GATE OPERATION FOR OPTIMUM SEDIMENT REMOVAL FROM THE POLGOLLA RESERVOIR TO ATTAIN UNINTERRUPTED HYDROPOWER DIVERSION

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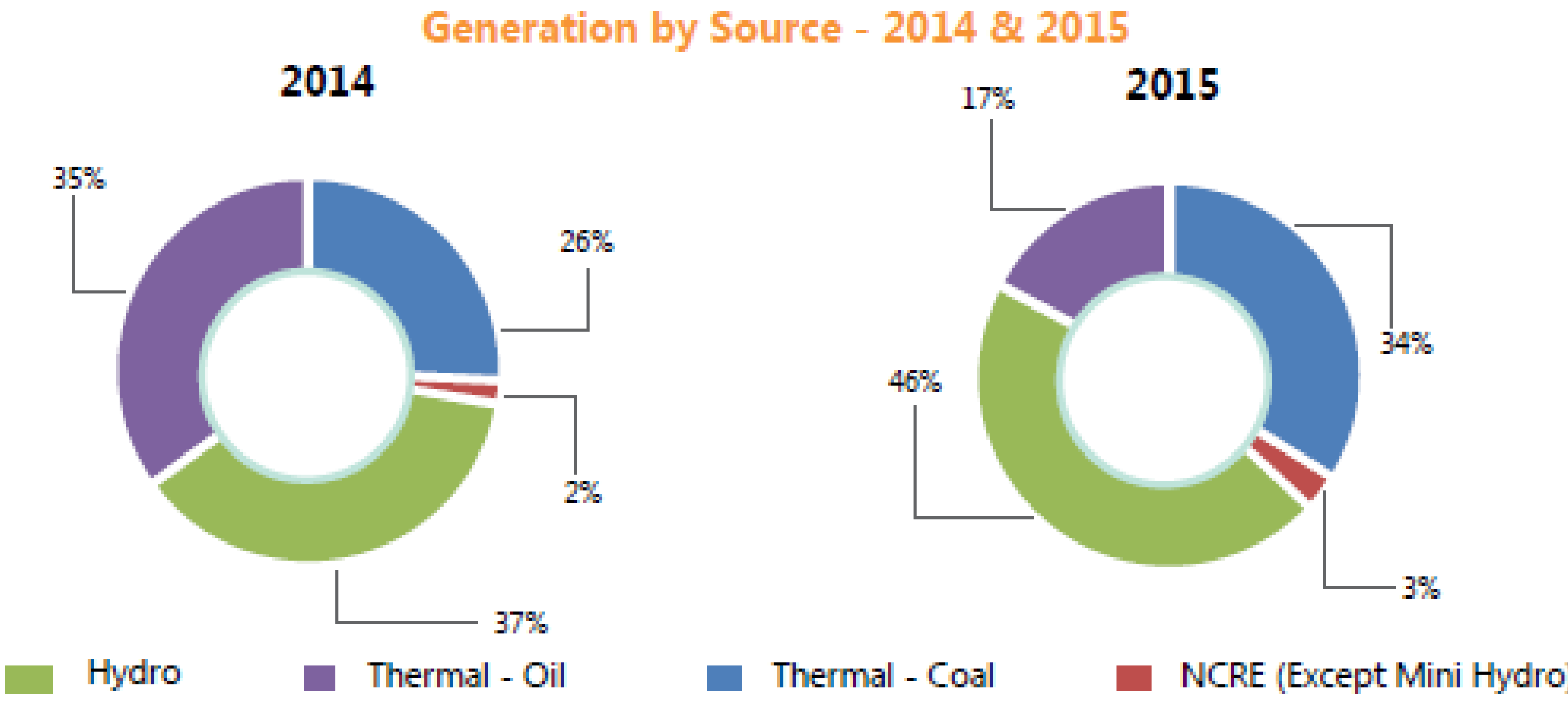
Electric Power Generation in Sri Lanka

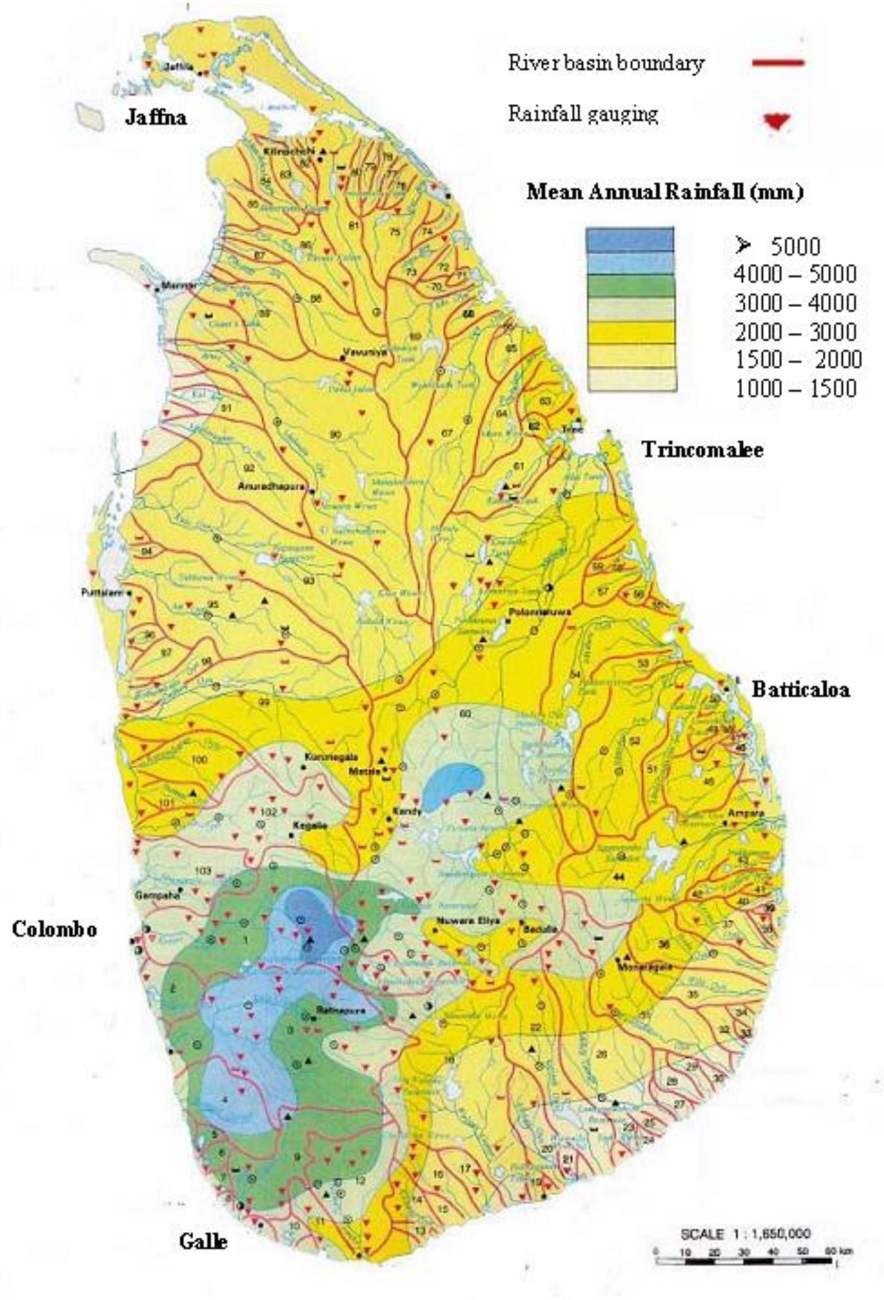


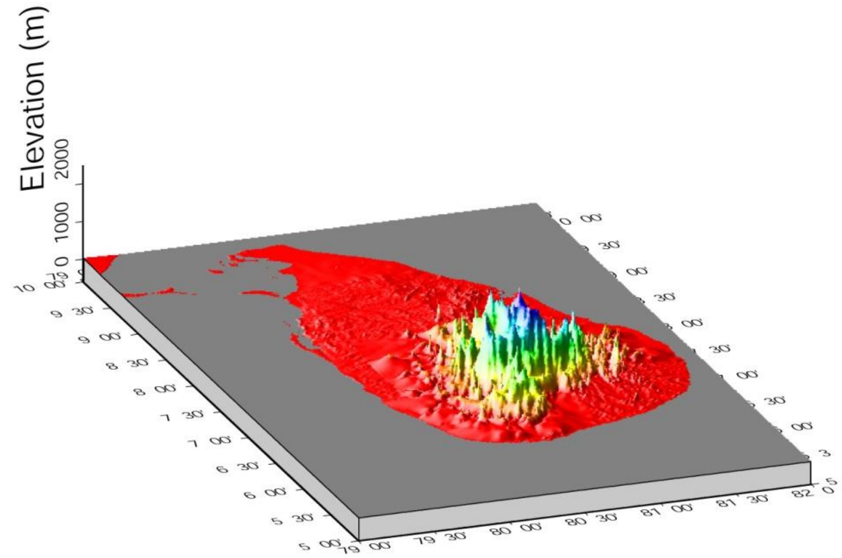
Electric Power Generation in Sri Lanka

Ownership & Source	Generation - GWh			Percentage of Total	
	2014	2015	% increase	2014	2015
C.E.B. - Total	**8,532**	**10,399**	**21.9%**	**69%**	**79%**
- Hydro	3,632	4,904	35.0%	29%	37%
- Thermal-Oil	1,696	1,050	-38.0%	14%	8%
- Thermal-Coal	3,202	4,443	38.8%	26%	34%
- Wind (NCRE)	2.1	1.1	-50.2%	0%	0%
P.P.P. - Total	**3,825**	**2,691**	**-29.6%**	**31%**	**21%**
- Thermal	2,610	1,225	-53.1%	21%	9%
- NCRE Mini Hydro	902	1,065	18.0%	7%	8%
- NCRE - Wind	270	342	26.6%	2%	3%
- NCRE - Other	43	59	38.1%	0%	0%
Total Generation *	**12,357**	**13,090**	**5.9%**	**100%**	**100%**
Av. Daily Generation GWh/day	**33.86**	**35.86**	**5.9%**		

