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AN ECONOMIC ANALYSIS OF POLICY OPTIONS FOR MANAGING WATER POLLUTION IN THE KELANI RIVER

By
Philip J DeCosse
Shan Bhuvendralingam
Pradeep Liyanamana
and
Sanath Ranawana

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About the Authors

Philip J DeCosse is an economist with International Resources Group, Ltd , in Washington, DC (IRG, 1211 Connecticut Ave, Suite 700, Washington, DC 20036, Tel 202-289-0100, Fax 202-289-7601, E-mail pdecosse@irgltd com)

Dr Shan Bhuvendralingam is a lecturer in the Department of Civil Engineering at the University of Moratuwa in Sri Lanka (Tel 94-1-647 567, Fax 94-1-647 622, E-mail sbhuvend@civil mrt ac lk)

Pradeep Liyanamana works for International Resources Group, Ltd , and is the management information systems specialist at the Natural Resources and Environmental Policy Project in Colombo, Sri Lanka (1 Gower Street, Colombo 5 Sri Lanka, Tel 94-1-586 099, Fax 94-1-583 175, Email pradeepl@sri lanka net)

Sanath Ranawana works for International Resources Group, Ltd , and is the environmental economist at the Natural Resources and Environmental Policy Project in Colombo, Sri Lanka (1 Gower Street, Colombo 5, Sri Lanka, Tel 94-1-586 099, Fax 94-1-583 175, E-mail narepirg@sri lanka net)

Abstract

This study assesses the costs and benefits of alternative policy options for control of water pollution in the Kelani River in Colombo, Sri Lanka The cost of policy options for control of Biological Oxygen Demand (BOD) and chromium are estimated using the World Bank's Decision Support System for Industrial Pollution Control Results from the analysis make it clear that costs differ significantly between the two policy options of enforcing current point source standards for all industries and just meeting ambient water standards through more socially optimal reductions by select industries The study also demonstrates that it is technologically beyond the capacity of the industries currently located on the river to reduce their BOD loads sufficiently to bring the ambient water standard below the minimum desired level The study's conclusions imply a shift in priorities and approach for the Central Environment Authority

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Acronyms

BOD	Biological Oxygen Demand
CEA	Central Environment Authority
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DSS/IPC	World Bank's Decision Support System for Industrial Pollution Control
EA1P	Environmental Bank 1 Program
EPL	Environmental Protection License
GOSL	Government of Sri Lanka
ISIC	International Standards of Industrial Classification
MCM	Million Cubic Meters
NWSDB	National Water Supply and Drainage Board
WASP	Water quality Analysis Simulation Programme

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Executive Summary

Like many polluted water bodies in Sri Lanka's Colombo district, the Kelani River has not escaped the impacts of a growing population and economy Recent studies conducted by the Central Environment Authority (CEA)/ University of Moratuwa on water pollution in the Kelani River (Bhuvendralingam et al 1995) uses the CEA's "proposed inland water quality standards" to show that (subject to sampling and analytical uncertainties) levels of Biological Oxygen Demand (BOD), chromium, lead, and fecal coliforms exceeded acceptable ambient water quality standards

The immediate objective is to assess the costs and benefits of alternative policy options for control of water pollution in the Kelani

Background

The CEA is attempting to enforce compliance with established point source concentration-based standards Because industries are the easiest identified of the point source polluters, reduction in their effluents has been identified as the primary means of bringing water pollution problems under control It is implicitly assumed in such an approach that if each of the point source polluters could be forced to reduce their emissions, the net effect on the Kelani River would be to bring ambient water standards within acceptable norms Yet, until the completion of the study referenced above, the CEA did not have the formal means of estimating the relationship between point source emissions and ambient water quality Since every watershed is characterized by a different assimilative capacity, policy planning without this point-source-to-ambient-environment link includes a considerable amount of guesswork With the CEA/Moratuwa study completed, it is now possible to model the relationship between point source emissions in the watershed and the quality of the Kelani water body at different points in the river This modeling exercise marks a significant step forward in developing a capacity for basing environmental policy on formal and estimable models

Approach

The approach of the study is to identify a number of different policy options for controlling water pollution in the Kelani River and then to estimate the costs and benefits of those alternative options To simplify the analysis, we restrict our focus to two major pollutants BOD and chromium In each case, the pollutant levels in the Kelani significantly exceed even the ' minimum quality" CEA ambient water standards Chromium is selected because it is generated almost exclusively by industries and thus represents a pollution problem that must be resolved through direct interaction between the CEA and industry

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Results

Chromium

The results from the analysis make it clear that there are significant cost differences between enforcing CEA's current point source standards and ensuring only that required quality standards of ambient water are maintained The long-run marginal costs to industries of meeting the CEA's point source effluent standards is $88,893, while the marginal cost of reducing chromium pollution just enough to meet the ambient water quality standard is only $1,452 Since the most strict ambient water quality for chromium is met at the relatively low marginal cost of $1,452, any additional expenditure by industry beyond this point is fundamentally inefficient (assuming there is no designation of the river body for which the chromium levels need be lower than for "fish and aquatic life") since it cannot markedly improve the quality of the river

Biological Oxygen Demand

The primary study area for application of the BOD economic model policy issues was the San Sebastian Canal Policy conclusions, however, can be drawn for the Kelani River as a whole The analysis suggest that it is technologically beyond the capacity of the industries currently located on the canal to reduce their BOD loads sufficiently to bring the ambient water standard below the minimum desired level Even at rapidly rising marginal costs, industries can remove only 200 tons/year, yet the excess load of 357 tons/year is beyond the technical capacity of the firms The total daily load of BOD in the San Sebastian Canal is 1,800 Kg/day and the industry accounts for only 10 percent of this total load Thus, even if industries were to stop producing BOD altogether, it would have a minimal impact on the total BOD in the canal

