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Soft Systems Methodology and the Ecosystem Approach: A System Study of the Cooum River and Environs in Chennai, India

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ABSTRACT / This paper discusses the integration of soft systems methodology (SSM) within an ecosystem approach in research to support rehabilitation and management of the Cooum River and environs in Chennai, India. The Cooum is an extremely polluted urban stream. Its management is complicated by high rates of population growth, poverty, uncontrolled urban development, jurisdictional conflicts, institutional culture, flat topography, tidal action, blockage of the river mouth, and monsoon flooding. The situation is characterized by basic uncertainty about main processes and activities, and the nature of relationships among actors and elements in the system. SSM is an approach for dealing with messy or ill-structured problematic situations involving human activity. In this work SSM contributed techniques (such as "rich picture" and "CATWOE" tools) to description of the Cooum situation as a socio-ecological system and informed the approach itself at a theoretical level. Application of three general phases in SSM is discussed in the context of the Cooum River research: (1) problem definition and exploration of the problem situation, (2) development of conceptual models of relevant systems, and (3) the use of these to generate insight and stimulate debate about desirable and feasible change. Its use here gives weight to the statement by others that SSM would be a particularly appropriate methodology to operate the ecosystem approach. As well as informing efforts at management of the Cooum system, this work led the way to explore an adaptive ecosystem approach more broadly to management of the urban environment for human health in Chennai.

The Cooum River is one of several rivers of the Madras Basin in southern India. It flows east to the into the Bay of Bengal through the center of the Chennai (formerly Madras) Metropolitan Area. With an estimated population of 4.2 million within the city limits in 2001 (and 6.4 million in the urban agglomeration), Chennai is the fourth largest city in India (Census of India 2001). It is the dominant urban center in the south of the country.

The location of the Cooum River in the heart of Chennai and the city's situation as a metropolis in a developing country, with concomitant problems of such cities (e.g., inadequate sewerage and storm water systems, jurisdictional fragmentation, lack of funds, a mechanistic management environment, corruption, and poor adherence to municipal regulations) as well as unfortunate physical characteristics of the area, have contrived to make the Cooum River an extremely polluted stream. There have been numerous attempts to clean this highly visible waterway, but there has been no long-term improvement of the situation. In fact, the problem has worsened.

This paper reports part of a participatory process that approaches the Cooum River situation in a more holistic manner than past attempts at management of the river. The research on which it is based employed an ecosystem approach operated by tools and techniques borrowed from adaptive environmental management and soft systems methodology (SSM). This paper addresses the adaptation of theory and techniques of SSM within this process. SSM (Checkland 1981, 1999, Checkland and Scholes 1990) is a systems-based approach in the management field that is designed to address complex problematic situations involving human activity. It informs a process by which iterative operation of the methodology promotes learning and stimulates action for desirable and feasible change in the situation.

The use of SSM within an ecosystem approach, and its application in the Cooum River context are described below. A general overview of the ecosystem approach and soft systems methodology are provided. This is followed by discussion of adaptation of SSM techniques in this work for expression of the problem situation, conceptual modeling, and comparison of conceptual models to the real-world situation to stimu-

KEY WORDS: Urban environmental management; Soft systems methodology; Adaptive management; Participation; Conceptual modeling; Ecosystem approach

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Figure 1. A stretch of waterway in the Cooum system within Chennai. Photo by Martin J. Bunch, February 1999.

late debate about change. First, the problem situation is outlined.

The Cooum River and its Environs

The Cooum River is a highly polluted slow-moving stream. During the nonmonsoon season the upper reaches of the river are dry, and flow in the lower reaches can be attributed to input of wastewater and sewage from the surrounding city. The river passes through a very flat landscape on a coastal plain. On the coast, changes in littoral currents due to construction of the Madras Port have resulted in formation and migration of sand bars that block the river mouth. This leads to stagnation of water in the dry season and reduces what little cleansing action tidal mixing might have on the lower reaches of the river.

Although parts of the city are serviced by primary and secondary sewerage treatment, much raw sewage is diverted by industries, institutions, and households into the waterways and ocean (Government of Tamil Nadu 1981, Srinivasan 1991). A study by Wardrop Engineering in 1995 identified 116 wastewater outfalls into the main river within the city (Government of Tamil Nadu 1997). In 1986 at least 37 unimproved slum (hutment) areas were located along its banks (Bunch 2001). Debris dumping, animal husbandry, clothes washing and other activities are obvious along the course of the Cooum throughout Chennai.

The very poor quality of water in the Cooum River is demonstrated by values of the 5-day biochemical oxygen demand (BOD_5), which indicates organic content in the water. These values have been reported to be >300 mg/l, in lower reaches of the Cooum River and in connecting canals within the city (Government of Tamil Nadu 1997, Gunaselvam 1999). Compare this to the expected BOD_5 value of raw sewage in Chennai of 250 mg (Ananthapadmanabhan 1998). Silt and organic (fecal) sludge have also accumulated along the bottom and banks of the river. On the bottom of the river soft sludge has an average depth of 0.3–0.7 m and is even thicker in the lower reaches. On the riverbanks, soft sludge is found at an estimated average depth of 0.5 m and organic dry sludge has accumulated to an average of 0.4 m. Pathogenic parasites such as *Ascaris lumbricoides* and *Trichuris trichuria* have been found in this sludge. It is also assumed to contain *Cryptosporidium* and enteric pathogens such as *Vibrio cholerae* (Mott MacDonald Ltd. 1994).

Figure 1 presents a view of the Cooum River system in Chennai. Note the debris, organic sludge on the banks, animals (water buffalo) on the left bank, and the huts of a slum area on the right bank of the waterway.

The Cooum problem is well known and long-standing. Many government agencies [such as the state Public Works Department, Chennai Metropolitan Development Authority, Corporation of Chennai, Chennai Metropolitan Water Supply and Sewerage Board (Metrowater) and the Slum Clearance Board] have attempted to improve the situation. However, over the decades, the problem has continued to worsen. This is partly because previous attempts to address the problem have been piecemeal and used engineering-oriented approaches based in a reductionist-positivist paradigm. For example, various reaches of rivers and canals within the city have been dredged of sludge, their banks lined, and once a (short-lived) sand pump and regulator were installed at the mouth of the Cooum River to keep it clear of sand. Such interventions resulted in short-term improvement of the situation, but have repeatedly failed to solve the problem (Appasamy 1989, Sahadevan 1996).

