Mendiondo, E. M. (2005) Flood risk management of urban waters in humid tropics: early-warning, protection and rehabilitation, **Invited Paper** In: C. Tucci & J. Goldenfum (orgs.) Workshop on Integrated Urban Water Managmt. in Humid Tropics, UNESCO IHP-VI (Int. Hydrol. Program), 2-3 April 2005, Foz de Iguaçu, Brazil.

FLOOD RISK MANAGEMENT OF URBAN WATERS IN HUMID TROPICS: EARLY WARNING, PROTECTION AND REHABILITATION

Eduardo Mario Mendiondo
Escola de Engenharia de Sao Carlos, Universidade de Sao Paulo
SHS/EESC/USP, Cx.P. 359, CEP 13566-590 Sao Carlos, SP – Brazil, emm@sc.usp.br

Abstract: The main purpose of this paper is to present strategies for flood risk management of urban waters in humid tropics, based upon case studies of early warning, protection and rehabilitation. The paper discuss on how to handle new challenges in flood risk management in order to focus on urban development planning. A brief introduction in flood risk management is presented and scenarios of South American floods are summarized, with lessons learned and experienced gained to influence flood management strategies in urban areas of humid tropics.

Keywords: flood risk management / urban water / urban development planning

INTRODUCTION

According to figures from UNESCO's Division of Basic and Engineering Sciences, for every $100 spent by the international community on risk and disasters, $96 go towards emergency relief and reconstruction, and only $4 on prevention. Yet, each dollar invested in flood prevention reduces by up to $25 the losses incurred in the case of natural disasters. This situation points the starting point to manage flood hazards and the way to cope with potential flood disasters.

Flood hazards are brought about by the natural environmental forces, but flood disasters are caused by flood hazards interacting with human activities. The interaction of such external forces and activities in different situations makes the extent of disaster and rehabilitation methods from the disaster different. Figure 1 outlines the map of maximum 24-hour precipitation, with seasonal focus expressed in Roman numbers related to months of rainy season (Munich Re Group, 2000) and Figure 2 shows the relative significance of floods in global disaster occurrences (EM-DAT-CRED, 2003).

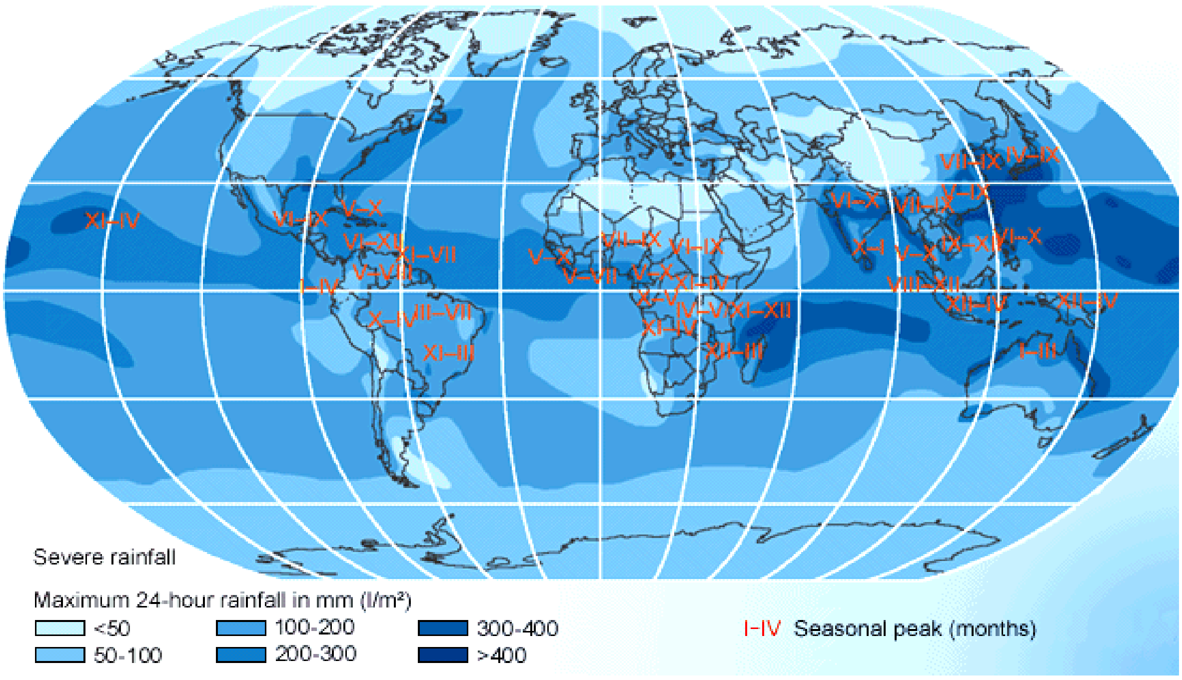


Figure 1- Map of torrential rain (maximum 24-hour precipitation) and seasonal focus, with emphasis in tropical areas. Source: Munich Re Group (2000).

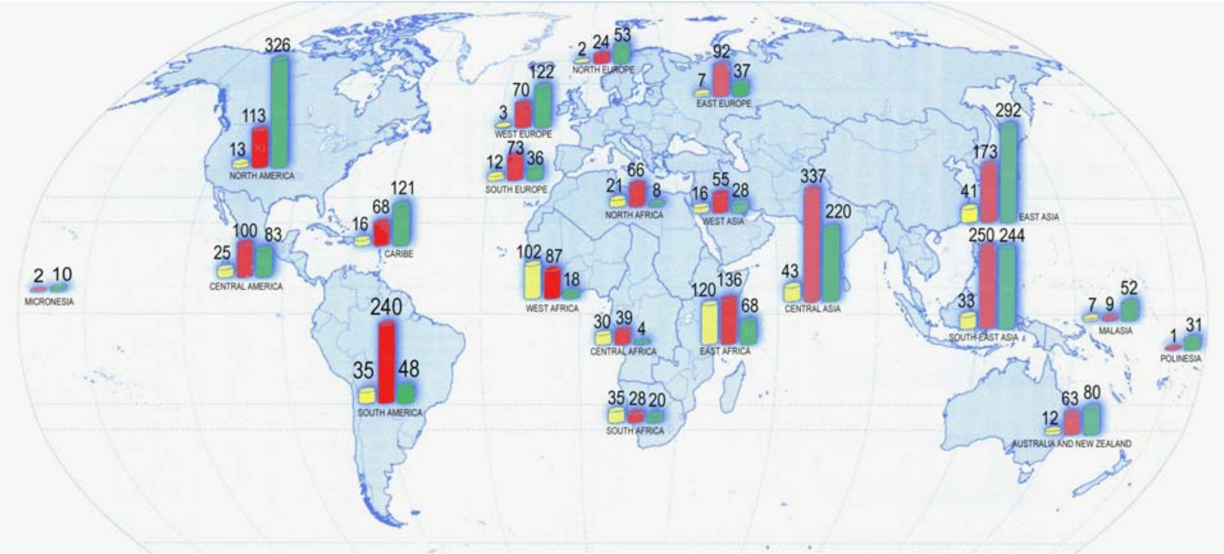


Figure 2- Occurrence of droughts, floods and windstorms (respectively left, centered and right bars) during 1973-2002, according to following criteria: >10 people killed, 100 people affected, a call for international assistance, AND/OR declaration of emergency state. Source: EM-DAT-CRED (2003).

In the subject of urban waters in humid tropics, flood risk management is derived from: 1) the guidelines on flood estimation (see "inner cycle", Figure 3), and 2) statutory principles of flood disaster ("outer cycle") in urban areas. In this way, flood risk management involves operational actions before, during and after floods occur. Respectively, these actions depict early warning and scenario prediction, contingency plans and restoration. The actions and costs associated are different. For instance, whereas early warning actions cost ca. 1 unit, contingency plans 4 units and hard control 25 units (see Table 1).