Households, on the other hand, account for more than half of the total load in the San Sebastian Canal A sewage treatment system has the potential for reducing loads in the San Sebastian Canal by an amount greater than the excess load and thus returning the canal's ambient water quality to an acceptable level

Recommendations

Priority issues and recommended actions are shown in Table A

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Table A Priority Issues and Recommended Actions

Priority Issue	Policy Implications/Recommended Action
Designate use of water bodies	Water pollution control strategies for an integrated watershed management approach Use of water bodies within the watershed clearly designated before development of appropriate policies for them
Prioritize target pollutants	A shift in emphasis from surrogate pollutant measures to toxic and refractory anthropogenic chemicals
Enhance water quality monitoring and standards	A shift in emphasis from pollutant concentrations based on pollutant load-based monitoring and standards setting

Conclusions

The conclusions to the study imply a shift in priorities and approach for the CEA While the shift at first may appear to be a fundamental shift of priorities, implying significant upheaval and uncertainty, it is important to note that there is significant precedent for the recommendations being made in this study Regarding the shift from concentration-based to load-based monitoring and from surrogate measures to toxics, the experiences of a number of countries in the region can be of assistance to Sri Lanka The use of hydrological and economic models to manage pollution problems has a long history and has become increasingly accessible and low cost as technology has improved This study clearly reflects an urgent need for much higher priority and concomitant action to move ahead as soon as possible on development of appropriate infrastructure to manage major causes of pollution in similar water bodies in Sri Lanka We believe that the highest priority for CEA at the present, in light of the government's policy for industrial growth, is to rethink its pollution monitoring and management strategies and shift them toward the new vision elucidated here

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1. The Problem

Recent times have seen a proliferation of stories in our press about pollution of well-known water bodies Pollution of the Lunawa Lagoon near Moratuwa has all but caused it to disappear Anecdotes abound about raw household sewage and industrial effluent being pumped into the Bolgoda Lake And the Kandy Lake emits a noxious odor on certain days that is well-known to those who live there

Like these other water bodies, the Kelani River has not escaped the impacts of a growing population and economy A recent Central Environment Authority (CEA) / University of Moratuwa study on pollution and water quality in the Kelani River (Bhuvendralingam et al 1995) uses the CEA's "proposed inland water quality standards" to show that (subject to sampling and analytical uncertainties) levels of Biological Oxygen Demand (BOD), chromium, lead, and fecal coliforms exceeded acceptable ambient water quality standards

Faced with such pollution, the institutional response of the Government of Sri Lanka (GOSL) via CEA has been to attempt to enforce compliance with established point source concentration-based standards Because industries are the easiest identified of the point source polluters, reduction in their effluents has been identified as the primary means of bringing water pollution problems under control It is implicitly assumed in such an approach that if each of the point source polluters could be forced to reduce their emissions, the net effect on the Kelani River would be to bring ambient water standards within acceptable norms Yet, until the completion of the study referenced above, the CEA did not have the formal means of estimating the relationship between point source emissions and ambient water quality Since every watershed is characterized by a different assimilative capacity, policy planning without this point-source-to-ambient-environment link includes a considerable amount of guesswork With the CEA/Moratuwa study completed, it is now possible to model the relationship between point source emissions in the watershed and the quality of the Kelani water body at different points in the river This modeling exercise marks a significant step forward in developing a capacity for basing environmental policy on formal and estimable models

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2. Objective of the Study

The ***objective*** of this study is to build on the hydrological modeling work of the CEA and University of Moratuwa ***to understand and model the economic implications of environmental policy decisions*** The immediate objective is to assess the costs and benefits of alternative policy options for control of water pollution in the Kelani

The longer-term objective of this study is to explore the potential for use of physical, chemical, and economic models for finding solutions to environmental problems We would hope that such models also might assist in understanding the relationship between environmental policy decisions and their impact at the local level

3. Methodology

3.1 General Approach

The approach of the study is to identify a number of different policy options for controlling water pollution in the Kelani River and then to estimate the costs and benefits of those alternative options To simplify the analysis, we restrict our focus to two major pollutants BOD and chromium In each case, the pollutant levels in the Kelani significantly exceed even the "minimum quality" CEA ambient water standards (see Table 1) Chromium is selected because it is generated almost exclusively by industries and thus represents a pollution problem that must be resolved through direct interaction between the CEA and industry

Table 1 Select Proposed Inland Water Quality Standards

Parameter	Unit	Drinking Water with Simple Treatment	Fish and Aquatic Life	Minimum Quality
Total chromium (Cr)	µg/l max	50	2	50
BOD (5 days 20° C)	mg/l max	2	-	4

BOD is selected not only because it is one of the most important determinants of environmental quality, but also because its sources are considerably more varied than chromium, being generated by households, industries, and even natural systems The CEA's response to problems of BOD pollution thus represents a much more complex set of issues than the chromium case The CEA/Moratuwa study found that only 8 percent of the BOD load in the Kelani River can be attributed to industry, with the remainder coming from household sewage and a number of non-point sources (e g , from natural systems and farmlands)

The policy options examined for reducing levels of chromium and BOD differ slightly The analysed policy options for reducing levels of ***chromium*** are the following