*Refers Net Generation

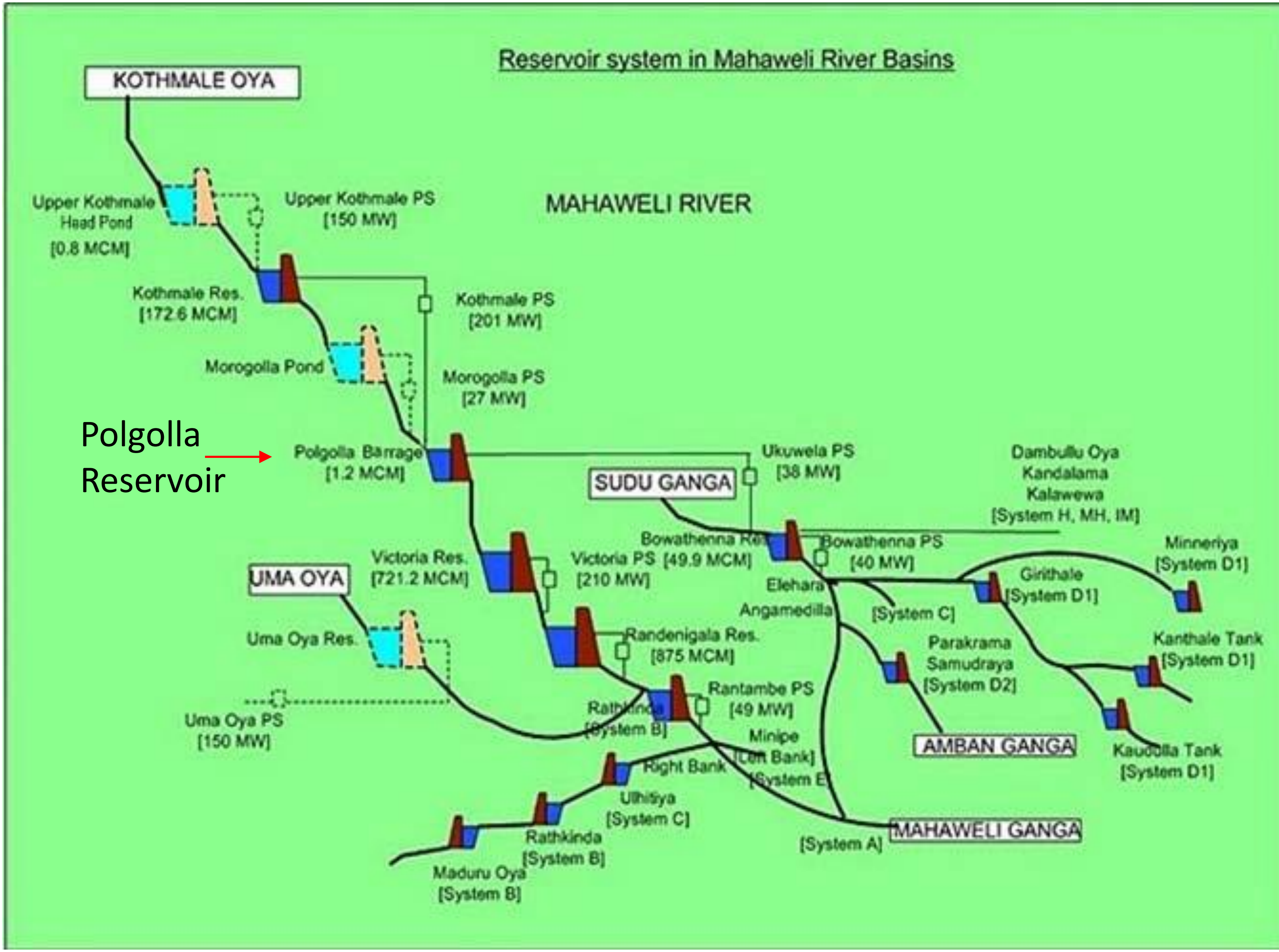
Water Resources in Sri Lanka

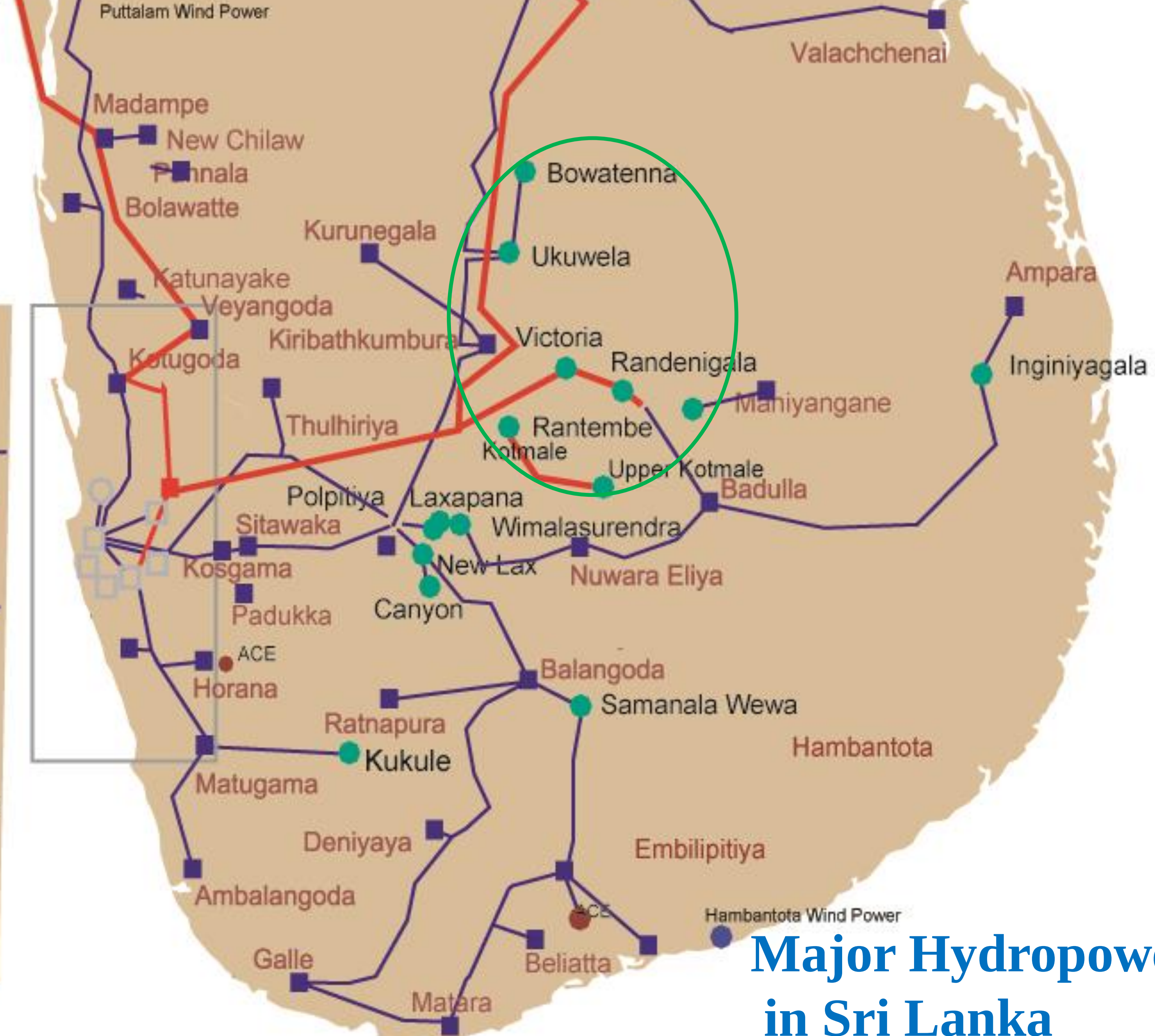




Cascade of Reservoirs the Mahaweli River

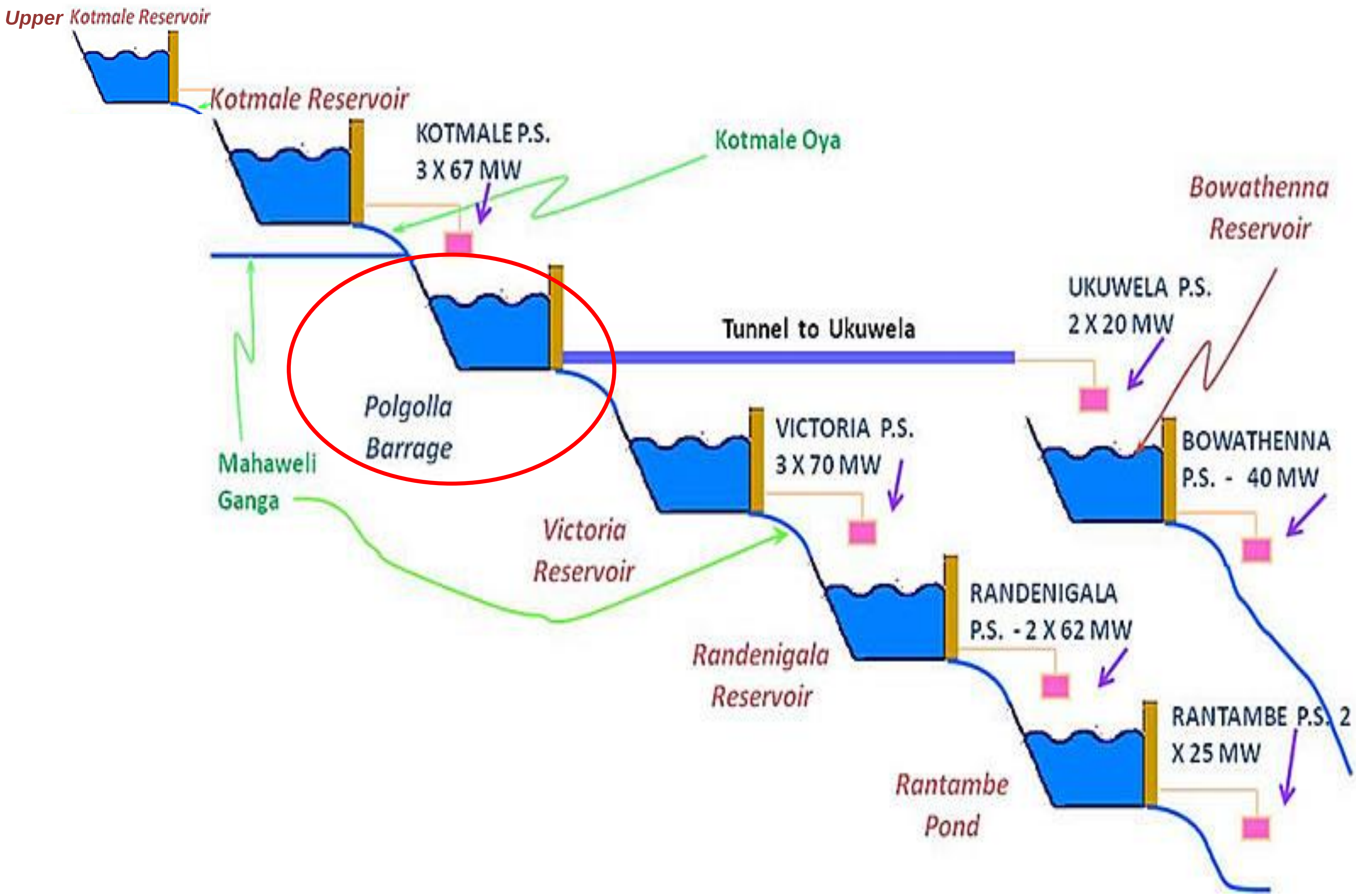