A CONCEPTUAL FRAMEWORK FOR FLOOD RISK MANAGEMENT (FRM)

Statutory principles: the 'outer circle'

The statutory principles (see Fig. 3) invoke flood disaster preparedness, control, management, urban infrastructure and urban logistics, in terms of: 1) flood risk evaluation, methodology of flood disaster prevention and management, 2) presentation of multi-source infrastructure and logistics and its information, 3) acquiring strategy of flood safety control of urban space and urban function, and 4) developing plan considering the disaster prevention measure with social development and environmental changes.

Integrated urban planning and management of disaster risk is a step-by-step process to cope with the vulnerability of urban areas, especially at tropical cities, exposed to extreme water related disasters like floods. Modern cities consist of large complex systems, and the effects of a disaster also tend to be sensitive at several dimensions. In this way, urban flood vulnerability is the susceptibility of the urban areas (prone areas, old drainage systems, non-trained personnel for flood disasters, etc.) towards harmful flood influences at the river basin scale.

Approaches of flood risk management (FRM) are proposed to survey flood hazards (i.e. see Depettris et al, 2000; Neiff et al, 2000; Mendiondo & Valdes, 2000; Tucci & Bertoni, 2003; Sivapalan et al, 2003). In this paper, FRM estimations are presented as an example from the utilitarian approach of environmental services, expressed as $ per inhabitant per square meter affected by flooding. Obviously, this unit varies across countries and latitudes, but could be a relative yardstick to compare several approaches to cope with floods, especially with preparedness, infrastructure & logistics, safe control and disaster management.

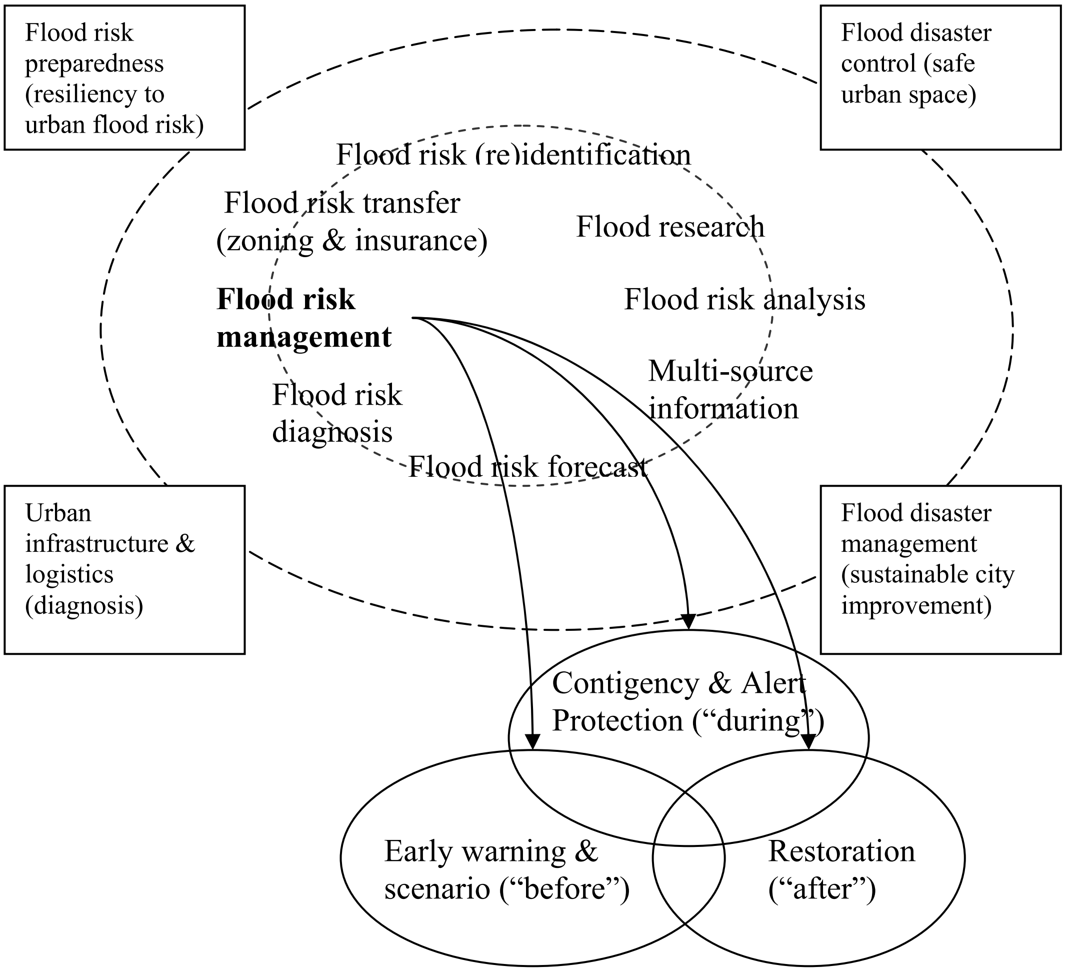


Figure 3- The concept of flood risk management in urban waters (ellipse intersection), related to guidelines on flood estimation (inner cycle) and surrounded by statutory principles of flood disaster (outer cycle). Flood poverty cycles (FPCs) happen not only when neither principles nor actions are claimed by stakeholders, but also when no intersection (ellipse's intersection) of flood risk management could be attained at decisionmaking level.

FRM actions in urban waters (ellipse intersection, Fig. 3) are related to guidelines on flood estimation (inner cycle, Fig. 3) and surrounded by statutory principles of flood disaster (outer cycle). Flood poverty cycles (FPCs) happen not only when neither principles nor actions are claimed by stakeholders, but also when no integration of FRM actions (ellipse's intersection) could be attained at decisionmaking level. Examples from lessons learned of FRM (i.e. FINEP/FIPA/EESC-USP/DAEE-SP, 2004) are explained at following paragraphs (see also Table 1).

Flood risk preparedness steps are: 1) analysis and evaluation of flood disasters risks, 2) management-support information systems for urban diagnosis, 3) participatory flood disaster planning and adaptive management, 4) incorporation of flood risk management into urban management, and 5) flood disaster risk-oriented sustainable management. Their costs vary from 1 to 5 US$ inhab^{-1}.m^{-2}.

Urban infrastructure and logistics: focused on reliable enhancement of infrastructure such as: lifeline systems, development of flood disaster response, development of effective logistics, as integrated management for infrastructure & logistics, quality standard of infrastructure, economic analysis of disaster risk, disaster risk communication, policy analysis of flood disaster mitigation, and disaster response analysis. Cost: 10 to 35 US$ inhab^{-1}.m^{-2}.

*Safe flood control of urban space***:** with risk evaluation methods for urban spaces, high-quality living spaces, and safe amenities, development of best management practices (BMPs), optimal urban design

methods, and development of disaster risk management. Products: Cost: 25 to 60 US$ inhab^{-1}.m^{-2}.
Flood Disaster Management: encompasses also natural flood disasters, flood collapse disasters, flood pollution disasters and flood culture disasters. Cost: 5 to 15 US$ inhab^{-1}.m^{-2}

Feasible actions of FRM on urban areas: the 'inner circle'

Both hard-control and post-event rehabilitation cost about 20 to 30 times greater than early-warning and preparedness approach. Lessons learned from case studies of urban floods show that there is a need of comprehensive methodologies to deal with risks. To build up effective strategies for flood disaster risk, it is necessary to carry out research and development based on risk analysis and FRM. Hardly any urban area in the humid tropics is safe from floods that occur at frequent intervals along rivers but also far away from them. The areas affected are linear strips of land rather than broad expanses so that if it is hardly feasible to represent them on small-scale hazard maps. The two main types of flood are river flood and flash flood.

Flash flood: is a flood event of short duration with a rapidly rising flood wave and a rapidly rising water level. Flash floods are caused by heavy, usually short precipitation, torrential rain, and occur in areas that are often relatively small (typically in conjunction with a thunderstorm). Forecasting of flash floods is problematic, but not impossible because of short-term hydrometeorological prediction or very-short-term warning devices called "nowcasting" (see i.e. Fig. 12). Flash floods occur in humid tropics and are therefore responsible of the more-frequent indirect costs from floods.

