Abstracts

of the

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on

Water in the Humid Tropics

Kandy, Sri Lanka

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Water in the Humid Tropics

Dec 04, 2006, Kandy, Sri Lanka

Venue **Earl's Regency Hotel**

08.00 – 08.30	Registration
08.30 – 8.45	Welcome addresses

Keynote lectures

08.45 - 09.15	Water in Monsoon Asia and Global Water Crisis -Prof. Yutaka Takahasi, Senior programme advisor, UNU
09.15-09.45	What is sustainability? Is it a holy grail or is attainable -Prof. Monte Cassim, President, APU
9.45 – 10.00	Tea
10.10 – 10.40	Rainfall Changes and Risk Management in the Humid and Semi–humid Regions in China -Prof. Massatishi Yoshino, Senior programme advisor, UNU
10.40 – 11.10	Sustainable Water Management in the 21st Centuary -Prof. Sontak Lee,President, IEHS

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Climate and environmental impacts

11.11 – 11.30	Variabilities of Rainfall Seasonality in the Monsoon Humid Tropics -Prof. ManfredDomroes, Maniz University
11.30 – 11.45	Adverse Impacts on Agriculture and Fisheries from Environmental Change have Important Implication for the Humid Tropics -Dr . Max Finalayson, IWMI
11.45 – 12.00	Discussion
12.00 – 13.00	Lunch
13.00 – 13.15	Direct Runoff Hydrograph for Ungauged Basins in the Hill Country of Sri Lanka -Dr. S. B Weerakoon, University of Peradeniya
13.15 – 13.30	Predicting Water Availability in Sri Lanka -Prof. K.D. W Nandalal, University of Peradeniya
13.30 – 13.45	Trophic Alteration in Reservation of Sri Lanka – an Outcome of Monsoon Driven Seasonal Hydrology -Prof. E. I.L Silva, IFS Kandy
13.45 – 14.00	Oxygen Transfer by Air Entrainment at Risparian Riffiles -Prof. Jin-Hong Kim, Chung – Ang University

14.00 – 14.15	The Effect of Flow Regime Alteration on Ecosystem Responses in Thegeum River basin, Korea -Prof. Ick-Hwan Ko, Director, Water Resources and Environmental Research Centre, Korea
14.15 – 14.	30Water Quality Issues in Lower Kelani Basin -Dr. Gemunu Herath, University of Peradeniya
14.30 – 14.45	Discussion
14.45 – 15.00	Tea

Session 2 - Sustainability

15.00 – 15.15	Recovery of urban water cycle -Dr Srikantha Herath, UNU
15.15 – 15.30	River Environmental Consideration for Restoration of the Degraded Urban River in Korea - Prof. Shamhee Lee, Research Fellow, Department of Water Resources, Korea Institute of Construction Technology, Korea.
15.30 – 15.45	Turbidity Problem and Management in Imha Reservoir - Prof. Deuk-Koo Koh, Head Researcher, Korea Institute of Water and Environment.

15.45 – 16.05	Issues in Environmental Impact Assessment of Large-Scale Reservoir Development Projects in Humid Tropics: The Case of Kalu Ganga at Laggala Pallegama, Sri Lanka. Prof. C.M. Madduma Bandara
16.05 – 16.25	Environment Philosophy for Water Management in the Humid Tropics with Reference to Bali and Lijiang - Prof. Kayane Isamu, Aichi University, Japan.
16.25 – 16.40	Sustainable Management and Conservation of Water Prevalent in the traditional systems - Mr. Udula Bandara Ausadahami, CECB.
16.40 – 17.20	Panel Discussion
17.20 – 17.30	Vote of Thanks

Water in Asian Monsoon and Global Water Crisis

Yutaka Takahashi
Senior Programme Adviser, United Nations University
Professor Emeritus, the University of Tokyo

Water crisis is one of the most critical challenges among the global environmental issues, mainly in Asian Monsoon Area, due to rapid increase in population, energy consumption, severe urbanization and modernization.

Sixty percent of the world population resides in the Asian monsoon area and there will be a rapid increase in the first half of the 21st century. Energy consumption will increase simultaneously with the increasing population, active industrial growth, and the improvement of standard of living. Severe urbanization will advance in most of the big cites in the area, especially in South-Eastern Asia, China and India. Modernization will change the lifestyle and the social structure resulting rapid water demand increase, grave water pollution, serious collapse of eco-system in water bodies, and also water-related crises such as land subsidence, floods etc.. Global warming will accelerate the crises with the increasing torrential storms.

In considering the water crisis in Asian Monsoon Area, it is necessary to recognize the characteristics of the Area. Paddy cultivation plays an important role, as it preserves the water cycle environment by managing floods storms rainfall, recharging ground water, and keeping water in farmlands. Rapid urbanization is now removing paddy fields in every country without considering the effect on the hydrological cycle. The rich forests, where the environmental equilibrium has sustained through ages is now facing crises due to excessive deforestation. This will bring serious impacts not only to runoff, but also to normal discharge. Coastal line of the Asian countries is also are affected, owing to decrease of sandy beaches.

One of the most serious and difficult tasks for the people in Asian Monsoon Area is the harmonization between European modernization and Asian traditional philosophy which esteem "the divine providence". They should cope up with the contradiction between European rationalism and Asian thought, which promote living with Nature. The contradiction will appear clearly in the water society of the Area. European rational thought should be introduced, while preserving the Asian life style.

For example, Japan has applied the modern European scientific method for flood control since the end of 19th century. Japanese river engineers tried the modern difficult engineering method in flood controlling and succeeded to some extent. After the Second World War, Japan suffered successive huge flood damages, especially from 1945 to 1959. One of the reasons is the surprising increase on flood discharge due to record-breaking torrential rainfall, as well as active river improvement works to concentrate the flood flow in the artificial river courses. It implies the difficulty to control the huge flood flow in Asian Monsoon rivers not only by the river improvement works but even with comprehensive and the integrated engineering methods including the land planning. Characteristics on the land policy in Asian Monsoon Area are deeply related to the peoples' relation to paddy fields.

Plans on flood control, water resources development and conservation, and water environment including water scenery must recognize the hydrological, socio-economical and historical characteristics of Asian Monsoon, without simply imitating modernization developed in Europe.

Rainfall Changes and Risk Management in the Humid and Semi-humid Regions in China

Masatoshi Yoshino
Senior Advisor, SED, United Nations University,
Emeritus Professor University Tsukuba, Japan

Earthquakes result in great amounts of damages among natural disasters, but as far as frequency is considered, floods, landslides, breaks of river banks and dams etc., caused by unusually heavy rainfall, are the most significant factors for impacts on sustainable development. The ratio of the damage to GDP was more than 170% in the case of earthquake in Armenia in 1988, in contrast to 11% in the cases of flood in Yemen in 1982 and 6% in Nepal in 1987. This is a comparison of only one event with another. Number of floods shows a more distinct increase in the worldwide trends of natural disasters, particularly since 1975.

Due to improvement of forecasting accuracy, establishment of information systems, investment for disaster reduction, coordination mechanism, public awareness, collaboration among stakeholders, number of deaths caused by floods and landslides are decreasing in Japan. In particular, damage reduction from small to medium class typhoons has been very clear as seen from the numbers of deaths.

In the present paper, secular variations of monthly rainfall in South China are taken into account, comparing with the general tendencies in the humid and semi-humid tropics of Monsoon Asia, and their regional and local differences are shown.

