

Water Supply for Monrovia (Liberia)¹: During and after the civil war

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Background

The Water Treatment Plant (WTP) of White Plains was initially built in 1960 to cope with the increased needs of the town's population, which could no longer be covered by the old infiltration galleries on Bushrod Island. The plant is located on the banks of the Saint Paul River, some 12km from the town. Several extensions were made to the plant in 1968 and 1982. The total capacity was increased to 60,000 m³/day, or 16 million US gallons per day (MGD), with loans from the World Bank and the Government of Finland. This included a new intake with water diverted directly from

the Mount Coffee dam to the station, the older intake being affected by salty water due to low water levels in the Saint Paul River during the dry season. From the intake, raw water was piped by gravity some 5km downstream through a main transmission pipe 42 inches in diameter. An average of 60,000 to 65,000 m³/day (16-17 MGD) was delivered to the station and then treated. The design treatment capacity of the station was set at close to 60,000 m³/day (16 MGD). The treated water was then pumped to the town through two principal transmission mains of 16" and 36" diameter.

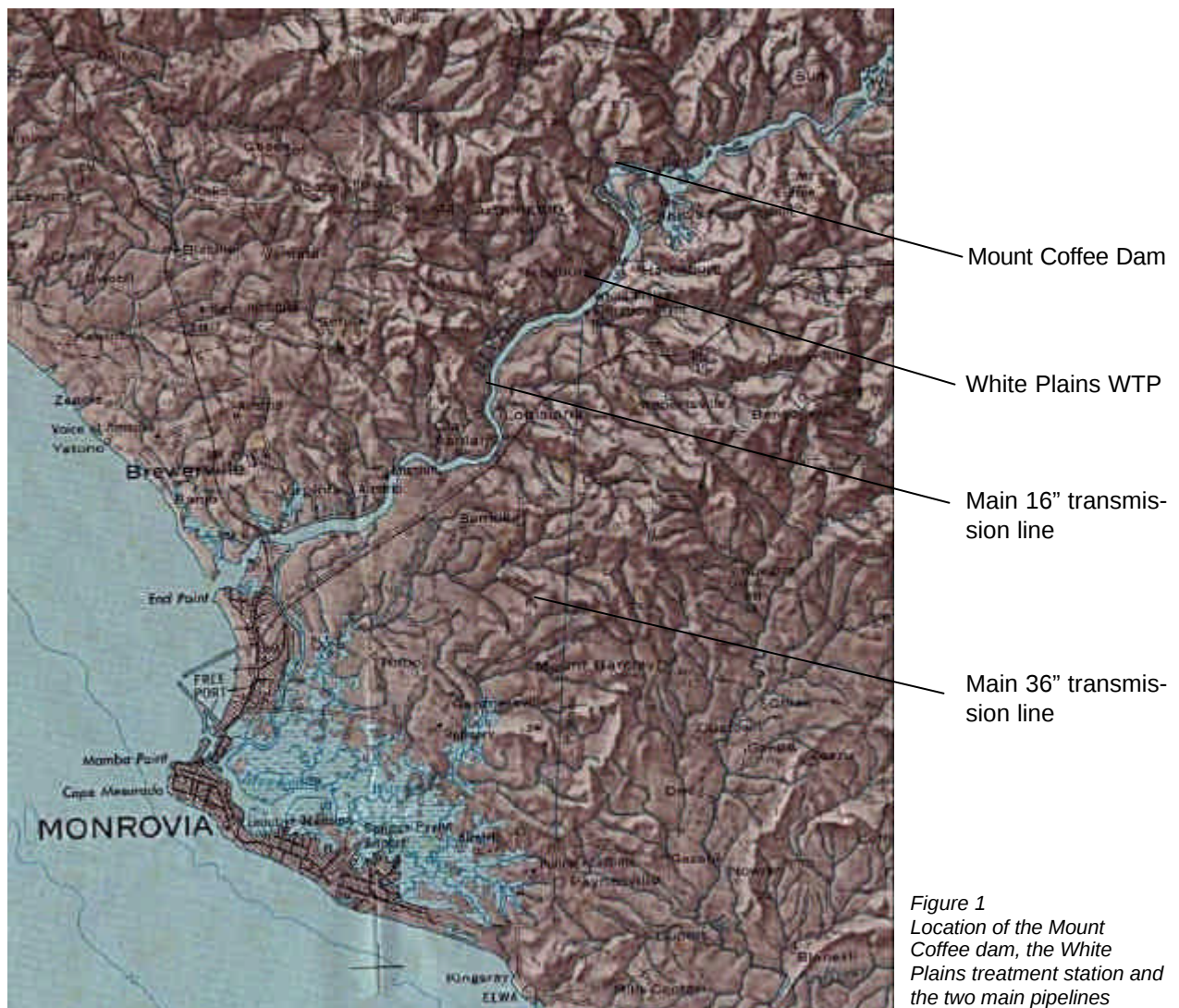


Figure 1
Location of the Mount Coffee dam, the White Plains treatment station and the two main pipelines

¹ The opinions expressed in this paper are those of the author and do not necessarily reflect the views of the ICRC, of Geoscience, of the Liberia Water and Sewer Corporation, of the Government of Liberia or any other institution quoted.

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In normal times some 60-65,000 m3/day (16-17 MGD) were delivered to the 400 to 500,000 townspeople, an average apparent daily delivery per capita of more than 100 litres, although the real figure is closer to 50 litres per day if losses in the distribution network are taken into account. Before the war, the station was already in bad condition due to poor maintenance. Figure 1 shows the location of the facilities:

The White Plains station

The station was designed to treat water in a conventional way. Turbidity is removed with aluminium sulphate, the water is then allowed to settle in four sedimentation basins (each with a 500,000 gallon capacity), and then filtered through eight rapid sand filters equipped with high-pressure backwash facilities. There is a provision for pre- and post-chlorination. The former was abandoned and only the latter was being done, using gas chlorine. The treated water was then stored in two clear water reservoirs with a capacity of 2.5 MG (about 9,500 m3). The water was then pumped into the transmission mains via four high-service pumps (three Worthingtons and one KSB) with a maximum capacity of 8 MG/day (1,200 m3/h) each.

A brief description of the transmission system

