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ENVIRONMENTAL EVALUATION MODEL FOR WATER RESOURCE PLANNING. STUDY CASE: Piabanha hydrographic basin, Rio de Janeiro, Brazil

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ABSTRACT

The availability of water-environmental knowledge has led to a demand to make this knowledge available. This paper describes an application of Battelle method which is a valorous tool in environmental impact assessment. The results showed 54.3% of environmental degradation in studied area. The perception of continuous and equal development stays the largest challenge for the humanity and, being like this, becomes important to separate that the effects caused through degradation of a hydrographic basin, contemplate, directly, in the public and environmental health.

Key words: Environmental impact assessment, Piabanha Hydrographic Basin, Battelle method, Environmental monitoring, Public health

RESUMO

A disponibilidade de saberes sobre águas ambientais conduziu essa demanda a possibilitar que este conhecimento se torne disponível. Este artigo descreve uma aplicação de método de Battelle que é uma ferramenta valorosa em avaliação de impacto ambiental. Os resultados mostraram 54.3% da degradação ambiental na área estudada. A percepção de desenvolvimento contínuo e eqüitativo permanece o maior desafio para a humanidade e, sendo assim, torna-se importante separar que os efeitos causados através de degradação de uma bacia hidrográfica, reflitam, diretamente, na saúde pública e ambiental.

Palavras-chave: Avaliação de Impacto Ambiental, Bacia hidrográfica do Piabanha, Método Battelle, Monitoramento ambiental, Saúde pública

1 INTRODUCTION

Due to the extensive and increasing number of known and unknown pollutants and the difficulty of predicting their collective effects in receiving ecosystems, there is a need for process of identifying and evaluating impacts in what must recognize that the determination of impact implication is intrinsically an anthropocentric concept.

Integrated water resources management is based on the concept of water being an integral part of an ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its use. A water source that is reliable, in terms both of its quantity and its quality, is a prerequisite for the survival of human civilization and socio-economic development. Water scarcity, gradual deterioration, aggravated pollution and infrastructure development has increasingly created conflicts over the different uses of this resource. The river basin management approach is an example of an incentive-based participatory mechanism for solving conflicts and allocating water between competing users, including natural ecosystems.

The key of environmental challenges that we are facing relate to the nexus of environmental degradation with poverty in its many dimensions, and economic growth. These challenges are intrinsically connected with the state of environmental resources, such as land, water, air and their flora and fauna. The proximate drivers of environmental degradation are population growth, technology and consumption choices, and poverty, leading to changes in relations between people and ecosystems, and development activities such as intensive agriculture, polluting industry, and unplanned urbanization. However, these factors give rise to environmental degradation only through deeper causal linkages, in particular institutional failures, resulting in lack of clarity or enforcement of rights of access and use of environmental resources, policies which provide disincentives for environmental conservation (and which may have origins in the fiscal regime), market failures, (which may be linked to shortcomings in the regulatory regimes), and governance constraints. In the water effective administration it is necessary that the sectorial public politics, as the hydric resources, be elaborated and managed, relating to the natural and ecological dimensions, that means implement compatible territorial units with these logics, and that, in the hydric resources case, it sends us to the hydrographic basin concept being, this way, an unit of environmental planning and administration.

Consequently, water resource development projects, at the same time as facing the same problems of high cost and adverse environmental impact already seen in the developed countries, also encountered new and different problems that all too often resulted in poor performance, even for those limited purposes that the projects were intended to accomplish. By the last decade of the twentieth century, the international aid agencies had begun to reappraise and respect the world, specially, searching for more promising development strategies (SCRIVEN & YUONG, 1998; GOYAL & DESHPANDE, 2001).

The main objective of this article is to argue and to give focus to the uses of a hydrographic basin, for its importance in the maintenance of the related cities. For this, the actions had been used that affects the environment for the sanitation actions, having themselves as parameter of validation of ambient degradation the Battelle method. This way, in this context, water resources management means not only manipulation and management of the physical resource but also influencing the ways in which people use scarce water resources.

Not only water, but also human actions, must be managed. The aim of such management is sustainability, which may be defined variously from maximizing the present value of the well-being of all future humans to maintaining the viability of all existing natural systems. Each of these concepts captures vital considerations, which go far ahead of the conventional goals of water resources development; goals now collectively regarded as too restricted. A present view of sustainability attempts to strike equilibrium between these two concepts (SAUNDERS, 2004).