River flood: the overflow of river course is usually the result of prolonged, copious precipitation over a large area. Usually, a warning can be given a few hours or days beforehand on the basis of flood forecasts. River floods occur associated to large river systems in humid tropics and are therefore responsible of the less-frequent direct costs from floods. The risks and management strategies of these two types of flooding are described below.

Risk: in general terms, risk is the possibility of a loss resulting from exposure to a hazard. Specifically, risk is the loss expectancy value, i.e. the product of occurrence probability or exceedance probability and the associated outcome (loss). The loss is sometimes given as the product of the exposed value and vulnerability. Example: the annual risk of a urban loss (outcome) that results from a loss of US$ 1,000 generated by a flood, associated to a tropical precipitation with a return period of T= 100 years, i.e. with an exceedance probability of 0.01, comes to R = 0.01 x US$ 1,000 = US$ 10. In insurance, risk is the object to be insured. But in FRM, risk is the input to decisionmaking system.

Flood risk management (FRM): is a composite process of integrating management and operation steps of early-warning, flood control and rehabilitation, in order of taming floods and associated risks. Urban waters are especially important in FRM because many people concentrate in urban settlements and cities where flood-hazard areas are most expressive. Techniques for preventing flood damage in a flood-hazard area are known as *flood proofing*. The *flood warning* is the advance notice that a flood may occur in the near future at a certain station or in a certain river basin and *flood control/protection* is the protection of land areas from overflow, minimizing damages caused by flooding.

Table 1- FRM actions, statutory principles, timing and costs. Source: FINEP/EESC-USP/DAEE-SP (2004).

Statutory principle (outer boxes, Fig. 3)	Timing on flood	Cost (US$. inhab^{-1}.m^{-2})				Action derived (ellipse intersection, Fig. 3)
		Min.	Max.	Median	Total	
Flood risk preparedness	*"before"*	1	5	2	2	Early warning: nowcasting & scenario development
Flood disaster management	*"during"*	5	15	9	9	Protection: Contigency Plan & Alert Systems
Urban infrastructure & logistics	*"after"*	10	35	19	57	Rehabilitation: Restoration, Recovery, Reconstruction
Safe urban flood control	*"after"*	25	60	39		

FLOODS ON SOUTH AMERICAN URBAN AREAS: A CASE STUDY

Almost 47 % of the Earth's freshwater flows through South America, carrying 13 % of total suspended solids delivered by all rivers to oceans. Geobiochemical freshwater processes are related to flood pulses across nested basins usually ungauged or poorly gauged. Social impacts from floods are expensive. Accumulated losses due to South American floods during 1995 and 2004 were ca. US$ 25 billion, including investment (INV) and Operation & Maintenance (O&M). Post-flood restoration plans transfer annual debts to population of US$ 30 per capita (NIBH/SHS/EESC/USP, 2004).

The failure of policy-makers to promptly respond to flood crises results not only in massive unnecessary death in urban areas, but also in a vicious circle of poverty and policy instability. This circle is caused by non-preventing floods which are converted in social disasters, the so called "flood-poverty-cycle" (FPC). In this way, South American countries are yearly impacted in 2 to 5 % decrease of Gross Domestic Product (GDP) caused by FPCs (Mendiondo, 2005).

Natural hazards have had a lethal and destructive flood impact in South America. Of the total number of registered events between 1900 and 1998, 66 % were weather or climate related, and 34 % due to floods, especially on urban areas. Millions of people have been affected as their housing, sources of income and communities were damaged or destroyed by extreme floods. Estimates of damages caused by Mitch in Central America are approx. US$ 6 billion in 1998, the equivalent of 16 % of last year's GDP, 66 % of exports, 96.5 % of gross fixed capital formation and 37.2 % of the total external debt. Before Mitch, the Central America's projected GDP growth for the years 1999 to 2003 was 4.3 % per year (Mendiondo & Valdes, 2002; Tucci & Bertoni, 2002). As measured by the GDP, the losses in Argentina and Brazil 1991-2 floods were US$ 5 billion, (~2% GDP); in Venezuela the 1999 mud flows caused US$ 3.2 billion of damages, (3.3% GDP), and in Honduras 1998 Mitch hurricane caused losses of approximately US$ 4 billion (~100% GDP).

On prospective policies on FRM, some assets come from alternative scenarios is built under the limits of Millennium Assessment global scenarios of "Global Orchestration", "Order from Strength", "Adaptive Mosaic" and "Technogarden". Figure 4 depicts a brief summary of prospective, global scenarios until year 2100 and critical uncertainties (after Cork et al, 2005). Figure 5 outlines the trends towards early-warning strategy from prediction in ungauged basins.

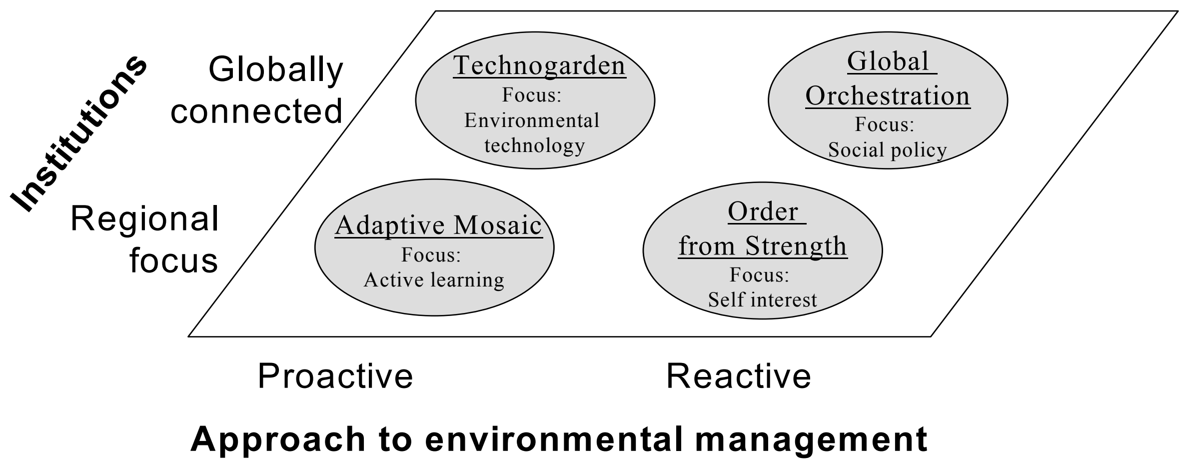


Figure 4- Critical uncertainties for long-term scenarios (adapted from Cork et al, 2005). Proactive scenarios are well-suited for early-warning strategy on floods. Reactive scenarios are more expensive in protection and post-flood rehabilitation.

Flood poverty cycles merged on South America's scenarios

The worst-case scenario in Figure 5 shows a rather abrupt increase in FPC loss (higher for Global Orchestration and Order from Strength, respectively) midway through the period, which flattens out after appropriate countermeasures are developed (moderately-behaved for Adapting Mosaic and Technogarden scenarios). Towards the end of the scenario period, the rate of loss starts to decline as new knowledge is developed. The attainment factor is composed with a trio of elements to minimize the FPC threats with resilience thresholds of ungauged basins at South American biomes, scaling factors of hydrological regionalization which attend to reduce predictive uncertainty and also the coupling with public flood policies in transboundary basins. These elements are proposed in a "early-warning" protocol, called Hydrosolidarity protocol (Mendiondo & Valdés, 2002). This protocol was used in assessing the scenarios (Figure 6) and their impacts. South America's scenarios of flood risk management until year 2100 are proposed through the 'water compromise', defined as the ratio of 'FPC costs' and 'early warning costs' from floods. Scenario of 'Order-from-Strength' (regionally-and-reactive based scenario) is the most expensive and crescent in front of 'Technogarden' (globally-and-proactive based). Note that until year 2025, all scenarios are equally behaved, with annual rate of + 10 % of cost increase. Since year 2050, downhill behavior of proactive scenarios is expected because early-warning strategies on urban areas.