3 1 1 Policy Options Chromium

1 ***Enforce Compliance with Existing CEA Point Source Effluent Standards*** Under this option we calculate the costs to industry (additional enforcement costs of the CEA are not calculated) of reducing their pollution levels to meet the CEA point source standards

2 ***Require that Industry's Total Effluent Levels are Reduced Sufficiently to Meet Ambient Water Quality Standards for "Fish and Aquatic Life"*** Under this policy, an institution

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would be identified and given the mandate to ensure that the ambient water quality in the Kelani was the guiding principle in determining the allowable amounts of pollution that can be emitted into it No restrictions are placed on the effluents of any single firm, so long as the total effluents entering the river do not push pollution levels above 2 µg/l, the maximum allowable level for fish and aquatic life

3 ***Require that Industry's Total Effluent Levels are Reduced Sufficiently to Meet Ambient Water Quality Standards for "Drinking Water with Simple Treatment"*** Similarly to option 2 above, no restrictions are placed on the effluents of any single firm, so long as the total effluents entering the river do not push pollution levels above 50 µg/l, the maximum allowable level for drinking water with simple treatment

The policy options explored for reducing levels of ***BOD*** are the following

3 1 2 Policy Options BOD

1 ***Enforce Compliance with Existing CEA Point Source Effluent Standards*** Here we calculate the cost to all identified point sources of compliance with existing standards

2 ***Meet Ambient Water Quality Standards Via Reductions by Industry Only*** Under this option, the burden of reducing BOD levels is given to industry, who must reduce their BOD output sufficiently to meet the ambient water quality standard

3 ***Meet Ambient Water Quality Standards Via Installation of a Sewage Treatment Plant Only*** Under this option, installation of a sewage treatment plant is assessed as a means of reducing BOD levels to acceptable standards Costs are estimated using data from similar sewage treatment plants along with population data from the study site

4 ***Meet Ambient Water Quality Standards Via Installation of a Sewage Treatment Plant and Initiation of a Non-point Source Pollution Program*** Although specific costs cannot be estimated with this policy option, some conclusions can be drawn about the potential for pollution management using the option

The 'minimum quality" (4 mg/l max) ambient standard is used for all of these BOD policy options

3 2 Modeling Framework

To model these policy options, the CEA/Moratuwa model of the Kelani River is taken as a starting point The developers of this model measured the ambient water quality levels of the Kelani River and estimated the pollutant loads (point source and non-point source) discharged to the river The CEA/Moratuwa modeling team established a water quality model for the Kelani River mimicking its dose-response behavior, where the dose was the external pollutant and the response

was the resulting water quality level encountered in the water body The fundamental relationships of the model were given by the Water quality Analysis Simulation Programme (WASP), which is generally used to help interpret and predict water quality responses to natural phenomena and man-made pollution for various pollution management decisions [1]

To examine the economic implications of alternative policy options, the World Bank's Decision Support System for Industrial Pollution Control (DSS/IPC) was used The DSS/IPC allows the user to stipulate an ambient water quality standard and then to compute the costs that would be required for polluters to reduce their emissions sufficiently for the ambient body to meet the standard The model uses long-run marginal cost functions for different International Standards for Industrial Classification (ISIC) codes to estimate investment costs necessary to reach reduced loads for a given firm The costs of pollution reduction investments are derived from international market prices for known pollution reduction technologies and are linked to the physical and chemical processes typically used by different industries Use of the DSS/IPC in combination with the CEA/Moratuwa models therefore allows the user to calculate the investment costs required by polluters to meet a variety of ambient water quality levels [2]

3.3 Underlying Economics of Costs and Benefits

The investments made by polluters to reduce pollution levels represent "deterrence costs" and therefore provide a proxy for some of the benefits of pollution reduction Other benefits and costs not included in the DSS/IPC may also be associated with changes in pollution levels The general categories under which economic costs and benefits can be identified as a result of changes in water (or other ambient) pollution are productivity, amenity, and human health (OECD 1995, 39-40) Amenities refer to issues such as contact and non-contact recreation, aesthetics, etc This study does not make an attempt to formally estimate any of these categories

When defining the "costs ' of pollution control, the DSS/IPC model places primary emphasis on long-run marginal costs as opposed to total or average costs Long-run marginal costs are calculated using total investment costs, the interest rate, number of years for which the pollution control machinery will be functional and effluent parameters The emphasis is on the marginal costs that arise between choosing between one pollution management option and the next

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4. The Study Site

The Kelani River is the third largest river in Sri Lanka The river originates in the central hill country of the island and flows in a mainly westerly direction until it reaches the sea at the northern limits of the city of Colombo The river basin, which is located entirely in the wet zone of the country, has a catchment area of 2,280 sq km and an annual runoff of 5,500 million cubic meters (MCM)

The Kelani River itself is formed by the confluence of two smaller rivers, Kehelgamu Oya and the Maskeliya Oya These two rivers are dammed further upstream, forming Castlereigh and Mousakelle reservoirs, respectively, both of which are constructed and utilised for the purpose of hydro-electric power generation Approximately 3 km upstream of Hanwela, the Kelani River is joined by a small tributary called the Wak Oya, which is dammed further upstream forming the Kalatuwawa and Labugama reservoirs, the initial water supply sources for the city of Colombo The river loops around the northern limits of Colombo before flowing out to the sea

The river segment between Glencorse and the sea mouth (including significant tributaries) was ***selected as the broad model area*** This is presently the area with the most industrial activities and is of vital importance to the area of Greater Colombo due to the presence of Ambantale Water Intake and Treatment Plant providing potable water to its inhabitants