Management efforts have also been constrained by jurisdictional boundaries and a mechanistic (programmed) management environment. The Government of India (1999) recognized some of the institutional aspects of these kinds of environmental problems in India when they stated that,

> There is no effective coordination amongst various Ministries/Institutions regarding integration of environmental concerns at the inception/planning stage of [projects]. Current policies are also fragmented across several Government agencies with differing policy mandates. Lack of trained personnel and comprehensive database delay many projects. Most of the State Government institutions are relatively small suffering from inadequacy of technical staff and resources.

The situation of the Cooum River and the surrounding area is characterized by complexity and uncertainty. The complexity is due as much to human factors (population growth, poverty, uncontrolled urban development, jurisdictional conflicts, modes of behavior of the citizenry, and institutional culture) as to the physical characteristics of the system (flat topography, tidal action, blockage of the river mouth by sand bars, and monsoon flooding). Uncertainty in the situation is both structural (regarding main processes and activities in the system and the nature of relationships among the various actors and elements), and parametric (regarding scarcity, poor quality, and restricted access to data).

An Adaptive Ecosystem Approach

This research applied an ecosystem approach in support of rehabilitation and management of the Cooum River and its environs. Ecosystem approaches in general recognize that problematic situations can be usefully conceptualized as systems of interrelated elements and actors. Identification of system characteristics such as various levels of hierarchy (subsystems, wider systems), emergent properties, and communication and control mechanisms (feedback loops) can be a powerful aid in understanding environmental problems.

Such approaches necessarily involve identification of the ecosystems that they target. In undertaking system identification, practitioners of ecosystem approaches emphasize that humans are embedded in ecosystems, not external to them (Caldwell 1970, Allen and others 1994, Grumbine 1994, Christensen 1997, Mitchell 1997). However, even though many examples of ecosystem management incorporate elements of stakeholder participation, mobilize local and traditional knowledge systems, or otherwise attempt to develop an understanding of the cultural, social, economic, and political context of a problem, it is usually the biophysical system that emerges to be expressed in conceptual, mathematical, and computer simulation models.

Attempts to manage environmental problems based on models of biophysical components of the situation may, in fact, be misdirected or at least insufficient. As Kay and Schneider (1994) noted, it is our interactions with the physical environment that need to be managed, not the physical environment *per se*. This suggests that models within an ecosystem approach should address not only biophysical elements and processes, but human activity and relationships. Attempting to account for such things as intentions and values associated with human activity, however, presents problems for modelers. There is a need for theoretical and methodological tools to deal more effectively with such considerations in environmental management. To emphasize the central importance of human activity, I refer to systems identified and conceptualized in an ecosystem approach as socioecological systems.

Kay and others (1999) present a framework for the ecosystem approach in which identification of the system of interest is explicit in a systems description based on an understanding of both ecological and human components of the situation (Figure 2). This ecosystem approach draws upon systems-based methods and collaborative processes to develop a qualitative understanding of the problem situation. In initial stages of the approach, practitioners explore biophysical and human aspects of the problem and produce a description of a socioecological system relevant to the situation. This understanding is used to selectively direct further inquiry in the situation to develop knowledge about key actors, components, and interrelationships.

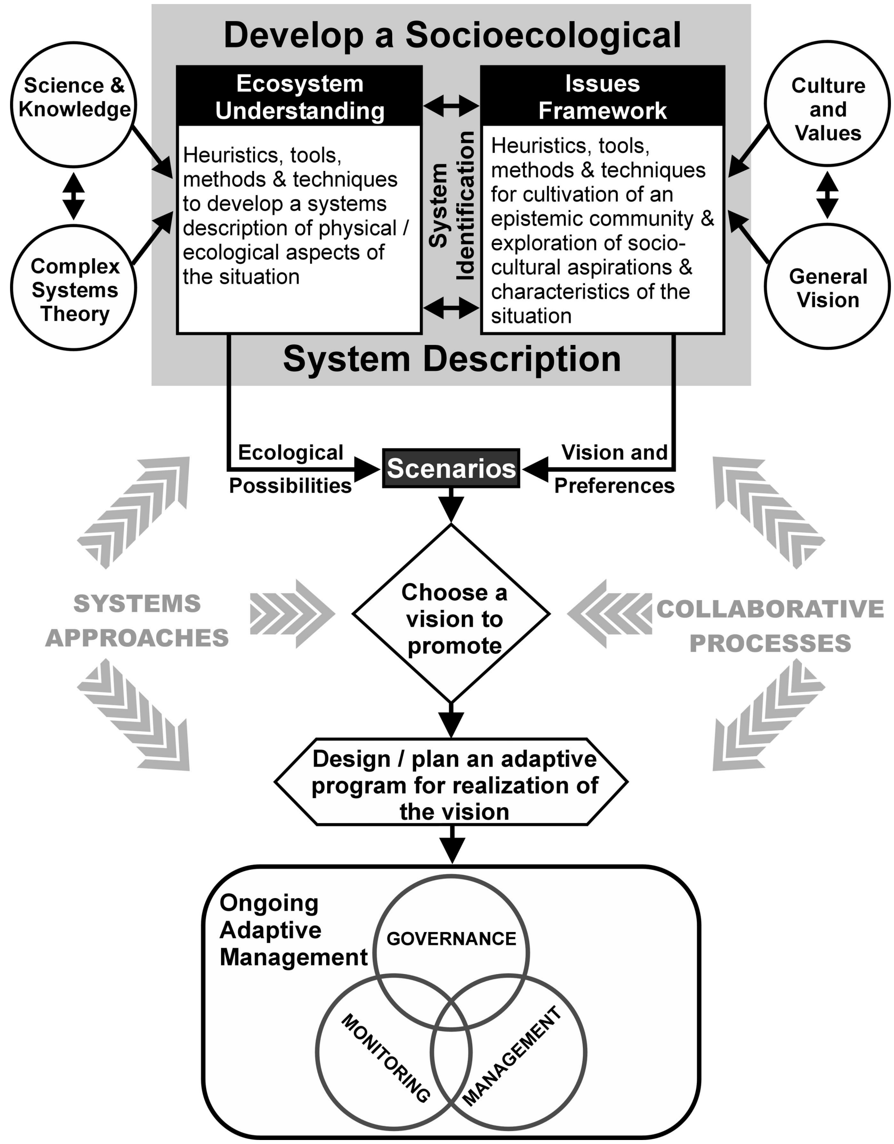

Figure 2. The diamond diagram—a schematic of the ecosystem approach (Bunch 2001, adapted from Kay and others 1999).