Long-term changes of ratios (15- year mean) of collapsed houses to population and those of numbers of deaths to population caused by unusual meteorological hazards in whole of China have become one fifth and one fourth respectively, for the duration of 1980 - 1994 compared to the duration of 1950-1964. Similar values or more sharp decreases can be estimated for the cases of severe rainfall in tropical and subtropical China, considering the secular variations of rainfall mentioned above.

Economic losses caused by natural hazards are increasing in China: It is around 2,500 million US-dollars in the coastal regions of East China every year, including the delta regions of Yangtze River (Changjiang) and Zhujiang. Discussion is made on the change of numbers of deaths, collapsed houses and ships, and direct economic losses caused by tropical cyclones, which hit the coastal regions of China. Developments of insurance for these hazards are also analyzed for consideration into risk management during the recent years.

In the last part of the study, the time-space scales in risk management are discussed considering the circular-type-economic activities of human societies, since frame work of interactions between human societies/ecosystem services and rainfall changes etc. are developing in various ways in global, regional and local scales, which are generally corresponding to the time scales from long-term to short-term respectively.

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Sustainable Water Management in the 21st Century

Soontak Lee
Distinguished Professor, Yeungnam University, Daegu 712-749, Republic of Korea

In many areas of the world, the growing human population is rapidly depleting available freshwater supplies. During the 20th century, the global human population increased fourfold to more than six billion. Water withdrawn from natural freshwater ecosystems increased eightfold during the same period. Facing an ominous specter of increasingly severe water shortages in many areas of the world, water managers and leaders are exploring strategies for managing water resources sustainably. This quest for sustainability centers on managing human uses of water as well as maintaining healthy freshwater ecosystems for future generations in the 21st century.

The sustainable management as a new paradigm since 1992 is to manage water supply and demand in an integrated way, taking into consideration both socio-economic requirements and the intrinsic capabilities and limitations of ecosystems to support, over the long-term, a particular suite of human activities. Furthermore, ecologically sustainable water management protects the ecological integrity of affected ecosystems while meeting intergenerational human needs for water and sustaining the full array of other products and services provided by natural freshwater ecosystems.

Variabilities of Rainfall Seasonality in the Monsoon Humid Tropics

Manfred Domroes

Prof. Dr. Department of Geography

Mainz University, Germany

Though controversially discussed and defined, the tropics occupy a wide belt around the equator, considered by many scientists as a region experiencing a rather unlimited surplus of rainfall and temperature that leads to the most diversified ecosystems on the globe. Climatologically, the tropics experience highly diverse rather than uniform conditions. Monsoon humid tropics are strongly governed by a striking seasonality of its water budget resulting from the seasonally alternating atmospheric circulation patterns and hence creating great intra-annual rainfall variability. Commonly, summer represents a wet season while winter occurs as a dry season. Summer and winter, however, strikingly differ in their hygric nature, given by the variable length of each season and the rainfall conditions. Monsoon humid tropics are, therefore, experiencing rather uneven climatic conditions over space and time and lead to a wide range of humid tropical ecosystems and landuse patterns.

In view of the climatic resources of monsoon humid tropics the intra-annual variabilities of rainfall were studied in order to explain the magnitude of hygric seasonality aiming to underline the great extent of seasonality under the monsoon forces. Methodologically, intra-annual rainfall variabilities were calculated by the number of months per year that experience above- and below-normal rainfall conditions. Assuming an even distribution of rainfall all-year round, each month of the year (January, ..., December) would experience a 8.3 percent value of the annual total. Any month with a value >8.3 percent would represent a surplus month of rainfall, vice-versa, any month with a <8.3 %-value a deficit month. Under such approach, the annual course of rainfall at any climate reference station would be divided into surplus and deficit seasons which vary in their length and intensity. As a basic approach, the number of surplus and deficit months of rainfall can simply be related to the corresponding month(s).

In a more detailed approach, the magnitude of rainfall surplus or rainfall deficit can be divided into various classes (categories) according to their extent of surplus or deficit. In the present study, the following categories of rainfall were introduced referring to the following monthly percentages of rainfall:

above 10.4 %:	"surplus" (month)
9.2 - 10.4 %:	"semi-surplus" (month)
7.5 – 9.1 %:	"normal" (month)
6.2 – 7.4 %:	"semi-deficit" (month)
below 6.2 %:	"deficit" (month)

The range of a "normal" month was defined by a 10 percent rainfall surplus and deficit each related to the average percentage value (8.3 %/month). A "semi-surplus", resp. "semi-deficit" month was defined by another 10 %

surplus resp. deficit of rainfall. A "surplus" month exceeds a 10.4 %-value of rainfall while a "deficit" month drops below a 6.2 %-value of rainfall.

Under such assumptions, the study area comprises of the Asia-Australia region where the tropics were defined by the TROLL climate classification scheme. Accordingly, the boundary of the tropics was defined by the "Gleichgewichtslinie" ("equilibrium line") between the mean daily and annual temperature range. Applying this definition, the tropics comprise all the area that experiences a greater daily than annual temperature range. The tropical region (abbreviated "V", by Troll) was subdivided into five types, based on the number of humid/resp. arid months, as V1, V2, V3, V4 and V5 (according to the increasing number of arid months, resp. decreasing number of humid months). The total number of reference stations accounts for 136 (referring to all stations in MÜLLER's "Handbuch der Klimastationen der Erde" 1996).

Considering only the division into surplus and deficit months (by monthly values above an 8.3 percentage, resp. below an 8.3 percentage), the computation of the number of surplus and deficit months of rainfall clearly expresses a greater number of deficit months accounting mostly for 6 to 8 occurrences against only 4-6 surplus months. This indicates a greater tendency towards a more pronounced season of deficit months rather than surplus months, which, instead, tend to persist only for a shorter season.

Taking also into consideration the division into sub-humid and sub-arid months, together with the definition of "normal" months, the computed

numbers of months concerned account on average:
for "semi-surplus" months: below 1,
for "normal" months: 2, and
for "semi-deficit" months: below 1

As a result, the number of surplus and deficit months accounts for:
surplus months: 4
deficit months: 5

In all, the observations clearly express the greatest values for the number of surplus and deficient months against a low number of normal months as well as semi-surplus and semi-deficit months. This observation clearly shows a striking variability of the annual range of rainfall and, at the same time, an uneven distribution of rainfall for the monsoon humid tropics. It can simultaneously be seen that the annual range of rainfall between surplus months and deficit months must strikingly be taken into consideration expressing a remarkably deficient, dry season against a strikingly surplus, wet season. In such cases, the monthly surplus values may even exceed for individual months 20 percent against less than one percent for the most deficient months. Hence, the remarkably large seasonality of rainfall in the monsoon humid tropics must be considered as a governing climate force.

However, the great differences of rainfall variabilities according to the number of surplus and deficient months are associated by great variabilities over space as far as surplus and deficient months are concerned. In most parts of the Asia-Australia study region, summer represents the surplus season, winter the deficient season. This alteration may be basically changed in case of the wet winter monsoon comprised with a dry summer monsoon. Such alteration is experienced in case of a wet passate circulation when the originally dry airmasses are labilized into wet airmasses as increase of the eastern sides of South- and Southeast Asia.

From the analyses of rainfall surplus and deficient months it can be followed that rainfall seasonality greatly varies in the monsoon humid tropics, both over time and space. Such disparities, however, negatively affect, for example, the annual crop calendar based on more striking deficient than surplus conditions. Under deficient conditions water becomes a climatic stressor for plant growth and ecosystems.

