0.5mm. This is very much in line with what has been measured.

The specified maximum placement temperature of RCC was 23°C, there was then a measured increase from placement temperature of approximately 10°C due to the heat of hydration. The

temperature then reduced gradually to fluctuate about approximately 16.5°C which is the long term mean temperature of the region. The range of the seasonal fluctuations in temperature is much higher on the downstream edge of the dam associated with the larger seasonal variation in temperature.

4.1 Three Dimensional Crack & Tilt Meters

Three dimensional crack and tilt meters are installed across eight induced joints on either side of the spillway. The instruments are installed in a small recess at the downstream side of the non-overspill crest. The instruments are electronic and take readings at set intervals. The reading are transferred to a data logger in the outlet house.

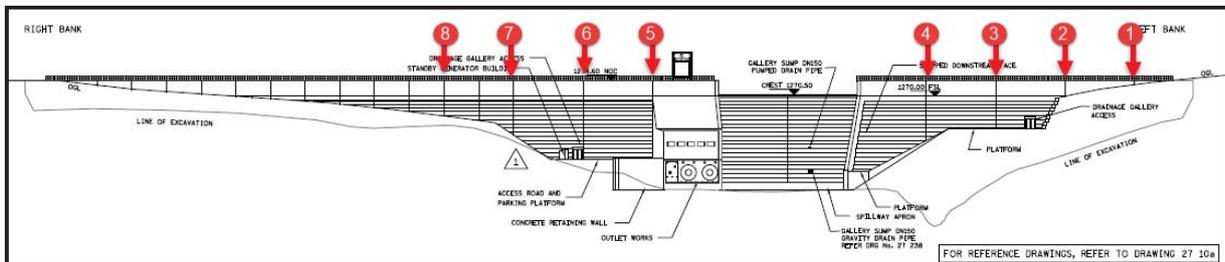


Figure 4. Position of 3D crack meters and tilt meters

Right bank has shown little to no rotational movement.

Left bank has shown two distinct rotations in time. On the 2011/01/03 when Bramhoek dam experienced rapid rise in water level due to heavy rainfall (158mm in 24 hrs), tilt meters 1, 3 and 4 showed rotational movement. Tilt meter 2 showed no relative movement, where gauge 3 showed the most significant movement. Then on the 2011/01/26 when Bramhoek dam was approaching the FSL, tilt meters 1, 2 and 4 indicated a rapid rotational movement with gauge 2 showing the biggest movement.

Tilt meter 3 and 4 showed the most significant overall rotation. These gauges are located at the highest point of the dam and the left bank is on residual mudstone. It is important to note that all the tilt meters have shown no significant additional movement since the last movement occurred just after the first filling of the dam at the end of January 2011.