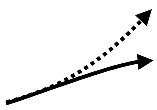
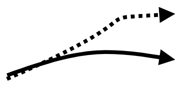
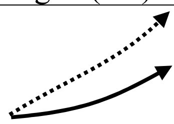
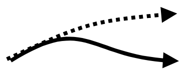
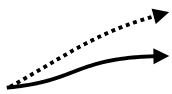
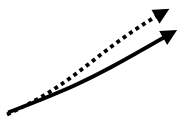
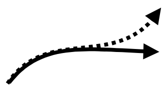
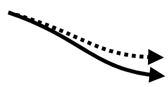
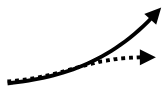
	Scenario development for period 2010-2100 (horizontal axis)			
Component	"Global Orche-stration" (GO)	"Technogarden" (TG)	"Order from Strength"(OS)	"Adapting Mosaic"(AM)
Flood prone areas impacted (total area degraded)				
Direct Drivers:				
Hard Flood Control	++	+ → 0	0	0 → -
Risk Exposition	+	0	++	+ → 0
Climate Change	++	+	+	+
Land-use Change	+	0	++	+ → 0
FPC threats (frequency of flood disasters)				
Major Drivers:				
Poverty	-	0	- -	+ → 0
Climate Change	++	0	++	+
Flood exposition	-	+	+	0
Security to cope with flood disasters				
Elements:				
Preparedness	-	+	- -	+ +
Capacity building	0	+	- -	+
Early Warning Act	0	+ +	0	+

Figure 5- South American impacts on floods from global scenarios between 2000 and 2100 (adapted from Cork et al., 2005). Arrows indicate the development over time of issues named in the left-most column. Full lines indicate the best case, dashed lines the worst case envisaged for each scenario. The row below the arrows for each issue contains a qualitative indication of changes in the relevant drivers. The symbols indicate: '++': strongly increasing pressure by this driver; '+':increasing pressure; '0':no change when compared to today; '-': decreasing pressure; '- -': strongly decreasing pressure; '→': a change in the pressure of the driver during the scenario. Source: Mendiondo (2005).

Hydrosolidarity protocol, merged into proactive scenarios of early-warning, serves to (1) account integrated impact assessment of floods for specific river basins under the effects of global change (Fig. 7), (2) compare of considered impacts amongst river basins with respect to vulnerability to climate change and efficiency of management strategies and (3) to evaluate of risks and mitigation strategies (Table 2).

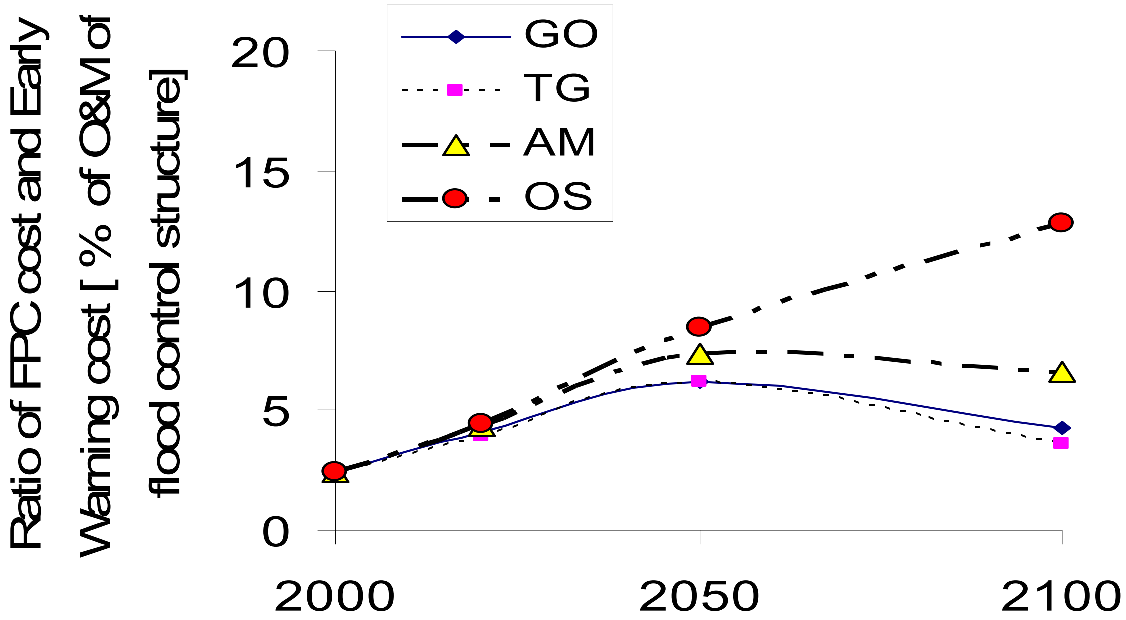


Figure 6- South America's scenarios of flood risk management until year 2100 through the 'water compromise' relations, defined by the ratio of 'FPC costs' and 'early warning costs'. Scenario of 'Order-from-Strength' (regionally-and-reactive based scenario) is the most expensive and monotonically crescent in front of 'Technogarden' (globally-and-proactive based). Note that until year 2025, all scenarios are quite similar, with annual rate of +10% of cost increasing. Since year 2050, downhill behavior of proactive scenarios is expected because early-warning strategies would manage better the flood risks at urban areas. Source: adapted from Mendes et al (2004).

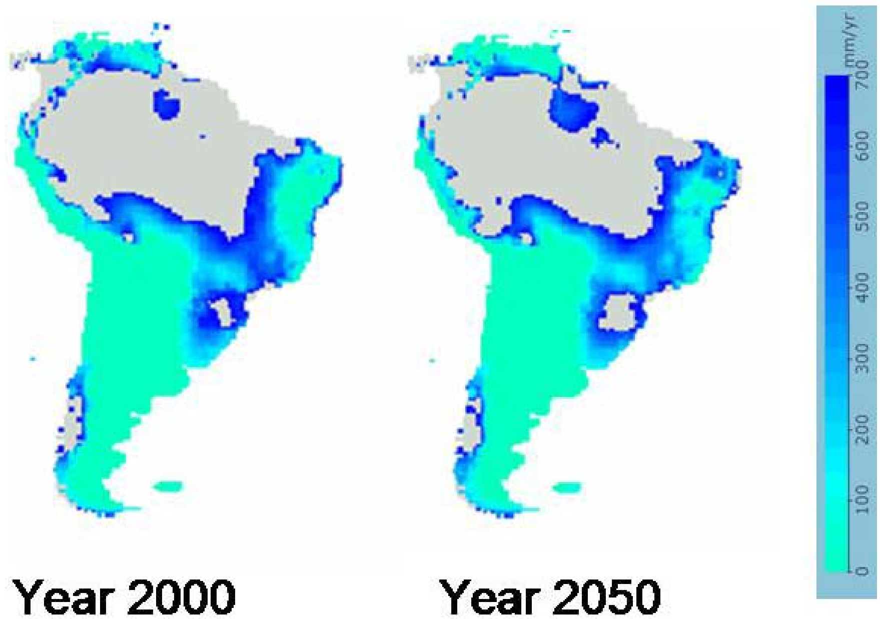


Figure 7- Comparison of precipitation surplus from 2-year-return-period flood for reactive scenarios in South America in 2000 and 2050. Vertical scale depicts the intensity from low (lighted) to high (dark) surplus values. Maximum values are saturated (i.e. Amazonia region). Frames show regions of O&M cost assessments of Table 1. Source: Mendiondo (2005).

Impacts of floods: towards early-warning strategies

Until year 2010 there will be a net positive increase of O&M flood losses in ca. US$ 2 billion a year, especially because of either poor prevention or contingency flood plans. Examples are clear: storms which a lag-time of peak discharge of 1 week are perfectly foresighted by research centers but incredibly non-attended by contingency flood evacuation plan. Regional scenarios from 2010 to 2020 show that coping with floods will demand new elements of management flood risk in South America. For this period, trend signals of climate change are still masqueraded by other signals like land use change, thereby regarding agriculture expansion and urbanization maximum, and the failure of preparedness to manage flood risk. Alternative scenarios show that O&M costs could be reduced to US$ 0,5 billion a year until 2020 if early warning systems are included in river committee plans, with increasing the monitoring and forecast of impacts ungauged basins (Figure 8 and Figure 9). Municipality early-warning systems could be calibrated in order to propose integrated strategies (better, cheaper and faster) to take account human life and socioeconomic factors.