For the purposes of this study, the ***San Sebastian Canal*** was selected as a sub-site The canal is part of the Colombo canal system and discharges storm water, industrial effluent, and sewage collected from a large urban area into the Kelani River via the north lock situated just upstream of Victoria Bridge The land adjoining the canal is home to a huge shanty settlement, where people live in conditions where sanitary and waste disposal facilities are non-existent A large number of industries are present along the canal banks, utilising the canals for liquid waste disposal The collective result of these influences makes the San Sebastian Canal the most polluted water body in the city of Colombo

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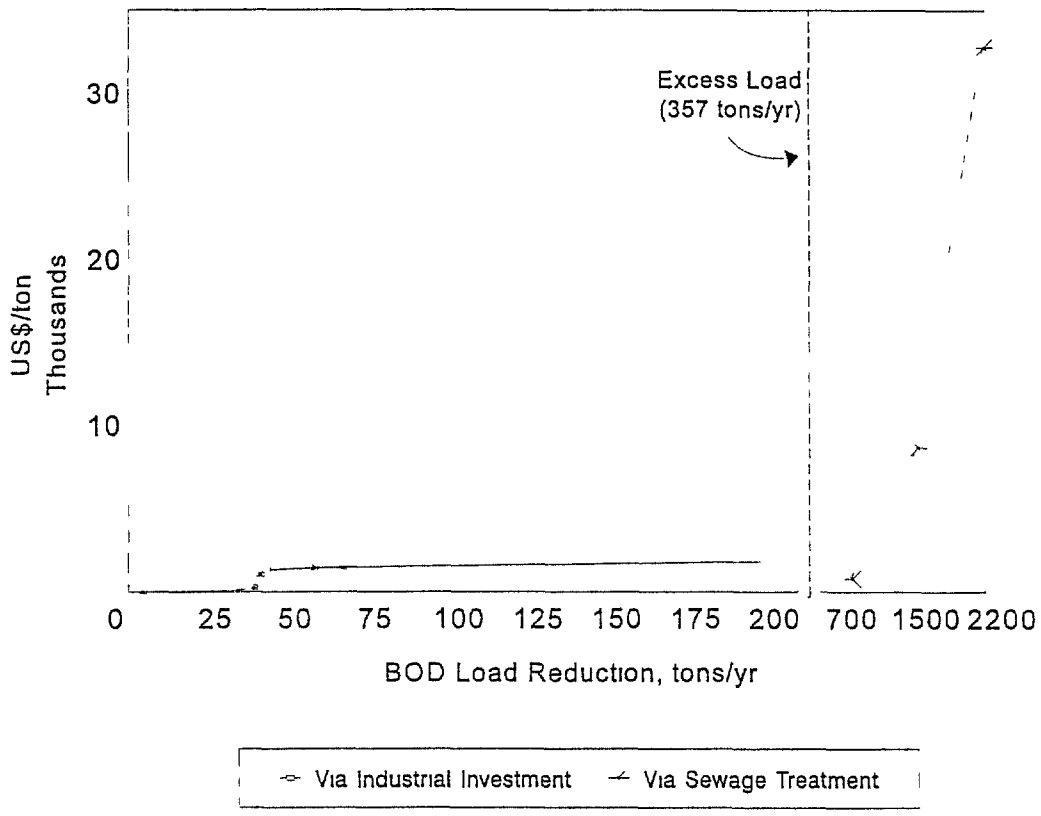
5. Results

5.1 Chromium

Results to the chromium analysis are shown graphically in Exhibit 1 Since the Kelani River already meets the ambient standards for "drinking water with limited treatment," the marginal cost to industry in meeting that standard under policy option) is $0

The more striking results from the chromium analysis arise from a comparison of policy options 1 and 2 Results from the analysis make it starkly clear that there are significant cost differences between enforcing CEA's current point source standards and ensuring only that high quality standards of ambient water quality are maintained The long-run marginal costs to industries of meeting the CEA's point source effluent standards is $88,893, while the marginal cost of reducing chromium pollution just enough to meet the ambient water quality standard is only $1,452 Since the most strict ambient water quality for chromium is met at the relatively low marginal cost of $1,452, any additional expenditure by industry beyond this point is fundamentally inefficient

Exhibit 1 Marginal Cost of Controlling Pollution in San Sebastian Canal



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(assuming there is no designation of the river body for which the chromium levels need be lower than for "fish and aquatic life") since it cannot markedly improve the quality of the river

5.2 Biological Oxygen Demand

5 2 1 Policy Conclusions

The primary study area for application of the economic model to BOD policy issues was the San Sebastian Canal Some policy conclusions can be drawn for the Kelani River as a whole

The marginal costs of pollution control by industry and by sewage treatment are shown in Exhibit 1, as is the excess load in the canal The excess load is the amount of the pollutant that needs to be removed before the desired ambient water standard is reached, in this case 4 mg/l The graph, and the data underlying it, strongly suggest that it is technologically beyond the capacity of the industries currently located on the canal to reduce their BOD loads sufficiently to bring the ambient water standard below the desired level Even at rapidly rising marginal costs, industries can remove only 200 tons/year, yet the excess load of 357 tons/year is beyond the technical capacity of the firms

One reason industries alone cannot resolve the San Sebastian Canal BOD problems is explained by the pie charts in Exhibit 2 The small pie on the left represents the total daily load of BOD in the San Sebastian Canal As shown there, industry accounts for only 10 percent of this total load Thus even if industries were to stop producing BOD altogether, it would have a minimal impact on the total BOD in the canal

