Eutrophication and Pathogenic Contamination of Lake Chivero: Lessons for Sustaining Technological Interventions in Lake Basin Management

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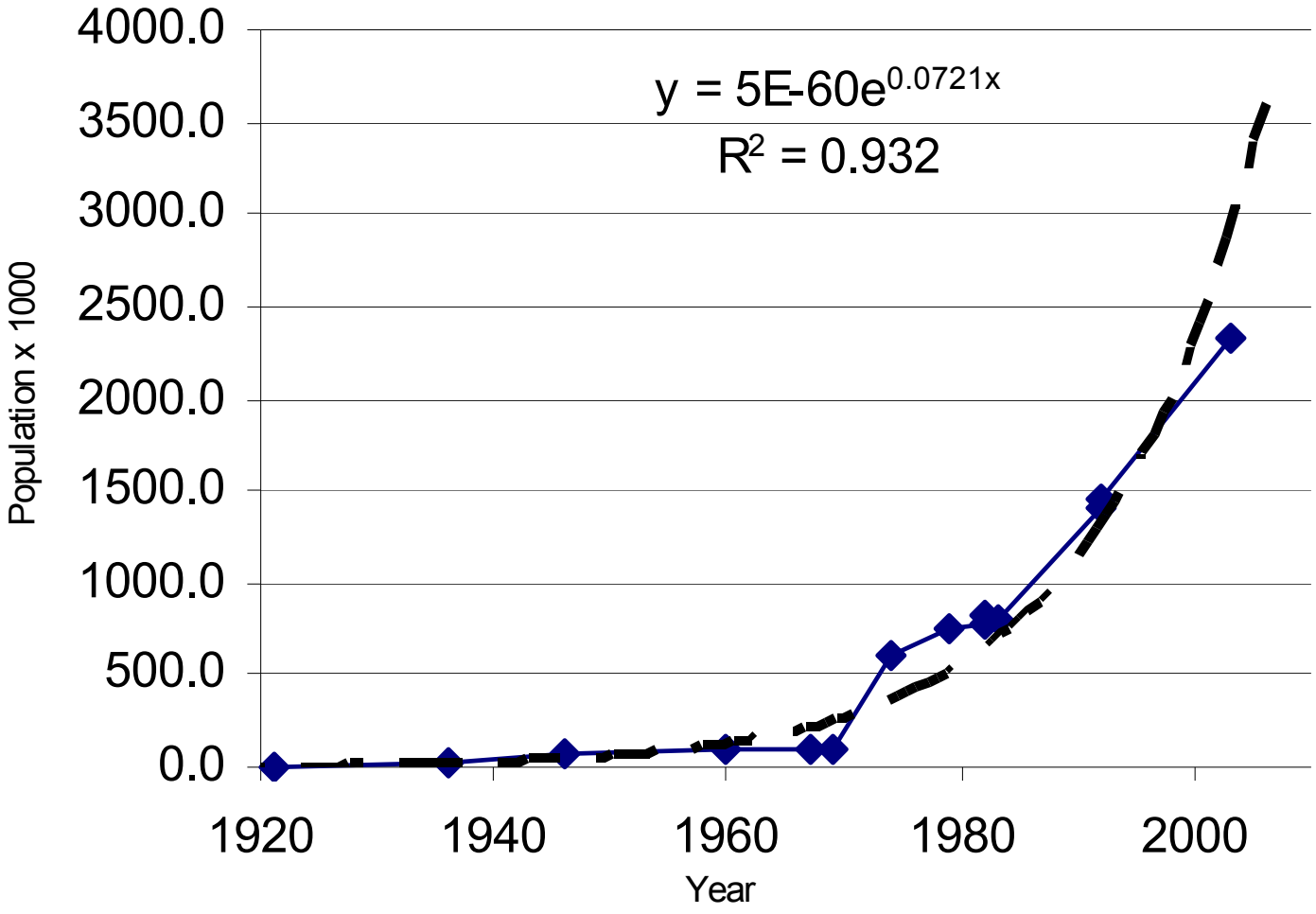
Historical