Adverse Impacts on Agriculture and Fisheries from Environmental Change have Important Implications for the Humid Tropics

Max Finlayson

International Water Management Institute

PO Box 2075, Colombo, Sri Lanka

Several reputable international assessments have recently assessed the status and trends and future scenarios for ecosystems, water and agriculture. These assessments have been based on globally relevant data and incorporate efforts to outline scenarios and responses at regional and/or local levels. As with all assessments the quality of the analyses are dependent on the availability and certainty of data and information. This immediately raises constraints when dealing with data scarce areas, as is the case with large parts of the humid tropics. In such cases the assessment may be built on expert knowledge and extrapolation. While explaining the caution that should accompany such extrapolation, the issue of how the loss of biodiversity can adversely have an impact on water management in agriculture and fisheries in the humid tropics is explored. This is done by examining examples from different ecosystems and identifying key lessons for managing water whether for ecosystem, agriculture or fisheries purposes in the humid tropics. Examples include the effect on agriculture and/or fisheries of the development of near-shore anoxic zones, the loss of pollinators or pest control, the fragmentation of rivers, and the spread of invasive species. The underlying messages are: i) that environmental change

is having adverse effects on agriculture and fisheries; ii) this can have far-reaching social and economic consequences; and iii) the smartest response may be to prevent further adverse environmental change rather than expect to recover at some later stage of development. We are only now coming to grips with the existence of step-wise and irreversible change in ecosystems – at the same time we are seeing the consequences of adverse environmental change on our water and agricultural and fisheries activities. The implications for social resilience and equity as a consequence of our water management practices that have contributed to adverse environmental change need exploring both now and in the longer term. Water is a shared resource – shared between many agricultural and fisheries activities and regulated by ecosystems that are valuable for people and which are being degraded principally by agricultural and water management practices

Direct Runoff Hydrograph for Ungauged Basins in the Hill Country of Sri Lanka

P. B. Hunukumbura, S. B. Weerakoon

Department of Civil Engineering, University of Peradeniya, Sri Lanka

and

Srikantha Herath

United Nations University, Tokyo, Japan

The need for new methodologies to make improved predictions in ungauged basins is well recognized as in many cases the management of basin water resources has to be done without sufficient past hydrological data. Long practiced method of derivation of synthetic unit hydrograph for prediction of direct runoff in ungauged basins is the Snyder's synthetic unit hydrograph. The method is based on two regional parameters identified for the given basin, which are derived from hydrologically similar gauged basins. In developing countries, most of the basins are totally ungauged and regional models or development of a regional set of parameters is not feasible. Thus, method to predict reliable stream flow in ungauged basins is extremely beneficial to these countries for sustainable water resources development and flood mitigation. This paper describes a model, which can be used to obtain direct runoff hydrographs for ungauged basins using basin's topographical, land use, soil, stream network and rainfall data. The model parameters are obtained from the topographical, stream network, soil and land use GIS data of the basin. Special care has been taken to make the model user friendly and simple by using a small number of parameters that can be derived from physical information of the basin

The basin is considered as a collection of grid cells and a canal network. The slope of each grid cell is taken as the maximum slope to its neighbouring eight cells. Grid cells of the basin first produces overland flow from the effective rainfall and then flows to the basin outlet through canal network of the basin. The total time taken to flow water from each grid cell to the basin outlet is calculated after applying 1mm/hr continuous constant effective rainfall rate over the basin. The S-curve for the basin is developed using total travel time distribution of the basin. Unit hydrograph of required duration is then obtained from the S-curve. The direct runoff hydrograph for a given effective rainfall time series is obtained using the unit hydrograph of the basin by superposition.

Overland flow is modelled as a sheet flow and the flow velocities are calculated using Manning's equation. In the canal network, flow velocity is calculated using kinematic wave approach. Total travel time for a flow originated from a grid cell is calculated using the velocity and travel distance through the grid cells and the canal segments. A constant infiltration loss rate model based on the flow travel time through grid cell and soil type is used in the model for calculating the effective rainfall.

The model is coupled with GIS data of the basin to form a computer based model. The slope, flow accumulation and flow direction grids are prepared using a digital elevation model. The land use raster grid for the basin is prepared using land use and land cover maps of the basin. The Manning's roughness coefficient for overland flow in each grid cell is selected from a look up table. The flow velocity grid, contains flow velocity values through each grid cell of the basin. The flow travel time through each grid cell is obtained using slope distance and the flow velocity through each grid cell and the canal segments. The total travel time grid of a flow from each grid cell to the basin outlet is computed as total travel time grid.

The model was applied to the Upper Kotmale basin for the period of April-September 2003 where model verification was possible. The Upper Kotmale basin of 304 km^2 above Thalawakelle (Lat. $6^0 56' 4.4''$ N, Lon. 80^0 39' $45''$ E) is the upper most basin of the Mahaweli River, one of the most important water resources in Sri Lanka. The basin lies in the central hills of the country and the elevation varies from 1200 m to 2500 m above mean sea level. The terrain of the area is generally mountainous with steep slope. Most of the high elevations are covered with natural forest and grasslands. The basin situated in the wet zone of the country and the average annual rainfall of the basin varies from 2200 mm to 2600 mm. It is under varying land use comprising of tea 44%, forest 36%, home garden 7%, grass 5%, cash crops 5% and scrub. The basin is covered with three main soil series of Sri Lanka.

The UH obtained from the model was compared with the UH derived from the observed data and the Snyder's UH using regionalized parameters. The parameters of the model predicted UH and the observed UH agree satisfactorily, especially compared to the agreement of the parameters of the Snyder UH. The model predicted direct runoff hydrograph predictions for three rainfall events were compared with the observations and the agreement is satisfactory. The model is a useful tool to derive the direct runoff hydrograph for ungauged basins with reasonable accuracy, as it demands only the basin topographical, land use, rainfall and stream network data.

Predicting Water Availability in Sri Lanka

K.D.W. Nandalal

Department of Civil Engineering, University of Peradeniya, Sri Lanka

Sri Lanka is a country rich in water resources. The mean annual rainfall ranges between 900 mm and 6000 mm, with an island wide average of about 1,900 mm, which is about two and a half times more than the world annual mean of 750 mm. Thus, the total volume of fresh water received annually is 13,230 million m^3. Though Sri Lanka has abundant water resources in aggregated terms this overall picture is misleading owing to the high degree of variation in the availability of water, both seasonally and regionally.

An improved understanding of the water availability in Sri Lanka will benefit those who are involved in planning new water resources development schemes or expanding existing schemes in the country. Traditional approach used in this process is based on projections of population growth, unit water demand, agriculture production, industry growth, etc., which were used to estimate future water demand and water balance. Future water projections are variants of current trends and as such are subject to considerable uncertainty. Dynamic character of main variables such as climatic change, socio-economic change, institutional change, environmental change etc., and how they affect water use in future are not captured in the traditional approach. Therefore, the prediction of future water use and balance is subject to a wide margin of error. In contrast, a novel approach, "system dynamics" offers a new way of modeling the future dynamics of complex water systems increasing the ability to correctly assess and predict availability, use and balance of water.

System dynamics is a theory of system structure and a set of tools for representing complex systems and analyzing their dynamic behavior. The most important feature of system dynamics is to elucidate the endogenous structure of the system under study, to see how the different elements of the system actually relate to one another, and to experiment with changing relations within the system when different decisions are included.