Households, on the other hand, account for more than half of the total load in the San Sebastian Canal The marginal costs for BOD reduction via investments in sewage treatment are shown on the right-hand side of Exhibit 1 Clearly, investment in a sewage treatment system has the potential for reducing loads in the San Sebastian Canal by an amount greater than the excess load and thus returning the canal's ambient water quality to an acceptable level

It must be kept in mind that there may be an error in the calculation of land values for the sewage plant While the land price used to calculate land values in the model is assumed to be correct, the political problems involved in clearing settlement to establish a waste treatment plant may drive up costs considerably

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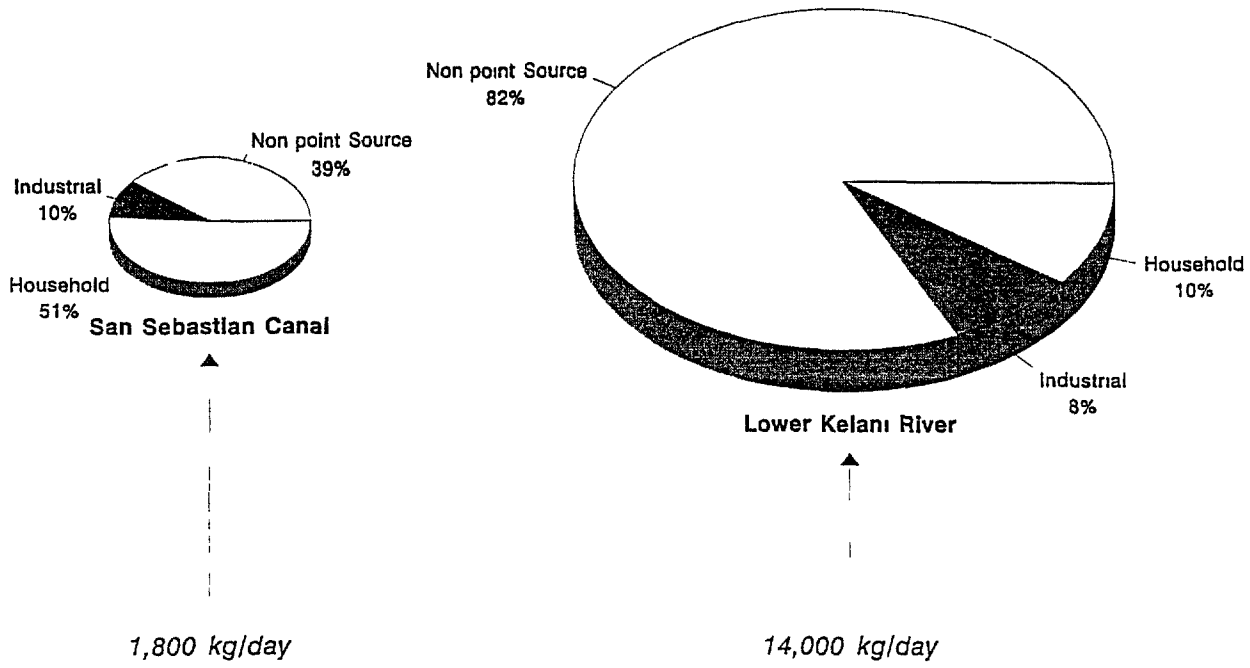
Exhibit 2 Sources of BOD at Selected Points on the Kelani River



Size of pie indicates total BOD load (kg/day)

5 2 2 Implications for the Lower Kelani River

While the DSS/IPC model was not applied for BOD to the Kelani as a whole, some implications from the San Sebastian model can be extended to the larger river First, just as industrial effluent is relatively insignificant compared to other pollution sources in the San Sebastian Canal, so too are both industrial effluent and household effluents insignificant when compared to non-point sources in the river as a whole The larger pie on the right-hand side of Exhibit 2 indicates the total BOD load in the lower Kelani River As shown there non-point sources are estimated to account for 82 percent of the total daily load while industrial and household sources account for only 8 and 10 percent respectively Thus, although investments in sewage control in the San Sebastian is a viable means of creating sufficient ambient water quality in that water body, they are likely to be inefficient when considered alone, as a means of bringing down BOD levels in the Kelani as a whole ***Rather, some combination of non-point source control measures and point source control measures will need to be sought if the policy decision of the government is to significantly reduce BOD in the Kelani***

A summary of the effectiveness of the four BOD policy options in reaching a common goal is shown in Table 2 Each policy is tested against whether it has the potential of reaching the

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Table 2 Expected Water Pollution Policy Effectiveness

Details of Policy*	San Sebastian Canal	Lower Segment of Kelani River
	Policy has potential to achieve stated goal?	
1 Enforce industrial compliance with BOD point source effluent standards	No	No
2 Meet ambient water quality standards via reductions by *industry only*	No	No
3 Meet ambient water quality standards via installation of a *sewage treatment plant only*	Yes	No
4 Install sewage treatment plant and initiate non-point source pollution programs	Yes	Yes

**Goal of Policy* BOD levels in water body fall within minimum quality (4 mg/l) standards of CEA

ambient water quality goal stipulated at the top of the table The information in the table demonstrates the importance of assessing whether a policy has the technical capacity of reaching a stated goal before embarking upon it

As the table makes clear, resolution of BOD pollution problems in the San Sebastian Canal can only be resolved via investments in sewage treatment, perhaps in combination also with enforcement of some industrial compliance with point source standards If the government maintains the de facto goal of reducing BOD significantly in the larger Kelani River (a goal which is called into question below), then it must begin embarking on non-point source control programs