Polgolla Reservoir



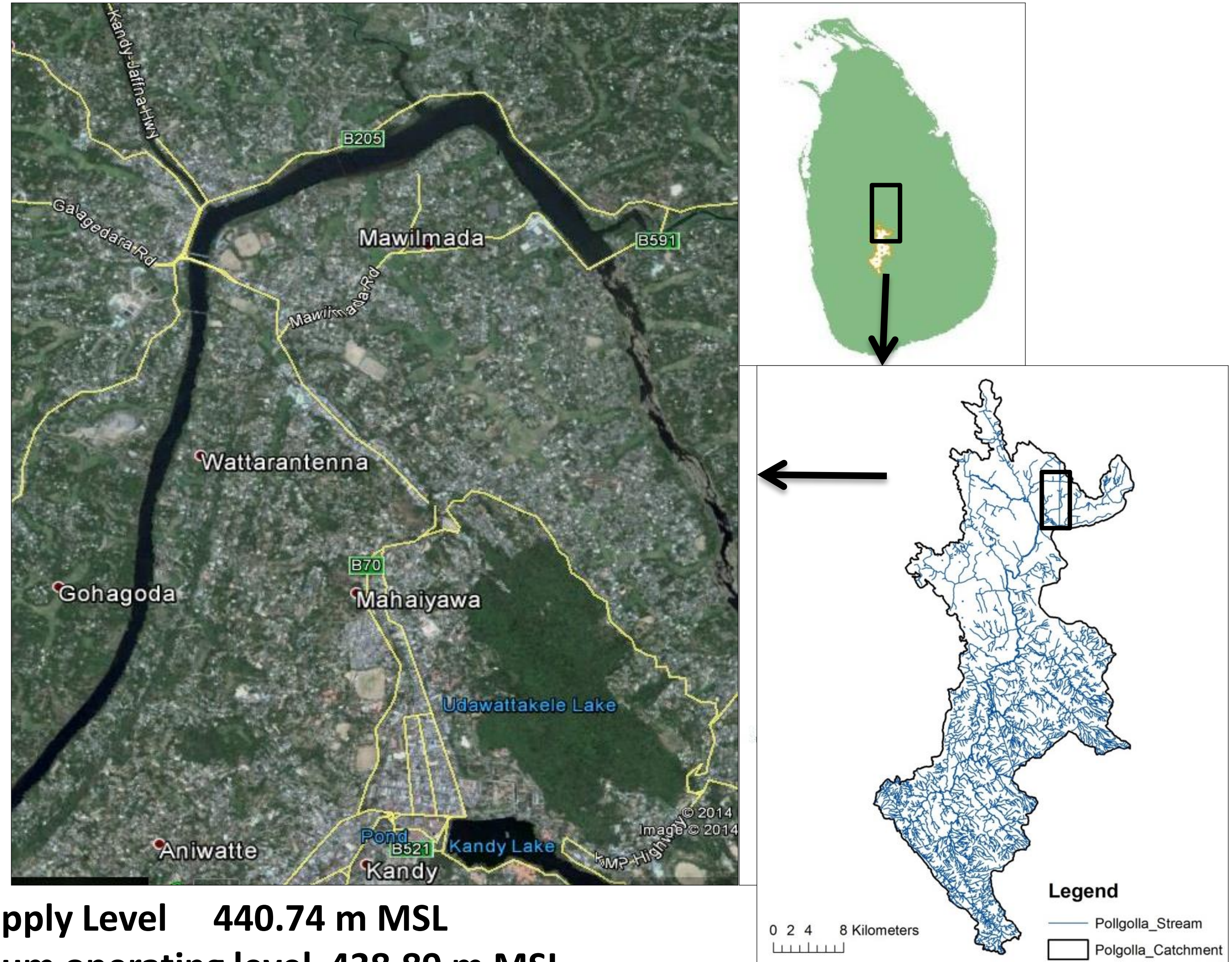


Major Hydropower Plants in Sri Lanka

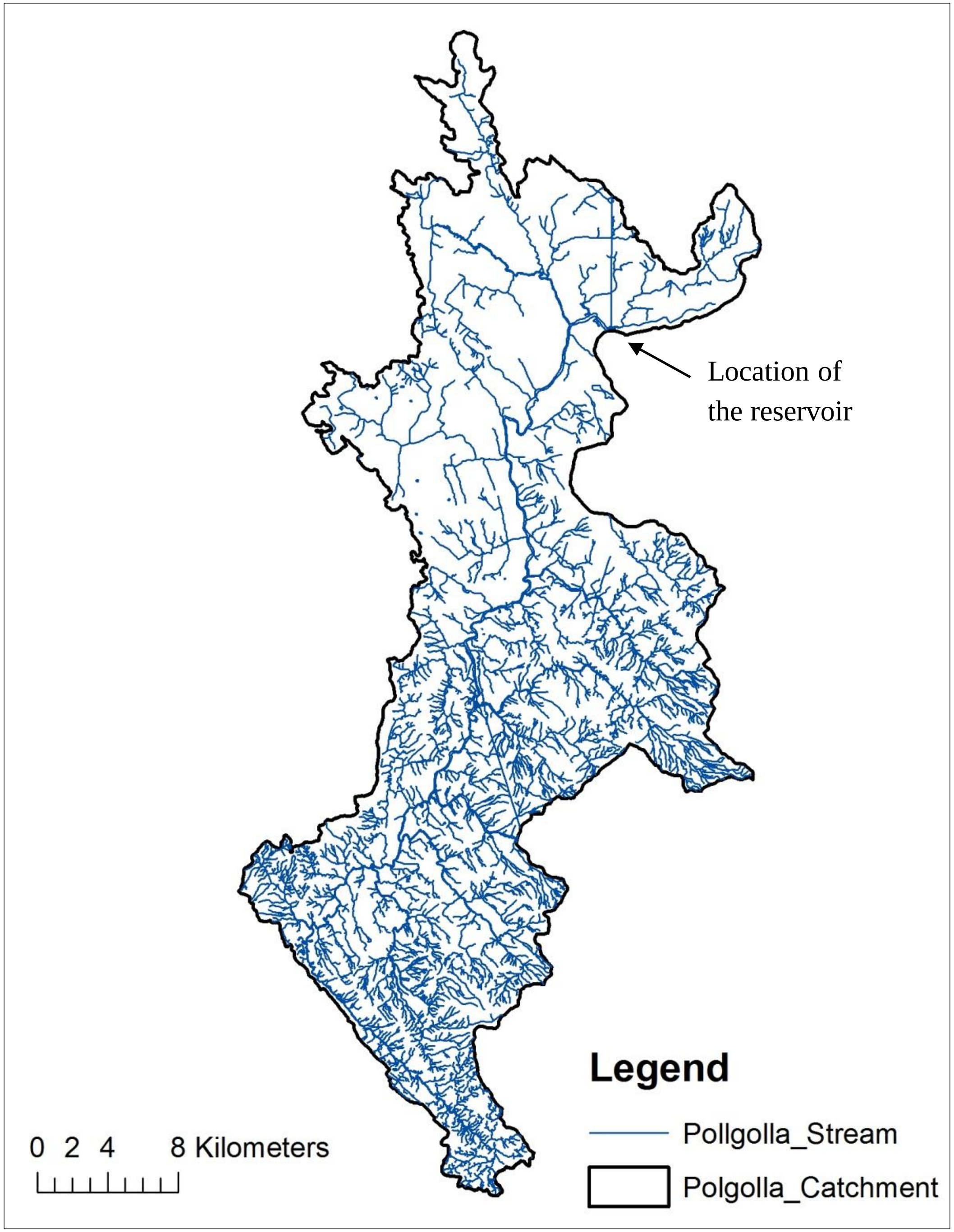
Hydropower Plants along the Mahaweli River