The distribution mains consist of a 16" cast iron (CI) pipe that reaches the town via Caldwell along the UN Drive. It narrows to 12" at the bridge over the Mesurado Channel and continues on to Mamba Point. The 36" pre-stressed concrete main reaches Paynesville from White Plains, continues on to Congotown and Sinkor and narrows to 24" and then to 16" before reaching the Mamba Point Booster. A 16" pipeline links the Paynesville and UN Drive mains along the freeway. There are reservoirs at Ducor (2,200 m3) and City (3,785 m3).

Overall, there are 48 km of 36" mains and 26 km of 16" mains. Before the war, they supplied approximately 75 % of the city through nearly 20,000 connections. The recent history of the water supply of the town of Monrovia is intimately linked with the onset of the conflict in early January 1990 and with its evolution during the first years of the civil war. The location of the White Plains water treatment plant made it vulnerable to attack by the warring factions. The civil war reached Monrovia in June 1990 and the plant ceased operating on 27 June, following military action in the area.

The chronology of events since the beginning of 1990 is given in Table I.

The situation at the treatment plant in mid-November

Security was one of the main problems to be solved if regular operation of the plant was to be maintained. During the attacks, the plant suffered minor to heavy damage. LWSC (Liberia Water and Sewage Corporation), with the assistance of MSF-Belgium and other organisations, attempted, in precarious conditions, to repair some of the damage. However, access remained one of the major difficulties, as did the lack of power, chemicals and people to operate the plant.

1990	
January	Civil war breaks out.
May	The last commercial flight leaves Robertsfield International Airport.
June	Fighting is reported between the two rebel factions of Taylor and Prince Johnson at Gbarnga.
June	White Plains is controlled by Taylor and water stops flowing to the town. Rebels reach Monrovia. Fighting within the town between government troops (S. Doe) and rebel factions. Electricity supplies are cut.
July	Mount Coffee hydroelectric dam collapses, as floodgates cannot be operated for unknown reasons. Widespread looting and destruction in Monrovia.
August	ECOMOG peacekeeping forces arrive in Monrovia on 25 August.
September	Death of President Doe.
October	Aid workers (MSF and Catholic Aid) withdraw from Kakata as Taylor's forces are pushed back by ECOMOG.
November	Taylor's rebels attack White Plains on 9 November and seriously damage the transformers, several motors and electrical panels of the station. An intensive operation is launched by ECOMOG/INPFL to clear and regain

*Table I
A chronology of the main events that affected water and power supply in 1990*

On 21 November it was possible to replace the damaged transformers and carry out other repairs. The stock of treatment chemicals (3 MT) supplied by MSF-Belgium (*Médecins Sans Frontières Belgique*) was in principle sufficient for six weeks and operators were available to run the station. But water was not distributed until 24 November due to lack of power. After the destruction of the Mount Coffee hydroelectric dam, Monrovia was without a reliable source of electrical power due to the lack of fuel (diesel) to operate the gas turbines. The only power unit still operational (a Mitsubishi electrical generator) was running erratically and therefore unreliable.