5 3 Technical Results Pertaining to Use of the DSS/IPC Model

A number of constraints were identified in using the DSS/IPC model Most importantly it was noted that the decision support system uses quite simplified water quality models for its calculations Calculations of BOD loads also presented problems The critical BOD load is calculated on the basis of the minimum required Dissolved Oxygen (DO) level Target BOD level (ambient BOD standard) is not considered in calculating the critical BOD load In fact the system (DSS/IPC) does not calculate the maximum BOD level encountered in the river but only calculates the BOD level at the point of the river where the critical DO level (minimum DO) is encountered Finally, the river BOD model incorporates only the upstream boundary condition and does not consider the downstream boundary condition in its calculations This limitation inhibits the model from incorporating the background effect (due to non-point source run off) in the calculations

5 4 Results Summary

Summary data for chromium and BOD are shown in Table 3 Results to the analysis are organized by the pollutants

Table 3 Summary Pollution Load Data for BOD and Chromium

Pollutant and Water Body	Current Load (tons/yr)	Ambient Standard	Critical Load (tons/yr)	Excess Load (tons/yr)	Percent Excess Load
BOD in San Sebastian Canal	1 821	4 mg/l	1 464	357	19 6%
Chromium (Cr) in lower Kelani River	1 77	2 µg/l	1 42	0 35	19 7%

6. Conclusions, Implications, and Next Steps

6.1 Economic Modeling and Environmental Management

The current study has used the World Bank's DSS/IPC model along with the CEA/Moratuwa WASP model (see Bhuvendralingam et al 1995) to show that economic and hydrological models can be effectively used to assess the cost implications of alternative water pollution policies In spite of a number of technical constraints, the model was relatively easy to install and apply In light of its effectiveness in assessing the costs and benefits of alternative pollution control policies, it is ***strongly recommended that the further testing and application of economic models, such as DSS/IPC, be done in other watersheds*** Initial priority should be given to the Bolgoda Lake and Lunawa Lagoon water systems in the Ratmalana-Moratuwa industrial area and the Ja-ela Canal and Dandugama Oya in the Jaela-Ekala industrial area Both are regions of industrial importance with significant actual or potential pollution impact on the local population Other areas that might be considered for follow-up applications of the model include the Negombo Lagoon and the Kalu Ganga, although the water quality of both of these water bodies is influenced mainly by non-point sources Since cost reduction for non-point sources with DSS/IPC cannot be estimated, however, water bodies where pollution comes predominantly from point sources should be given priority Any follow-on applications of the model should be preceded or accompanied by parallel investment in data collection

Potential further applications of models such as that developed here are numerous and include the following

- Supporting the development of national, regional, and local action plans for management of industrial pollution
- Reorienting the development of environmental monitoring systems by identifying the pollutants and the locations that should be monitored more closely
- Giving analytical support and transparency in the design of pollution prevention strategies, such as environmental impact assessment, land use planning, and sensitive areas management
- Educating non-specialists in the potential economic impact of environmental policies on industrial activity in a given area (Sebastian and de Koning 1996 11-12)

It may be especially effective to use the DSS/IPC model for supporting the education and engagement of non-specialists in the pollution management process Because the model places the pollution debate in terms anyone can understand (rupees and general water quality), it can be effective in engaging broader participation in the development of environmental policy Policy-makers can show how changing effluent levels at the household and firm add up to changes in ambient water quality and how ambient quality might be better managed The CEA ***should consider***

using the model, or one like it, to explain the gravity of pollution problems to other government officials or local communities, or to justify why they are taking one approach over another

6.2 Water Pollution and Human Health

In spite of its potential applications, the model can estimate only a narrow range of possible environmental costs and benefits [3] Egregiously missing from the model's assessment of costs and benefits is the lack of any health functions At present in Sri Lanka, there is a virtual absence of data with which to understand the human cost of toxic water pollution In such water bodies as the Lunawa Lagoon, where toxic pollutants are being released, ***it is imperative that dose-response relationships be established via primary data collection*** It is troubling to note in Bhuvendralingam (1995) that lead levels in the Kelani River remain above proposed ambient water quality levels, even at the Ambatale water intake point [4] The potential impact of lead and other toxic pollutants must be estimated if models, such as the DSS/IPC, are to provide well-rounded policy-making support

6 3 Linking Pollution Policies to Major Pollution Sources

Bhuvendralingam et al (1995) demonstrated that industrial pollution is relatively unimportant in determining the level of BOD in the Kelani River This study has gone further to show that, at least for the highly polluted San Sebastian canal, investment in a sewage treatment system is more cost effective than industrial investments in pollution reduction equipment [5] The CEA must begin discriminating more carefully in its identification of priority polluters Rather, they should recognize that ***more cost effective solutions[6] to pollution problems can often be found in efforts to control household and non-point source pollution*** than in pursuit of industrial polluters

The study also showed that even large investments in industrial and household pollution control would have a minimal effect on BOD levels in the Kelani River, where non-point source pollution accounts for the majority of the total load If reductions in surrogate measures, such as BOD, continue to be considered as the primary goals of the CEA, then the strategy for water bodies such as the Kelani should be re-directed toward non-point source control In the near term it is ***recommended that small-scale studies be launched to identify major non-point pollution sources*** In the case where non-point source runoff contributes significantly to the pollution load policies leading to optimal application of agro-chemicals (such as pesticides and fertilizers) may contribute significantly toward pollution reduction