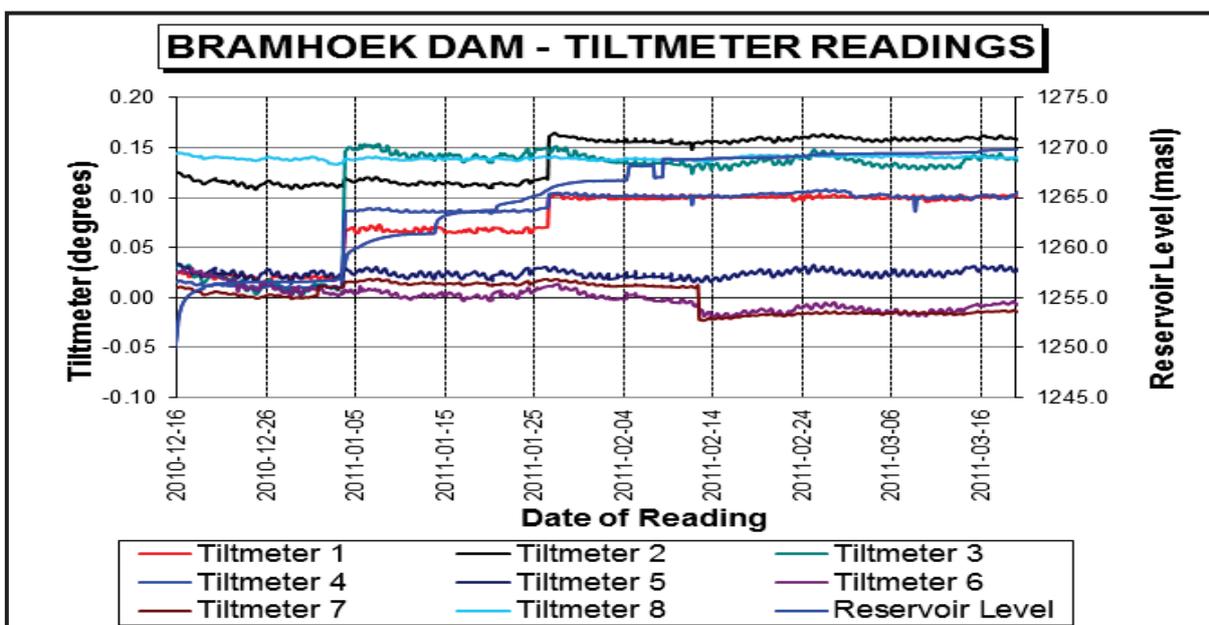


Figure 5. Bramhoek Dam Tilt Meter readings

The 3D crack meters indicated, the movement in the X direction was in the range of 0.6mm to 1.3mm with the blocks in the middle opening more than the blocks towards the abutments.

The results indicated that all the measured joints opened and that there is a definite seasonal movement in the joints, opening and closing is approximately 0.5mm between winter and summer.

4.2 Piezometers

A row of piezometers are installed in 76mm diameter drilled 3m deep into the foundation on four lines, in an upstream-downstream direction beneath the dam wall. The location of the lines are beneath the high point on the left bank, on the induced joint in the middle of the spillway, under the outlet block and immediately to the right bank side of the end of the drainage gallery on the right flank. The cables for the piezometers are routed via a conduit in the upstream face GE-RCC to the gallery and subsequently to the data logger in the outlet house.