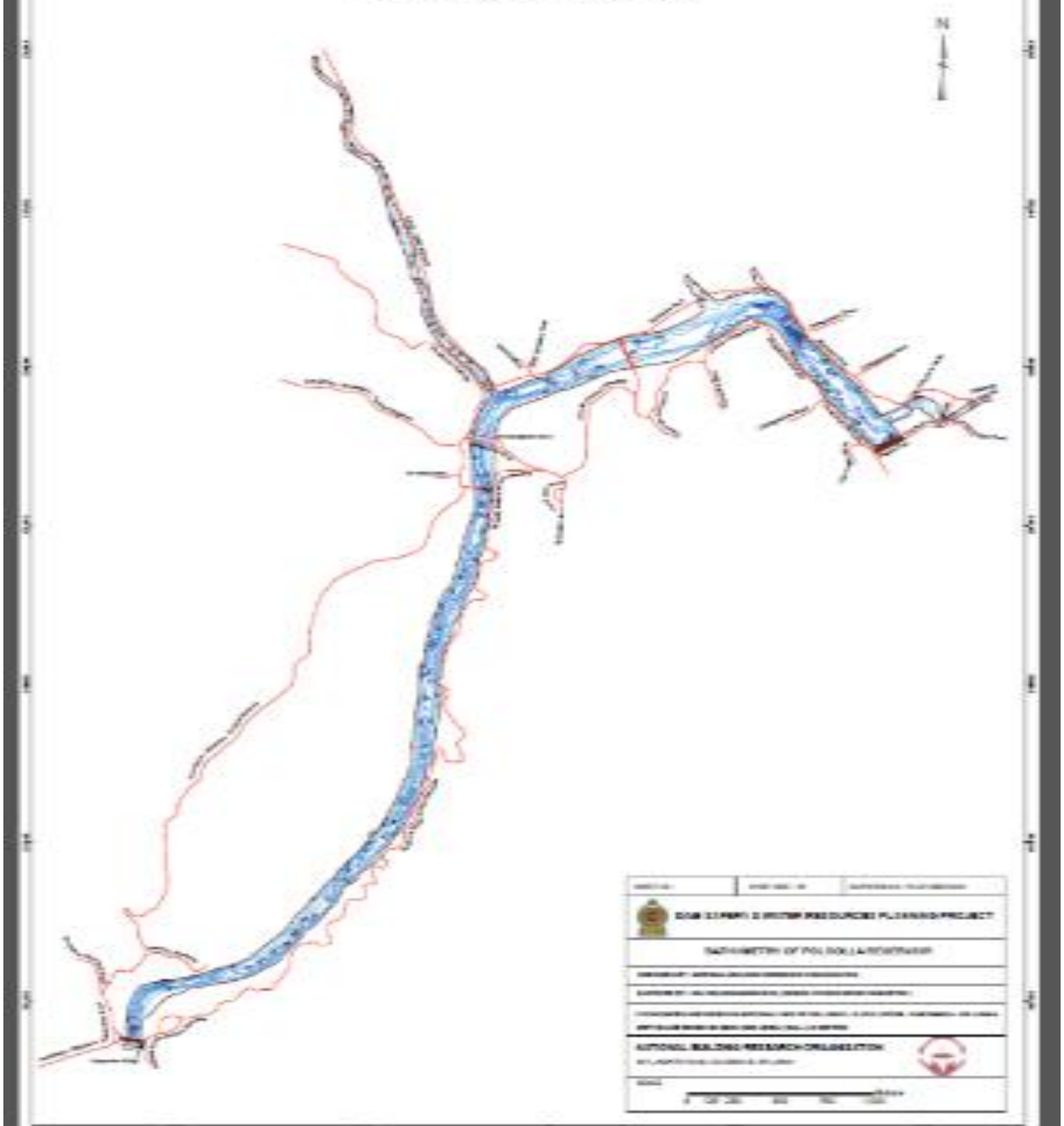
Polgolla Reservoir



Full Supply Level 440.74 m MSL
Minimum operating level 438.89 m MSL
High Flood Level 443.76m MSL
Original storage capacity at FSL 4.6 MCM, Catchment area 780 km^2

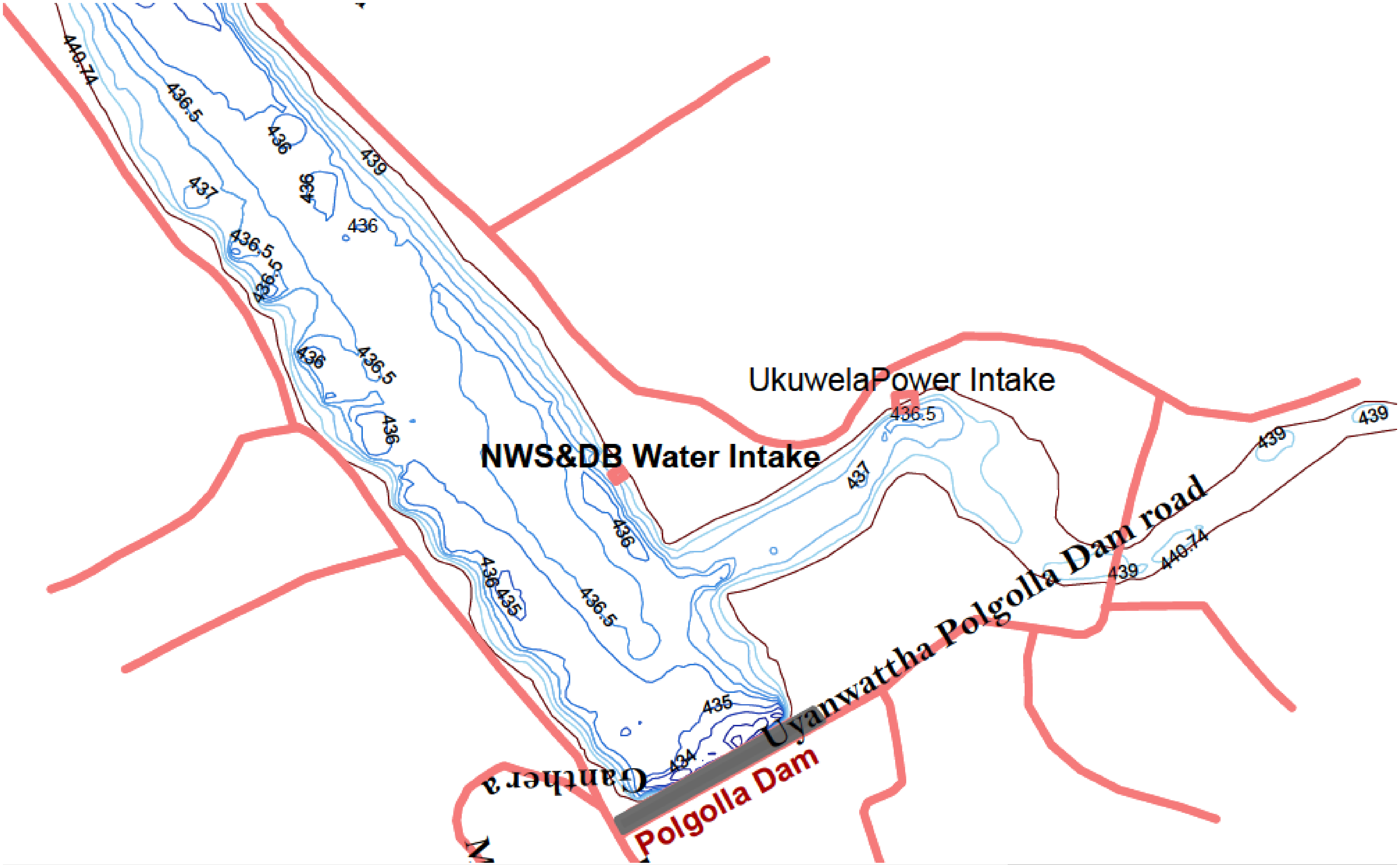

Location of
the reservoir
Legend
Pollgolla_Stream
Polgolla_Catchment
0 2 4 8 Kilometers

BATHYMETRY OF POLGOLLA RESERVOIR




BATHYMETRY OF POLGOLLA RESERVIOR
N
182000
183000
184000
185000
186000
238000
237000
236000
235000
234000
233000
232000
Kandy - Jaffna High Way -A9
Madawala Road - B 205
Katugastota - Kurunegala - Puttalam High Way
Old Katugastota Road
Main Water Distribution Pipe
C L Rathwaththe Mawatha
P B J Weerakoon Mawatha
Katugastota - Medawala - Bambarella Rd
UkuwelaPower Intake
NWS&DB Water Intake
Polgolla Dam
Water Treatment Plant
Peradeniya Halloluwa - Katugasthota Road
Hanging Bridge - Dodanwala
LOCATION WITH RESPECT TO SRI LANKA
SCALE : - 1; 6000
SHEET NO
SHEET SIZE :- A 0
SURVEYED ON :- OCT.2013
DAM SAFTEY & WATER RESOURCES PLANING PROJECT
BATHYMETRY OF POLGOLLA RESERVOIR
PREPARED BY --- NATIONAL BUILDING RESEARCH ORGANIZATION
SURVEYED BY --- PALITHA BARANASURIYA (SENIOR HYDROGRAPHIC SURVEYOR)
COORDINATES ARE BASED ON NATIONAL GRID OF SRI LANKA
DEPTHS ARE BASED ON MEAN SEA LEVEL (M.S.L.) IN METERS.
NATIONAL BUILDING RESEARCH ORGANIZATION
99/1, JAWATTA ROAD, COLOMBO 05, SRI LANKA
SCALE
Meters
0 125 250 500 750 1,000

Polgolla Reservoir - Bathymetry



Polgolla Barrage

Polgolla Barrage

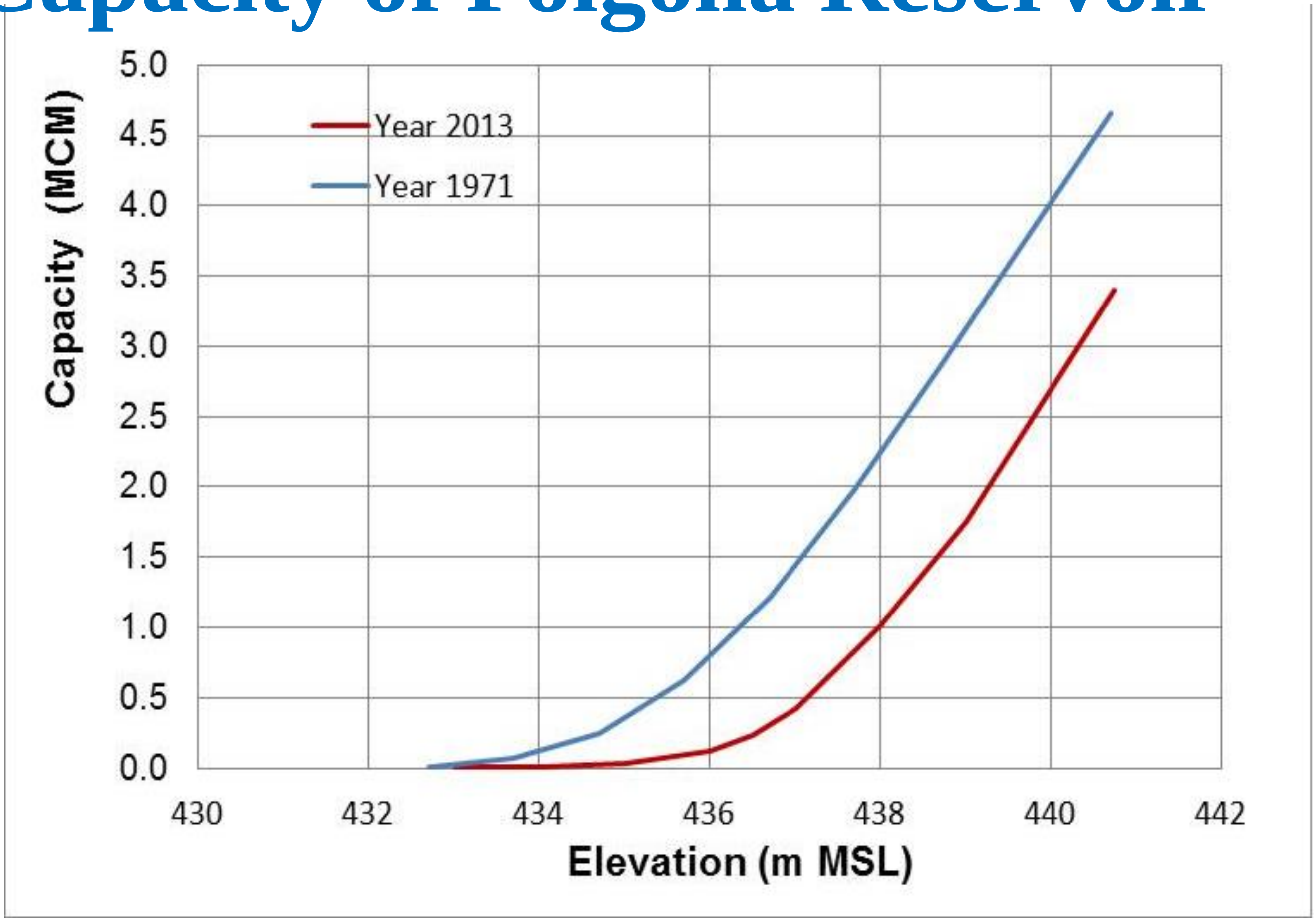
10 Nos of 12 m wide gates

Storage capacity at FSL
Original 4.6 MCM
Now 3.4 MCM

Siltation in Polgolla Reservoir

Polgolla Hydropower Intake

Capacity of Polgolla Reservoir



Full Supply Level 440.74 m MSL, Original storage capacity at FSL 4.6 MCM

Reservoir sediment is flushed by opening gates. For erosion of deposited sediment, the bed shear stress should exceed the critical shear stress. The bed shear stress is proportional to the vertical velocity gradient.