Table 2- Detailed costs of operation and maintenance (in million US$) and social impacts assessed from a 2-year flood on urban areas in Brazil. Method adopted: reactive scenarios for year 1950, 2004 and 2050 and for three independent runs of expert consultation. Source: Macedo et al (2004).

Time Step	**Year 1950**			**Year 2004**			**Year 2050 (without Early Warning)**			**Year 2050 (with Early Warning Act)**		
Simulation	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
House	13.1	10.2	7.6	189.8	70.5	83.2	605.0	108.1	164.2	423.5	81.1	38.3
School	1.8	30.6	6.9	26.5	106.0	75.7	84.5	162.5	149.4	59.1	121.9	34.9
Nutrition	0.2	0.6	0.2	3.4	4.0	1.7	10.8	6.5	3.4	7.6	4.8	0.8
Unemployment	2.2	3.7	1.9	32.6	25.5	20.4	104.0	41.5	40.3	72.8	31.1	9.4
Refugees	1.5	4.8	3.2	21.6	33.3	35.0	68.9	51.1	69.1	48.2	38.3	16.1
Health	1.7	0.5	0.1	24.1	1.7	1.0	76.8	2.8	2.0	53.7	2.1	0.5
Rural area	46.8	51.0	16.5	173.3	176.7	180.3	450.7	270.9	355.7	315.3	203.2	83.0
Infrastructure	14.7	17.1	16.7	59.3	59.3	83.3	172.1	96.7	164.5	120.4	72.5	6.7
Total	82.0	118.5	53.1	530.7	476.9	480.6	1572.7	740.0	948.4	1100.7	555.0	189.6

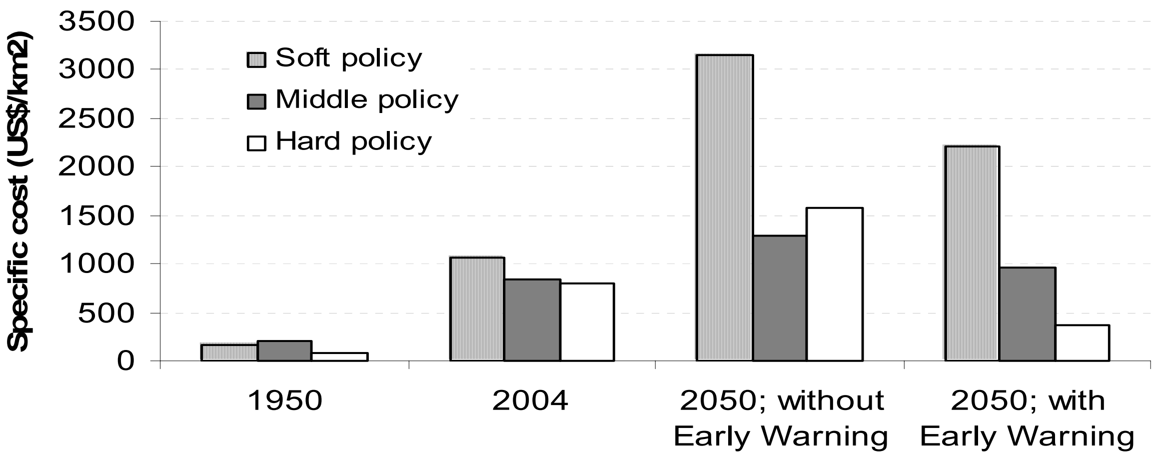


Figure 8- Evolution of total O&M costs for a 2-year flood and according to scenario simulation survey for reactive scenarios in Brazil. Disparity of costs increase for flood policies with proactive scenarios aided by early warning systems (2050_PP), due to prevention, capacity building and contingency plan. Source: Macedo et al (2004).

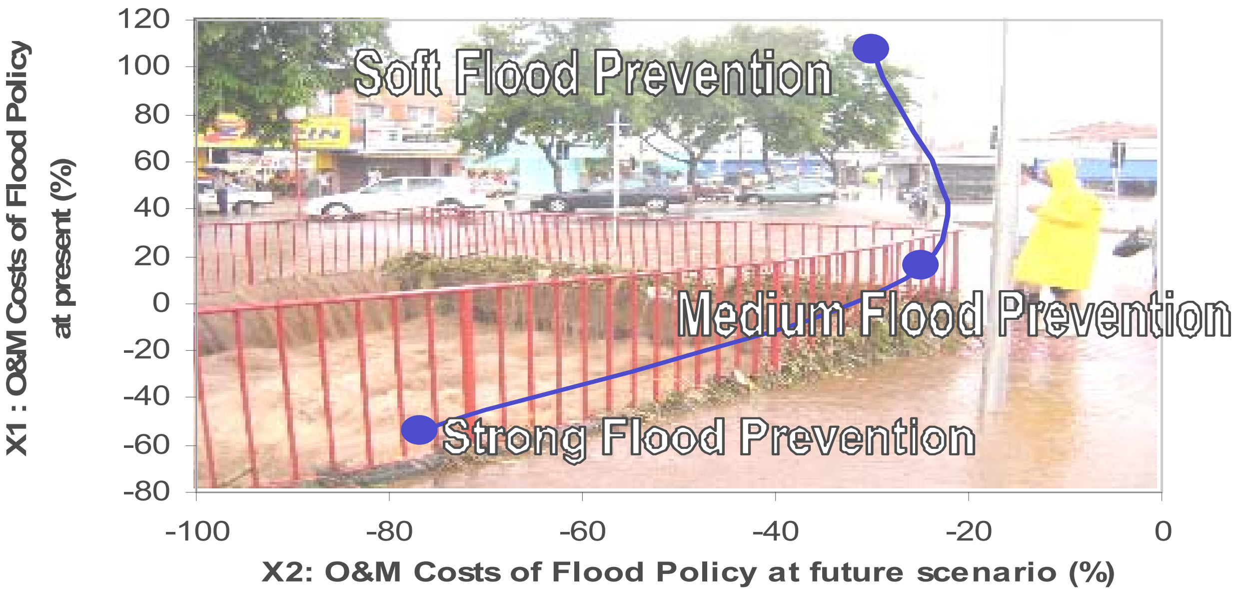


Figure 9- Curve of comparison of O&M costs and efficiency of early warning policies. Middle flood prevention policies at future are nearly the same of present (2005) O&M costs and depict the best marginal efficiency of intervention scenario with early warning systems (Mendiondo, 2005).

OPPORTUNITIES ON FLOOD RISK MANAGEMENT

Flood risk management of urban waters in humid tropics, thereby regarding to some case studies of early warning, protection and rehabilitation, need for more innovative and networking partnerships than former times. The main question is how to handle new challenges in order to focus on urban development planning. Some proposed strategies are outlined herewith, with some lessons learned from flood risk management in South America urban areas.

Risk-based decision making

Flood insurance mechanisms are promissory in South America. Figure 10 outlines the performance of a test run of an insurance model applied in an urban river throughout one hundred years. These results are obtained from the application of hydrologic modeling and marginal-cost surveyed in flood-plain urbanized areas. In this simulation test (Fig. 10), the insurance fund has positive performance with well-behaved inter-decade revenues and profits to cope with risk transfer.