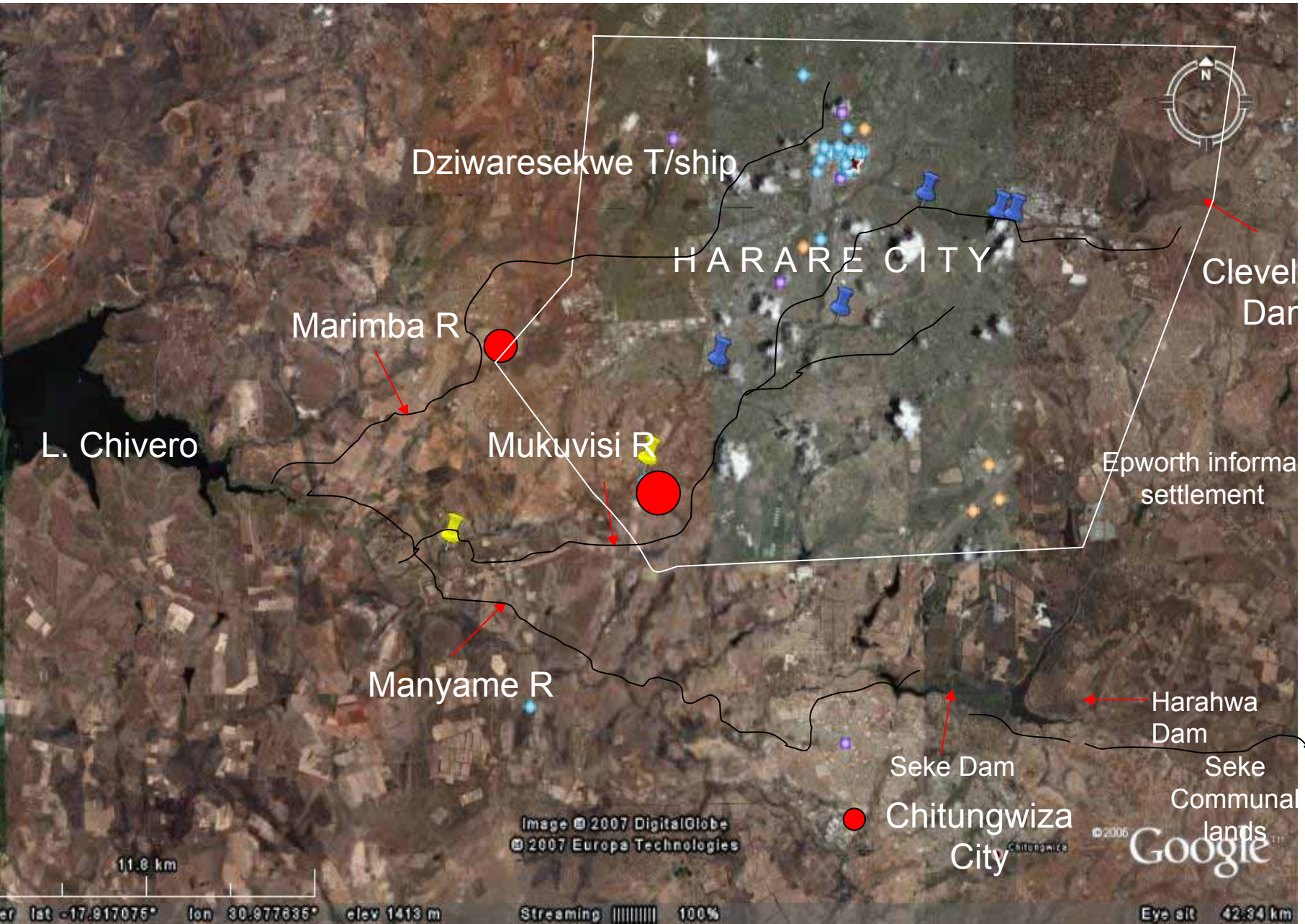
- The city, now called Harare, began as a settler settlement, in 1890
- It became a municipality in 1897 and a city in 1935.
- Cleveland Dam, was constructed upstream of the city, and supplied the city until the city outgrew the dams capacity
- A bigger dam, Prince Edwards, (now called Seke Dam) was constructed on the Manyame River, with a capacity of 3.38 ML.
- Later this was supplemented by Harahwa (Henry Harlem) Dam with a 9.03 ML capacity
- By the 1950s the water supply of the Harare city from the existing Manyame River dams was approaching the limits of their supply capacity. A bigger supply reservoir was needed.
- The new dam, L. Chivero, was located downstream to waste effluent outfall.
- The city was now drawing water from the dam into which its waste water flowed.