System Dynamics Based Model

A system dynamics based simulation model that integrates water with population and agricultural sectors is developed to assess and predict water resources in Sri Lanka at district and national level. Sri Lanka is divided into twenty five units in the model, administrative district boundaries being their borders. Since the availability of most of the data required for the model is at district level, this division was used in the model. Each unit comprises of four sectors, viz., water quantity, population, agriculture and food sectors. All twenty five units, each with the above four sectors, are integrated to build the overall model for the whole country. The model has been developed using the VENSIM (Ventana Systems Inc., 2004) modeling environment. Figure 1 provides the basic model structure of different sectors including the main variables with their multiple dynamic feedback causal links.

The model was calibrated using data, such as meteorological data, land use, population data etc., for a ten year period from 1991 to 2000 and verified for a period of four years from 2001 to 2004. Subsequently, the model was used to predict water availability in Sri Lanka at district level up to the year 2025.

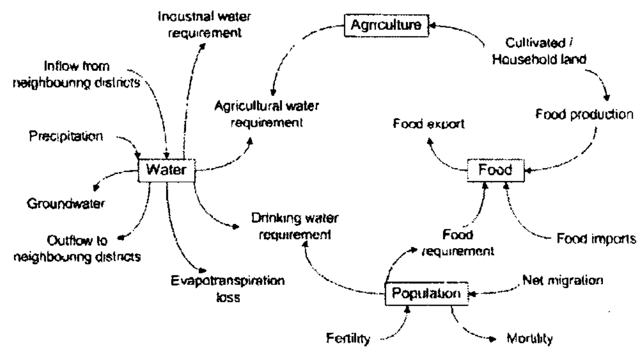

Figure 1. Basic model structure

Puttalam, Gampaha, Hambantota, Mannar and Colombo districts were observed to be having *medium to severe* water scarcity conditions according to the Falkenmark water scarcity criterion. Colombo and Mannar districts will fall to *severe* condition by the end of the year 2025. Water scarcity condition of the Jaffna district will be *moderate* up to 2025 while Kurunegala and Kandy districts fall to the condition from *little or no* to *moderate* after the year 2014. All the other districts fall into the *little or no* water scarcity condition. Though the water scarcity conditions of districts show different conditions with respect to water scarcity, the whole country will have little or no water scarcity upto the year 2025 as shown in Figure 2.

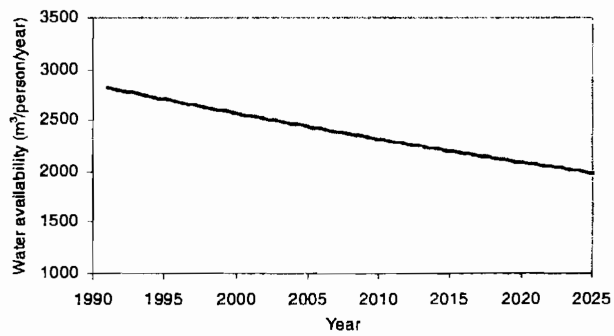

Figure 2. Per capita water availability in Sri Lanka

Conclusions

A system dynamics based simulation model that integrates water with population, agriculture and food sectors is developed to assess and predict water resources in Sri Lanka at district and national level. The model, which was calibrated and verified based on data for a period of 15 years, was used to predict water availability at district and national levels up to the year 2025.

The results indicate that in several districts water availability will decrease rapidly while others will not get much affected. During the period analyzed, Sri Lanka will have abundant water resources in aggregated terms, but this overall picture is misleading, as some districts will face water scarcity conditions.

References

Ventana Systems Inc. (2004) *Vensim DSS Version 5.4 User's Manual*

Acknowledgements

Financial assistance provided by the National Science Foundation, Sri Lanka to carry out this research is greatly acknowledged.

Trophic Alteration in Reservoirs of Sri Lanka – an Outcome of Monsoon Driven Seasonal Hydrology

E.I.L. Silva and W. Kangara

Institute of Fundamental Studies, Hantana Rd, Kandy, Sri Lanka

The catchment geochemistry and land use determines the external loading of plant nutrients (P, N and DSi) into surface water bodies with organic material and toxic substances. The morphometry of the water bodies – e.g. depth, basin shape, littoral development and hydrology (seasonal draw-down, hydrological residence time) are decisive for internal nutrient loading processes. Nutrient recycling in the water column is significantly enhanced by wind-induced stirring and re-suspension of sediments, bio-turbation by fish and by seasonal draw-down. Climatic factors operate via irradiance, wind and precipitation. Irrigation and hydropower generation determine conditions with regard to water level, inflow, outflow and hydrological residence time. These conditions determine the immediate driving forces of algal growth or chlorophyll- a content in other words trophic signatures.

Chlorophyll-a content (Chl-a) is used as the standard measure for phytoplankton biomass and the trophic state of a water body. A majority of reservoirs in Sri Lanka lie within the meso- to eutrophic range with reference to OECD standards for temperate zone water bodies. However they exhibit a high seasonal variability. Also, there are instances of sie-specific extreme situations. In general, in shallow irrigation reservoirs, for example, the total phosphorous levels reach four times higher at low water conditions in August-September compared to filling seasona from December to January or it may reach ten times depending on autochthounus and allochthonous inputs. This clearly demonstrates that shallowness has a strong impact on nutrient concentrations due to internal loading from the sediment. Furthermore, evaporation losses during this period is extremely high concentrating dissolved ions including phosphorous. The physiographic features of water-bodies (size, wind-fetch, shallowness and draw-down) in combination with wind and convection are decisive. Such seasonal changes are less pronounced in the cannion-shaped deep hydropower reservoirs compared to shallow irrigation reservoirs located in the lowlands.

Pelagic-benthic coupling by shallowness and wind enhances the internal loading, however, sediment re-suspension, on the other hand, increases the light attenuation. The underwater light climate is influenced by sediment re-suspension especially in shallow basins and primarily by the self-shading of densely grown planktonic algae, mainly cyanobacteria. The algal biomass in suspension contributes a major portion of the attenuation coefficient.

The taxonomic composition of the phytoplankton and its size structure are relevant for understanding its trophic signatures. They are also indicative with regard to the operative physiographic and biotic conditions. The nature of the phytoplankton assemblage in Sri Lankan reservoirs has been analysed by several authors. Species composition in the individual water bodies differed strongly at high water level depending on water chemistry to a certain extent but numerical dominance of cyanophytes representing potentially toxigenic species such as *Cylindrospermopsis* or *Microcystis*. However, their relative abundance is primarily determined by N: P ratio. Centric diatoms – *Stephanodiscus*, *Cyclotella*, *Aulacosira* – and Cyanophytes – *Cyanodictyon*, *Merismopedia*, *Planktolyngbya*, *Cylindrospermopsis*, *Aphanizomenon*, *Microcystis*- Zygnimaphytes (desmids) – *Staurastrum* attained under various conditions of high biomass values under high water. In contrast, either *Cylindrospermopsis* or *Microcystis* or both contribute to the algal biomass under low water.

The importance of the knowledge on trophic changes in reservoirs of Sri Lanka recognized recently since some of them are being used as source water for drinking after conventional treatment. Authorities in the water supply sector are concerned about emergence of cyanobacteria blooms with potentially toxigenic species and effects of blooms on treatment facilities. The results of a study conducted on nutrients (N.P and DSi) and phytoplankton (species composition and biomass) in several major irrigations systems in relation to seasonal hydrology are discussed here highlighting the significance of seasonal hydrology in trophic changes and numerical dominance of different taxa of planktonic algae in Sri Lankan reservoirs.