- Selecting appropriate gate operation under different inflows

Governing Equations

- Continuity equation

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0$$

- Momentum equations in x and y-directions

$$\frac{\partial (uh)}{\partial t} + \frac{\partial (hu^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = -gh\frac{\partial H}{\partial x} - \frac{\tau_x}{\rho} + D^x + \frac{F_x}{\rho}$$

$$\frac{\partial (vh)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2)}{\partial y} = -gh\frac{\partial H}{\partial y} - \frac{\tau_y}{\rho} + D^y + \frac{F_y}{\rho}$$

In which;

Governing Equations

$$\frac{\tau_x}{\rho} = C_f u \sqrt{u^2 + v^2} \qquad \frac{\tau_y}{\rho} = C_f v \sqrt{u^2 + v^2}$$

$$D^x = \frac{\partial}{\partial x}\left[\nu_t h \frac{\partial u}{\partial x}\right] + \frac{\partial}{\partial y}\left[\nu_t h \frac{\partial u}{\partial y}\right]$$

$$D^y = \frac{\partial}{\partial x}\left[\nu_t h \frac{\partial v}{\partial x}\right] + \frac{\partial}{\partial y}\left[\nu_t h \frac{\partial v}{\partial y}\right]$$

$$\frac{F_x}{\rho} = \frac{1}{2} C_D a_s h_v u \sqrt{u^2 + v^2} \qquad \frac{F_y}{\rho} = \frac{1}{2} C_D a_s h_v v \sqrt{u^2 + v^2}$$

Computation of flow pattern

Computational Model:

iRIC Model (The International River Interface Cooperative)

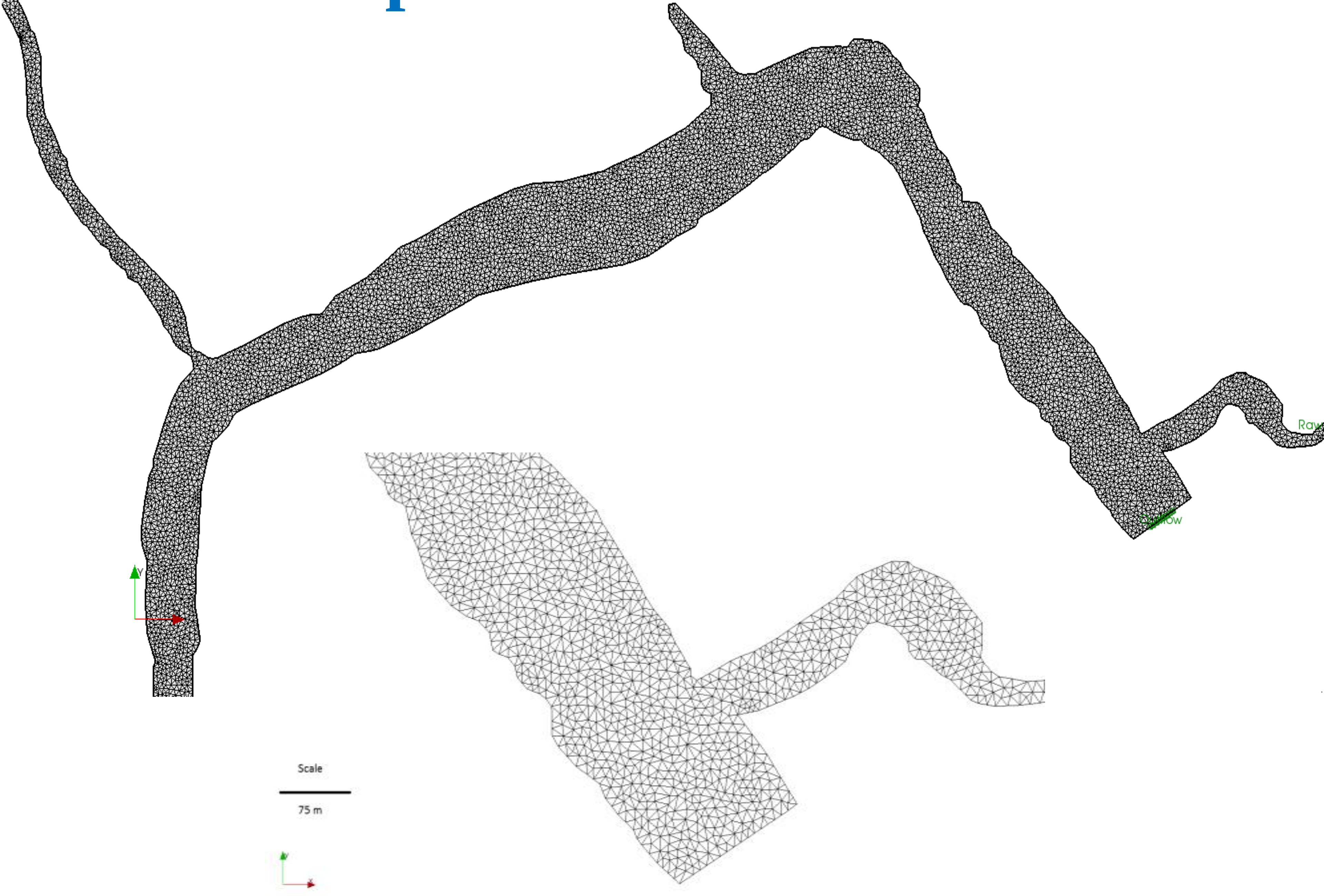
SToRM module

System for Transport and River Modeling.

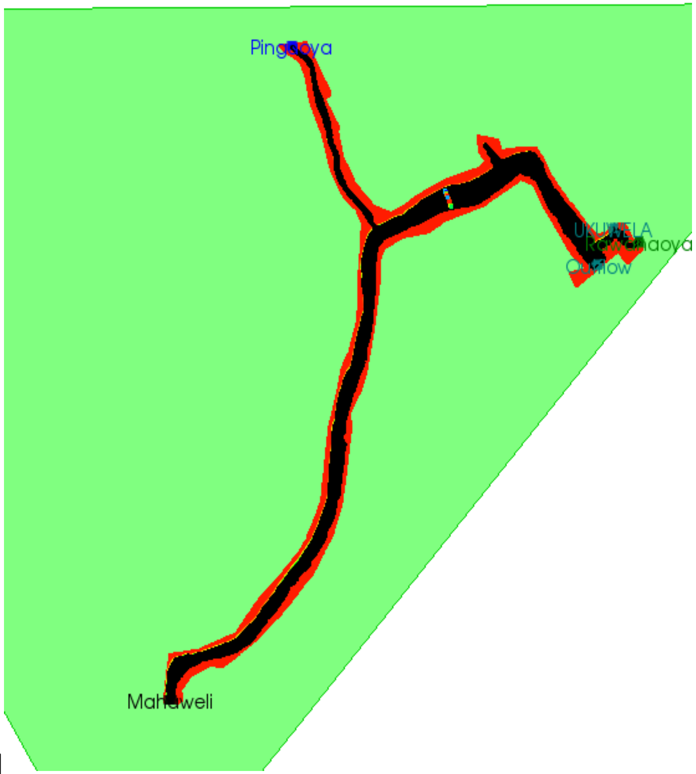
This model is a two-dimensional depth-averaged flow model using a completely unstructured coordinate system described by a triangular mesh.

Ref : *Jonathan M. Nelson, Yasuyuki Shimizu, Hiroshi Takebayashi, Richard R. McDonald, 2010. The International River Interface Cooperative: Public Domain Software For River Modeling*