6 4 Prioritizing Target Pollutants

At present, the CEA emphasizes the importance of reductions in ***surrogate pollutant measures***— such as BOD, Chemical Oxygen Demand (COD) and suspended solids—as its strategy for reducing pollution Since these surrogate measures are affected by both human and natural processes, however, they may not be the best priority for a pollution management strategy This study has shown, for example, that BOD pollution levels in the Kelani River are a function primarily

of non-point source processes When the effort to control BOD is pursued with industries, the paradoxical situation has arisen in which industries introduce ***more*** toxic metals into their effluent stream because such metals may ***lower*** their BOD levels and thus their effluent concentrations

On the basis of this study, we ***argue that a shift in emphasis from surrogate pollutant measures*** (which are affected by natural processes as well as human) ***to toxic and refractory anthropogenic chemicals*** (which result directly from human activities) ***would serve the interests both of the affected populations and the CEA*** By their very definition, toxic pollutants pose a greater threat to human populations than do the biodegradable substances captured by the BOD measure The CEA would also stand to gain from making reduction in toxic pollutants a priority The public, after all, would have an easier time understanding the threat of toxic chemicals (the effects of which can be portrayed graphically and visually) than the effects of high BOD or COD levels (which cannot be captured in a single impact) Though the CEA should continue to monitor BOD and COD as rough checks on effluent quality, they need not tightly monitor and enforce the standards relevant to these parameters for industries discharging to large water bodies Certainly, a shift in priorities toward monitoring of toxic chemicals would involve greater laboratory and monitoring costs, but the potential benefits to human health would very likely outweigh the costs Furthermore, funding for laboratory and monitoring improvement under the Environmental Action 1 Program (EA1P) might be used to begin this process

6 5 Water Bodies and Their Designated Uses

Two points are made evident from the study ***(1) that water pollution planning is strengthened when it focuses on integrated and discrete <u>watersheds</u>*** and ***(2) that the uses of the <u>water bodies</u> in these watersheds must be clearly designated before appropriate policies can be developed for them***

Focusing on discrete watersheds benefits planners because it allows them to take into account the unique physical and hydrological characteristics of each watershed and the consequent applicability of models to them The type of land use encountered in a watershed plays a major part in determining the background quality of the waterbody While smaller water bodies are influenced primarily by point source emissions contributing either biodegradable organic matter in the case of Beira Lake or by point source emissions, which are toxic and refractory in the case of Lunawa Lagoon Large water bodies such as the Kelani Ganga and Kalu Ganga, on the other hand are dominated by watersheds that are vegetative in nature In such watersheds, non-point source emissions generally determine the background quality of the waterbody Hence, it would be more effective if planning occurs separately for these different types of watersheds

Just as watersheds differ in their basic characteristics, so too do the uses of water bodies in those watersheds differ Thus identification of appropriate policies for chromium control in the Kelani must be a function of the agreed upon use of the Kelani watershed as well as the assimilative characteristics of the waterbody itself Chromium levels in the lower Kelani exceed the CEA's proposed ambient water quality levels for "fish and aquatic life" but are acceptable if the river is to be used for "drinking water with limited treatment " ***It is imperative, if ambient water quality***

standards are to have any relevance for planning, that the CEA and other partner institutions, perhaps under the leadership of the national Water Resources Council, begin designating uses of water bodies within select watersheds Methods for the engagement of the general public in these processes have been well documented at sites around the world [7]

6.6 Concentration Versus Load Monitoring

The CEA's point source monitoring data, and indeed its point source pollution standards, are based on concentration of pollutants in the effluent stream rather than the total load of pollutants Allowing industries' pollution levels to be measured on the basis of the concentration gives them incentive to dilute their effluent streams just enough to meet the required levels Such dilution, being contrary to water conservation, often calls for pumping of additional groundwater at a time when, as the National Environmental Policy notes, "ground water is being extracted without concern for the permanent lowering of the water table and the intrusion of salt water into coastal aquifers" (M/TEWA 1997, 14) Equally important for management purposes, it is the pollutant load (and not the concentration of the pollutant) that degrades the quality of the receiving water body In light of this situation, we ***recommend that the CEA switch immediately from concentration-based to load-based monitoring and standards***

Admittedly, load data costs more to collect Measurements are taken over a period from 5 to 30 days rather than the single visit measurements used for concentration data Yet we would argue that the investment in improved base information is essential if the sorts of river bodv modeling done in Bhuvendralingam et al (1995) or economic modeling done here are to be extended to other river bodies In addition, load data at firm level is an essential prerequisite to application of economic incentive measures pertaining to effluent charges, tradeable permits, and a number other economic instruments (see discussion below)

6 7 Economic Incentives for Pollution Management

The recent National Environmental Policy makes an explicit call for the increased use of economic instruments and incentives" for waste minimization In particular, it calls for the use of load-based Environmental Protection License (EPL) fees Steele and Hassan (1995) examined the potential for introduction of effluent charges They recognized that effluent charges and trading concepts has significant potential for application but not in an institutional context in which enforcement was not taking place Thus an essential condition to introduction of economic incentives for pollution management is ***the enforcement of well thought out regulations***

Modeling efforts of the sort attempted here can be particularly helpful in introducing economic incentives for water pollution management The aggregate long-run marginal cost curves generated here can be used to set initial rates for load-based EPL fees The model developed here for the Kelani sub-catchment can be used as a test basin for the introduction of these fees as well as an assessment of the impact of fees on water quality Were estimates of health and amenitv costs

at different ambient water quality levels available, they could be used to conduct a more comprehensive benefit/cost analysis of pollution policies than allowable at present