Oxygen Transfer by Air Entrainment at Riparian Riffles

Jin-Hong Kim

Department of Civil engineering, Chung-Ang university

72-1 Nae-ri, Daedeock-myeon, Anseong-si, Gyeonggi-do, 456-756, Korea

Artificial riffle structure is sometimes installed for ecological habitat. It is also efficient for improving the water quality by air entrainment when the water flows over the riffles. The flows over riparian riffles are characterized by the large amounts of self-entrained air. The macro roughness of the riffles leads to a sharp increase in the thickness of the turbulent boundary layer. When the boundary layer reaches the free surface, air is entrained at the so-called inception point of air entrainment. Dissolved oxygen will be made and with this effect, plenty of algae, aquatic insects and fish can inhabit at riffles.

The relationship between the oxygen transfers by flow characteristics are shown in Fig. 1. Flow condition changes from a nappe flow to a skimming flow as the flow velocity and Froude number increases. The transition between nappe and skimming flow was shown to occur at region of v = 0.56-0.79(m/s) and Fr = 1.32-1.51. This was due to the undular profile of the free surface, acceleration above filled cavities and deceleration at nappe impact as was suggested by Chanson and Toombes (2004).

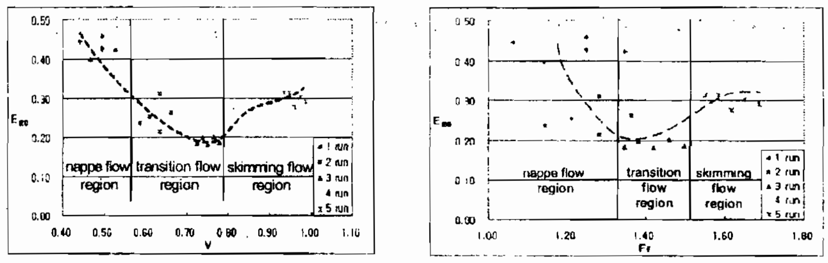

Fig. 1. Relationship between Oxygen Transfer and Flow Parameter

Oxygen transfer becomes smaller and reaches the minimum value at the beginning stage of a skimming flow, but becomes larger in the region of skimming flow because air entrainment is made mainly through a free-falling nappe impact, a hydraulic jump and an air pocket in the region of nappe flow. The average values of the oxygen transfer efficiency in the region of the nappe flow and in the region of the skimming flow are about 0.45 and 0.28, respectively. The riparian riffles were found to be efficient for ecological habitat associated with substantial air entrainment.

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The Effects of Flow Regime Alteration on Ecosystem Responses in the Geum River Basin, Korea

Ick-Hwan Ko

Water Resources and Environmental Research Center, Korea Institute of Water and Environment, Korea Water Resources Corporation, 462-1 Jeonmin-dong, Yuseong-gu, Daejeon, 305-730, Korea

Jeongkon Kim, Sang-Young Park, Chang-Lae Jang and Jinwon Seo.

Senior Researcher, Korea Institute of Water and Environment, Korea Water Resources Corporation

462-1 Jeonmin-dong, Yuseong-gu, Daejeon, 305-730, Korea

Most major rivers in Korea have experienced extensive modifications including construction of artificial structures. Since 1990's, many river restoration projects have been initiated, focusing on improving physical characteristics for river channels and water quality to facilitate public use. However, less attention has been paid for understanding flow regime changes and its consequences and restoring the changes close to natural flow regimes. Recently, we have initiated an international research project to study the impacts of river alterations on physical and ecological changes in the Geum River, Korea. The results of this study will be used to (1) isolate operational impacts from other basin changes, (2) assess the manifestation of operations-based influences on downstream physical processes, (3) link

physical process evaluation with biological processes and ecological function, and (4) be used in a predictive capacity. Eventually, these qualities will allow river managers to isolate the physical and biological effects associated with the dam and develop river management strategies to mitigate negative impacts of river modifications. This paper presents preliminary results of our recent study.

Water Quality Issues in Lower Kelani Basin

Gemunu Herath and Uditha Ratnayake

Department of Civil Engineering, University of Peradeniya, Sri Lanka.

Developing countries, particularly that are industrializing, experience most of the water quality problems. With limited technical, scientific and economic resources available, these countries are under tremendous pressure to overcome these problems. The United Nations "World Water Report-2003" estimates that globally some two million tons of waste (including industrial waste and chemicals, human waste and agricultural waste) are disposed of within receiving waters everyday of which 1,500 km^3 is disposed as wastewater. Further, recent estimates suggest that with a discernable trend towards more frequent extreme weather conditions such as lower and more erratic rainfall as a result of climate change, will account for about 20 percent increase in global water scarcity in the future (UN-World Water Report-2003). Hence, two of the main critical challenges that lie ahead of the World are coping with progressive water shortages and water pollution as climate change, increased pollution loads and higher water temperatures resulted low-flow periods may well decrease available water and water quality will undoubtedly worsen. The water problems in Sri Lanka are no exception from the above eventhough it is located in the tropics. In tropical countries it is commonly expected to have relatively constant environmental characteristics such as water quality due to higher temperatures (Payne, 1986). Hence this paper focuses on water pollution problems in Sri Lanka considering the water quality variations in the Kelani River.

Kelani River is the third largest watershed in the island and it plays an important role with respect to the overall economy of Sri Lanka (Figure 1). The Kelani River is 144 km long and drains an area of 2292 km^2 originating at levels above 1500m of the central highlands and descent through the western low land valley collecting water through a number of tributaries in many directions before emptying into the Indian Ocean on the west coast just a few kilometres north of Colombo.

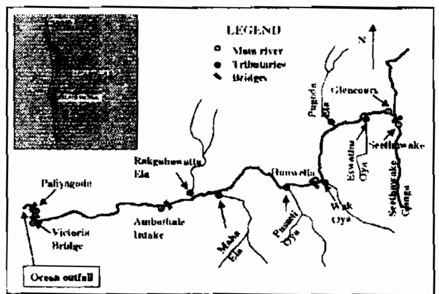

Figure 1. The Kelani River

Kelani river is the main source of water to the Greater Colombo Metropolitan Area providing almost about eighty percent of the drinking water requirement and about ninety percent of the industrial water requirement. In addition many dams in the upstream generate a fair amount of electricity to the national grid and the aquatic ecosystems within this basin, especially in the lower estuary area, provide many resources to the settlements around the river. With the recent rapid development in the region in addition to increased settlements, a large number of high polluting industries such as textile bleaching, dying and washing, food processing, tanning, brewery, paint and rubber processing etc too are situated in the river basin. As a result the Kelani River is under serious threat of degradation from continuous discharge of polluted effluent from these industries and also from domestic sewerage discharges along the river.

A previous study on the Kelani river by the Danish Hydraulic Institute 1999, suggest that even though the water quality of the mid-catchment was within expectable limits, apart from localized pollution close to small towns, the quality in the lower flood plains had indicated a trend of increased pollution with occasional fish kills due to industrial and domestic effluent discharge. It was also identified that this pollution is a threat to the Greater Colombo water supply intake at Ambatale, estuary ecosystem and socio-cultural uses of the river. Hence in year 2002 the authorities instigated a comprehensive program to monitor the river basin with the aim of developing a policy for setting up new industries in the region and to review the existing pollution standards. This paper discusses the main quality concerns that surfaced during this investigation.