Computational Grid



Model Calibration



- Upstream boundary condition

  Mahaweli River 62.6 m3/s,

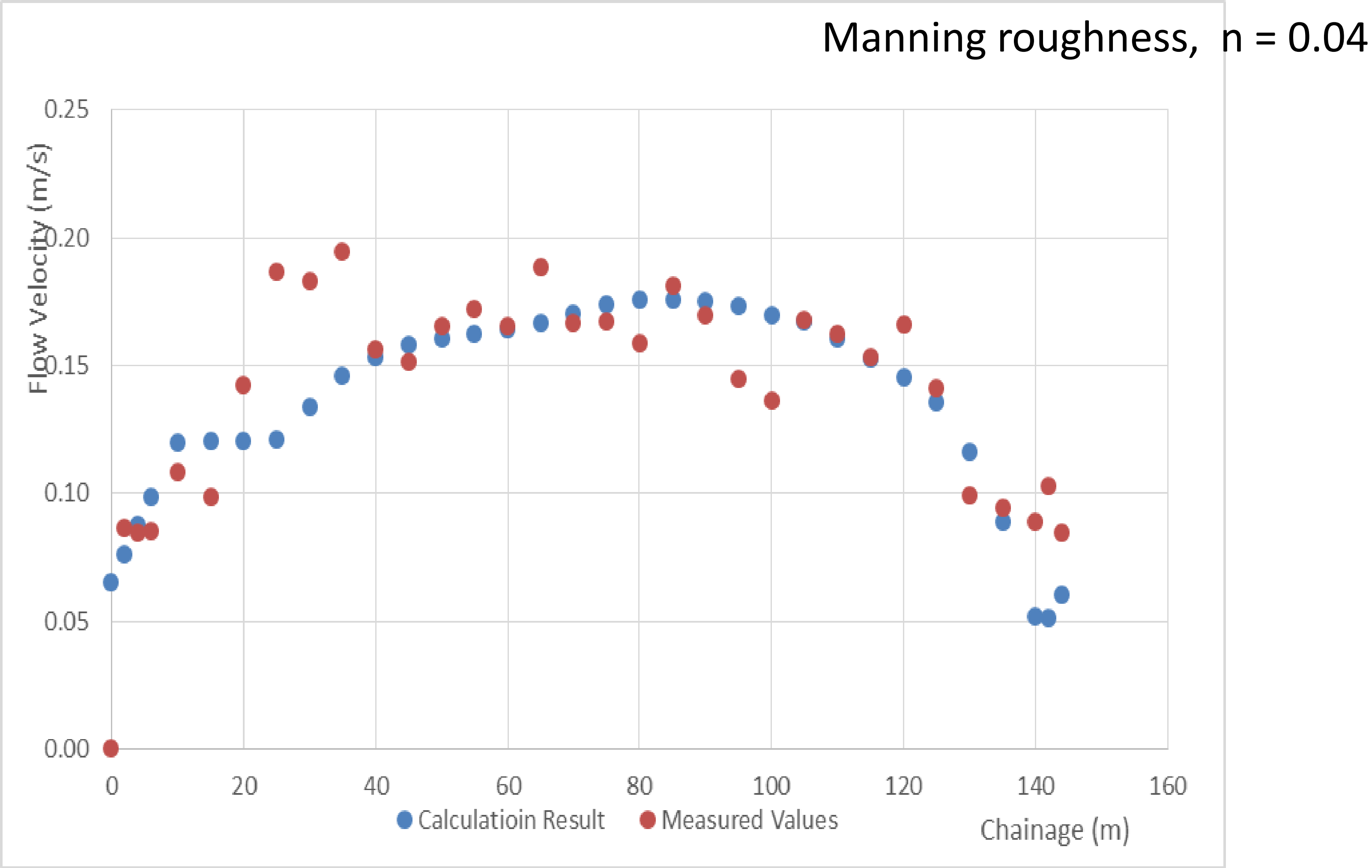
  Pinga oya 0.6 m3/s

  Rawan oya 0.1 m3/s

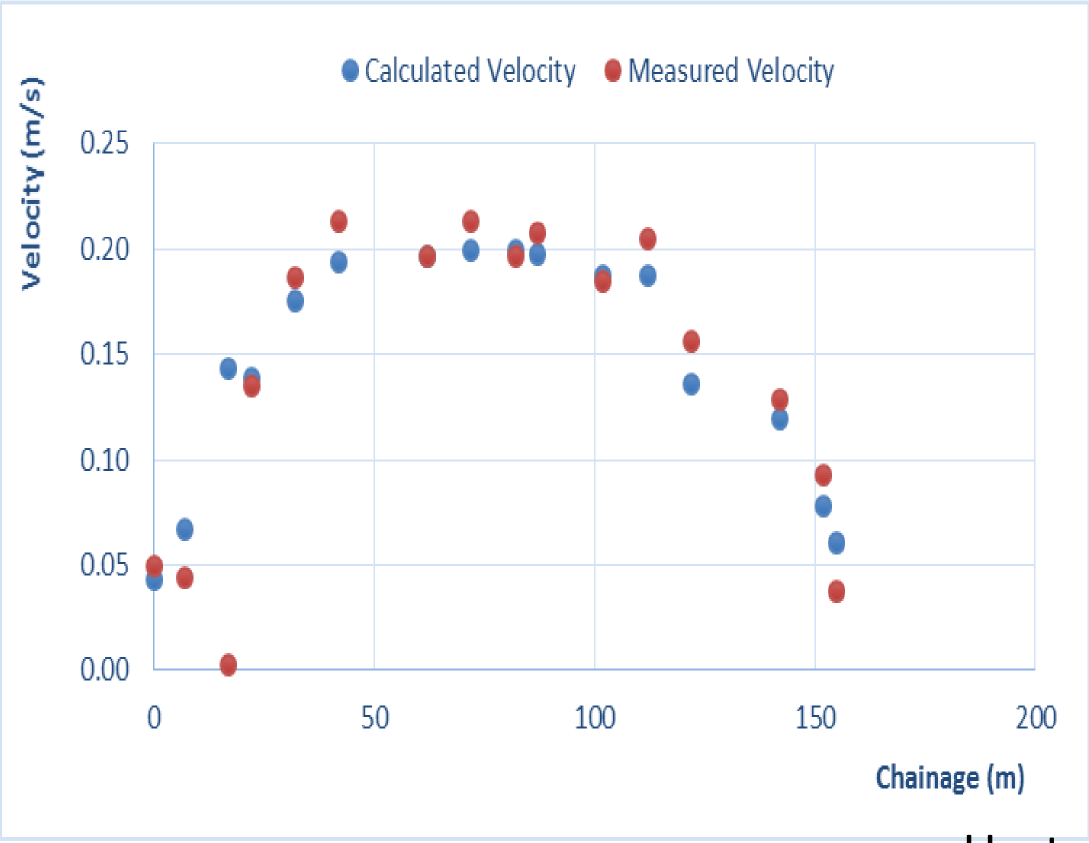
- Downstream boundary

  Water surface elevation 440.03 m MSL

Model Calibration



Model Validation



Upstream boundary condition

- Mahaweli River — 84.76 m^3/s
- Pinga oya — 0.20 m^3/s
- Rawan oya — 0.025 m^3/s

Downstream boundary

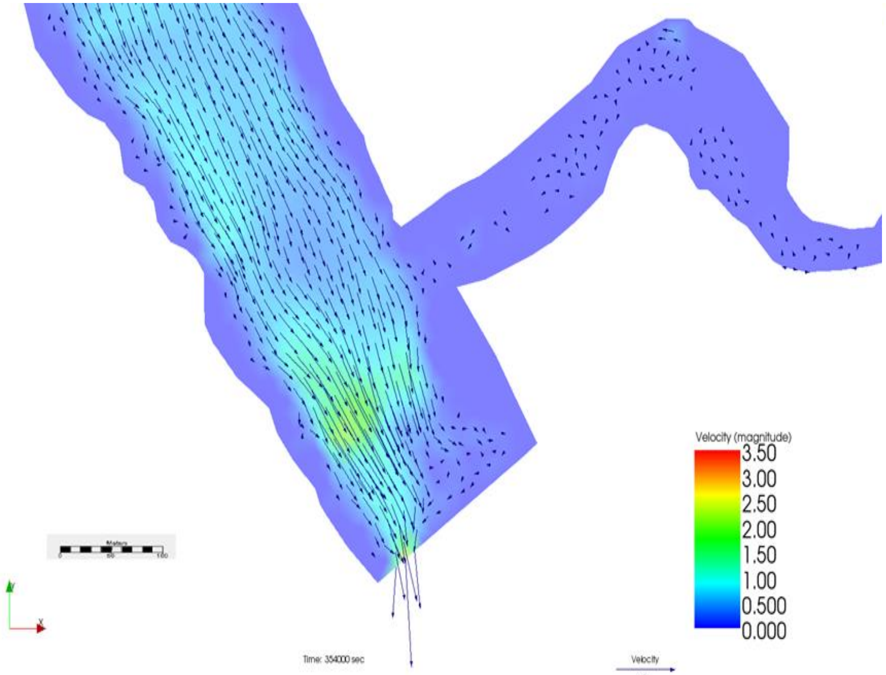
- Water surface elevation — 440.78 m MSL

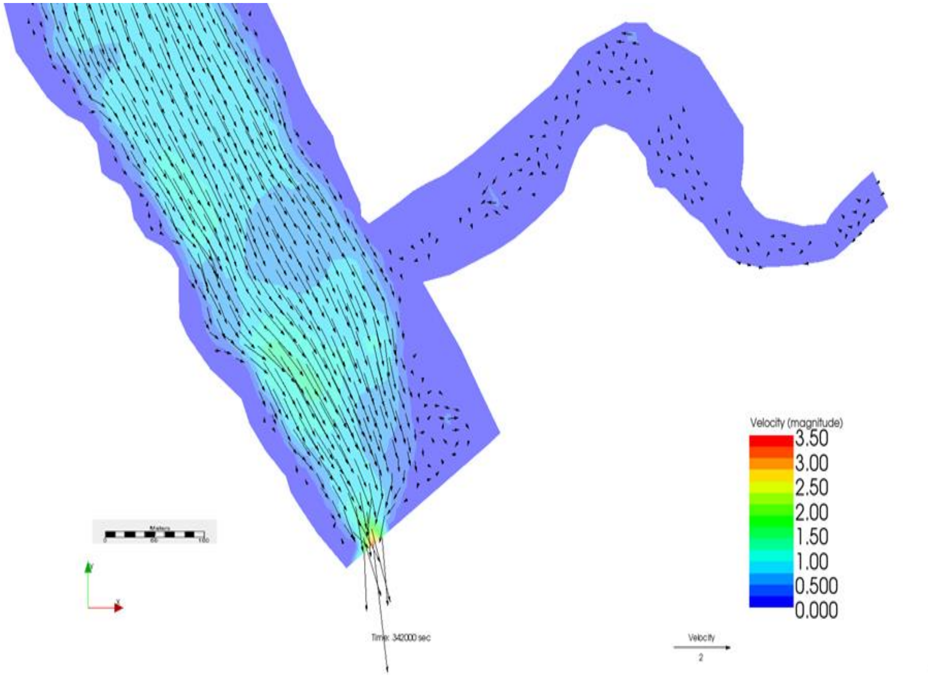
Application for different cases – Combinations of flow and gate openings

Case	Discharge (m^3/s)	Gate opening
Case 1	55	2 gates at the right bank are fully open
Case 2	111	
Case 3	55	2 gates at the left bank are fully open
Case 4	111	
Case 5	277	All 10 gates are fully open
Case 6	555	
Case 7	137	5 gates at the middle of the spillway are fully open
Case 8	277	