The socioecological system description represents knowledge of both ecological possibilities for evolution of the system and values and preferences for desirable and feasible future system configurations. A set of scenarios representing such system configurations is then generated. One of these is chosen and an adaptive plan to realize the vision is generated and implemented. The process then becomes an ongoing program of adaptive management. New knowledge and experience generated from making interventions in the real world reinforms understanding of the situation and may lead to reconceptualization of relevant socioecological systems and modification and/or generation of scenarios or plans to achieve them. Throughout the process, methods and techniques may vary but should be appropriate and responsive to the situation.

For this work, the ecosystem approach framework depicted in Figure 2 was operated by methods and techniques adapted from adaptive environmental assessment and management (AEAM) and soft systems methodology. Adaptive management (Holling 1978, Walters 1986, Lee 1993, Gunderson and others 1995) is a systems-based approach to environmental and resource management in situations characterized by uncertainty and complexity. The methodology emphasizes communication among stakeholders, experimentation for the express purpose of learning from the experience of managing ecosystems, and responsive-

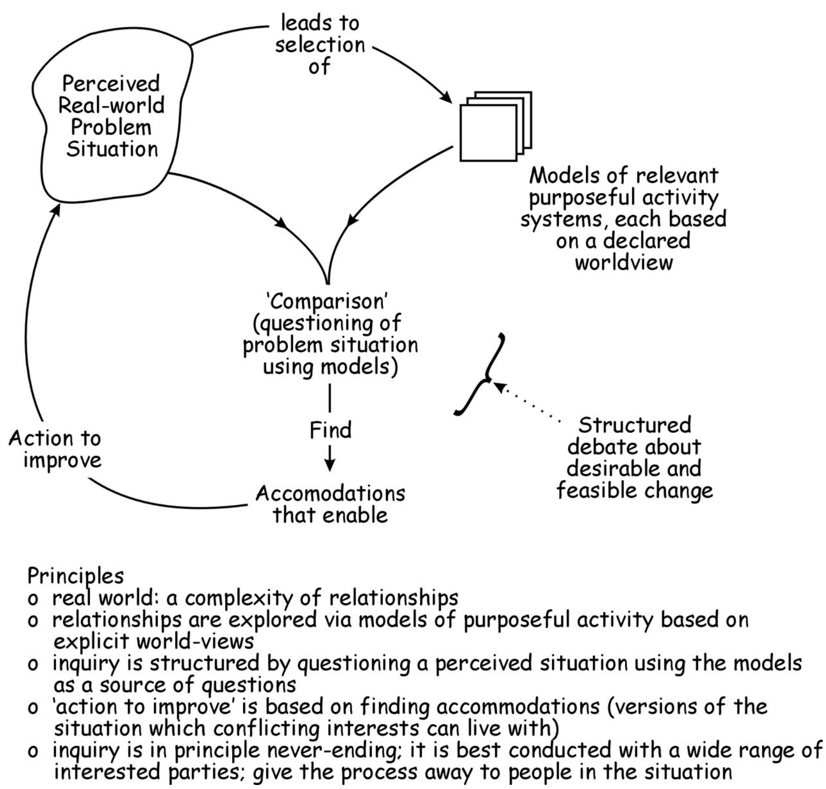

Figure 3. The inquiring/learning cycle of SSM. After Figure A1 of Checkland (1999).

ness to evolving goals and new knowledge. By intentionally operating a learning cycle, the management process becomes adaptive.

Operationally, AEAM is characterized by a series of stakeholder workshops. These bring together scientists, planners, policy-makers, and public representatives to mobilize the best-available knowledge and to design interventions in environmental and resource management situations. Another common component is the collaborative development of simulation models. The development and use of such dynamic system models is intended to promote system understanding and facilitate exploration of management scenarios.

Soft systems methodology (Checkland 1981, 1999, Checkland and Scholes 1990) is a methodology for dealing with complex, unstructured problematic situations. Developed by Peter Checkland and colleagues at the University of Lancaster's Department of Systems Engineering, SSM evolved in response to the failure of systems analysis to adequately address "messy" problems involving human activity. It was designed for, and has been applied in the context of, human organizational and institutional change. A more recent orientation of SSM is the design and implementation of information systems in organizational settings (Checkland and Holwell 1998).

SSM provides techniques and general guidelines for expression of situations that are considered to be problematic. Out of this expression, key themes can be identified and modeled as systems of purposeful human activity that are relevant to debate about the situation. Comparison of these conceptual models to the expression of the real-world situation is intended to stimulate debate about systemically desirable and culturally feasible change. Action in the real-world, informed by such debate, changes the situation, which in turn requires new expression, etc. The process is intended to be iterative and ongoing (Figure 3). Thus, as with adaptive management, SSM formally operates a learning cycle, employing learning from the experience of applying the methodology to further inform action in real-world situations (Checkland and Scholes, 1990, Checkland 1999).

Figure 3 presents several important principles of SSM. In particular the reader should note that identification and conceptualization of relevant systems are undertaken from explicitly stated perspectives (world views or *Weltanschauungen*). Models of the same situation, based on different world views, may be quite different from each other. At the core of conceptual models is *purposeful* human activity. Human activity systems are imbued with values, intentions, and norms that are rooted in the *Weltanschauungen* that make each system meaningful in the context of the problem situation.

SSM offers a methodological approach and toolbox to deal with human activity in complex problematic situations. It is human activity that so often makes environmental problem situations complex and intractable. Declaration of world views and accompanying bundles of values, intentions, and norms that drive the expression and evolution of such situations is a promising route to deal with complexity in urban and environmental management.

Operating the Approach with SSM

Workshops

This research operated a participatory process in which, during two workshops in 1998 and 1999, stakeholders identified and expressed the Cooum River problem situation; undertook conceptual modeling of relevant systems; generated and debated goals, objectives, and interventions for management of the Cooum River and its environs; developed a framework for a GIS-based decision support system (DSS) and environmental model, and used the DSS to develop exploratory management scenarios.

Workshops combined paper presentations and working sessions in a blend of Indian and Western styles. Indian "workshops" usually involve formal inaugural and valedictory sessions with addresses by highly placed persons, between which are formal paper presentations and discussion designed to generate a set of workshop recommendations. Interspersing working sessions with paper presentations maintained a familiar format for participants. Paper presentations provided background about selected aspects of the situation and working sessions involved participants in exercises to identify, scope, conceptualize, and debate the problem situation and potential action to improve it.