In this study, two samplings per month at twelve pre-selected locations were done starting from November 2002 to June 2004 (Figure 1). This frequency is well above the required minimum for an effective study (Blind and Aaiderink, 1998). As most of the pollution takes place on the lower 55 km segment of the river and hence six stations along the main river and six on major polluted tributaries within this stretch is investigated (Figure 1). They are Seethawaka confluence (S), Glencorse (G), Hanwella (H), Ambatale (A), Victoria Bridge (V) and Paliyagoda on the main river and close to the confluences of tributaries Eswathu oya (EO), Pugoda ela (PE), Wak oya (WO), Pusseli oya (PO), Maha ela (ME) and Raggahawatte ela (RE). Parameters pH, conductivity, turbidity, temperature, dissolved oxygen (DO), biochemical oxidation demand as BOD_5, chemical oxidation demand (COD), Chloride, dissolved Chromium, dissolved Lead, Nitrate, Phosphate and total coliform concentration were obtained. The temperature, DO, pH, conductivity and turbidity were measured on site, while BOD_5, COD, NO_3-N, Orthophosphate, Cr, Pb, chloride, and total coliform in the laboratory following the book of Standard Methods (Eaton et. al., 1995).

Referring to the land usage in the basin, it is expected that the run-off of fertilizer, from agricultural activities is the principal source of nutrients of the river. The current application of Nitrogen and PO_4 as fertilizer is estimated to be about 6900 MT and 1,920 MT per year (Danish Hydraulic Institute, 1999). The effluent discharge above Ambatale includes the large volume of treated effluent from the industrial parks. Occasional discharges of oils and sludges from these industrial parks have forced the closure of the intake on a few previous occasions.

The obtained results indicates almost a constant temperature along the river (24-31^{0}C), where the variation can mainly be due to seasonal fluctuations in ambient temperatures and the pH was almost constant at around 6 to 8. Except for few occasional high turbidity values in the estuary (350 to 425 NTU) at sampling points V and P mainly due to sand mining and soil erosion from development activities in the area, values recorded in the other locations were reasonably low as the upper basin watershed is in fairly good condition, with balanced land use.

The chloride content shows high variations especially in the lower reaches. Main reason is seawater intrusions as a result of low river flows and sand mining. Occasionally this saline water even reaches the Ambatale water supply intake during prolonged droughts interrupting the water supply to the Colombo area. However this saline-water intrusion can be a major problem in the future as many recent studies have shown that rainfall compared to few decades back have significantly reduced with lengths of the dry periods increased and the lengths of wet periods decreased all over the country (Ratnayake and Herath, 2005).

The DO, biochemical and chemical oxygen demand levels in Ambatale and down stream was often in excess of the Sri Lankan inland surface water standard required for bathing or as drinking with complete treatment (current standards are 5 mg/l for DO, 4 mg/l for BOD_5, and 20 mg/l for COD respectively). In most tributaries and the lower river estuary, very low DO values (occasionally below 1 mg/l) and the low BOD_5/COD indicate high industrial waste disposals. Further, the observed levels of dissolved Cr and Pb too indicate extensive industrial pollution especially in the estuary area. However, the nutrient levels observed in the river are smaller than what was anticipated considering the loads of applied fertilizer in the catchment. Nonetheless these concentrations are far adequate for eutrophication to occur (Muller, 1999) and periodic algal blooms are observed in the shallower areas, especially in stagnant waters during periods of low flow.

Also the observed high coliform counts well over 15,000 cfu/100ml in almost all monitoring stations shows the high degree of urban sewage discharge too.

The study shows that most of the time, the water quality at Ambatale is found to be within the standard for drinking water with conventional treatment but not suitable as a source of drinking water with simple treatment. The water quality data obtained so far show that industrial and urban effluents pollute the river above the Greater Colombo water intake at Ambatale. The river below Ambatale is more polluted, by both urban and industrial sources, and the water quality is poor endangering the aquatic life and severely affecting the ecology of the estuary. Analysis of the organic loads show that the contributions from industrial sources are much higher compared to the urban load. Also it appeared that significant degradation of organic material occur between Hanwella and Ambatale during all seasons. The nutrient loads measured in the river are somewhat less than the values expected compared to the applied fertilizer load to the catchment. Trapping of nutrient by hydropower reservoirs may be the main reason for this difference. The fairly high dissolved Cr and Pb concentrations necessitate an investigation of heavy metals and toxic organic matter on use of this water.

Given the current and future importance of the Ambatale intake, the construction of a salinity barrier appears to be a priority to protect the water supply during prolonged dry periods. The flow at intake is currently protected from large industrial effluent discharges by a government policy not to site such industries above Ambatale. However, the river water quality should be monitored and modelled so as to extend the sustainability.

Recovery of Urban Water Cycle

Srikantha Herath

Environment and Sustainable Development Programme

United Nations University, Tokyo, Japan

Urban Water Management

Rapid concentration of population into urban areas and expansion of urban areas, referred to as 'urbanization', has been a worldwide phenomena in the later half of the 20th century. Japan in particular is one of the most urbanized countries, and has experienced a rapid and intensified urbanization since World War II, through a period of high economic growth from 1960 to 1973. Such urbanization inevitably changes the hydrological regime of river basins in both quantity and quality. This requires various countermeasures, and they fall within the title 'urban water management'. Urban water management is strongly affected by climatic, physiographic and socio-economic conditions, and institutional arrangements. Consequently, detailed procedures and measures in urban water management may vary among countries, or even regions. In this presentation, the problems and management concepts are described considering the historical development of water management experiences in Japan. This process is expected to provide important lessons for other countries, especially the rapidly developing countries that are yet to experience some of these problems.

Changes in Hydrological Cycle due to Urbanization

Among various aspects of urbanization, the increase in population density and the expansion of urbanized areas creating a higher building density, have the most prominent influence on changes in hydrological processes. One of the main out comes of changes to hydrological cycle is an increase of flood peaks due to higher direct runoff and reduced time of concentrations. Throughout 1960's and 70's river-zone flood control measures in Japan, such as river channel improvement, floodways, retarding basins etc., had been carried out as countermeasures against Urban Flood Disasters. However, river-zone improvement alone was not enough to cope up with the problem and the need for a comprehensive basin wide flood mitigation plan became evident. In 1978, the Ministry of Construction had prepared such a plan termed 'Comprehensive Flood Control Measures'. This plan included temporary stormwater storage and preservation of natural flood regulating environment as flood control measures to be adopted for a catchment. After about ten years, use of infiltration facilities was added to these measures.

The main purpose of river improvement works up to then had been control of flood as efficiently as possible. These measures generally gave rise to straight and lined river channels, which were not aesthetically pleasing. At the same time a growing public concern demanded utilization of public water bodies for recreational purposes. In response, new kinds of river construction projects termed 'Water Friendly' projects were undertaken. These include expanding greenery and beautification of urban rivers, including aesthetically pleasing embankments, revetments designed to create a suitable environment for fish to grow, etc. The direction of these measures over the years is towards the management of both flood and ordinary flow in rivers, by integrated planning and management of basin scale water environment.

Understanding Urban Water Cycle

The implementation of integrated water management concept would now depend largely on taking decisions based on stakeholder consensus. In order to achieve this, quantification of urban water cycle and tools for analyzing various measures are required.