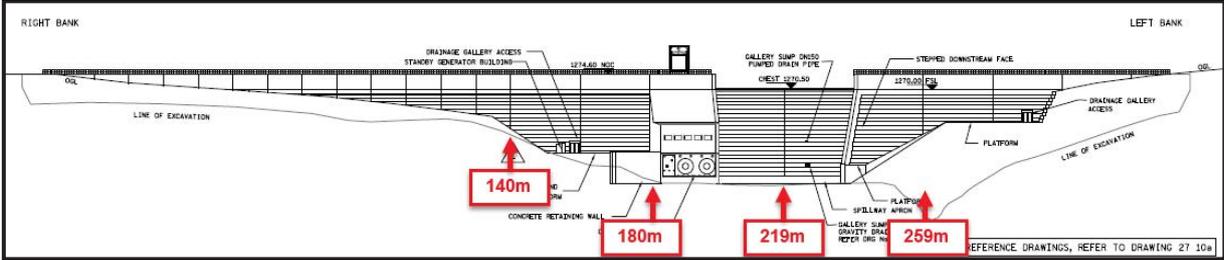


Figure 6. Bramhoek Dam Position of Piezometer rows

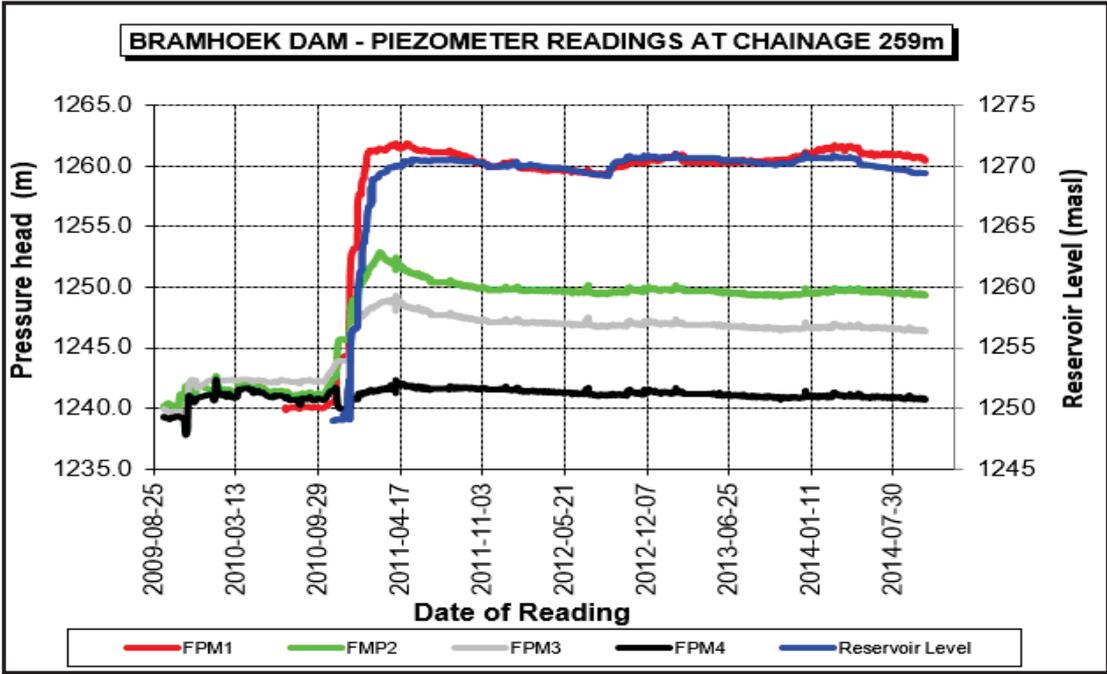


Figure 7. Bramhoek Dam Piezometer readings on the left bank

Piezometer 1 is close to the upstream face of the dam and piezometer 4 is the near to the downstream toe of the dam. Impoundment started on the 4th November 2010. Bramhoek dam filled rapidly in the beginning of January 2011. Bramhoek Dam was at the full supply level by April 2011. All the piezometers reacted rapidly to the increase in upstream water level as shown on Figure 7. The rapid increase in water pressure was of concern to the designer and the piezometers were carefully monitored after first filling to confirm the stability of the dam should the water pressure under the foundation continued to rise rapidly. However the water pressure did stabilise and even reduced slightly to the levels assumed in the design for most piezometers. A few of the furthest downstream piezometer did go marginally above the expected design water pressure levels. The stability was then rechecked for these measured water pressures.

4.3 Strain Gauges

An array of strain gauges are installed at chainage 237m on the gallery level to measure the development of strain in an upstream-downstream direction close to the highest section of the dam wall.