2 LITERATURE REVIEW

2.1 General aspects for the environmental impact assessment

Literature on impact assessment tends to utilize terms such as techniques and methods in an unfocused manner. Theoretically, methods can be distinguished from techniques. A technique provides data on some parameter and the data is then utilized by a method, which might present and evaluate them. A technique may be used to evaluate or present information but is basically a building block for a method. An environmental impact assessment may use more than one technique, and the application of methods is usually controlled by published guidelines or rules (HILDEN, 1996; ROSSOUW, 2003).

2.2 Impact Identification

The concept of significance is at the core of impact identification, prediction, evaluation and decision-making. Deciding whether a project is likely to cause significant environmental effects is central to the practice of Environmental Impact Assessment (EIA). Whatever environmental effects are addressed and whatever methods are used, the focus of EIA always narrows down to a decision about whether the project is likely to cause significant adverse environmental effects.

A number of methods can be used to identify the major impacts of a proposed development. Methods for impact identification have been divided by MUNN (1979) and CANTER (1996) into the generic classification of matrices, networks and checklists. These methods for impact identification include:

- *Ad hoc* approaches (e.g. project, sector or environment specific guidelines);
- Checklists (i.e. the listing of potential impacts);
- Matrices (e.g. the Leopold Matrix, Bettelle Method);
- Networks (i.e. the presentation of higher order impacts and linkages using directional diagrams);
- Overlay Maps (e.g. the McHarg technique); and
- Modelling procedures (i.e. computerised, mathematical, physical scale models or descriptive models).

Most methods and techniques for identifying, measuring, and assessing impacts rely on expert judgment. In fact, many checklists, matrices, and models used in EIA represent decades of experience accumulated by numerous experts. The experts themselves are heavily involved in all aspects of the assessment, they are used to help identify the potential for significant impacts, plan data collection, and monitoring programs, provide their judgment on the level of significance for specific impacts, and suggest ways of reducing or preventing impacts.

The EIA is the cluster of systematic studies on the repercussions previsible, direct or indirect, which can product a human intervention wherever the environment is implicated. Also includes all accomplishment of environment administration and all action whose previsible impact on environment that should not be ignored. The evaluation environmental raisin, initially, for an earlier definition of the environmental system (classification of what comes to be the environment in subject), soon after the formalization for the objectives evaluation, the criteria evaluation and the method to be applied, for lastly the quantification quantitative and/or qualitative for those criteria to be established (ECONOMOPOULOS, 1993; CANTER & CANTY, 1993; MARQUES *et al*., 2004).

For an informed decision to be made, the decision makers need to understand the nature and extent of potential impacts and the trade offs involved (Fig. 1).

STAGE IN THE EIA PROCESS	OBJECTIVES	APPROACHES AND METHODS
Screening	Process, which determines whether a project should be subject to an EIA because of its associated potential significant impacts.	Approaches used at this stage include: (d) Checklists of projects, activities or impacts; and/or (b) Predefined criteria such as thresholds of significance.
Scoping	Process in which key (significant) issues are raised and the focus is on determining the specific issues or significant impacts that need to be addressed in the EIA.	Approaches used at this stage include: (a) Facilitation; (b) Stakeholder engagement; (c) Negotiation; and (d) Mediation.
Specialist studies	This stage involves the identification and prediction of project impacts by specialists and the evaluation of their significance.	Approaches used at this stage include: (a) Numerical calculations or modelling; (b) Experiments of tests; (c) Physical or visual simulations; (d) Mapping; and (e) Professional judgment.
Environmental Impact Report	This stage involves the preparation of a report by the EIA practitioner. The EIA practitioner integrates different forms of information and uses impact description and significance criteria to present the results to the decision-maker.	Approaches used at this stage include: (a) Predefined criteria for evaluating impacts; (b) Professional judgment; (c) Verbal description; (d) Visualization; (e) Mapping; and (f) Matrices.
Decision-making	The decision-maker uses judgment to rate and determine the significance and acceptability of impacts.	Approaches used at this stage include: (a) Professional judgment; and (b) Predefined criteria for evaluating, rating and weighting significant impacts.

Figure 1 - Criteria for evaluation the acceptability of environmental impacts methods

3 METHODS

3.1 The Battelle Method for environmental impact assessment

The Battelle method (DEE *et al*., 1973; THOMPSON, 1990; ALSHUWAIKHAT, 2005) is one of the oldest and most established of methodologies for structuring a judgemental process. It makes use of sets of numbers as means of mapping beliefs and facts into attitudes, attitudes into positions and ultimately positions into judgements, subject to a multiplicity of criteria.