Urban hydrological system consists of many different components that include the natural and artificial inflows, components related to water utility and various measures adopted for flood control and amenity as described. These components are interconnected in a complex manner, and have to be systematically represented to understand the overall nature of the urban hydrology. The flows taking place in an urban hydrological system can be classified into three courses. The first consists of the natural hydrological processes such as rainfall, infiltration, evapotranspiration, runoff etc., and the second consists of artificial paths for the drainage of storm water such as gutters, drain pipes, drainage canals, retarding basins etc., and the third is the water course arising from the municipal water supply system feeding the sewerage system. These flow paths are not fully independent but partly connected to each other. To fully understand the urban hydrological system, it is necessary to quantify each of these components and their interrelationships in the system. Experimental studies in two catchments have shown that careful observations can be used to develop mathematical models that can be used to simulate the catchment responses to both natural and artificial water cycles of urban catchments in both spatial and temporal domains. For the predictive purposes, the most challenging components of quantifying water cycle are the estimation on evapo-transpiration components and the artificial water usage paths. Here it was also observed that estimation of human water usage patterns are more predictable than an making an accurate accounting of evapotranspiration processes, due to large heterogeneity at catchment scale.

Restoring Urban Water Cycle

One of the major adverse effects of urbanization has been the increase of impervious areas that has resulted in an increase of surface runoff, both in volume and peak discharge, and the associated reduction of infiltration and groundwater recharge that leads to reduced river low flows in dry periods, deteriorating amenity functions and water quality. In order to restore the urban water cycle, artificial infiltration through infiltration facilities has been proposed, where infiltration trenches and collection boxes installed at residential areas collect rainwater and let it infiltrate, recharging the groundwater. A number of studies carried out in experimental installations have shown infiltration systems are effective in reducing direct runoff and restoring the ground water recharge, so that basin water cycle can be brought back close to its original state.

A simulation study of a typical urban catchment in the suburbs of Tokyo has also shown that if infiltrating drainage systems for rainfall runoff are installed, for newly constructed houses and those that are renewed; the effects of surface runoff reduction and ground water recharge can more than offset the urbanization effects.

Concluding Remarks

It is clear that global population is converging more and more of to urban areas. It is important to learn from the experiences of heavily urbanized areas to make the urban transition as well as ultimate urban environment a pleasant one for the newly urbanizing areas. Conserving the water cycle is one of the approaches that can be taken to reduce the adverse impacts and improve urban living quality, in the urbanizing world. In the future we need to look in to how natural ecological processes can be utilized to offset adverse changes to water cycle through human impacts in achieving this objective. It requires us to explore new domains of modeling where systems need to be treated as active interconnected elements rather than passive objects that transform external inputs to hydrological outputs.

River Environmental Consideration for Restoration of the Degraded Urban River in Korea

Samhee Lee
Research Fellow, Dept. of Water Resources, Korea Institute of Construction Technology, Korea

Hongkee Jee and Soontak Lee
Yeungnam University, Korea

The Anyang River which is located in an urban area near Seoul had been managed, focusing on supplying municipal and industrial water and preventing floods, coping with rapid industrialization and urbanization. Consequently, it changed into a deadly river within a time period of 25 years. Its channel was straightened with concrete, and water quality deteriorated to BOD 190mg/l. In addition, water quantity decreased rapidly drying up the river. Also, with serious deteriorating of the river ecosystem, landscape, water-friendly function, and so forth, people turned away from the urban river.

From 2001, the master plan under the 10-year has been actively carried out focusing on the achievement of healthy river in which fish inhabit, safe river free from floods and droughts, and pleasant river where citizens visit. As a result, its water quality was remarkably improved to BOD 5mg/l in 2005 and some upper zones were improved enough to allow people to swim. Moreover, various animals including fish and birds gather around the river. Anyang River Restoration Project is recognized as the first comprehensive and systematic nature-friendly urban river improvement in Korea.

Turbidity Problem and Management in Imha Reservoir

Deuk-koo Koh, Yong-Kon Yi, Guen-Sang Lee

Senior Researcher, Korea Institute of Water and Environment

Korea Water Resources Corporation

462-1 Jeonmin-dong, Yuseong-gu, Daejeon, 305-730, Korea

and

Young Do Kim

School of Environmental Science and Engineering, Inje University

607 Obang-dong, Gimhae, Gyeongnam, 621-749, Korea.

Imha Multi-purpose Dam with the gross storage capacity of 595 million \$ is located at 10 km upstream from the city of Andong and 350 km from the estuary of the Nakdong River, Korea. The watershed area of Imha reservoir is 1,361 km^2. Major streams that flow into the reservoir are Ban-Byeon Stream, Yong-Jeon Stream, and Dae-Gok Stream. During both spring and summer, turbid water used to flow into the reservoir due to a large amount of rainfall, causing various environmental and social problems. Turbidity currents in a reservoir can carry a large quantity of sediments, nutrients and chemical substances. Especially long lasting turbid water in the reservoir as well as in the downstream river may not cause only the aesthetic problems, but it may also affect the drinking water intake and ecosystem at the downstream. The watershed of Imha reservoir had huge amounts of rainfalls due to Typhoon Rusa in 2002 and Typhoon Maemi in 2003. Turbidities of the water in Imha reservoir were more than 800 NTU (Neuphelometry Turbidity Unit) right after the typhoons and they slowly decreased with time, but the turbidities remained above 100 NTU for more than five months. This study has focused on finding causes and countermeasures of impounded turbid water in the Imha reservoir. In the scope and extent of this study, followings are included such as: (1) to figure out source areas of such a sediment-laden current, (2) to analyze the mixing behavior of turbid currents in Imha reservoir, and (3) to find out an effective discharge scheme of turbid water in a stratified reservoir with a 3-dimensional numerical modeling.

Issues in Environmental Impact Assessment of Large - scale Reservoir Development Projects in the Humid Tropics: The Case of Kalu Ganga at Laggala Pallegama, Sri Lanka

C.M. Madduma Bandara

University of Peradeniya, Sri Lanka

As a means of increasing food production, hydro-power generation, and the multi-purpose harnessing of available water resources for national development, large-scale reservoirs have been increasingly constructed in many parts of the humid tropics in the last few decades. During the period before the 1960s, environmental impacts of such significant transformations of natural ecosystems did not constitute a major public concern. Since then, a growing concern for environmental conservation in Sri Lanka, culminated including environmental impact assessment (EIA) as a legal requirement for all prescribed projects under the National Environments Act. Under these legal provisions among other things, no major reservoir development project could be undertaken without environmental clearance granted through a proper EIA process. This requirement is also a policy conditionality among the leading international donor and lending agencies.

This paper provides an account of the experience gained in conducting an EIA on the proposed Kalu Ganga Development Project at Laggala Pallegama in the Matale District of Sri Lanka. This project combined with the earlier proposed Moragahakanda scheme is considered a social necessity in order to provide water to those agricultural areas that suffer from severe water scarcities in the rural North Central regions. Although these proposals remained in the agenda of the greater Mahaweli Development Programme for at least three decades, they did not materialize due to a variety of reasons, both technical and political. Having passed through a number of episodes of feasibility studies, the present Kaluganga – Moragahakanda project had been re-formulated to satisfy a variety of community needs in the areas concerned.

The development of large-scale reservoir systems in a humid tropical context requires, using methodologies that have the capability of capturing significant environmental impacts on not only the fauna and flora of the affected areas, but also on the social, economic and cultural concerns of the communities that inhabit the areas within and near the project sites. An EIA in this context had become essentially an exercise in inter-disciplinary research. It also proved not just a passive and static learning experience, but also a highly dynamic process where involvement of the local communities had become absolutely essential. The developments in modern interactive GIS technology, on one hand and learning from the accumulated experience of conducting EIAs in the recent decades, proved exceptionally useful in almost all relevant studies.