Reconstructed Harare population

Fig 2A. Population grow th of Harare and satellite settlements



Google earth view of L. Chivero watershed with overlays

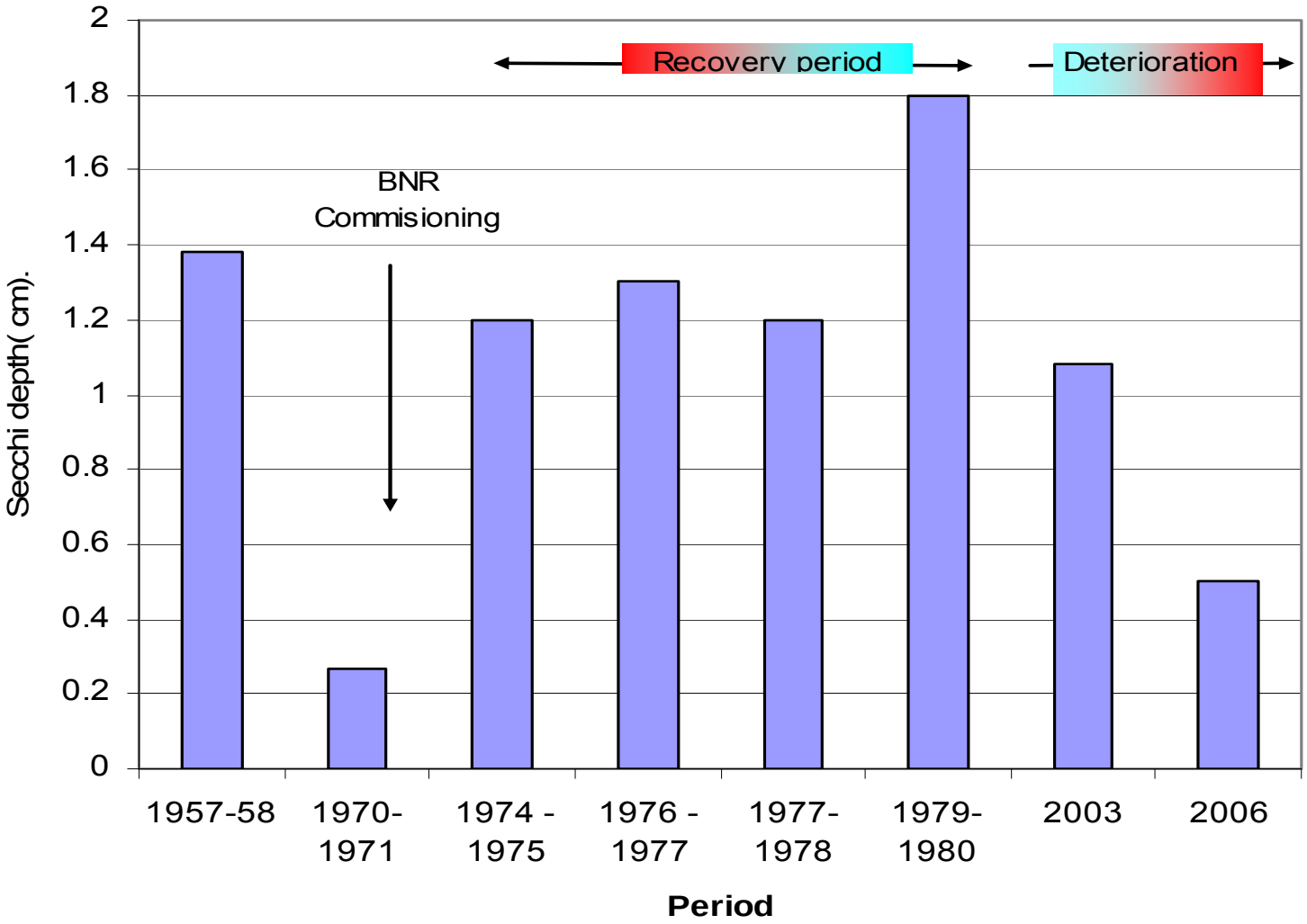


Google earth view: Firle BNR sewage works. Green colour of reactors and clarifiers indicate dysfunctional state.

Table 1. Historical changes in phosphorus regime in L. Chivero (after Thornton, 1982*, Magadza 1997).

Parameter	1967: Initial onset of eutrophication	1978: Post remedial measure recovery period	1996: Post management breakdown era	2006 (Ndebele and Magadza 2006)
P-load (tonnes pa)	288 (11.52 g m^{-2})	39.6 (1.5 g m^{-2})	350 (14 g m^{-2})	
Mean P- conc. mgl^{-1}	2.25	0.13	1.8	2.67 (2.42 – 3.18)
Conductivity μScm^{-1}	160	120	800	2124.5 μScm^{-1} (Wet season values)

Secchi disc changes following restoration measures (data from Thornton 1982, Ndebele and Magadza 2006, Magadza unpublished. The 2003 data refer to wet period.)



The post 1980 era

Water Hyacinth in L. Chivero. (Photo C.H.D. Magadza)

Dog on uncollected refuse heap

Breached sewer effluent flowing along suburban road in a middle to high income area

Table. 2. Waste water treatment capacity (ML/day) at some of the Manyame watershed sewage works, excluding Chitungwiza City. (Data: Harare City Council pers. Com)

Plant	Trickle filter	Year constructed	Activated sludge (BNR)	Year constructed	Ponds	Year constructed	Total capacity	Present flow	Deficit
Firle	36	1960	18	1982			144	250	106
			18	1974					
			72	1998					
Crowborough	36	1957	18	1992			54	120	76
Donnybrook					2.3	1953-1972	2.3	10	7.7
Marlborough					2	Post 1980	2	7	5
Total							202.3	387	184.7

Non point source nutrient export from Harare suburbs in wet season only

Catchment/ Suburb	Type of suburb	Phosphorus		Nitrogen		Total export		
		Tonne km^{-2}	Kg $Capita^{-1}$	Tonne km^{-2}	Kg $Capita^{-1}$	P tonne	N - Tonne	P/N ratio
Kuwadzana	High density	0.08	0.17	0.47	0.96	2.88	16.75	5.81
Budiriro	High density	2.30	0.23	13.77	1.35	22.08	132.17	5.99
Mukuvisi	Mixed low, high density + industrial	10.28	1.00	39.98	3.89	98.99	385.04	3.89
Epworth	High density informal	3.38	1.11	12.20	4.00	103.12	371.88	3.61
Glenview	High density	0.30	0.39	1.09	1.44	30.23	111.39	3.68
Marimba	Mixed/ low density /industrial	0.13	0.77	0.86	4.98	9.28	60.31	6.50
Mean or total		2.75	0.61	11.40	2.77	**266.59**	**1077.53**	4.91

From a hydrological point of view there have been significant changes in the lake's watershed.