The workshops included a core group of about 25 stakeholders, primarily from government agencies, NGOs, and academe. These were initially identified through existing networks developed during previous research in Chennai. Others were identified using a "snowball" technique during preworkshop interviews of potential participants. Public participation was invited through notices in English and Tamil newspapers. Participants from governments agencies and departments included those with jurisdiction for direct physical intervention in the system (the Tamil Nadu Public Works Department, Chennai Metropolitan Water Supply and Sewerage Board, Tamil Nadu Slum Clearance Board, and Corporation of Chennai) as well as those with regulatory control (Chennai Metropolitan Development Authority, Tamil Nadu Pollution Control Board, Directorate of Public Health and Preventative Medicine, Department of Environment and Forests, and Department of Ocean Development). Eight environmental, business, and heritage NGOs were represented at the workshops, notably Exnora International and INTACH (Indian National Trust and Cultural Heritage). There were also representations from consultancies and corporations, academic institutions, and the general public. This was an educated group. Some stakeholders, such as slum dwellers, were not directly represented, although individual participants sometimes attempted to speak on their behalf. Research stemming from this work will more directly represent such stakeholders.

In the Cooum River situation, and in India generally, government agencies have (fragmented) jurisdiction and control over urban and regional development and environmental management. Management processes are mechanistic and are not participatory. Various citizen groups and environmental NGOs that would like input into environmental planning and management in Chennai find themselves in an adversarial role. Also Indian society and institutional culture are characterized by hierarchical structures. As a result, there was concern that some stakeholders attending the workshops may have been constrained in their participation due, for example, to rank, seniority, caste, sex or lack of jurisdiction.

Because of this I asked several Indian colleagues (of both sexes) to observe workshop participants and to note any such problems. In debriefing, only one minor issue arose—initially junior and young participants tended to defer overmuch to their seniors. This constraint disappeared as participants warmed up to the issue. Presumably the facilitator's status outside of the Indian system and the fact that the research program, despite being requested by officials at the CMDA, was designed and implemented independently provided a context in which participants were free to express their opinions without being constrained by considerations such as protection of jurisdictional turf.

The first workshop (18–20 March 1998) initiated the problem analysis in which stakeholders defined and scoped the problem situation, generated conceptual models of relevant systems, and discussed potential management actions. It was intended that this first workshop would promote a less jurisdictional, less disciplinary understanding of the situation, and guide exploration of the cultural climate of the Cooum situation, including the expression of values, norms, and vested interests that are dominant in the current situation and that influence stakeholders' preferences for desirable futures. A conceptual model of the Cooum system was developed at the first workshop on which a framework for a decision support system and simulation model was based.

The second workshop (24–28 February 1999) continued the process of problem analysis and stakeholder dialog on the Cooum system. It was intended to provide validation, refinement, and further development of the conceptual model of the Cooum system developed earlier by workshop participants. Participants also evaluated the prototype computer simulation model and decision support tool, based on the framework developed at the initial workshop, and used the DSS to develop management scenarios that could be compared via results of system simulation.

The Influence of SSM

Soft systems methodology informed this work from its inception. SSM contributed a set of techniques to the description of the Cooum situation as a socioecological system and informed the overall approach itself. Particularly obvious influences can be seen in adaptations of "rich picture" and CATWOE techniques. Woodburn (1991) identifies three general phases in early models of SSM. These are: (1) building a "rich picture" of the problem situation, (2) developing models of relevant human activity systems, and (3) using those models to stimulate thinking about organizational change.

These phases capture the purpose of various activities in the methodology. The first phase deals with the identification of a problematic situation and its unstructured (nonsystems) expression. The second stage consists of activities to draw important themes out of the expression of the situation and model them as systems. The third phase involves exercises to stimulate debate about desirable and feasible change in the situation. Activities within these phases do not necessarily occur in sequence in modern applications of SSM. However, the three-phase description is heuristically useful, and I use it below to organize discussion about activities in this program of research.

More important than the tools described in the SSM literature is the influence of SSM in adopting a soft systems mode of thinking. In this mode, the explicit design of new systems was avoided. Instead, the research was approached as the operation of a system of learning, which informs action to improve the situation. Rather than developing visions of the future as blueprints (fixing goals and targets to be attained) which would require a system to be engineered out of the "mess" of the real world situation, this work uses SSM techniques and systems concepts to construct conceptual models that are insightful narratives about a particular perspective on the situation. The process of constructing these models and their exploration in the context of the Cooum River problem situation led to ideas for the future of the situation that were fundamentally different from previous management efforts.

SSM can be used in a variety of ways to explore problematic situations. For example, Naughton (1981) prescribed a set of rules and tools to be applied in order to be said to be doing SSM. More mature applications use SSM to organize observation and understanding about a problematic situation and to generate debate about it, in the sense of "doing work using SSM" rather than "using SSM to do a study" (Krehler 1994). Checkland and Scholes (1990) refer to these two extremes as mode 1 and mode 2 applications of SSM. The Cooum River work is undertaken in the latter mode, in which the emphasis of the approach is as a set of guiding principles (Figure 3) within which tools and techniques are not prescribed.

Expressing the Problem Situation

Problem Identification

Initial exercises in studies using SSM are intended to explore and express a problematic situation. This typically involves identification and definition of various actors, components, interactions, and relationships within the situation. Without organizing observations as a system, this exploration is an analysis phase designed to answer questions of "what?" as opposed to "how?" (Checkland 1979). Checkland and Scholes (1990) indicate that it "has been found most useful to make the initial expression a building up of the *richest possible picture* of the situation being studied. Such a picture then enables selection to be made of a view point (or viewpoints) from which to study further the problem situation." The Cooum River research employed two key techniques to express the problem situation. The first was a set of problem identification questions. The second was the development of a rich picture of the problem situation, which is a popular diagrammatic technique associated with SSM.