The Battelle procedure is based upon a calculation of the weighted environmental impact sum of hierarchically structured environmental effects, ranging from general to specific. There are 4 environmental categories, divided into 17 intermediate environmental components and 78 environmental parameters under these components (Table 1).

Table 1 - The Battelle environmental classification. The bracketed numbers are relative weights

Ecology (240)	**Environmental contamination (402)**
Terrestrial species and populations	**Water quality**
Browsers and grazers (14)	Basin hydrologic loss (20)
Crops (14)	Biochemical oxygen demand (25)
Natural vegetation (14)	Dissolved oxygen (31)
Past species (14)	Fecal coliforms (18)
Upland game birds (14)	Inorganic carbon (22)
Aquatic species and populations	Inorganic nitrogen (25)
Commercial fisheries (14)	Inorganic phosphate (28)
Natural vegetation (14)	Pesticides (16)
Past species (14)	pH (18)
Sport fish (14)	Stream flow variation (28)
Waterfowl (14)	Temperature (28)
Terrestrial habitats and communities	Total dissolved solids (25)
Food web index (12)	Toxic substances (14)
Land use (12)	Turbidity (20)
Rare and endangered specie (12)	**Air quality**
Species diversity (14)	Carbon monoxide (5)
Aquatic habitats and communities	Hydrocarbons (5)
Food web index (12)	Nitrogen oxides (10)
Land use (12)	Particulate matter (12)
Rare and endangered specie (12)	Photochemical oxidants (5)
Species diversity (14)	Sulphur oxidants (10)
	Other (5)
Aesthetics (153)	**Land pollution**
Land	Land use (14)
Geologic surface material (6)	Soil erosion (14)
Relief and topographic character (16)	**Noise pollution**
Width and alignment (10)	Noise (4)
Air	
Odour and visual (3)	**Human interest / social (205)**
Sounds (2)	**Education / scientific**
Water	Archaeological (13)
Appearance of water (10)	Ecological (13)
Land and water interface (16)	Geological (11)
Odour and floating material (6)	Hydrological (11)
Water surface area (10)	**Historical**
Wooded and geologic shoreline (10)	Architectural and styles (11)
Biota	Events (11)
Animals – domestic (5)	Persons (11)
Animals - wild (5)	Religions and cultures (11)
Diversity of vegetation types (9)	Western frontiers (11)
Variety within vegetation types (5)	**Cultures**
Man-made objects	Indians (14)
Man-made objects (10)	Other ethnic groups (7)
Composition	**Mood / atmosphere**
Composite effect (15)	Awe / admiration (11)
Unique composition (15)	Isolation / solitude (11)
	Mystery (4)
	Oneness with nature (11)
	Life patterns
	Employment opportunities (13)
	Housing (13)
	Social interactions (11)

3.2 Weight assignment procedures in evaluation of impacts

The measurements on the specific environmental parameters are transferred into an Environmental Quality (EQ) value through value functions conventionally determined by the 'judgment of experts'. Thence, making use of EQ values, which lie in the range [0;1] environmental effects are calculated as a weighted sum of commensurate units called Environmental Impact Units (**equation 1**). The relative weights of individual environmental aspects are expressed in parameter importance units (PIUs). The total of 1000 PIU is used for weighted estimation. The final score of the environmental effects on a certain proposed intervention is obtained as the difference between the two phases for expected future environmental conditions; without the proposed project and taking into account the implementation of the intervention. Mathematically, it is represented as follows:

$$\Delta(EIU) = \sum_{i=1}^{m} (EQ_i)_1 \cdot PIU_i - \sum_{i=1}^{m} (EQ_i)_2 \cdot PIU_i \qquad (1)$$

Where:
E: environmental impact
(EQi)$_1$: EQ unit *i* with project
(EQi)$_2$: EQ unit *i* without project
M: number of environmental parameters

The weighting technique used in the Battelle procedure is based on a sociopsychological scaling technique. A variety of such techniques are used to ensure that the comparison between elements is consistent and systematic. In the original Battelle procedure the ranked pairwise comparison method is used in order to assign weights.
In this approach, the elements to be compared are ranked according to the selected criteria and the comparisons made between contiguous elements so as to select the degree of difference in importance for each element pair. As mentioned before, the parameter weights reflect the relative importance of respective parameter measurements.