Flushing rates of L. Chivero

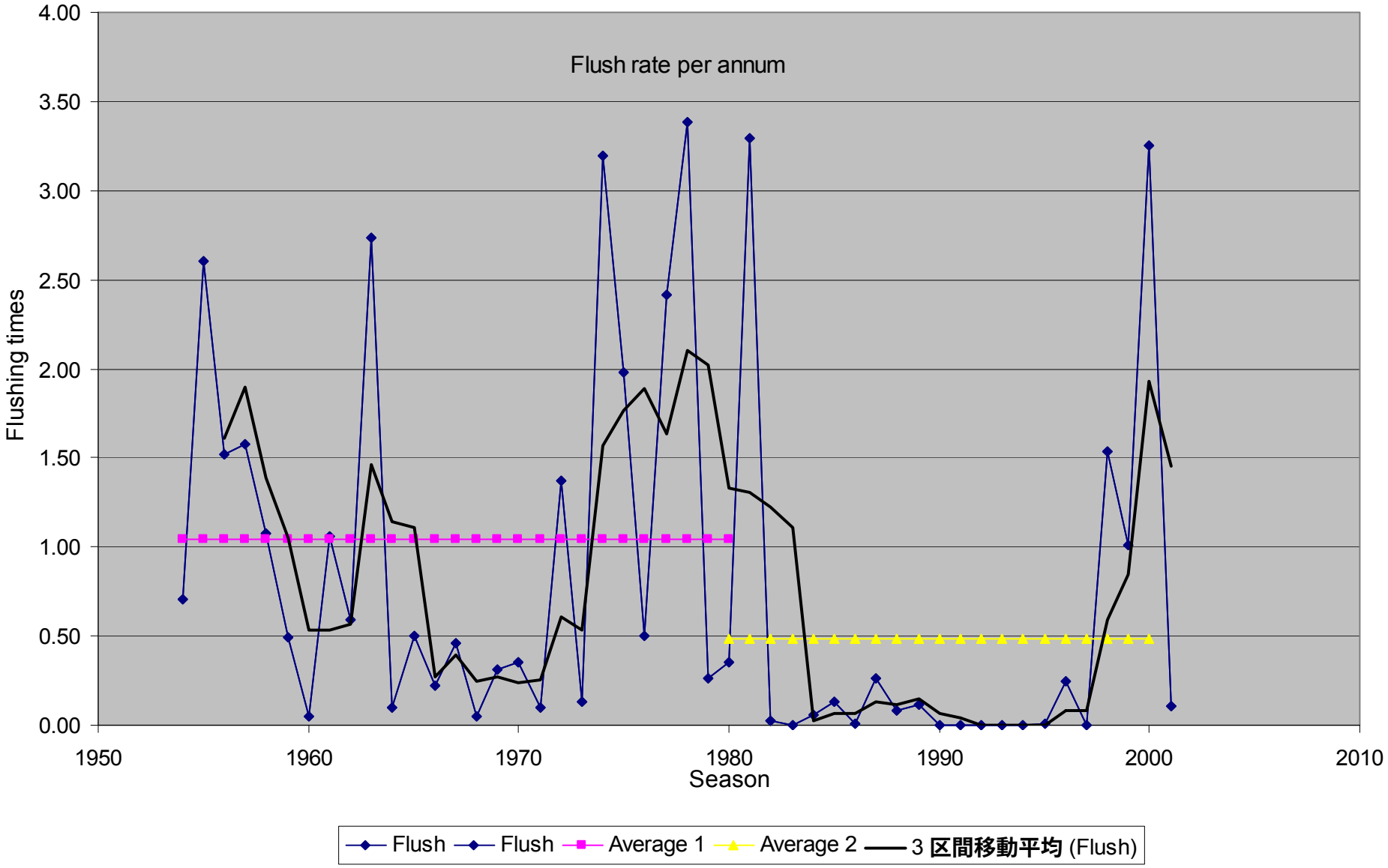
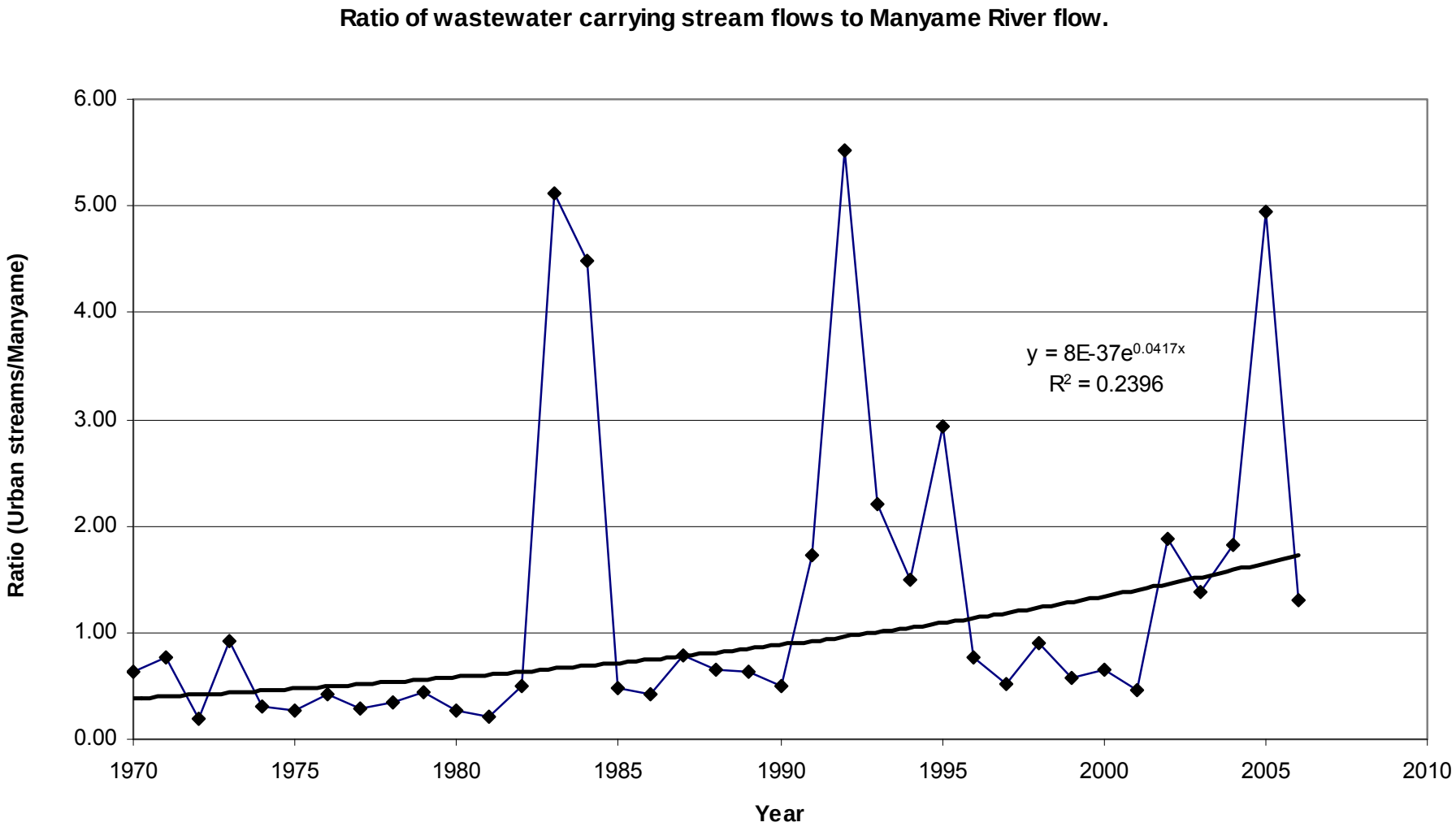