The first working session in the 1998 workshop consisted of written responses to eight questions borrowed from a UNCHS (Habitat) (1991) action research manual for urban managers. These questions were:

1. What is the problem? (Start with a rough description and underline the key words and phrases).

Table 1. Problems associated with the Cooum River situation identified by workshop participants

Category	Items	Example of identified problems
Sensory aspects	3	visual eyesore; city image threatened; foul smell
Health hazards	11	mosquito breeding; habitat for rodents; breeding ground of intestinal parasites; contact threat to population in the vicinity
Objectionable land and land use	6	illegal encroachments along banks of the river; location of slum developments; non-coverage by the sewerage system of approximately 30% of the population along the banks of the Cooum
Hydrology	8	flooding and overflowing during monsoon; slow flow and stagnation (dry season); blockage by sandbar at the mouth, no free flow to the sea
pollution and related factors	20	heavy pollution load—high biochemical oxygen demand, low or nil dissolved oxygen, high suspended sediment concentration; illegal sewage outfalls; illegal dumping of building rubble, debris; open air defecation
Population	4	population growth; densification; slum development
Tourism and recreation	4	no walkways, lawn, gardens, parks; unsafe for pleasure boating, bathing, swimming, fishing; denial of a sustainable tourism asset
Political, social and management aspects	15	citizen and government inaction, neglect, lack of political will; lack of communication and coordination among institutions; inability to solve environmental problems, improper/inadequate management, poor planning; lack of knowledge; lack of public awareness

2. Why is it a problem? What would the problem look like if it were solved?
3. Whose problem is it? Who owns it? (Once you have determined who the problem belongs to, go back and underline all those you believe are willing to invest in its solution and, finally, circle the individual, group or organization you believe is the most important in the problem solving venture).
4. Where is it a problem? Is it localized and isolated, or is it widespread and pervasive?
5. When is it a problem? (e.g., every Monday morning at 8 a.m.? Once every full moon? Continually?) As with other questions be as specific as possible in your answer.
6. How long has it been a problem? If it is a long-standing problem, this may say something about the ability, will, or priority to solve it.
7. Really now, what is the problem? Go back to your statement in question 1 and determine whether: (a) the problem you defined is a symptom of a bigger problem, or (b) a solution to what you think is the problem. If you decide you are dealing with either symptoms or solutions, go back to question 1 and try to identify the real problem.
8. Finally, what would happen if nobody did anything to solve the problem?

There was a wide range of experience and a variety of perspectives among workshop participants. One of the objectives of this exercise was to capture the variation in participants' perception of the problem situation. The extreme range of their responses to these questions, even in the simple identification of problems, demonstrated how ill-defined and complicated the situation is. For example, after consolidation of responses to problem identification questions (questions 1, 2, and 7), 71 distinct problems were identified by participants. These were grouped into eight thematic categories (Table 1).

This problem identification exercise generated a wealth of information that served as input to later working sessions. Almost all issues identified by participants in this exercise were physical, observable manifestations of the problem situation. However, when asked to reconsider the problem ("Really now, what is the problem?") participant responses not only reinforced several of the problem categories (especially regarding hydrology and pollution), but practically defined the category of "political, social and management aspects" of the situation, which was considerably augmented with new input.

This category had to do with items identifying the problem as, for example, lack of political and public will, poor coordination and communication of agencies, inappropriate models for environmental problem-solving and basic uncertainty about the situation. It is interesting that this category should show so strongly, with the second highest frequency of items (15) after the pollution category (20). This highlights the importance of the human element in complex environmental problem situations. Items identified in this category are human issues that have not been addressed in academic studies and government reports having to do with the condition of the Cooum River. While many reports make reference to the problem of the Cooum as caused, for example, by untreated sewage being routed to the river (e.g., Sridhar 1982, Appasamy 1989, Sahadevan 1995, Government of Tamil Nadu 1997) and to physical and hydraulic complications (e.g., Mott MacDonald Ltd. 1994, Sahadevan 1996, Government of Tamil Nadu 1997, Inland Waterways Authority of India 1998), none discuss problems of coordination and communication among government agencies, absence of data sharing, and inadequate approaches to dealing with environmental problems as part of the problem itself.

Development of the Rich Picture

The use of diagrams to express problematic situations and describe relevant systems is characteristic of SSM. It has been found by SSM practitioners that diagrams are more effective than linear prose in presenting relationships and that pictorial representation of multiple interacting relationships promotes holistic thinking (Checkland 1999). The technique of rich pictures is a particularly common one associated with the methodology. A rich picture portrays actors and elements in a problematic situation and indicates relationships among them. From this pictorial overview, themes relevant to the problem situation may be identified and modeled as systems of purposeful human activity.

Rich pictures may be developed collaboratively with participants in a workshop environment or, after preliminary research into the situation, developed by a researcher or consultant and presented to stakeholders for validation or modification. In this research, a rich picture was developed collaboratively by way of facilitated discussion with stakeholders. Starting with a representation of the river itself, physical and human components of the situation were added, and their relationships to other components indicated. Actors, elements and relationships were added until workshop participants felt that all important aspects of the situation were represented. However, the rich picture was a living representation, being open to modification throughout both workshops. In fact, iteration (revisiting previous work after further consideration and having the benefit of new information) was important in exploration and analysis of the situation.

The rich picture technique was effective in representing the constellation of actors, elements, and interrelationships in the situation, without (initially) employing systems concepts for this representation. By presenting relationships among actors and elements at a single glance, the rich picture promoted a holistic approach. It also acted as a common reference for participants during both workshops and was a tangible output of the process of which participants took ownership. Figure 4 is part of this rich picture.

The rich picture was particularly effective in facilitating the development of, and then representing, a common understanding of the situation. Each actor, element, and relationship portrayed was developed in discussion with workshop participants and was sometimes revisited for further elaboration. For example, slum dwellers were not merely portrayed as actors who pollute the stream, but their relationships to other actors and elements in the system (e.g., protection by politicians, their role as vote banks, ownership of slum land by various government departments, the role of slum dwellers in animal husbandry, vulnerability to flood hazard and disease vectors, and more) was discussed throughout both workshops and portrayed in the rich picture.

Overall, the diagram was able to convey the feel of the situation for workshop participants and forced individual participants to rescope their conception of the situation. Participants from agencies having jurisdiction over the physical course of stream itself broadened their perspective to include the activity of the population within the Cooum's urban watershed and considered the roles of other government agencies and departments in the situation. Furthermore, over the course of the first workshop, participants identified distinctly different sets of activities occurring in the lower (urban) watershed and in the upper reaches of the river. Without explicitly setting out to do so, they began to characterize two separate systems at the same level of hierarchy, ultimately deciding that the lower urban Cooum system was most relevant to the problem situation and narrowing their focus to that system.

The rich picture acted as a focal point or reference for discussion throughout the two workshops. Although rich pictures are not typically used in this manner in the SSM literature, the diagram came to represent a common understanding of "the system" once the working sessions moved into systems analysis of the situation. Themes extracted from it were modeled as subsystems of this larger Cooum socioecological system. The rich picture also provided a link between workshops, and continual modification of the diagram to incorporate new understanding of the situation allowed several new participants to join in ownership of the earlier work.