Flow pattern - Case 1 and case 2

Case 1	55 m^3/s	Two gates at the right bank are fully open
Case 2	111 m^3/s	

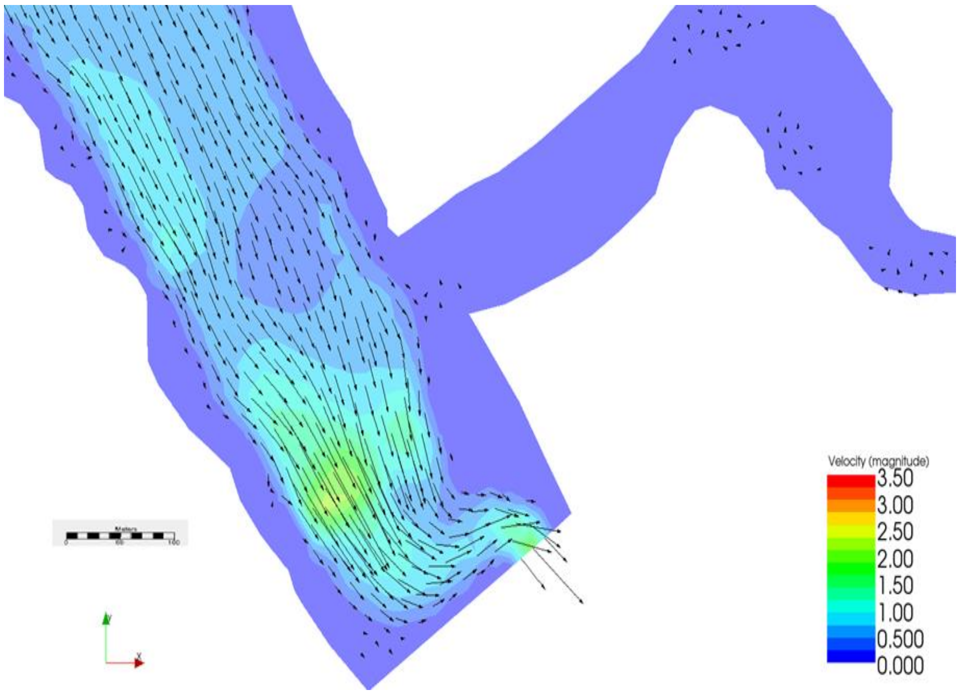


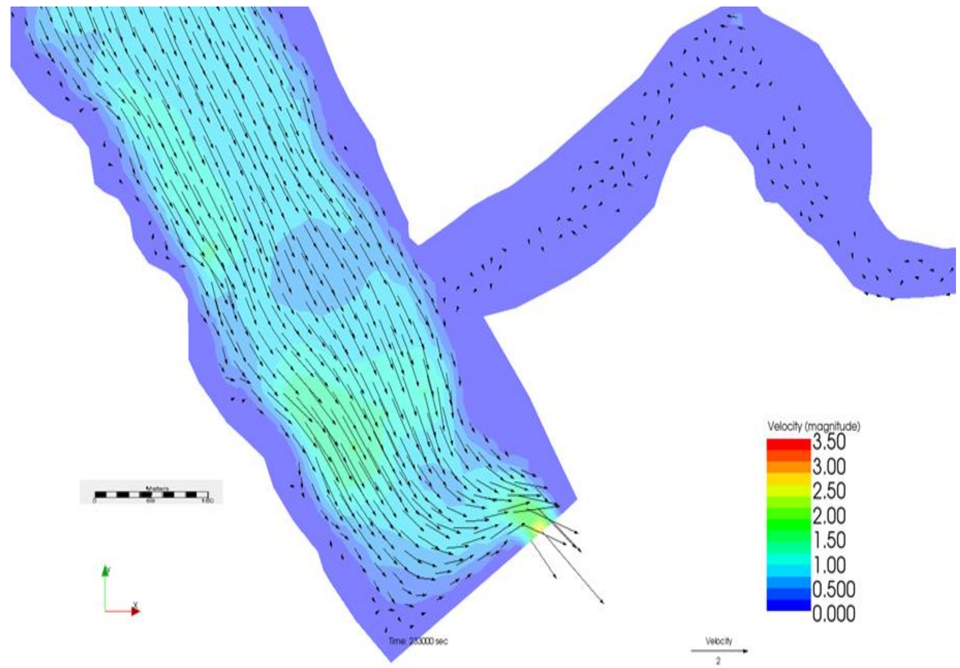


- Larger flow velocities are developed at right bank.
- Lower velocities close to barrage gates at left bank and power intake

Flow pattern - Case 3 and case 4

Case 3	55 m^3/s	Two gates at the left bank are fully open
Case 4	111 m^3/s	

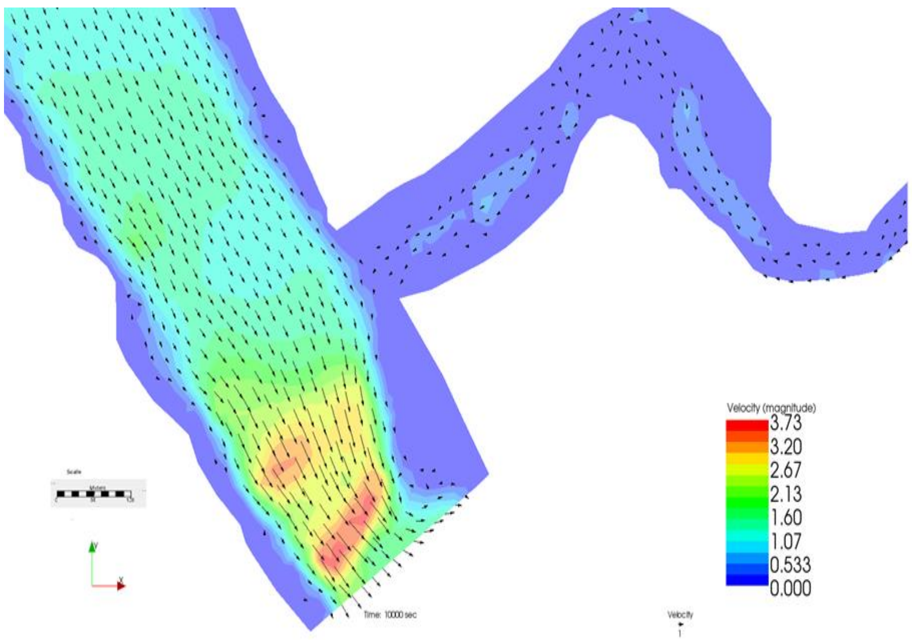


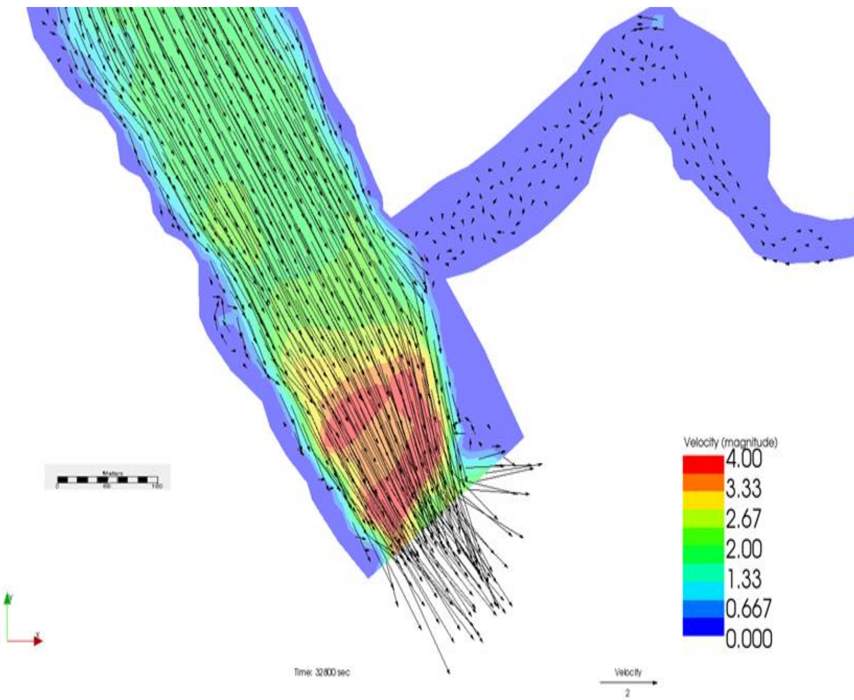


- Considerable velocity development close to the barrage except in extreme right bank. But the velocity at tunnel entrance is very low