An initial production target of 20% of design capacity was set. Production data were collected at the station in early March 1991 and are presented in Figure 2. The data collected give the number of hours of operation per day of the low-lift and high-lift pumps. Of the three operational high-lift pumps, two were generally used during this period. Three pumps were operated for only two days in December and four days in January. Volumes can only be extrapolated from the estimated pumping capacities of the pumps, given the total number of hours, as no flow metres were operational. As shown

by the graph, production was quite erratic, reaching, when volumes are computed using mean values, only about 20% of design capacity in December and about 25% in January. The values obtained are subject to systematic error, as the capacity of the pumps must be estimated. It was assumed that the two high-lift pumps in operation had an output close to 12.5 MGD, slightly higher than the 5 MGD used by LWSC for the 8 MGD Worthington pump. The only measurements available are from Williamson⁵, who estimated the flow in 1986 and 1987 by measuring the drop in the level of the clear water store. His conclusion was that, while in 1986 two pumps produced 15-16 MGD, this had dropped to 12.5 MGD the following year. The difference in the computed volumes differs only by about 5% and should not significantly affect the results of this study, as drastic changes will be observed during the following years. Mean values could lead to confusion as one might think the set target has been reached. Daily data shown in Figure 2 give a better idea of the problems faced by the utility. Production was irregular, with eight days without distribution in December and ten in January, leading to low average results typical of systematic power failures in conjunction with other technical problems.