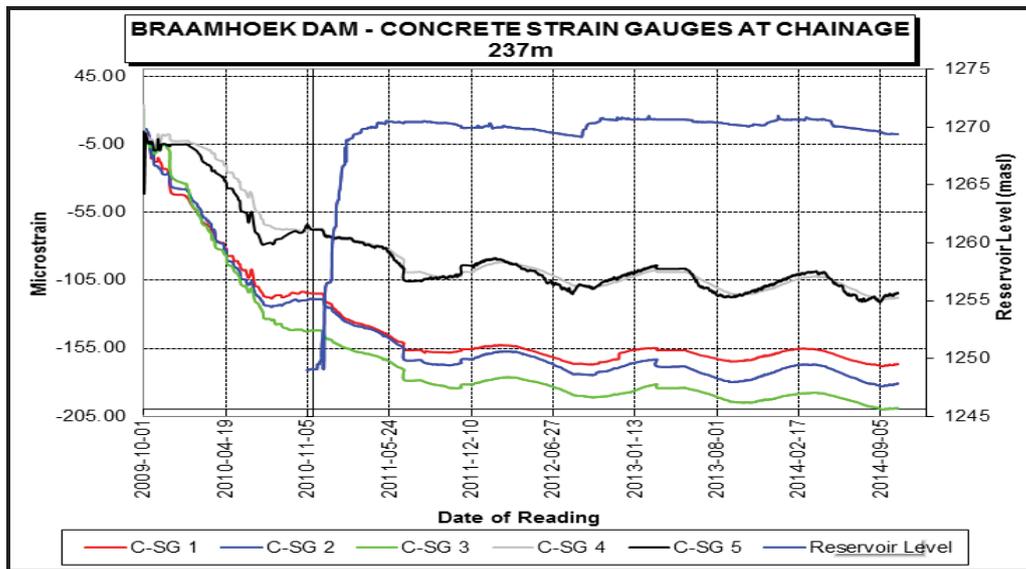


Figure 8. Bramhoek Dam Strain Gauge readings

Strain Gauge 1 is near the upstream face, Strain gauge 3 is in the middle of the dam section and strain gauge 5 is near the toe of the dam. The largest negative strain is in the centre of the dam section with a micro strain of approximately minus 200, the lowest strain is at the toe of the dam and is about minus 100 micro strain. The estimated stresses based on the elastic modulus of the RCC is about 3.5MPa in the centre of the dam and 2MPa at the toe of the dam. All strain gauges indicated compression stress only. The design strength of the RCC was 15MPa, the actual measured strength was above 25Mpa.

4.4 Temperature Gauges (Thermistors)

Gauges to measure air and water temperatures are installed in recessed boxes in the down- and upstream faces of the dam respectively. Thermistors are also be installed in the RCC at strategic locations. All cabling is routed back to the data logger in the outlet house.

Table 1. RCC seasonal temperatures

Description	Upstream	Upstream to middle	Middle	Middle to downstream	Downstream
Summer	19.0°C	18.7°C	18.6°C	22.3°C	24.1°C
Winter	14.4°C	15.3°C	16.4°C	18.3°C	13.7°C
Range	4.6°C	3.4°C	2.2°C	4°C	10.4°C
Average	16.1°C	16.4°C	17.1°C	17.2°C	16.7°C

As expected the temperature range about the mean is dependent on the location of the temperature gauge in the RCC. The maximum RCC measured temperature was 24.1°C and the minimum was 13.7°C with the largest seasonal variation of about 10°C recorded near the downstream face. The temperature in the middle of the dam ranges by only 2.2°C from summer to winter. The temperature range for the upstream face is approximately 4.6°C.

The water temperatures in Bramhoek Dam ranges from approximately 22°C in summer to 12°C in winter. The air temperature ranges from above 30°C in summer to 0°C in winter.

4.5 V-notch Weirs

V-notch weirs are provided in the drainage gallery to measure seepage entering the pump sump separately from left and right bank. V-notch weirs are also be located approximately 10m beyond the inclined (stepped) sections of gallery on either flank on the downstream toe of the dam. The arrangement allows the dam foundation and wall drainage to be divided into 4 zones.

SW1 is measuring leakage under the foundation on the left bank downstream of the dam toe. A leakage of approximately 1.5l/s occurred after construction, this amount has steadily decreased and has tended to zero in 2015.

SW2 is measuring leakage through the dam on the left bank in the gallery. After the dam had filled a leakage of approximately 0.5l/s has occurred. This leakage has also steadily decreased to approximately 0.27l/s in 2015.

SW3 measures leakage from the right bank and the outlet block in the gallery. SW3 has showed the most leakage from all V-notch weirs and was due to a damaged waterstop on the joint between the dam and the mass concrete outlet block at chainage 180. The leakage after construction was approximately 4.5l/s in 2011. This decreased to an amount of 1l/s in 2012. The leakage continued to further decrease to an annual average of 0.5l/s. This value now has a strong seasonal pattern between summer and winter as the joint at 180m opens and closes with temperature change. In 2015 the leakage ranges between 0.71l/s to 0.33l/s. Winter having the highest leakage.

SW4 measures the current leakage under the foundation on the right bank on the downstream toe. Leakages after construction amounted to approximately 3.49l/s, this amount has decreased over time and current leakage is approximately zero.

The current total measured leakage from Bramhoek Dam is approximately 0.8l/s. This amount varies between 1l/s in winter and 0.6l/s in summer; this is well below the limit of 10l/s stated in the operation and maintenance manual.