The procedure of pairwise comparison consists of 6 simple steps:

1. Rank the elements to be evaluated by relative importance by descending order;
2. Assign the value of 1 to the first element, then compare the second element with the first to determine how much the second is worth compared to the first. This can be expressed in decimal (0<x<1);
3. Continue this comparison until the end of the ranked list;
4. Compute percentages and express in terms of a common denominator, and average over all individuals in the process;
5. Adjust the decimal values if an unequal number of elements exist in the element groups that are being evaluated. This is done by proportioning the decimal values in proportion to the number of elements included in the group; and
6. Multiply the averages by the number of PIU to be distributed to the respective groupings.

This method has following important drawbacks:

- The input judgements are not quantified efficiently;
- It does not consider the consistency of judgement; and
- Only neighboring parameters in the list are directly compared.

3.3 Project site environmental setting

Piabanha hydrographic basin with 74 km of extension is one of the largest and more important sub-basins that compose the Paraíba do Sul River embracing one of the more developed industrial areas of the Rio de Janeiro State.

The current situation reflects a historical process of occupation characterized by the economical cycle's discontinuity, the regional socioeconomic unevenness and the environmental degradation. In the area, live about 5 million inhabitants distributed in an area of 56 600 km^2 that extends for São Paulo State with 13 500 km^2, Rio de Janeiro State with 22 600 km^2 and Minas Gerais State with 20 500 km^2.

The hydrographic basin corresponds to the area drained by the Piabanha River and its tributaries, from the east to the encounter of Paraíba do Sul River it is a system open geomorphologic, that receives energy through climatic agents along the river and it loses through aneffluvia. It rangers an area of approximately 2 000 km², comprising the municipal districts of Petrópolis, Teresópolis, Areal, São José do Vale do Rio Preto and Paty do Alferes (**Figure 1**). The rivers belonging of the Piabanha hydrographic basin are reserved to the irrigation, creation of species destined for human feeding, aquatic communities' protection, recreation and for domestic provisioning, by an appropriate treatment.