The rich picture was a tangible product of the workshops and represented a communal understanding of the Cooum situation about which participants were universally enthusiastic. As such, its development helped to promote communication and coop-

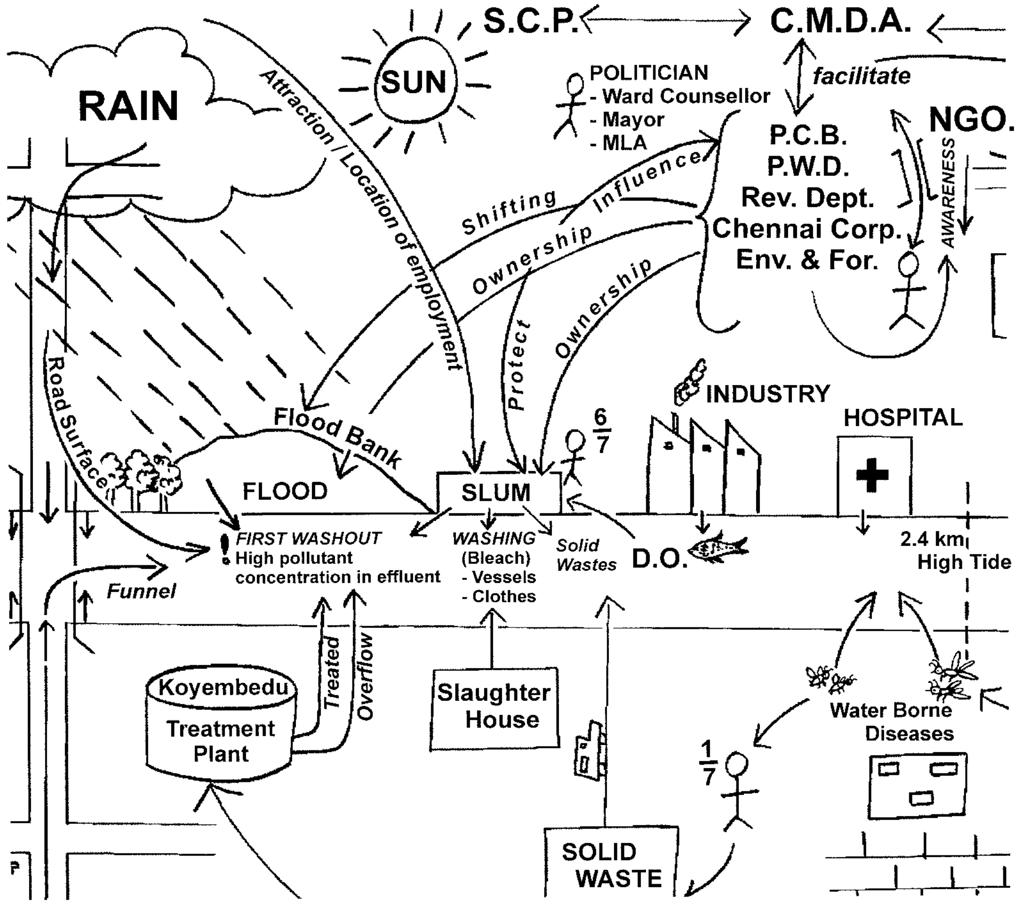

Figure 4. Part of a rich picture of the Cooum problem situation redrawn from the one developed by participants in the Cooum River Environmental Management Research Program. Some of the acronyms and short forms represented here are: SCP, Sustainable Chennai Project; CMDA, Chennai Metropolitan Development Authority; PCB, Pollution Control Board; PWD, Public Works Department; Rev. Dept., the State Revenue Department; Chennai Corp., the Corporation of Chennai; Env. & For., Department of Environment and Forests; MLA, member of Legislative Assembly; NGO, nongovernmental organization.

eration among the various stakeholders. Although seemingly simple, the development of the rich picture was one of the most useful exercises undertaken during either workshop. Checkland (1999) complains that many studies that claim to use SSM simply involve the development of a rich picture and go no further. This is understandable. Identifying and clearly expressing the problem goes a long way toward solving it, particularly in "messy" unstructured situations. The development of a shared expression of the situation should also not be underestimated. Many participants in the workshop expressed their enthusiasm for this procedure. They indicated that, despite decades of intervention, this collaborative exercise was the first time that all of the relevant agencies and actors had come together to develop a common understanding of the problem.

Identifying and Conceptualizing Relevant Systems of Purposeful Human Activity

In SSM there is a distinct break between expression of the problem situation using techniques such as rich pictures and analysis rooted in systems thinking. Expression of the problem situation is useful to initiate thinking about the situation and for problem definition. Organizing aspects of this expression in systems terms is intended to highlight critical actors and relationships and stimulate insight into the situation.

Depending on the perspective taken on a problem situation, a variety of themes may be identified and modeled as systems. A common technique to initiate the process of conceptual modeling in SSM is the development of root definitions of human activity systems. These are based on explicit perspectives on the situa-

Table 2. CATWOE characteristics of population and sewerage provision systems

	General population system	Sewerage provision system
C	Citizens of Chennai	Citizens of Chennai
A	Citizens of Chennai	Chennai Metropolitan Water Supply and Sewerage Board (Metrowater)
T	Waste in need of disposal → waste disposed of	Areas in need of service by a sewerage system → properly serviced sewered areas
W	Waste should be disposed of in the most convenient and least costly manner to the household	Sewage should be properly treated before release into the environment
O	Chennai Metropolitan Water Supply and Sewerage Board ("Metrowater"), Chennai Metropolitan Development Authority, Corporation of Chennai	Chennai Metropolitan Water Supply and Sewerage Board (Metrowater), legislators
E	Inefficient sewerage system (with connection charges), storm water drainage accessible in many areas	Limited budget, some areas are inaccessible (e.g., objectionable lands)

tion and are usually built around elements of the mnemonic CATWOE (Checkland 1979):

C	Customer	Who would be victims or beneficiaries of this system?
A	Actor	Who would perform the activities?
T	Transformation	What input is transformed into what output?
W	Weltanschauung	What view of the world makes this system meaningful?
O	Owner	Who could abolish this system?
E	Environmental Constraints	What in its environment does this system take as given?

Root definitions describe fundamental characteristics of systems organized about important issues or major tasks relevant to the problem situation (Checkland and Scholes 1990). Typically in SSM, CATWOE analysis of a theme is used to develop a one- or two-sentence description (root definition) of the core nature of the system.