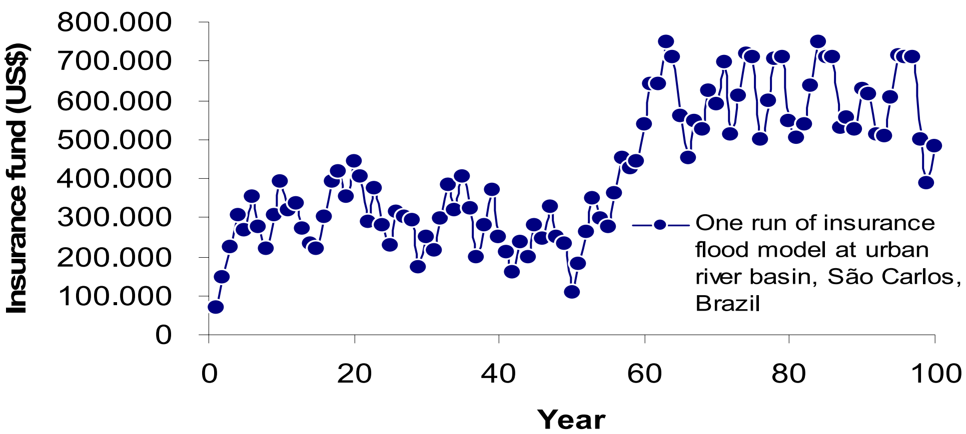


Figure 10- Prospective performance of one run of insurance flood model through a 100-year scenario at an experimental urban river basin (10 km^2), mostly affected by losses from floods, and with three hundred commercial users of flood insurance fund. Data source: FINEP/FIPAI/EESC-USP/DAEE-SP project (2004) and Righetto (2004).

Early warning

Early warning-based scenarios are looked for the steps of assessment of flood risk, mitigation of flood risk and transfer of flood risk. Assessment of risk: conside two aspects; one of determining the hazard associated with a potentially harmful extreme flood, and the second one of determining the consequences: damages, loss of lives etc. caused by extreme floods, based on economic considerations; Mitigation of risk: with structural and non-structural measures. Transfer of Risk: 50% of costs in natural catastrophes in developed, 2% in developing countries are paid by insurance companies. Argentina and Brazil are among 18 countries with losses larger than US$ 18 billion and among 14 countries (7 developing nations) with flood risks higher than 5 % GDP.

South American countries are annually impacted in 2 to 5 % decrease of GDP caused by non-preventable floods which are converted in social disasters- the so called “flood-poverty-cycle” (FPC). To highlight the lessons learned and the experienced gained in constructing prospective scenarios to help decisionmakers, flood policies are necessary to decrease FPC and to improve FRM. They could be carried out at crosscutting spheres of research and development, with practical capacity building and to attend societal needs. It is part of Working Group and sharing vision of Science Plan of the International Decade of Prediction in Ungauged Basins (PUB-Program) and linked to Scenarios Working Group of Millennium Ecosystem Assessment (ME). The merging of goals and methodologies of both programs, are a practical example focusing in flood risk management until 2050 and its societal benefits. A relative annual economy of + US$ 150 per capita until year 2050 due to a wise flood risk management in South America is possible, and to reduce ‘flood poverty cycle’ (FPC) in an order of magnitude of 50. The total ‘flood accountability’ in South America is around US$ 80 billion a year and will expand until 2075 (see Fig. 6). The necessary transition phase in South America river management is proposed: to move from mitigating flood disasters to early-warning systems (Mendiondo, 2005).

Figure 11 depicts a permanency curve of specific discharges obtained from flood events monitored at experimental urban basins with purposes of early-warning for Master Plan, thereby permitting regionalized predictions in ungauged basins. Monthly costs associated to this kind of curve are ca. US$ 100 per technician, including material and equipment. Also, comparison could be attained between predicted rainfall (filled bars) and observed rainfall (white bars), related to predicted flow discharges (bold lines) and observed flow discharges (dotted lines) used with model test runs of an empirical model of early-warning nowcasting for flash floods in urban areas (Figure 12). That is special significant for fitting either time-to-peak or peak discharge. This cost is presented in Table 1, as part of actions in flood risk management.

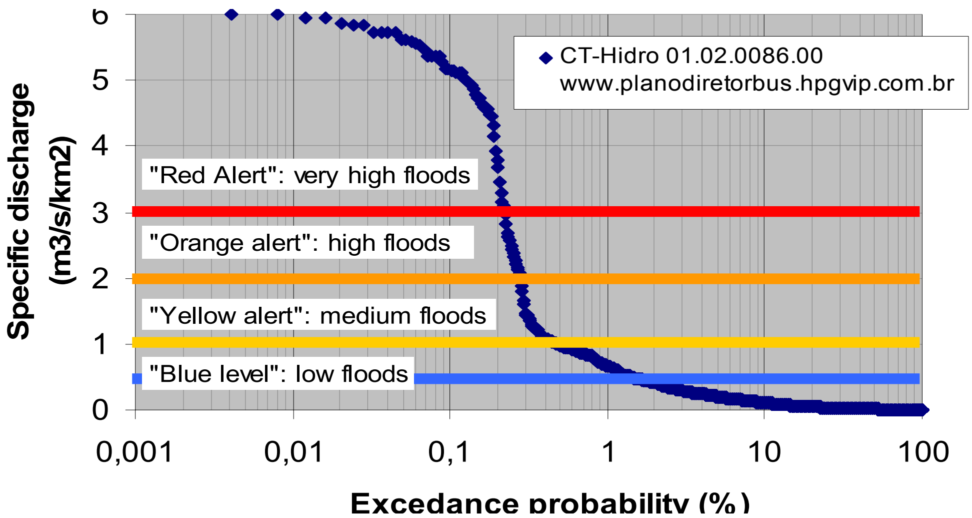


Figure 11- Permanency curve of specific discharges obtained from flood events monitored at experimental urban basins with purposes of early-warning for Master Plan. Source: FINEP/FIPAI/EESC-USP/DAEE-SP Project (2004).