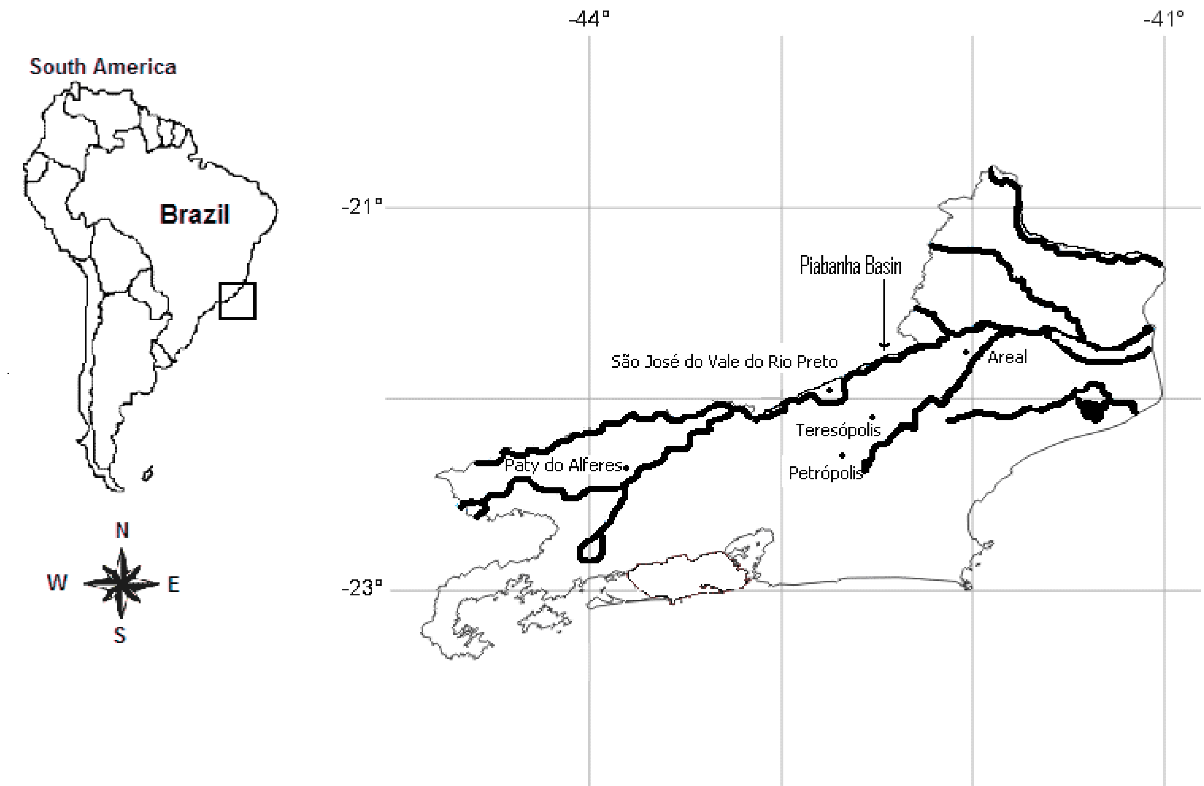

Figure 1 - Municipal districts in Piabanha Hydrographic Basin

4 RESULTS

The degree of environmental impact obtained for the Piabanha basin corresponds to the total value of 457 units, taking into account that there is not still specific project of recovery of the environmental degradation of this basin (**Table 2**).

Table 2 - Environmental impact at Piabanha Basin

Ecology		**Environmental contamination**		**Aesthetics Aspects**		**Human Interest Aspects**	
Species and populations		***Water pollution***		***Land***		***Characteristic values***	
Terrestrial		Basin hydrologic loss	0	Geologic surface material	05	Movement sedimentary	08
Browsers and grazers	09	Biochemical oxygen demand	0	Use types	10	Violation index	05
Crops	07	Dissolved oxygen	0	Deforestation	05	Sanitation	05
Natural vegetation	08	Faecal coliforms	0		20	Hydrologic	06
Pest species	08	Inorganic carbon	0	***Basin***			24
Upland game birds	08	Inorganic nitrogen	0	Framing	02	***Historical values***	
	40	Inorganic phosphate	0	Rivers	01	Economical cycles	05
Aquatic		Pesticides	0		03	Rude internal product	07
Commercial fisheries	05	Stream flow variation	0	***Water***		Quality index	07
Natural vegetation	08	Temperature	0	Appearance of water	05	Age structure	07
Pest species	08	Total dissolved solids	0	Land and water interface	06	Climate	08
Sport fish	10	pH	18	Odour and floating material	05		34
Waterfowl	08	Toxic substances	0	Water surface area	08	***Net of stations***	
	39	Turbidity	20	Wooded and geologic shoreline	05	Fluviometrics	07
Habitats and communities			38		29	Monthly water flow	05
Terrestrial		***Contamination by pollutant activities***		***Biota***		Hydrogeochemical	05
Food web index	**09**	**Industrial effluents**	**03**	**Diversity of vegetation types**	**07**		**17**
Land use	**08**	Domestic effluents	05	Hydric use	03	***Human Development***	
Rare and endangered species	09	Agricultural effluents	0	Air quality	03	Index of human development	09
Species diversity	09	Inundations and drainage	08	Hydric plan	02	Education	08
	36	Superficial water	05		15	Longevity	03
Aquatic		Underground water	10	***Forest***		Income	08
Food web index	**09**	**Erosive Process**	**03**	**Riparian zone**	**08**		**28**
Rare and endangered species	**08**		**34**		**08**	***Municipal characterization***	
River characteristics	09	***Land pollution***		***Conservation units***		Family vulnerability	08
Species diversity	09	Land use	08	Ecological stations	09	Population	05
	36	Soil erosion	08	Special elements	09	Habitation	09
Ecosystems			16		18		22
Descriptive only		***Contamination by solids residues***					
	-	Appropriate destination	0				
Sub total:	151		88		93		125
Total EIU = 457							

The methodical and inclusive identification and assessment of cumulative impacts is a challenge gradually more attracting the attention of researchers and in generating an emergent literature, much of it under the heading cumulative effects assessment. In the calculation of the global index of impact, is considered, the unit of environmental impact for project, which is given by the difference among the unit of total environmental impact with the accomplishment of the project and the unit of environmental impact without the accomplishment of the project, as shown in **equation 2**.

$$\Delta(EIU) = 1000 - 457 = 543 \qquad (2)$$

The global index of the basin found shows the necessity that 54.3 % of the recovery project must be implanted to improve the conditions of the basin, or that the plan of administration in water resources be implemented to minimize the found critical points.