In this work, CATWOE analysis was modified to provide structure to a facilitated workshop session which explored important themes in the rich picture of the Cooum situation. Further facilitated discussion explored critical activities associated with each relevant system, paralleling a standard conceptualization technique in SSM. This provided an effective means of highlighting primary activities and processes in the situation and modelling them (conceptually) as systems relevant to the problem situation. These were treated as subsystems of the larger Cooum socioecological system.

Themes modeled in this way were: activity of slum dwellers (squatters), provision of sewerage services, supply of water, the population of Chennai (polluters), animal husbandry, the stormwater drainage system—flood protection, the stormwater drainage system—sewage disposal, political protection of slums, and agency intervention and control (of management activities). Examples are presented in Table 2.

Analyzing these themes in terms of CATWOE elements helped to reduce the complex situation to a few key relevant systems. It also provoked debate about the nature of the Cooum system as a whole, leading to further modification of the Rich Picture. Discussion was triggered, for example, about what made each subsystem important in the context of the larger system and about their place in a hierarchy of systems in the situation. One result of such debate was a shift in participants' conception of what the Cooum system, overall, was really about (an emergent property of the system). Initial views of a natural river system gave way to characterizations of it as a sewage carrier within a larger urban system. As such it was perceived as a social system and not merely a biological and physical one. Chennai citizens were understood to be part of the system, not part of the environment and an external source of input. Similarly, the various government agencies were understood to be inside the system and not just part of its context.

The CATWOE technique was not as useful in addressing physical subsystems as it was in modeling the human activity systems for which it was designed. Because of this, subsystems dealing with physical aspects of the situation, such as the hydrology of the river and tidal action, were described more generically in terms of physical processes.

Comparison and Debate About Desirable and Feasible Change

In SSM there always occurs a process of comparison between models of relevant human activity systems and the expression of the problem situation. Checkland and Scholes (1990) comment that,

> . . .comparison between the two is the formal structure of a discussion about possible changes, a discussion held with concerned people in the problem situation. In order that the discussion shall be rich and wide-ranging, we wish to question *whether* various activities in the models are discernable in the real world, as well as—if they are present—*how well* they are being done. We also wish to discuss possible alternatives to the real world activities, alternatives suggested by the models.

Ledington and Ledington (1999) argue that processes of comparison are at the heart of SSM and that comparison of system models to real world situations is central to structured systems thinking. Comparison in SSM occurs in four main ways: using models as a source of questions to ask of the situation, informal discussion, development of scenarios based around models, and mapping of system models onto real-world activities (Checkland 1981, Checkland and Scholes 1990).

The idea and associated techniques for comparison in SSM have evolved in the context of institutional and organization change. The context of the Cooum River research is different, but the principle of comparing conceptual models to the real-world situation to stimulate debate about desirable and feasible change is transferable. The Cooum research employed techniques throughout the two workshops that touched upon all four general categories of comparison to stimulate debate about rehabilitation and management of the system. Formal questioning was employed in exercises that directed participants to further explore conceptual models in the context of the real-world Cooum River problem situation. Allowance was made in both workshops for informal debate and discussion after paper presentations and during working sessions. Mapping of models to the real world occurred via development (in the first workshop) of a framework for a GIS-based decision support system and simulation model. This DSS was used (in the second workshop) for the generation of exploratory management scenarios.

Techniques and exercises used for comparison in this work, however, differed from those used in typical applications of SSM where the problem context has to do with the operation of companies, departments, or institutions. For example, the working session following conceptualization of relevant systems addressed their spatial manifestation in the real world. In this scoping exercise participants were asked to identify levels of hierarchy in the situation (with respect to each system previously identified) and to distinguish systems from their environment by associating critical actors and elements with the extent of their activities and processes over space (Where do they occur?) and through time (For how long? How often?). Working sessions such as this were effective, both in stimulating debate about change, and in further contributing to understanding of the situation. It was during discussion associated with scoping exercises, for example, that participants agreed to distinguish between the upper and lower Cooum systems. This distinction had not been identified in past management attempts and has important ramifications for the nature of interventions and sets of actors involved in rehabilitation and management efforts.

A brainstorming exercise to generate objectives for management of subsystems (themes in the rich picture) is another example of the use of conceptual models as a source of questions to ask of the real-world situation. Once generated, questions were asked of each objective with respect to the problem situation: Is it specific? Is it measurable? What is the variable measured? Is it results-oriented? Is it realistic and attainable? Within what time frame? Who will do it? Who will benefit? When will it happen? How will you know if it has been successful? Participants also ranked objectives, related these to indicators in the system, and discussed interventions to achieve them. The purpose of these exercises was not merely to produce and record answers to formal questions, but to generate debate about change in the situation. Generation of objectives, for example, illuminated aspects of desirable future states of the system. Discussion about objectives led participants to express visions of an aware and involved citizenry, the river as a recreational resource, the river as a navigable waterway, and the Cooum as a clean river.

This information also supported development of a framework for a computer simulation model and decision-support system. The framework was based on a set of themes (above) that could be modeled as subsystems. The most important of these themes were operationalized in a prototype DSS and system simulation model (the Cooum DSS) that was developed between workshops. Key themes included the generation of sewage by the population, routing of sewage and its treatment by the sewerage system, routing of stormwater runoff, sewerage overflow and diversions by means of the storm water drainage system, and the transport of sewerage effluent and stormwater runoff by the Cooum River. The theme of slums, which had to do with production and disposal of sewage and solid waste in locations not serviced by the sewerage system, was incorporated into the population component of the model.

The expression of a framework for a system model is one way of attempting to map themes drawn and systems conceptualized from the rich picture back onto the real world situation. This process generated further debate about which of the activities and processes identified were critically important in the situation. Expression of those activities and processes, formally and algebraically, highlighted areas of uncertainty in the situation and generated further debate over assumptions made about the Cooum system. For example, when presented with the formal expression and assumptions associated with sewage generation, workshop participants debated and revised their understanding of the relationship between level of income, water consumption and sewage generation to allow for variation in water quality characteristics of sewage throughout the city.