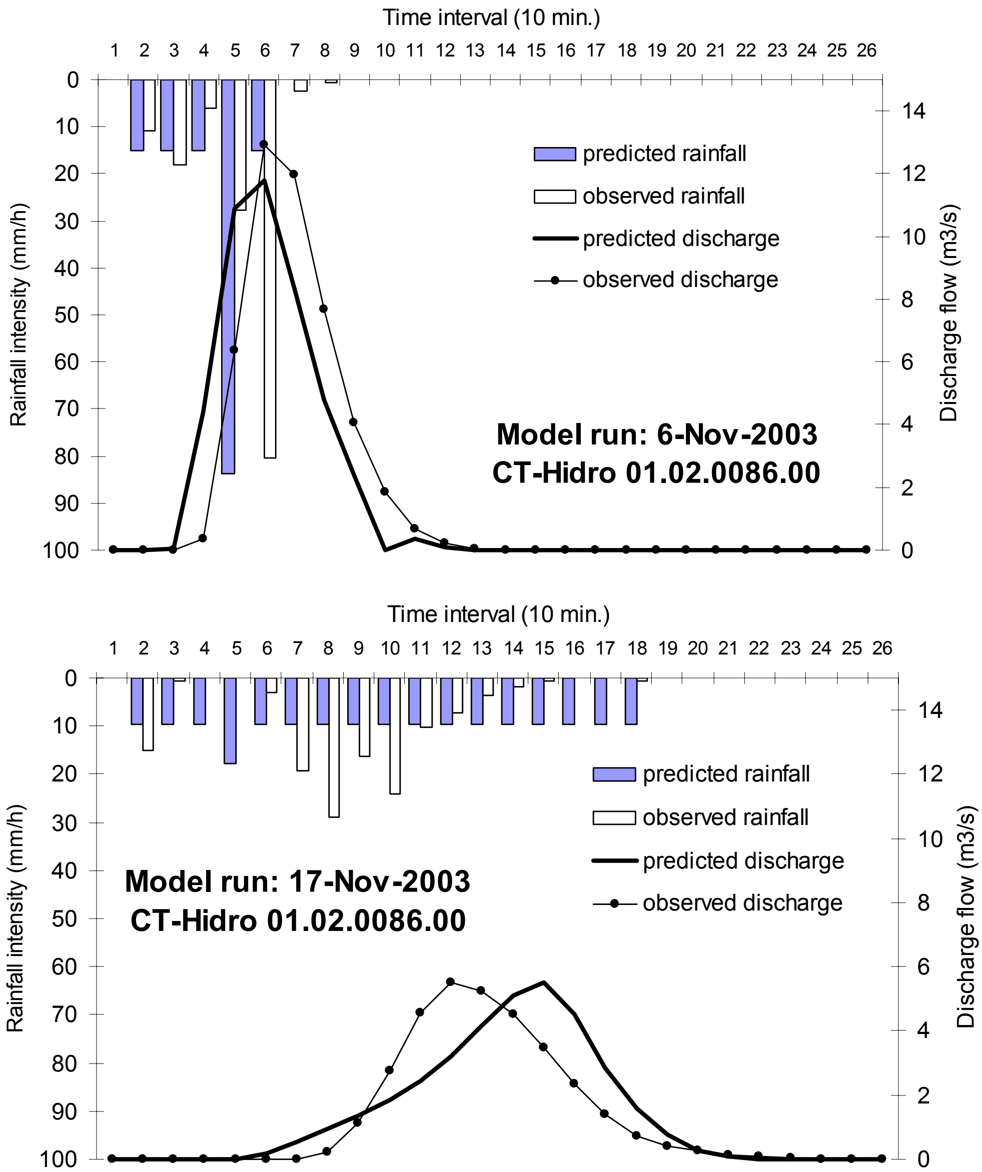


Figure 13- Comparison between predicted rainfall (filled bars) and observed rainfall (white bars), related to predicted flow discharges (bold lines) and observed flow discharges (dotted lines) used with model test runs of an empirical model of early-warning nowcasting for flash floods in urban basin of 10 km^2-area. Upper panel: time-to-peak fitting; lower panel: peak discharge fitting. Source: J. P. M. de Andrade (2005).

Rehabilitation and control

Restoration are feasible options to urban areas in humid tropics, in order to coping with very high flow discharges. Figure 13 shows two measured rainfall-runoff events, occurred on May 11th, 1993 (above) and October 22nd, 1994 (below), with a 10 min time interval. Concentrated rainfalls produced intense flood peaks of 9.5 and 9.1 m^3s^{-1}, respectively. These values have probability less than 10 % a year, according to permanency curves. In consequence, the REBRUSH model (Mendiondo, Clarke, Toensmann, 2000) performs retarding peaks and routing flood discharges with peak reductions of ca. 30 to 35 %. Figure 14 outlines the results of urban planning scenarios using restoration and control devices. In this figure, nested catchment regionalization of maximum specific discharges in urban basins with restoration and control scenarios is presented. Upstream and downstream river basin zoning and restoration are fully integrated with detention basins, such that pre-urbanization standards could be attained within the safe zone, below of the alert threshold of regionalized very high floods.

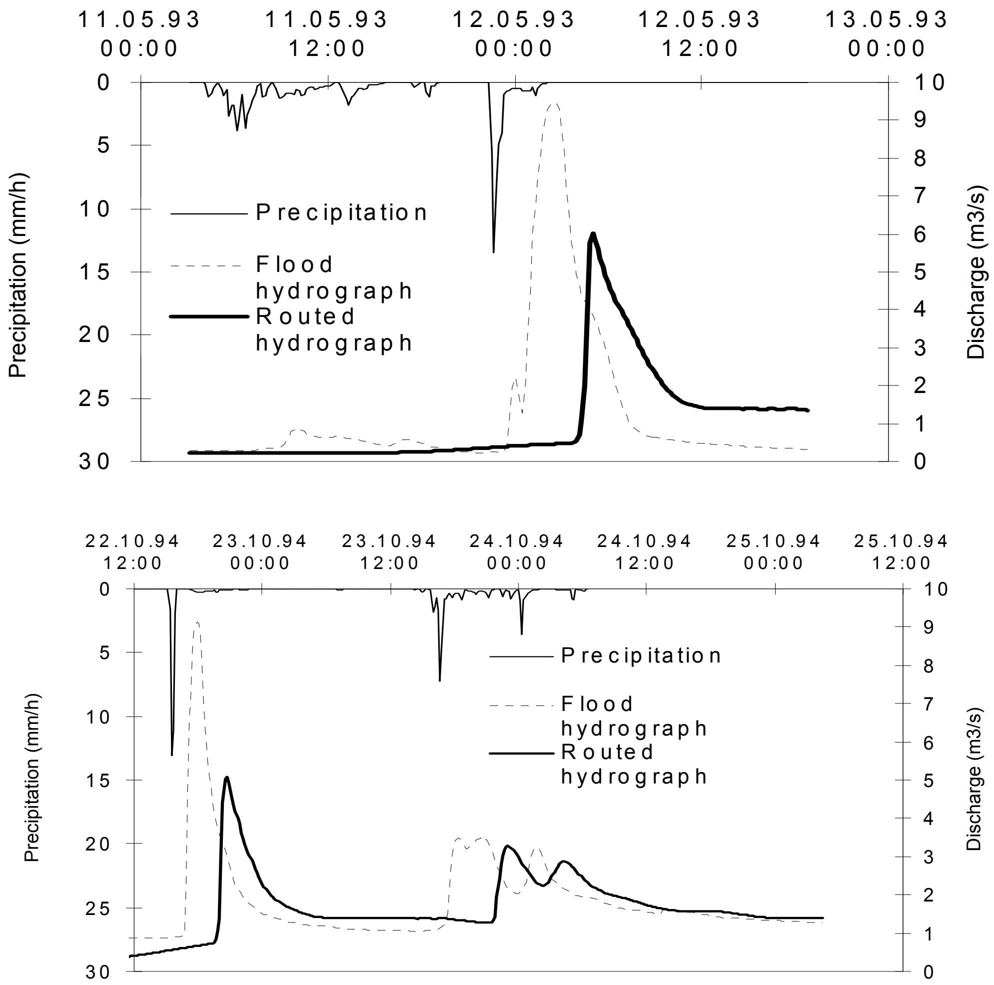


Figure 13: Rehabilitation scenarios using flood hydrographs routed through restored river reaches, with attenuation and delaying of peak discharges through the REBRUSH model at 20 km^2-area basin. Source: Mendiondo, Clarke & Toensmann (2000).

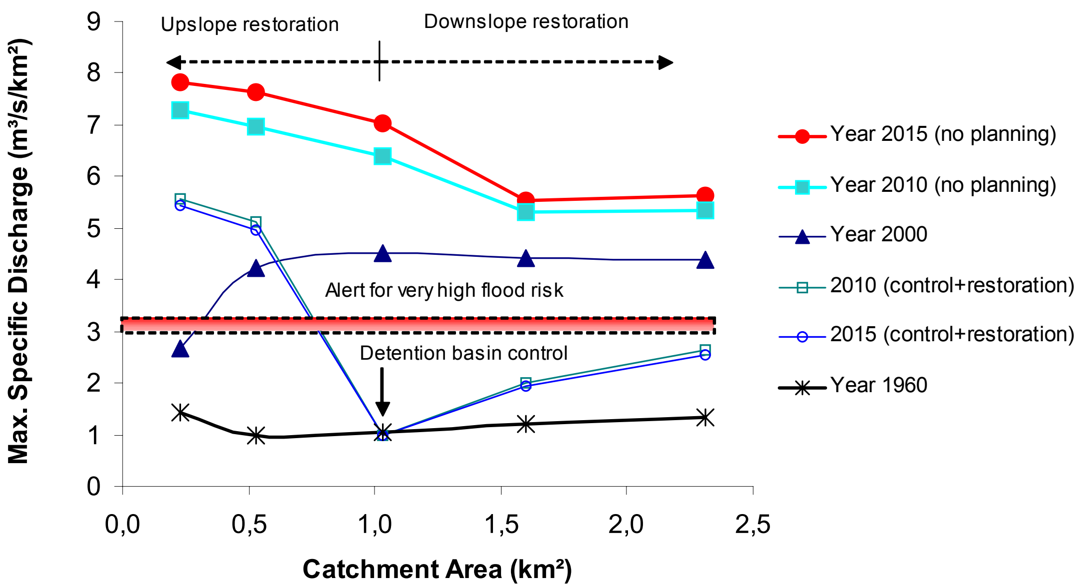


Figure 14- Nested catchment regionalization of maximum specific discharges in urban basins with restoration and control scenarios. Source: Mendiondo et al (2004)

OUTLOOK – TAMING THE FLOOD?