Flow pattern - Case 5 and case 6

Case 5	277 m^3/s	All 10 gates are fully open
Case 6	555 m^3/s	

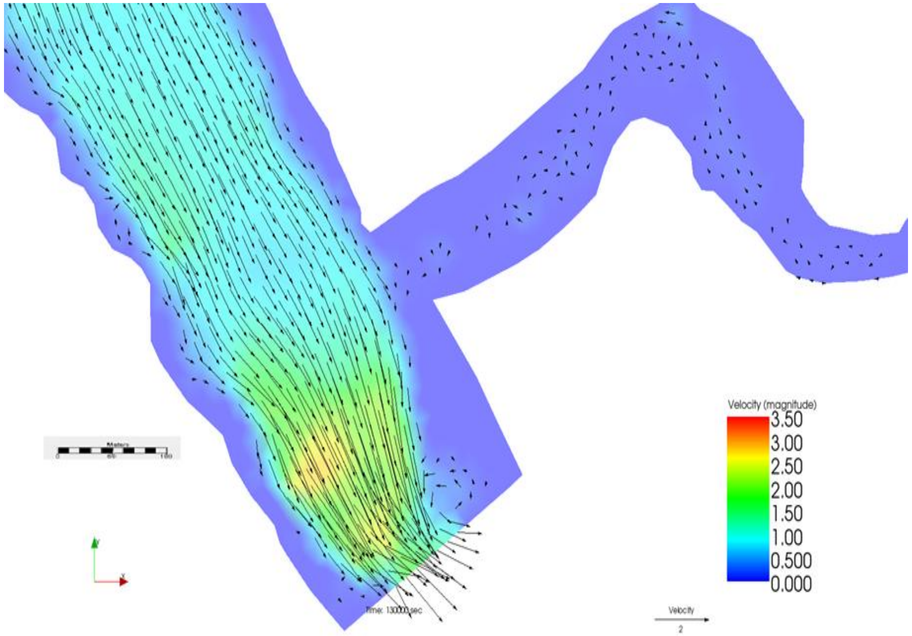


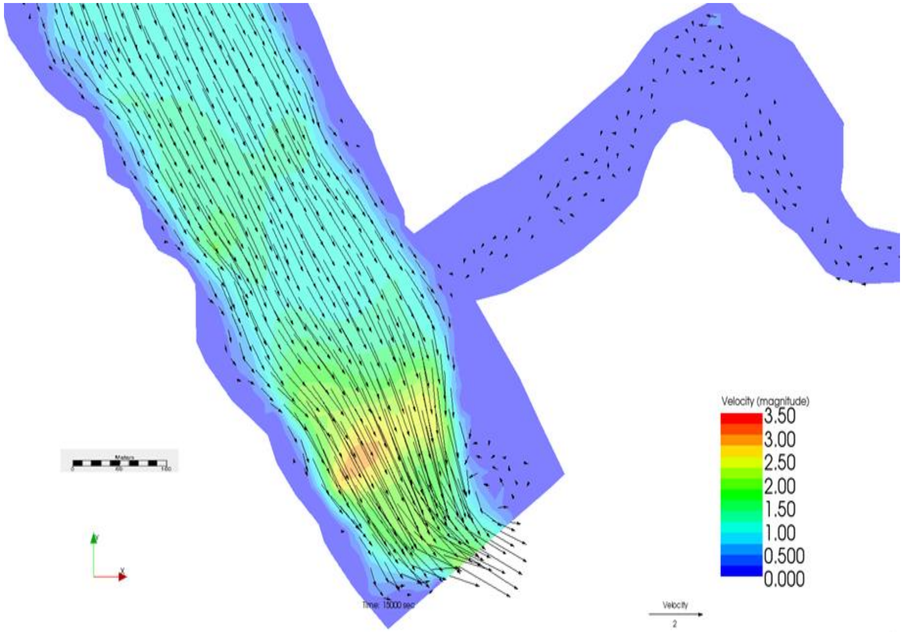


- ➢ Velocities could be seen developed though the reservoir which would cause better sediment sluicing.

Flow pattern - Case 7 and case 8

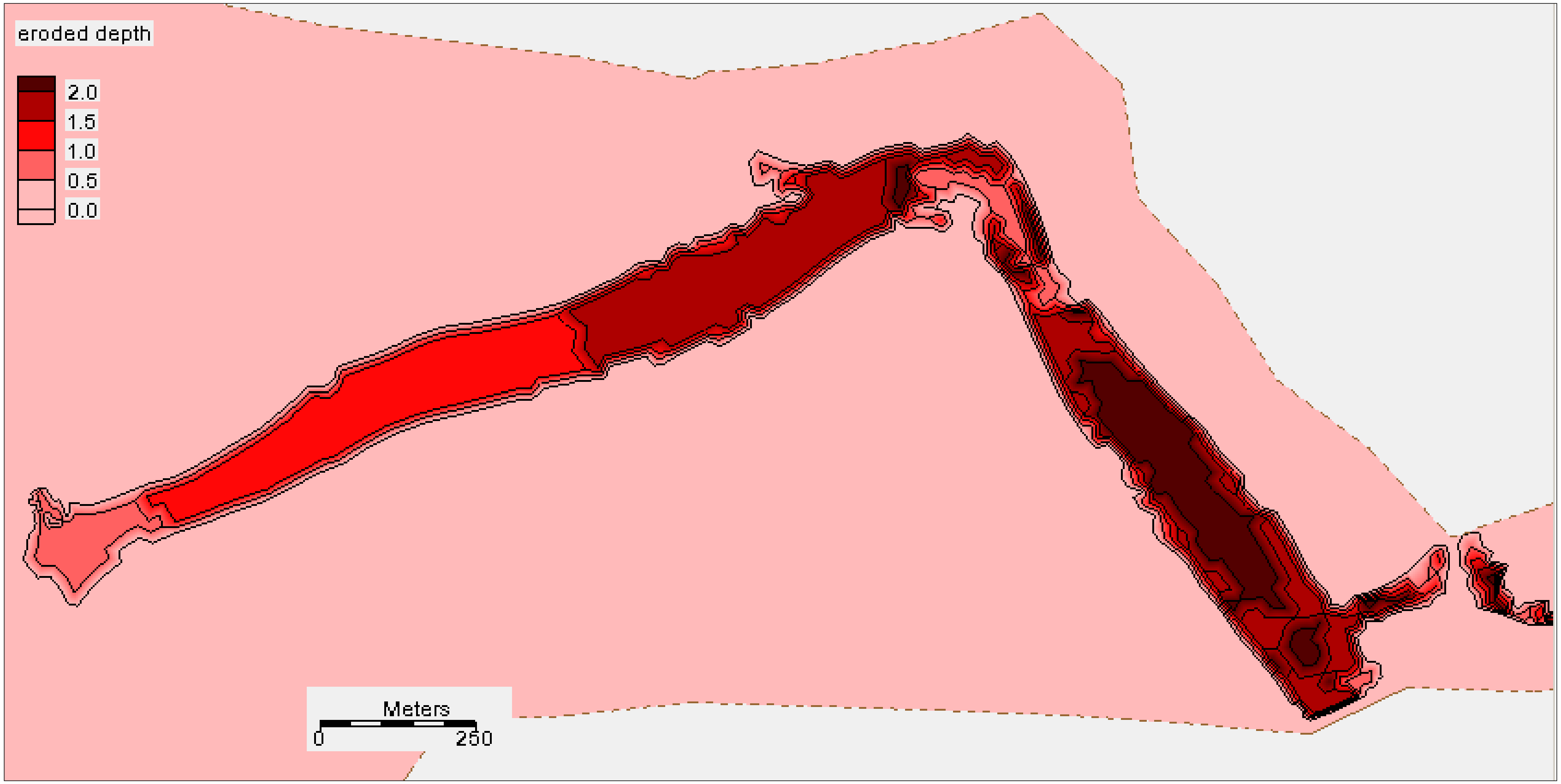
Case 7	137 m^3/s	Five gates at the middle of the spillway are fully open
Case 8	277 m^3/s	





- higher velocity developments in the reservoir. Velocities close to 1 m^3/s are shown at tunnel entrance and in other areas of Rawan oya as well.

Sediment Erosion



For erosion of deposited sediment, the bed shear stress should exceed the critical shear stress. The bed shear stress is proportional to the vertical velocity gradient

Eroded depths of sediment for an inflow of 250 m^3/s flow with 5 gates opened.

Eroded volume is computed to be about 300 thousand tonnes.

Critical shear stress

- On the surface 1.3 N/m^2, U.S. Geological survey Scientific Investigations Report 2008–5093
- At a depth of 1 m sediment deposition was selected as 2.07 N/m^2 (HR Wallingford, 1992)
- For a depth up to 2m the critical shear stress was selected as 5 N/m^2 (Mahamood, 1987).

CONCLUSIONS

- A two-dimensional hydrodynamic model has been set up for the Polgolla reservoir to compute flow patterns under different inflows and barrage gate opening combinations, and a model was introduced to to estimate erosion depths and volumes
- For efficient flushing of sediment , it is recommended that

5 gates are opened when the discharge is 200-300 m^3/s

all the gates are kept open with higher discharges of peak floods.

River downstream of the Polgolla Reservoir


Thank you!!!

Electric Power Generation in Sri Lanka

Owenership & Source of Power Station	No.of Power Stations			Installed Capacity in MW.		
	2014	2015	% Change	2014	2015	% Change
C.E.B. - Total	**25**	**26**	**4.00%**	**2,824**	**2,884**	**2.12%**
- Hydro	17	17	0.00%	1,377	1,377	0.00%
- Thermal-Oil	6	7	16.67%	544	604	11.03%
- Thermal-Coal	1	1	0.00%	900	900	0.00%
- Wind (NCRE)	1	1	0.00%	3	3	0.00%
P.P.P. - Total	**174**	**184**	**5.75%**	**1,108**	**963**	**-13.13%**
- Thermal	6	4	-33.33%	671	511	-23.85%
- NCRE Mini Hydro	144	154	6.94%	288	307	6.60%
- NCRE - Wind	15	15	0.00%	128	124	-3.58%
- NCRE - Other	9	11	22.22%	21	21	0.47%
Total	**199**	**210**	**5.53%**	**3,932**	**3,847**	**-2.17%**

NCRE - Non Conventional Renewable Energy (Solar, Dendro, Biomass, Wind, Mini Hydro)

- Data sources
  - Sri Lanka Mahaweli authority
  - National building research organization
  - Ceylon electricity board
  - Sri Lanka flood control and disaster management center
  - Previous researches carried out about Polgolla reservoir
  - Field measurements

Packages available for computational modelling

- 1D modelling
  - HEC River Analysis System
  - MIKE 11
- 3D modelling
  - FLOW 3D
- 2D modelling
  - NASIR
  - MIKE 21
  - MIKE 21C
  - TISAT
  - CE-QUAL-W2
  - CCHE-2D
  - GSSHA 2D MODEL
  - SMS River Modelling
  - iRIC
  - FLOW 2D

iRIC

- THE INTERNATIONAL RIVER INTERFACE COOPERATIVE: Public domain software for river modeling
- The iRIC software interface includes models for
  - Two- and three-dimensional flow
  - Sediment transport
  - Bed evolution
  - Groundwater-surface-water interaction
  - Topographic data processing
  - Habitat assessment

Jonathan M. Nelson, Yasuyuki Shimizu, Hiroshi Takebayashi, Richard R. McDonald, 2010. **The International River Interface Cooperative: Public Domain Software For River Modeling**, 2nd Joint Federal Interagency Conference, Las Vegas, NV, June 27 - July 1, 2010

Why IRIC

- Is freely available
- Allows easy modelling of very complex channel geometries and let multiple inflows and outflows to be incorporated
- Handles rapidly varied flows easily
- Has relatively simpler methods of setting boundary conditions at arbitrary shaped obstacles
- Provides easy methodology for users to change the models
- Can be accessed easily
- Comprises with more models with a wider range of sub model tasks
- Has better treatment of time variations and better tools for 3D visualization

Selection of the solver…

- NaysCube
- CERI1D
- FaSTMECH
- SToRM
- **Nays2DH**
- NaysFlood
- River2d
- Delft3d
- NaysEddy
- SRM

✓**Nays2DH**

➢ It is a combination of Nays2D and Morpho2D

➢ Nays2DH is a computational model for simulating horizontal two-dimensional (2D) flow, sediment transport,

Model Generation

- Selected interface – iRIC
- Bathymetry – NBRO
- .tpo (topography) file generation - ArcGIS
- 11940 grid points covering the reservoir area.

Data of Polgolla Reservoir (Polgolla Pond):
Full Supply Level 440.74 m MSL
Minimum operating level 438.89 m MSL
High Flood Level 443.76m MSL
Dam crest Elevation 447.45m MSL
Original storage capacity at FSL 4.657 MCM

The critical shear stress
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