Fig 5. Ratio of wastewater carrying stream flows to Manyame River flow

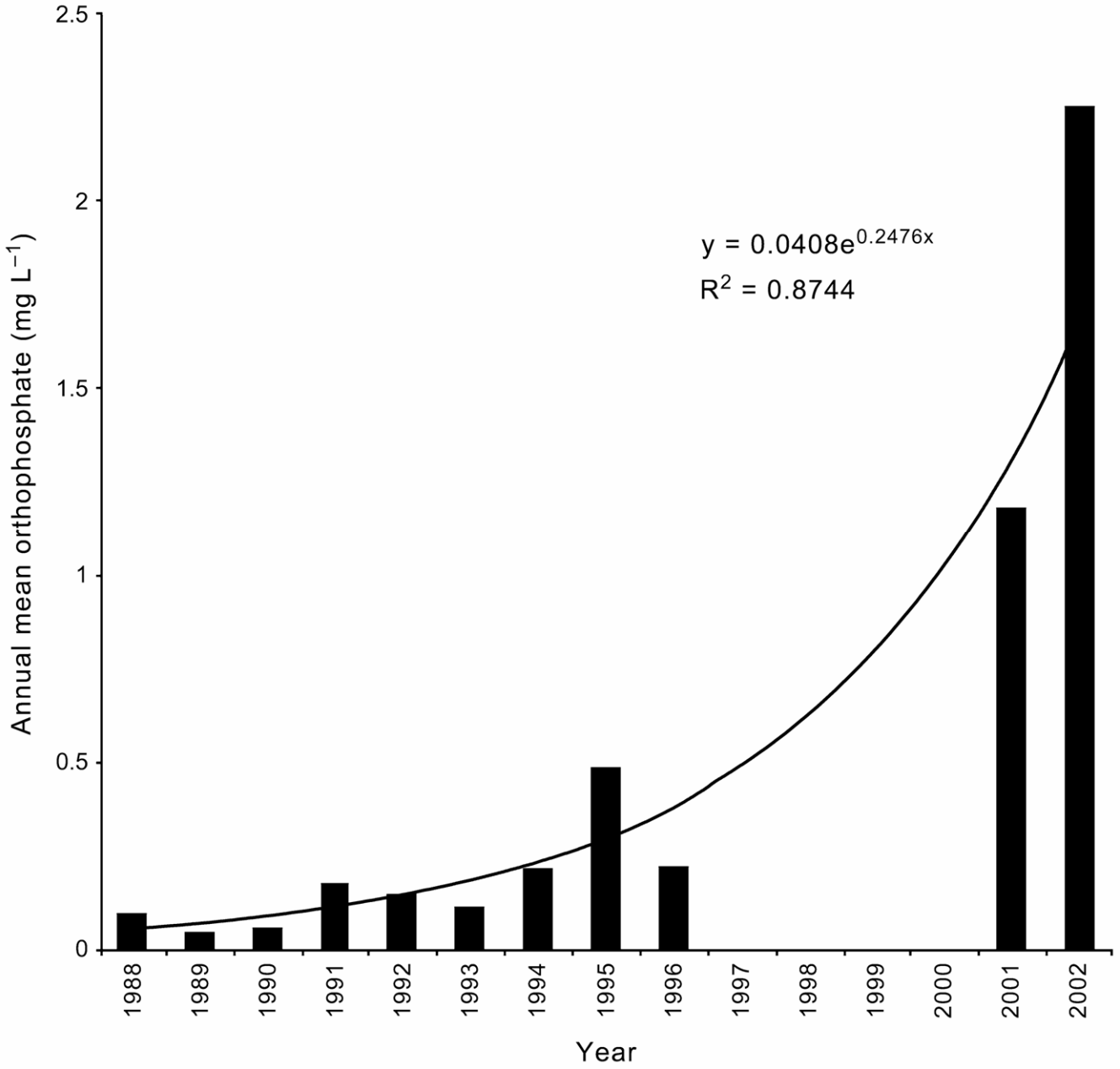


In summary

- Population growth in the Lake's urban watershed has outstripped the city's service capacity
- Unmanaged diffuse sources of phosphorus and nitrogen emanating from poor urban sanitation and sewer breaches constitute a significant cause of eutrophication.
- Poor maintenance of infrastructure has greatly compromised the urban settlement's ability manage their waste waters.
- Growth of high density satellite settlements with weak revenue bases poses funding problems for services provision and development.
- Changes in flow of the Manyame River have resulted in wastewater returns being a major component of the lake's hydrological income.
- Directed Scientific research on management of the lake has low priority.