After the flood – with disease looming, every urban administration launches a massive relief effort. Will the aid reach the flood victims in time? Moreover, the flood waves usually wipe out countless jobs and post flood rebuilding could take years in most cases. It is a similar case for millions of urban citizens whose livelihood has been lost through the flood. Jeffrey Sachs (Sachs, 2005) explains that '*disasters often hit the poor the hardest; it doesn't have to be that way*'. A world divided by ethnic and religious disputes, as prognosticated by reactive flood scenarios (Fig. 4, Fig. 5 and Fig. 6), will suddenly face its common humanity in a flood disaster of shocking geographic reach at humid tropics.

At least for the moment, the world has united to aid vulnerable people, mostly living at humid tropics under frequent flood-related disasters, trying to piece their lives back together in the wake of the devastation. If developed, rich countries continue with business as usual—with reactive scenarios—, responding generously to current disasters but failing to the address the dire underlying situation of the world's poor, the world will repeatedly confront the tragic arithmetic of life and death in post-flood. This is not merely a sound forecast based on the likelihood of future floods in urban areas, but for the urgent claim for flood risk management. World military spending outspaces development aid by roughly 30 to 1 (Sachs, 2005), and post-flood reconstruction is about 25 times the early warning costs. Obviously that scenario is overlapping the impacts of FPCs and flood disasters associated.

These figures enhance the impact of FPC (flood poverty cycle) regarded to urban waters in humid tropics where flood disasters are not earth-shattering news. It's not that people there don't value life deeply, but they have accustomed themselves to tragedy, and to facing tragedy with limited media attention, cash-strapped governments, few local charities and almost no insurance. Many people live on less than $2 a day: this is the submerged war that tropical countries are waging, and calling for a plea in terms of flood risk management. In this way, Figure 3 should be revisited many times.

The formentioned experiences and lessons learned allow both alternative early warning and flood prediction standards to be underpinned from experiences gained and lessons learned. Using participatory programs, i.e. FRIENDS, GEWEX, IGBP, HELP, GWP and UNESCO-IHP RSC-SEAP, the flood early warning systems could permit to help people living in risk of world's biomes, and, with appropriate recommendations, for win-win flood strategies and overseas partnerships. Governmental policies and international cooperation for better management of water-related disasters could be shared during the series of UN World Conferences on Disaster Reduction as a forum of people who are in charge of monitoring, prediction and mitigation of water-related disasters to discuss and exchange relevant issues in the areas concerned.

By using actual facilities among urban administrations worldwide is better addressed the way forward to prevent flood disasters, and FPCs respectively, than post-mitigate them. If novel working groups will continue to pose new challenges at catchment studies, then promissory advances of observational hydrology would be profited towards better understanding of experiments at field scale.

ACKNOWLEDGEMENT

Details of Millennium Ecosystem Scenarios are on www.millenniumassessment.org. PUB-IAHS information is on www.iahs.info. Details of experiments presented in this paper are public domain at www.shs.eesc.usp.br/laboratorios/hidraulica, and received contributions from colleagues of NIBH (Integrated River Basin Group). The author thanks to Prof. Dr. Joel A. Goldenfum and Prof. Dr. Carlos E. M. Tucci, conveners of the Workshop on Integrated Urban Water Management in Humid Tropics, Foz de Iguaçu, 2005, organized by UNESCO/IHP-VI (International Hydrologic Program). This paper has the support of grant # CNPq-PQ-301491/2003-8 and FINEP-CT-HIDRO 01.02.0086.00.

REFERENCES

Andrade, J. P. M. de (2005) Protocol of early-warning system for floods in urban basins, *Qualification Report*, PPG-SHS/EESC/USP, Sao Carlos, SP, Brazil (in Portuguese).

Cork, S., Peterson, G., Petschel-Held, G., Alcamo, J., Bennett, E., Carr, E., Deane, D., Nelson, G., Ribeiro, T., Alder, J., Colin, B., Mendiondo, E., Oluoch-Kosura, W., Zurek, M. (2005) *Scenarios Working Group of Millennium Ecosystem Assessment–* Global Assessment (in review process).

Depettris, J.J., Mendiondo, E.M., Neiff, J.J., Rohrmann, H. R. (2000) Flood defence strategy at the confluence of Parana and Paraguay Rivers, In: F. Toensmann & M. Koch (eds.) *River Flood Defence*, Kassel, Herkules,v.I, p.31-40.

FINEP/FIPAI/EESC-USP/DAEE-SP (2004) *Pilot experiment of integrated urban basin management for Master Plan*, CT-Hidro 01.02.0086.00 Project (www.planodiretorbus.hpgvip.com.br)

EM-DAT-CRED (2003) *International Disaster Database*, Univ. Catol. Louvain.

Macedo, R. F., de Andrade, J. P. M., Aires, S., Mendiondo, E. M. (2004) Scenarios of public policies related to inundations, In: I Sem. Latin. Políticas Públicas Rec. Hídricos, Brasilia, Brazil, 2004, *Proceedings*, ABRH (in Portuguese).

Mendes, H., Matsunaga, S., Vercosa, M., Mendiondo, E. M. (2004) Hydrosolidarity as mechanism of managing public policies for prevention hydrologic risks, In: I Sem. Latin. Políticas Públicas Rec. Hídricos, Brasilia, 2004, Brazil, *Proceedings*, ABRH (in Portuguese).

Mendiondo, E. M. (2005) Scenarios of South American floods : from Mitigating Disasters to Early-Warning Strategies, In: Int. Symp. Monit.,Predicting and Mitigating Water Related Disasters, , Kyoto Univ, Japan, *Proceedings*, DPRI – Disaster Prediction Research Institute.

Mendiondo, E. M., Valdes, J. (2002). Strategies for sustainable development in water resources systems, In: 2nd Int. Conf. New Trends in Water & Environ. Eng. Safety & Life, Capri, Italy, *Procedings*.

Mendiondo, E. M., Clarke, R. T., Toensmann, F. (2000) River restoration, discharge uncertainties and floods, In: F. Toensmann & M. Koch (eds.) *River Flood Defence*, Herkules Verlag, Kassel, v.2, p. 141-152.

Mendiondo, E. M., Ohnuma Jr., A. A., Peres, R., Benini, R. (2004) Simplified methodology of planning scenarios for environmental recovery of urban basins, In: XXI Latin American Congress of Hydraulics, Sao Pedro, Brazil, IAHR, *Proceedings* (in Portuguese).

Munich Re Group (2000) *World of Natural Hazards*, Munich: R&D/Geo.

Neiff, J.J., Mendiondo, E.M., Depettris, C.A. (2000) ENSO Floods on river ecosystems: catastrophes or myths ? In: F. Toensmann & M. Koch (eds.) *River Flood Defence*, Kassel Rep. Hydr. Eng., No. 9/2000, Kassel, Germany, Herkules, v.I(F), p. 141-152.

NIBH/EESC/USP (2004). Reflections on flood impacts and proposals of mitigating public policy, *Internal Report #2*, SHS-EESC-USP, Sao Carlos, SP, Brazil (in Portuguese).

Righetto, J. M. (2004) Model of flood insurance for hydrologic risks through integrated basin management, *Qualification Report*, PPG-SEA/EESC/USP, Sao Carlos, SP (in Portuguese).

Sachs, J. (2005) The class system of catastrophe, *Time*, Jan. 10, 2005, p.52.

Sivapalan, M., K. Takeuchi, S. Franks, V. Gupta, H. Karambiri, V. Lakshmi, X. Liang, J. J. McDonnell, E. Mendiondo, P. O'Connell, T. Oki11, J. Pomeroy, D. Schertzer, S. Uhlenbrook, E. Zehe (2003). PUB 2003-2012: Shaping an Exciting Future for the Hydrological Sciences. *Hydrol. Sci. Journal*, 48(6), 857-880.

Tucci, C. E. M. (2003) *Workshop for decision makers in floods in South America*, WMO/GWP/IPH-UFRGS, Porto Alegre, Brasil

Tucci, C. E. M. & J. C. Bertoni (2003) *Urban inundations in South America*, GWP/WMO/ABRH Public, Porto Alegre, Brazil. (in Portuguese)