6 8 Conclusion Summary

A summary of the study's conclusions and implications is presented below in Table 4

Table 4 Summary Matrix of Priority Issues and Recommended Actions

Conclusions	Policy Implications/Recommended Action
Designate use of water bodies	Water pollution control strategies for an integrated watershed management approach Use of water bodies within the watershed clearly designated before development of appropriate policies for them
Prioritize target pollutants	A shift in emphasis from surrogate pollutant measures to toxic and refractory anthropogenic chemicals
Enhance water quality monitoring and standards	A shift in emphasis from pollutant concentrations based on pollutant load-based monitoring and standards setting

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7. Conclusion

Conclusions to the study imply a shift in priorities and approach for the CEA While the shift at first may appear to be a fundamental shift of priorities, implying significant upheaval and uncertainty, it is important to note that there is significant precedent for the recommendations being made in this study There exists a significant body of literature making the case for the application of economic instruments to pollution management Regarding the shift from load-based to concentration-based monitoring and from surrogate measures to toxics, the experiences of a number of countries in the region can be of assistance to Sri Lanka The use of hydrological and economic models to manage pollution problems has a long history and has become increasingly accessible and low cost as technology has improved (see Bower, et al in Delaware River and Tokyo bay, for example) We believe that the highest priority for CEA at the present, in light of industrial growth, is to rethink its pollution monitoring and management strategies and shift them toward the new vision elucidated here

8. Endnotes

1 WASP is a dynamic compartment modeling program for aquatic systems The time varying processes of advection, dispersion, point and diffuse mass loadings, and boundary exchanges are represented in the basic program The basic principle behind the formulation of WASP is the conservation of mass and momentum The water volume and water quality constituent masses being studied are tracked and accounted for over time and space using a series mass and momentum balance equations Further information on the WASP model can be obtained in Ambrose, Wool, and Martin (1993)

2 The DSS/IPC contains a default database for emission factors, water, and solid waste associated with industrial process, the technologies applied in industrial processes or the backup technologies used to control pollution, and generalized pollution abatement cost functions for those technologies The system also has the flexibility of allowing users to change default database parameters to suit local study conditions and monitored data A full explanation of the processes used in the DSS/IPC can be found in Sebastian and de Koning (1996)

3 Avoided health cost in cleaning up the San Sebastian canal by installing a sewage collection and disposal system is estimated to be Rs 1 6 Mn per annum In addition, amenity benefits, such as fisheries, recreation etc , should also be taken into consideration

4 It is recommended that an intensive study be conducted in conjunction with the CEA and National Water Supply and Drainage Board (NWSDB) on non-point source run off bringing in contaminants (especially lead) near Ambantale water intake The study should concentrate on a period immediately after a storm when the initial flush of storm water brings the accumulated contaminants to the water body

5 The cost estimates for a sewage treatment plant included above are underestimated in that they do ***not*** include the human and financial costs of resettlement away from the waterbody and the proposed plant

6 Installation of sewage collection and disposal system properly designed and constructed storm water drainage system, including perhaps artificial wetlands, etc

7 See, for example, Bower and Takao (1993) and Spofford et al (1976)

9. References

Ambrose, R B , T A Wool, and J L Martin 1983 *The Water Quality Analysis Simulation Program Model Documentation and User Manual* Athens, Georgia Environmental Research Laboratory, US Environment Protection Agency

Basta, Daniel J , James L Lounsbury, and Blair T Bower 1978 *Analysis for Residuals—Environmental Quality Management* Washington, DC Resources for the Future

Bhuvendralingam, S , S S L Hettiaratchchi, W A D D Wijesooriya and H P V Vithana 1995 *Kelani Ganga Water Quality Monitoring and Modeling Study,* vol 2 of *Institutional Strengthening of the Central Environmental Authority in Industrial Pollution Control* Moratuwa, Sri Lanka Department of Civil Engineering, University of Moratuwa, and bkh Consulting Engineers

Bower, Blair T , ed 1977 *Regional Residuals—Environmental Quality Management Modeling* Washington, DC Resources for the Future

Bower, Blair T and Katsuki Takao eds 1993 *Who Speaks for Tokyo Bay?* Rotterdam A A Balkema

Kingsley, G Thomas, Bruce W Fertuson, and Blair T Bower 1994 *Managing Urban Environmental Quality in Asia* Washington, DC World Bank

Kneese, Allen V and Blair T Bower 1984 *Managing Water Quality Economics, Technology and Institutions* Washington, DC Resources for the Future

Organisation for Economic Cooperation and Development (OECD) 1995 *The Economic Appraisal of Environmental Projects and Policies A Practical Guide* Paris France OECD

Ministry of Transport, Environment and Women s Affairs (M/TEWA) 1997 *National Environmental Policy* Colombo Sri Lanka M/TEWA

Sebastian, Iona and Henk de Koning 1996 *Methodology and Results,* vol 1 in *Decision Support System for Industrial Pollution Control* Washington DC World Bank, World Health Organisation, and /Pan American Health Organisation

Steele, Paul and Rushdy Hassan 1995 *Introduction of Effluent Charges for Controlling Industrial Water Pollution* Colombo, Sri Lanka Institute of Policy Studies, Natural Resources and Environmental Policy Project (NAREPP)

Spofford, Walter O , Jr , Clifford S Russell, and Robert A Kelly 1976, *Environmental Quality Management An Application to the Lower Delaware Valley* Washington, DC Resources for the Future