The Cooum DSS was also used in the second workshop to develop exploratory management scenarios. Participants developed baseline and single-intervention scenarios to explore the effect on water quality in the Cooum of such interventions as provision of sewerage to nonserviced slum areas, population increase, improved sewerage system technology and increased capacity, artificial flushing, and initial storm flush runoff. It is beyond the scope of this paper to present descriptions and simulation results of such scenarios. However, the *process* of scenario building based on the Cooum system model itself was found to be useful. It generated debate, for example, about data quality, institutional issues related to data sharing, access to information, agency cooperation, and public participation in management programs. Debate about such issues in the second workshop was intense. These issues were considered so important that workshop participants insisted on setting time aside for an inaugural meeting of a multistakeholder working group to undertake data collection and guide research on the Cooum system and to continue model development and system exploration using the Cooum DSS.

A New Appreciation of the Situation

Workshop participants, through development of a qualitative understanding of the situation that incorporated human activity in a more central role, underwent a dramatic rethinking of the problem situation. Despite the common knowledge that pollution in the Cooum derived from the city population, previous attempts to deal with the situation conceived of it as a physical problem and targeted hydraulic characteristics of the system for intervention (such as removal of the coastal sand bar to relieve stagnation and allow tidal flushing, dredging of sludge, lining of river banks and removal of blockages to the flow along the course of the river).

The shift in the way participants thought of the Cooum River problem situation had implications for how they perceived that such a situation might be alleviated. As the workshops progressed participants began to propose systemic interventions aimed at altering characteristics of the system that underlie its organizational state, rather than targeting symptoms of it. These included educational awareness campaigns to change attitudes toward the environment and modify the behavior (polluting activity) of citizens, public participation in management programs, rainwater harvesting by individual house owners, and the promotion of tourism and recreation. This was a move away from the traditional engineering style of interventions that have attempted to deal, after the fact, with the presence of pollution in the Cooum River. It represented a shift from a systematic to a more systemic approach.

This is also reflected in recommendations of the two workshops. For example, participants at the first workshop indicated that an ongoing stakeholder process was critical to management of the system. The second workshop recommended the formation and support of a working group with representation from NGOs, government agencies, academia, and interested citizens to support management of the Cooum system, as well as measures to transcend the jurisdictional and communicative barriers which currently restrict agencies to deal in isolation, each with their small piece of the Cooum puzzle.

Another recommendation made by workshop participants was that the program of research be expanded to cover all of Chennai—not just the parts of it encompassed by the Cooum system. This and the recommendation to continue the stakeholder-based process for environmental management have been realized. It is a positive sign that government agencies and departments, NGOs, and others who participated in the Cooum River Environmental Management Research Program are once again collaborating in a program designed to continue this process in the broader context of managing the urban environment for human health across the whole of Chennai. This, and continuing requests by government agencies, professional consultancies, and researchers involved in management of the Cooum River for data and reports generated through this work, indicate the program's success.

Conclusions

The application of an adaptive ecosystem approach in research to support management and rehabilitation of the Cooum River and its environs in Chennai was intended to generate new knowledge about the system, that would inform action in the situation. Qualitative understanding of the situation that arose from this work, and its expression in the Cooum DSS and environmental model, was substantially different from models associated with past management attempts. Improved understanding of the situation was demonstrated by the realization of participants that their original concern—water quality in the Cooum River—was merely a symptom of a larger problem and that this was more usefully conceived as an indicator of the health of a wider socioecological system. The shift to an understanding that emphasized human activity, and the adoption of a more holistic approach to the situation, led to objectives for management, and proposal of interventions, that were fundamentally different from those associated with (failed) management programs of the past.

Soft systems methodology provided key techniques and important underlying theory to operate the ecosystem approach in this work. SSM informed a collaborative process of problem definition, identification of relevant systems, conceptualization of both the wider Cooum socioecological system and its subsystems, and comparison of these to the expression of the real-world problem situation. Development of a decision support system and its use in exploratory scenario analysis were undertaken in a soft systems mode, which promoted learning and fostered a shared understanding of the problem. The process generated an understanding that was expressed in a collaboratively developed, commonly owned conceptual model of the Cooum socioecological system. The model was characterized by human activity, an urban character, and processes of waste disposal. This influenced objectives for management of the system and, thus, choices of interventions in the system to achieve them.

Working sessions based on SSM techniques were effective and well received by workshop participants. The sessions dedicated to developing a rich picture to express the problem situation and conceptualization of subsystems based on CATWOE analysis not only met the objectives of their particular working sessions, but generated enthusiasm and fostered collaboration among workshop participants.

While conceptual modeling associated with SSM is not intended to lead to mathematical formulation, its use here did support the development of a DSS and simulation model. In a broad sense, the computer-based model was underpinned by a participatory process of problem identification and development of a robust qualitative understanding of the situation. A less disciplinary, less jurisdictionally constrained, and more appropriately scaled conceptual model of the system was targeted using techniques drawn from SSM to identify and elaborate important relationships and activities in the system, which could then be expressed algebraically. Attempting to formalize such relationships was found to be a stimulator of debate about assumptions and uncertainty in the situation. Such debate was oriented to improving the model but, in a demonstration of an iterative learning cycle, was also useful in further developing a commonly owned conception of the situation and, in the end, reaching some accommodation among stakeholders about change.

The use of soft systems methodology to inform the ecosystem approach both at the theoretical level and in the provision of techniques, has given weight to the recommendation by Allen and others (1994) that SSM would be a particularly appropriate methodology "for making operational the ecosystem approach." SSM has contributed participatory techniques to the process, stimulated a holistic approach to the problem situation, promoted learning, and addressed complexity by providing tools to identify important themes in a messy situation, model these as systems of purposeful human activity, and use them to generate debate about desirable and feasible change in the situation.

The program of research has been successful in stimulating insight into the situation, generating novel ideas for rehabilitation and management of the Cooum River environmental system, and bringing stakeholders in the situation together to pursue a solution to the problem. However, there is still a long way to go. Current institutional and jurisdictional arrangements have momentum. Plans for rehabilitation and management of the Cooum system are funded and progressing on several fronts, but these seem to be occurring largely in isolation. It will likely take further exposure to collaborative and holistic approaches to such problems, continued failure of traditional management approaches, and a worsening crisis to stimulate large scale change.

Such change is possible, however. For example, the Chennai Metropolitan Development Authority, which is responsible for control of development activities and coordination of programs in Chennai, participated in workshops and provided data and information for the Cooum River work. In further work on managing the urban environment for human health, the CMDA has increased its involvement and made an institutional commitment to sponsor the approach by hosting program activities such as workshops. Other agencies are providing material support and the National Environmental Engineering Institute has adopted the approach to address a similar problem with the Nag River in Nagpur. The approach is gaining ground in Chennai institutions.

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