Current status and some impacts of eutrophication of L. Chivero.

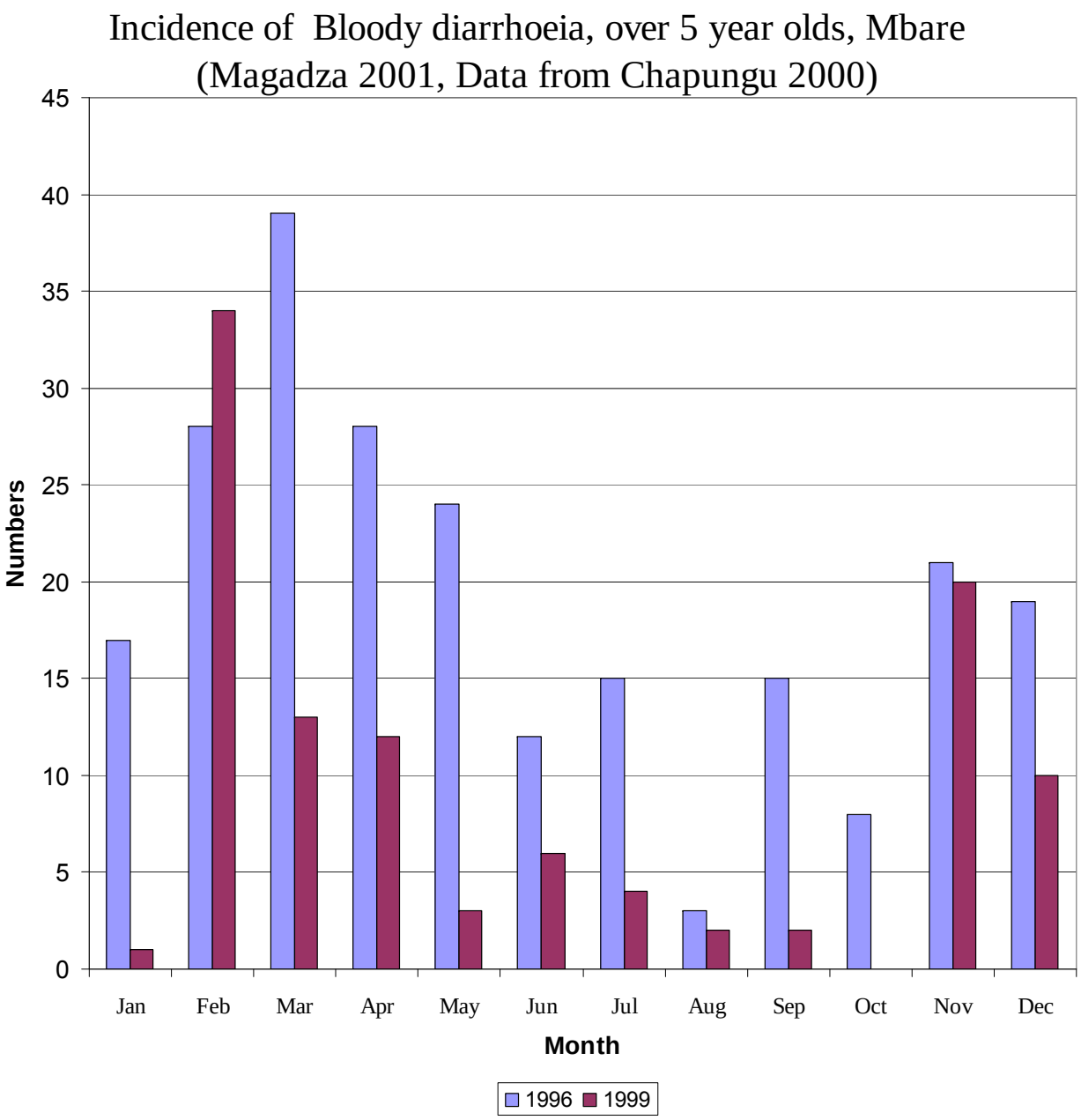
Increase in reactive phosphorus (mgl^{-1})



Algal scum, Chivero (Photo C.H.D. Magadza)

Sediment from municipal water supply in a bath tub (Photo C.H.D. Magadza)