5 DISCUSSION

Most of the formal methods for identifying, predicting and evaluating impact significance have been designed for application in specific contexts (e.g. water resource planning). The determination of impact significance from predictions of the nature of impacts is a source of debate in the field of environmental assessment. Of particular concern is the use of formal quantitative methods for comparing project alternatives in order to produce a total impact score for each alternative. It has been argued that these techniques remove the responsibility for the decision from the responsible authorities.

To ensure that sustainable development needs are implemented at local level and impact assessment to be considered a tool for evaluation, the Battelle method appears as adequated for aggregate data without loss informations.

In spite of the results evidence sanitary aspects potentially critical, during the last decades, the Brazilian government and several nongovernmental organizations have launched important initiatives to improve water-resources management, and to mitigate increasing losses of biodiversity and habitats. Very seldom do these efforts reflect a coordinated national strategy that integrates land uses, freshwater, associated living resources and coastal management. Historically, water has been seen as a valuable resource that must be managed in order to meet present and future human demands when conflicts and scarcity are expected to increase, particularly in those basins where water demands are higher than availability (HAUGG *et al*., 1984; CHERP, 1992). In this context, the aquatic environment as such is frequently neglected. Additional problems include: unevenly targeted conservation efforts among and within Brazil's main biomes; limited access to biodiversity information; insufficient participation in government projects by local communities and nongovernmental organizations; and limited public private partnerships. Efforts will be necessary to address the financial constraints to implementing water biodiversity conservation (EPA, 1993; BAZARTSEREN *et al*., 1999).

There is an interdependence of different water users and so it appears obvious that good integrated water resources planning and management should centre on the river basin as the planning and regulatory unit. However, the river basin is not a politically natural political basis for planning. Policy is an outcome of political processes, not hydrological processes, although they obviously heavily influence it. Solutions to water problems often tend to be influenced or determined by other systems or decisions from outside the basin.

Most fundamentally, water resources management activities help to determine the long-term sustainability of the socio-economic and environmental system of the river basin and of the nation as a whole. Of course, the state of our knowledge at any time severely limits our ability to recognize, measure, and appropriately consider all of these secondary effects, so the scope of water resource management is not static, but is continually expanding.

6 CONCLUSION

The most important criterion for all sanitation approaches is that the system forms a barrier against the spread of diseases caused by pathogens in human excreta. This is also one of the basic aims in sanitation systems, which have well-known drawbacks in downstream or groundwater contamination, eutrophication, and long-term destruction of freshwater ecosystems, coastal areas and loss of plant nutrients.

Great part of those problems is direct consequence of human actions on the environment, including, for instance, the risks of exploration of new ecological niches, the exponential industrial development, the social inequalities growth, the life conditions of the urban and rural populations, the new technologies in wide use in the feeds, medicines, the resistance to the antibiotics etc. (ROSSOUW, 2003; MARQUES *et al*., 2004). Those countless aspects constitute fragments of a complex health situation of the populations in their relationship with the environment. It is like this the complex panorama of the health and environment interrelations. Moreover, such relationships implicate subjects of social, public, community, individual practices and subjects of knowledge theoretical, empiric, scientific, of common sense.

The environmental degradation that put in risk the world ecossistemic sustainability has its direct implications in the conditions of the populations' survival. In the context of the environmental crisis in that we are submerged, the biodiversity and the antropic actions highlight as the principal themes of that problem. The discussion on those subjects has not just been revealing the risk that they represent for the future generations as well as they present clearly the knowledge uncertainties that is had on them.

A critical requirement for integrated river basin management is the introduction of land use and water planning and management mechanisms which focus at the river basin scale (SAUNDERS, 2004). There are many steps involved in promoting the integrated approach of water resources management. One of the key issues identified is the division of management responsibilities for one river basin between different administrative authorities, resulting in fragmented approaches to water resources planning and management. It is important to realise that water resource planning and management is a multidisciplinary process and therefore has to be promoted as a collaborative framework among all the relevant agencies operating nationally and those involved within the river basin itself, as well as local communities.

Another key issue is the lack of awareness of the cross-sectoral nature of water problems and the need for a new development paradigm towards integrating the technical, economic, environmental, social and legal aspects of water management. The development of administrative units in water resource management has to coincide with river basins' boundaries instead of political boundaries. The lack, or inadequacy, of water legislation and policies is another stumbling block to integrated management of river basin and optimal use of water resources.

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