Environmental Philosophy for Water Management in the Humid Tropics with Reference to Bali and Lijiang

Isamu Kayane
Aichi University, Japan

New philosophy doubts on modernity and on dualism, fundamental bases of the industrial capitalistic society, grew as serious environmental disruption including global warming increase. Dualism and determinism were already denied by the quantum theory in the early half of the 20th century. I think that philosophy of non-dualism presented by Ervin Laszlo (2003; 2004) established a scientific background for "theory of everything" proposed by Ken Wilber (2000). Water management based on the new philosophy is indispensable not only in the humid tropics, but also in any other natural environment in the world.

Nature and humans: According to recent scientific findings, existence of interaction between environments and humans cannot be denied. Nature and humans are not separable entities contrary to Cartesian dualism which is one of two poles supporting modernity together with Newtonian physics (Toulmin, 1990).

Theory of everything: Theory of everything is a scheme proposed by K. Wilber. His scheme is made of four quadrants; they are "it" quadrant, "they" quadrant, "I" quadrant, and "we" quadrant. "It" and "they" are something existing outside, and "I" and "we" are something existing inside. He thinks everything is woven within these four quadrants. He puts Nature and environment in the "they" quadrant. However I think Nature and environment are related to all things in four quadrants. This point is the essential difference between K. Wilber and I. Kayane (2006). If we classified academic disciplines, hard sciences are in the "it" quadrant, system sciences are in the "they" quadrant, spiritual disciplines are in the "I" quadrant, and cultural disciplines are in the "we" quadrant. I agree with the following Wilber's notion that things in the four quadrants evolve independently and spirally with time. I understand that environmental disruption is a symptom of unbalance between four quadrants.

Bali, Indonesia and Lijiang, China: We made a field survey of the famous SUBAK system in Bali, Indonesia. Our methodology was to understand Balinese culture and people through the water cycle in the island. The results are already published as a Japanese contribution to the IHP (Kayane, 1992). One of our contemporary conclusions is that "the SUBAK system is a system of post-modernity". Recently we investigated water and society of Lijiang (Kayane, 2006). Lijiang in Yunnan Province, China, is a small old town intimately harmonized with water, which was registered as World Cultural Heritage in December 1997. Though Lijiang is located in the subtropical highland, we understood that the basic concept of water management in Lijiang is same as that of Bali. We reached a conclusion that Bali and Lijiang are water communities with characteristics of post-modernity.

Harmony: Water, an essential element of Nature, is woven in the four quadrants clockwise in the following way; water cycle in the "it" quadrant, water management in the "they" quadrant, water culture in the "we" quadrant, and water belief in the "I" quadrant. In Bali and Lijiang these four quadrants are/were harmonized. We believe that many tourists visited these two places, were attracted to their water culture harmonized with things in other three quadrants. Harmony of Nature and humans is a key concept for environmental philosophy in the 21st century. Water management is an important software for establishing the harmony.

Water management: Water management in the 21st century, irrespective of the humid tropics and other climatic zones, should aim at harmonizing the four quadrants. Simulation model of hydrological cycle in the "it" quadrant is an essential tool for water management in the "they" quadrant, but sound water management should take into account as something inside i.e. water culture in the "we" quadrant and water belief in the "I" quadrant, as well as something outside. Balinese Hindu plays very important role for the water management in Bali, and Dongba religion of Naxi people does in Lijiang.

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Sustainable Management and Conservation of Water Prevalence in the Traditional Ecosystems of Sri Lanka

Udula Bandara Awsadahami

Central Engineering Consultancy Bureau, Colombo, Sri Lanka.

'The fate of the human race ultimately depends on the health of our planet, and that health depends on the preservation of biological diversity. Contrary to science fiction fantasy, there won't be a convenient new world to move to after we have destroyed this one'

Robert Bateman, 'Natural worlds' – Penguin Books

Unlike in the past, today, man kind collectively, irrespective of their level of economic and social developments exert much pressure on the earth causing its environment irrevocable damage. As a nation we are also contributing to this 'blind inhumanity'-the ruining of the earth- ruining the very home we live in. The occurrence of unpredictable changes in the climate - world wide flooding, increased risks of health hazards, food contamination, polluted water supplies are a few of the noted issues that add on to the growing list of consequences which have arrived at our door steps today.

The major historical root cause of this crisis is the built up myth of development, the misinterpretation and the misapplication of the modern sciences and technologies in order to exploit earth's resources in the direction of fulfilling the greedy demands of the human society and the continual bind application of the borrowed technological applications without questioning their repercussions. As a specific case, the cultures and the nations with long traditional technical backgrounds can be cited as some of the blind followers. They have either voluntarily moved away from their technological traditions or made to do so from their time tested traditions which have been the sustainable solutions for them throughout their long history.

The issues confronted today, especially in the field of conservation of water and soil are centered mainly around the land use practices of all the sectors of the country, at large. A sound policy aimed at conservation of water and soil, necessarily evolved with the comprehensive insight into the problems and drafted to implement through proper legal arms has to be formulated very soon. In order to gain a high level of efficiency with the policy of this nature, the gravity and the nature of the problems: the scarcity and the need of water against time, source of water pollution, maltransportation of water and the technologies applied in this direction, wrong use of water and inappropriate utilization of land for agriculture, settlements, water storage and for other infrastructure provisions which threaten water, soil and life have to be thoroughly understood. This exercise should not be, as usually, a mere treatment of hydraulic engineering applications any more. This should embody a high sensitivity of the ecological and social balance.

Summary of issues addressed and the methodologies adopted.

Issues:

1. Use of land in the central massif of Sri Lanka above some specific

elevations from the sea level and some terrains specially cleared for agriculture and human settlements are extremely hazardous and a threat to natural conservation of soil and water and give rise to the loss of essential soil nutrients.

2. Agro forestry practiced by the department of forestry of the government of Sri Lanka in the hill country and on the plains exposes a greater danger to water and soil conservation of the region. This has much aggravated with the use of tree species with the characteristic of excessive evapo-transpiration specially in the dry zone. Isolated hilly ranges which traditionally serve as water retention bodies – specially the fractured quartzite hills covered with indigenous forest species which are evergreens with minimal evapo- transpiration character.
3. Hydropower generation in the hilly zones which dominate the consumption of water for power generation diverts the natural flow of water to suit the power generation technicalities.
4. Disturbing the harvesting and use of local rain water within a basin with a high inflow created by transporting a large quantity of water from the distant basins thereby creating an imbalance of the eco systems and bringing in more polluted water to the end user as a result of the long travel through the man-made water ways etc.
5. Policy of the government to irrigate the maximum possible land under the command areas without leaving land masses to maintain the diversity.
6. Speedy transport of water along long distances make water carry suspended matter, salts and polluted agents create health hazards

and exposes the traditional land to salination and siltation.

7. Removal of a large number of traditional man-made water retaining structures that disrupted the micro environment existing around this traditional man made water bodies. No alternative structures came into place making the ground water table poor and depleting the rich bio-diversity.

8. Devastation of large expanses of traditional forest areas which were preserved to serve as catchments to the downstream contour canals and the reservoirs, with the introduction of the express water ways laid from the newly built far off water storage structures.

9. Laying of infrastructure disregarding to the existing ecosystems and water bodies.

10. Ignorance of the traditional irrigation systems and their role of preserving the bio-diversity and the social cohesion.