Bloody diarrhoea



Enteric diseases deaths

Fig 7. Enteritis deaths per thosant infectd

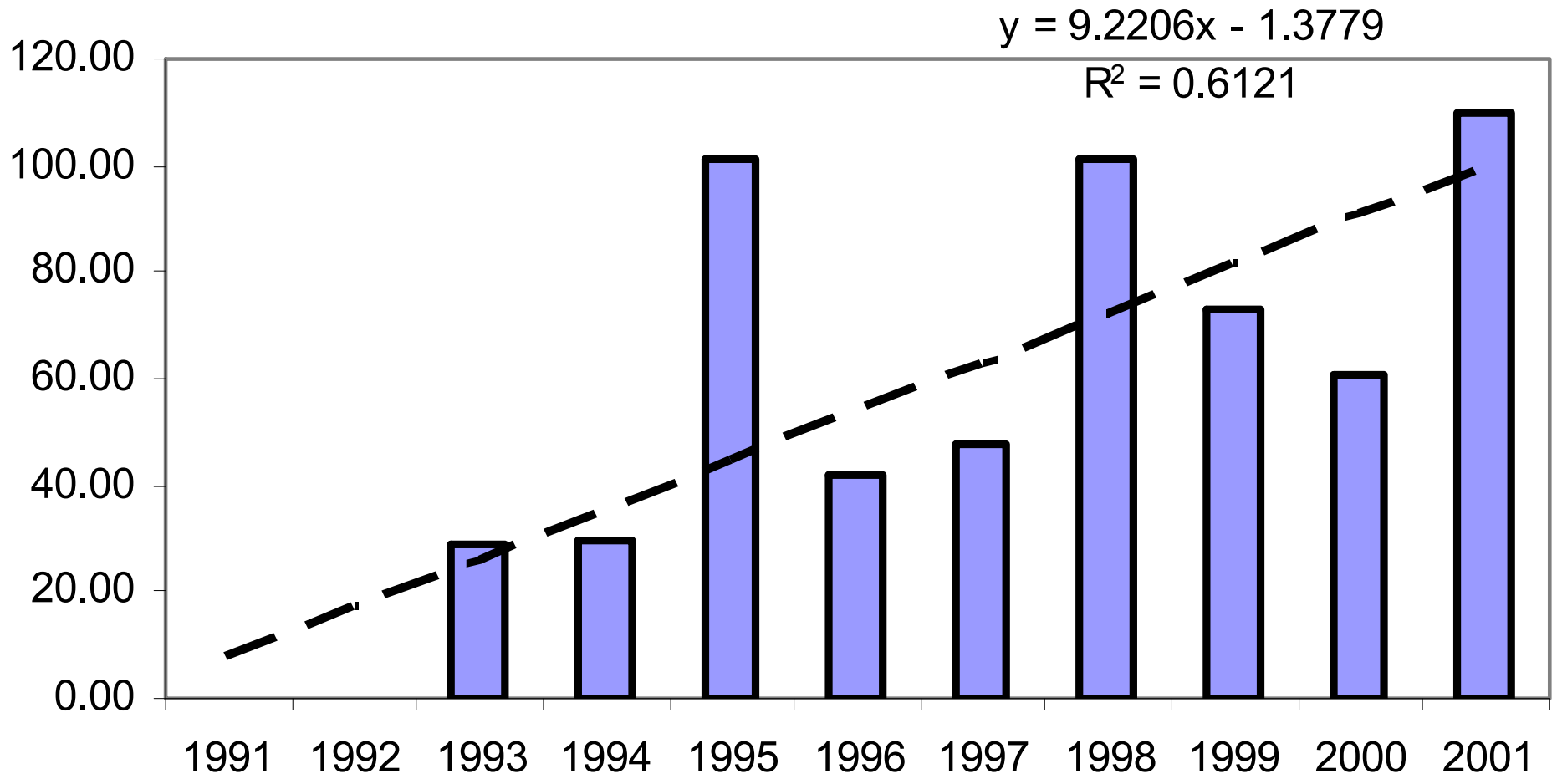
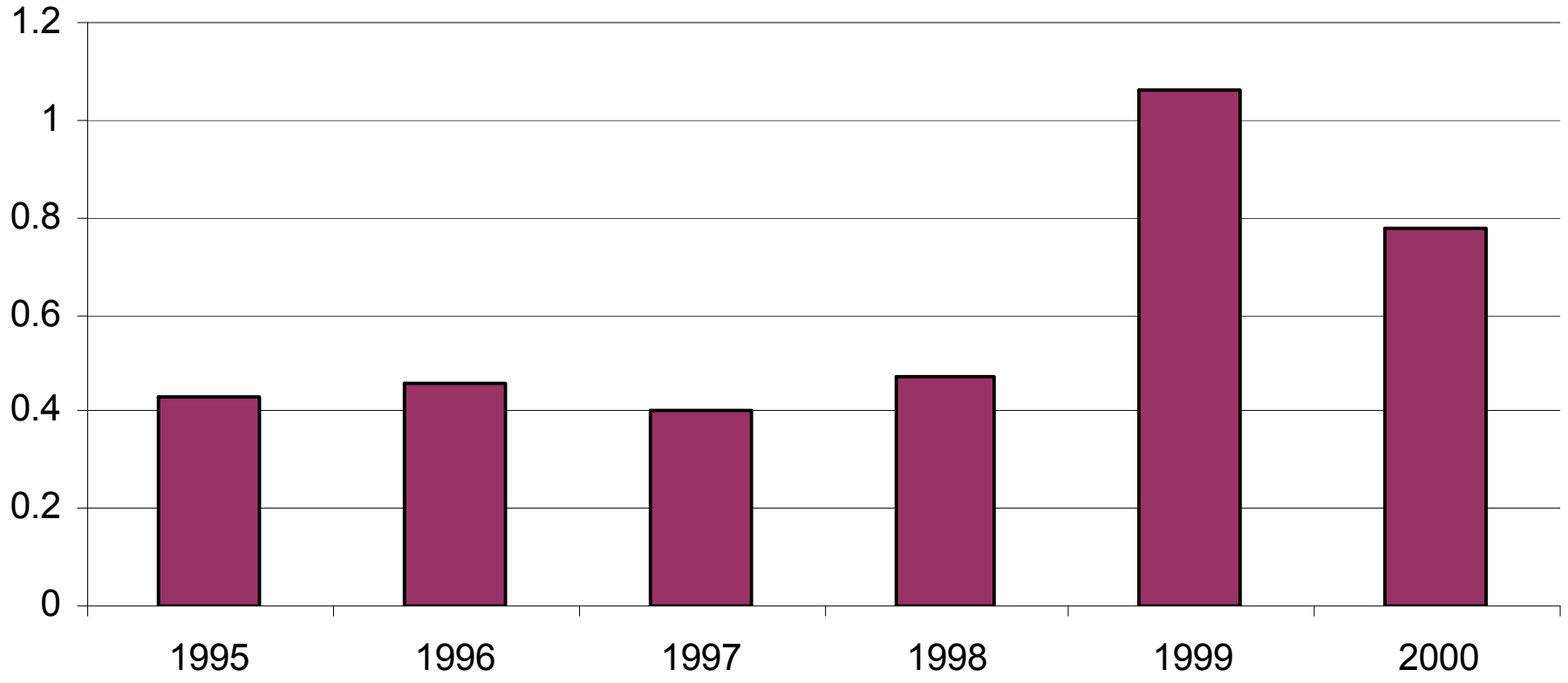