4.6 Downstream Crump Weir

In view of the environmental sensitivity of the scheme and the associated importance of observing the ecological water releases required by the Water Use Licence discharge metering facilities are provided by a flow measuring Crump weir downstream of the dam. On the basis of a water level readout displayed in the outlet house, the discharge is set using a calibrated table. Once the flow has stabilized, the release is checked and adjusted if necessary on the basis of measured flow data.

The downstream crump weir is designed for a gauging capacity of 175m³/s. The crump has three notched levels to improve the accuracy at lower flows. The releases are made according to those specified by the water use licence. A record is kept of the releases for environmental audits.

4.7 Reservoir Water Level Recorder

A Rittmeyer wall level recorder is located on the crest of the dam. This instrument measures the water level in the dam very accurately for operational purposes. The dam level measurement equipment provides an indication of the dam level to an accuracy of at least 10mm. This is provided by measuring the water level in the embedded 400mm water recorder pipe at the dam Intake Tower. The water level is transmitted via the SCADA system to the control room from where decisions are made on the operation of the water release system.

Bramhoek Dam started impounding in November 2010 and was fill by April 2011. The hydrology study estimated that it would take at least to average rainfall/run off years to fill Bramhoek Dam and should a drought occur it may have taken more than four years to fill, as a result of this study, Bramhoek Dam was on the critical path of the whole project. Bramhoek Dam has remained full since April 2011. Bramhoek will not be drawn down until the scheme is commission and the water pumped up to Bedford Dam.

5. CONCLUSIONS

The central joint in the dam has not opened. Most other joints opened by approximately 1.5mm. The joints opening fluctuates with the seasons by approximately 0.5mm.

The left bank rotated more than the right bank during first filling, due to the poorer founding conditions on the left bank.

The Piezometers reacted very quickly to the rise in upstream water level. Most piezometers indicate water pressure at the assumed design levels.

The maximum strain measured in the RCC dam was minus 200 micro strain.

The temperature of the dam now fluctuates about 16.5°C, the range is about 5°C near the upstream face, 2°C near the middle of the dam and 10°C near the downstream face.

The current total measured leakage from Bramhoek Dam is approximately 0.8l/s. This amount varies between 1l/s in winter and 0.6l/s in summer.

The use of instrumentation in RCC dams is well established in South Africa. The type and level of sophistication is dependent on the classification of the dam. It is important to maintain and continue to measure data in existing dams.

6. ACKNOWLEDGEMENTS

The author would like to acknowledge ESKOM, the owner of Bedford and Bramhoek Dams, for giving permission to publish this paper.

7. REFERENCES

- BCJV (2004). Eskom: *Design Criteria Memorandum*. Ingula Pumped Storage Scheme.
- BCJV (2005). Eskom: *Bramhoek Dam. Geotechnical Report*. Ingula Pumped Storage Scheme.
- BCJV (2007). Eskom: *Tender Documents for the Construction of Bramhoek Dam*.
- BCJV (2007). Eskom: *Bramhoek Dam Design Report*.
- BCJV (2015). Eskom: *Bramhoek Dam First Dam Safety Inspection Report*.
- BDJV. Eskom. (2009) *Method Statement 041 Bramhoek Dam Impoundment (Impoundment and Controlled First Filling)* Doc No. BR/MS/041.
- Eskom (2009) Bramhoek Dam. *Water release management and plant functional descriptions. Rev 5*.
- Eskom (2015) Bramhoek Dam. *Operational and Maintenance Manual. Rev 6*.
- Department of Water Affairs and Sanitation (2007) *Licence to construct a dam 12/2/V102/03*.
- Department of Water Affairs and Sanitation (2007) *Water Use Licence 27/2/2/V112/1/1*
- Department of Water Affairs and Sanitation (2014) *Water Use Licence 07/V12A/ABCDEFGHIJ/2439*
- United States Army Corps of Engineers (1995). *Gravity Dam Design*. Engineering Manual, EM 1110-2-2200.