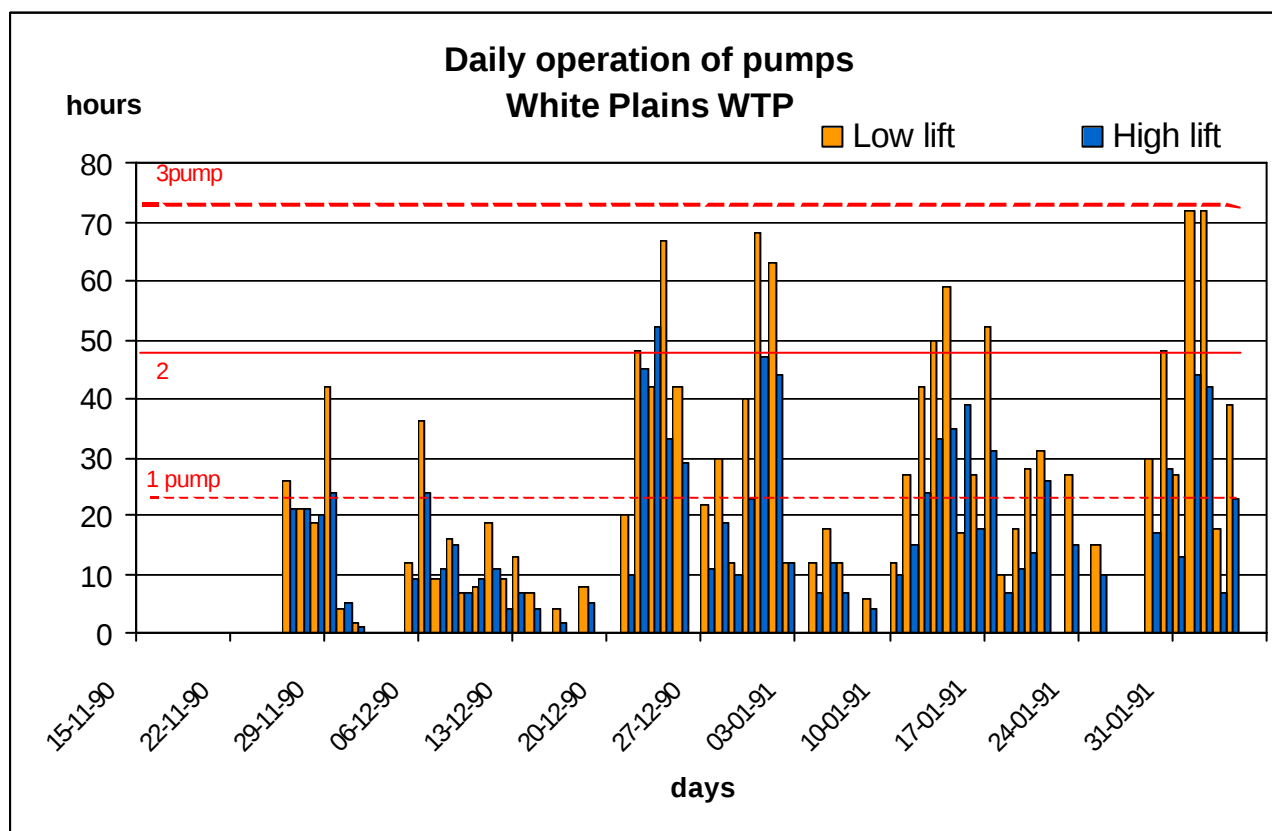


Figure 2
Hours of operation of the low-lift and high-lift pumps

⁵ Williamson, D., 1987 "Monrovia Water Supply - Transmission and Distribution", LWSC Internal Report, March 1987, 28 pp.

Water quality and chemical treatment

In principle, the technicians based at station's laboratory carry out hourly determinations of several parameters: pH, residual chlorine, turbidity, and colour. Fortunately, the raw water is of good quality. Turbidity rarely exceeds 20-30 NTU and is easily removed by coagulation with aluminium sulphate. Critical measurements such as the proportioning of aluminium and aluminium residual concentration in the clear water were not performed, as no instruments were available (visible spectrum photometer and Jar test apparatus). Aluminium was added with the use of mechanical feeders. The two mechanical feeders were quite corroded and only one was in working condi-

tion. Proportioning was done without benefit of any analytical test, as no Jar test instrument was available. Nevertheless, the water reaching the filters was of quite good quality, even though the flocculation paddles of sedimentation basins 1 and 2 were out of order. Mixing basins 3 and 4 were not equipped with any device, which did not produce any significant difference in the results. Aluminium sulphate was added to the water at a rate of 10 g/m3, as can be calculated from the daily consumption and from the computed raw water volumes, based on pumping hours. The values are consistent with previous data and should in principle reflect varying turbidity, but most probably only reflect the variation in the quantities produced.