Fig. 8. Liver cancer: incidence/1000. This disease is associated with microcystin from cynobacteria



Water borne parasitic diseases

The discharge of raw or partially treated sewage exposes the Greater Harare population to a variety of parasites, namely

- Protozoan (e.g. Endamoeba, Trichomonas, Giardia).
  - These are generally less than 10μ in size and can thus pass through sand filtration.
  - Their cysts are resistant to chlorination.

- Various nematode parasites also discharged as cysts (e.g. Strongiloides sp)

- Trematoda (e.g. Clonorchis, transmitted by ingestion of inadequately cooked fish

- Schistosomes transmitted by making contact with ware containing cercaria e.g. during fishing, or waster sport. Surveys generally show a parasitaemia of about 60% in under 18 year olds in urban Harare

Solutions??

What can be done?

What can be done?

- **An important strategic approach is the implementation of the Seven Principles recommended by World Lake Vision Committee (2003).**

- This requires a major mind shift on the part of the management authorities on the rights and obligations of stakeholders.

- On the part of the citizens, it requires a sustained educational and awareness programme to educate them in how they impact on their water resources:
  - As part of school curriculum
  - As part of in house training for public servants
  - As a sustained media programme for the public.

Table 4. Evaluation of the management of Lake Chivero against World Lake Vision Committee (2003) Seven Principles (International Lake Environment Committee (IEC)/ United Nations Environment Programme-International Environmental Technology Centre (UNEP-IETC).

Principle	Compliance status	Comment
1.A harmonious relationship between humans and nature is essential for the sustainable use of lakes	Conflicts between nature and human	Poor compliance of policy and legal provisions by society, industry and state institutions
2.A lake drainage basin is the logical starting point for planning and management actions for sustainable lake use	Principle not applied	No linkages between various jurisdictions and management authorities in the drainage basin, in spite of institutional structures (watershed councils) set up to facilitate this.
3.A long-term, preventative approach directed to preventing the causes of lake degradation is essential	No evident long-term plan	Management strategies now consist of responding to crises.
4. Policy development and decision making for lake management should be based on sound science and the best available information	Poor application of scientific approach.	In initial planning of the lake scientific knowledge on function of aquatic systems was limited, but subsequent research by independent researchers has built up a good knowledge base which can be used for management of the lake.
5.The management of lakes for their sustainable use requires the resolution of conflicts among competing use of lake resources, taking into account the needs of present and future generations and of nature	No attempt to resolve conflicts	The major conflict is the use of the lake for potable water supply, recreation and fisheries and as a wastewater receptacle at the same time. State is hostile to stakeholders involvement
6 Citizens and other stakeholders should be encouraged to participate meaningfully in identifying and resolving critical lake problems.	Principle not adhered to	The state system has very little room for inclusive participation by non state entities. There is no intension by managers to consult with rate payers, or consult other technical expert groups, such as universities and the Zimbabwe Academy of Sciences
7 Good governance, based on fairness, transparency and empowerment of all stakeholders, is essential for sustainable lake use.	Poor, but punitive governance.	Although the national water authority was set up in the spirit of this principle it has turned out to be principally a revenue collector for little services in return. Breached sewers go unattended for weeks or months. On the part of the municipality, refuse collection is infrequent.

Ecological methods

- **The other strategy is use of ecological methods for runoff water quality control.**
- Studies on the Mukuvisi River, one of the major nutrient contributors to the lake, have shown that the wetlands associated with this river have considerable water quality restoration (self purification) capacity (Machena 1997)
- A series of well landscaped constructed wetlands could reduce non point source nutrient loading
- Such wetlands could also contribute wetland ecosystem biodiversity.

Anticipatory planning

- Planning personnel in the water resource management have indicated to the author that a major development project cycle, from the initial decision, to commissioning, is often more tan ten years

- This means that the planned utility life span for the service being developed must be at least two to four times the demand doubling period

Lessons learned

- Population growth in L. Chivero urban areas is doubling every 12 years.
- Wastewater management development has lagged well behind wastewater processing capacity needs.
- Out of an estimated total daily wastewater flow of 387 Ml per day from greater Harare only total wastewater processing capacity is only 202 Ml per day, leaving a deficit of 185 Ml per day.
- In addition non point source effluent contribute more than 300 tonne phosphorus and 1000 tonnes nitrogen, sufficient to maintain the lake in a hypereutrophic state. Thus developing capacity to manage piped wastewater effluent without parallel capabilities in non point source pollution control will not solve the L. Chivero eutrophication problems.
- Microcystin levels in the lake now exceed recommended health limits by a factor of 20.
- Combination of inadequate wastewater processing capacity and frequent failures at wastewater processing facilities have now rendered the Lake Chivero water supplies a health risk o an urban pollution same 5 million people.
- Liver cancer and enteric diseases are on the rise.
- Poor governance leading to inadequate funding for development and maintained of wastewater treatment facilities is a major contributing factor.
- The situation calls for innovative technical methods in urban wastewater management in a developing country.