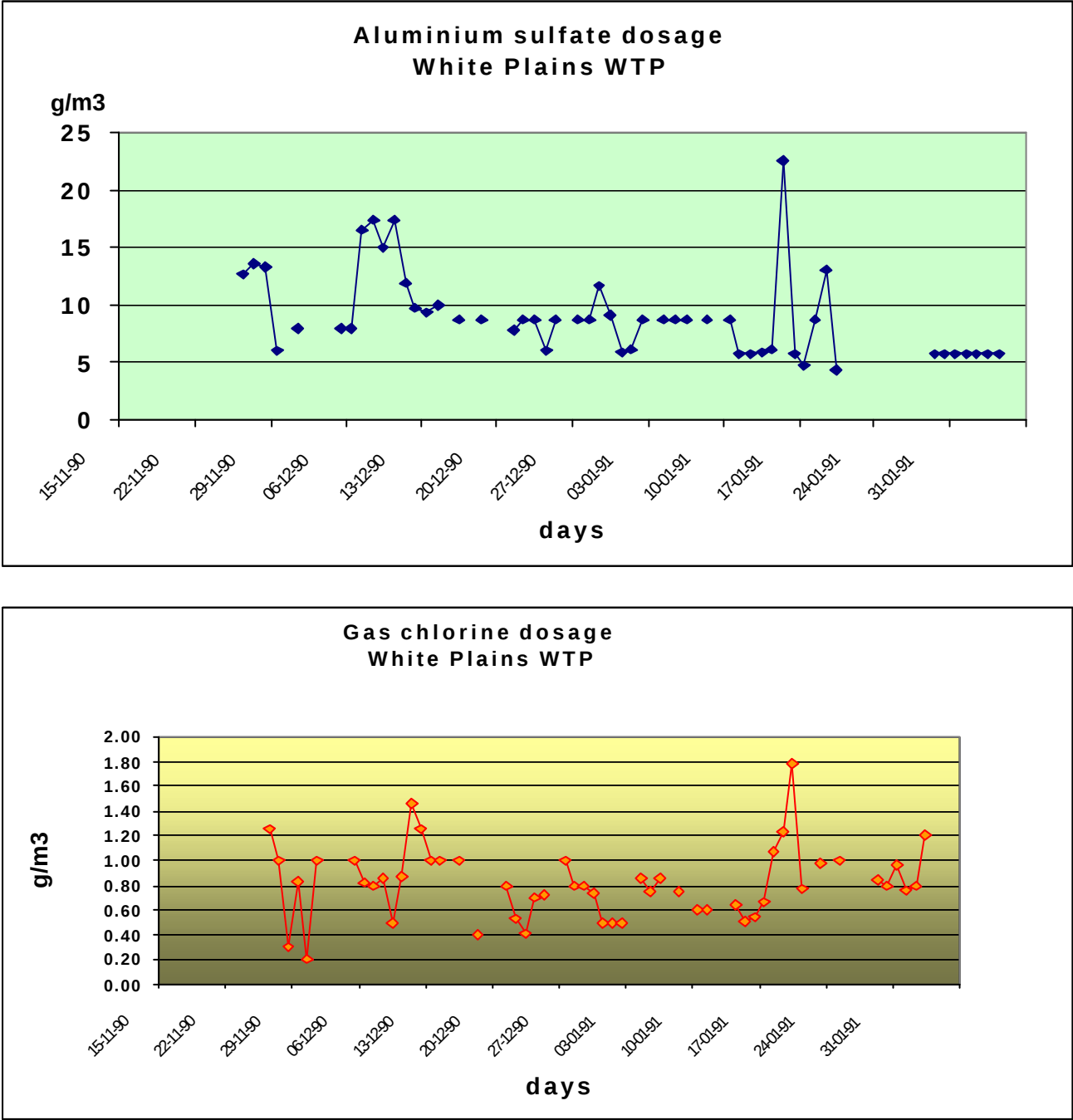


Figure 3, 4
Proportioning of aluminium sulphate and chlorine

In the two months following the resumption of water production, the average consumption of aluminium sulphate was 8.7 kg/1,000 m³ in December and about 6.0 kg/1,000m³ in January. Chlorine was added at a rate varying from 0.6 to 1.0 g/m³, which is confirmed by the rough concentrations calculated using the previous assumptions. Data on residual chlorine in the network were not available and no organised sampling programme was carried out.

The effects of the civil war on power production

Before the civil war, the bulk of Monrovia's power supply (46 MW base load and 65 MW peak load in 1985) came from the Mount Coffee hydroelectric dam on the Saint Paul River, 27 km to the north-east of the city. From May to October (rainy season) Mount Coffee provided up to 64 MW but this dropped to less than 2 MW at the height of the dry season. Monrovia's power needs were then met by a disparate assortment of oil burning generators at LEC's (Liberia Electricity Corporation) Bushrod Island Plant: four BBC (Brown Boveri Co.) diesel (gas) oil-burning turbines, with a total of 68 MW; three B&W (Burmeister & Wain) slow-speed 2-stroke heavy oil-burning diesel engines, of 13.6 MW each (Luke Plant); and two medium-speed Mitsubishi diesels of 5 MW each (Bushrod Plant). In addition, 15 MW were provided directly to the key consumers under an exchange agreement with Bong Mines. When the civil war reached Monrovia in July 1990, two B&Ws, both Mitsubishis and one BBC gas turbine were operational. Bong Mines was supplying only 7.5 MW because of a transformer failure. On 13 July the Mount Coffee dam collapsed, depriving Monrovia of its principal source of power. In September a voluntary force was set up to run the Bushrod power station. Mitsubishi Unit 2 was severely damaged and beyond repair. One Mitsubishi power generator was in operating condition. B&W Unit 3 was reduced to half power due to over-heating problems. Up until 23 November, when the diesel stocks ran out, power for the city was provided mainly by one 15 MW gas turbine. In early December MSF brought in two engineers with direct experience with B&W engines and Luke Unit 3 was restarted. At the end of January the unit again experienced problems, and again a specialist had to be brought in this time by UNICEF. By the end of March 1991 the Unit was able to produce 8 MW. The Mitsubishi was used intermittently and produced up to 2.5 MW.

The ICRC six-month programme: "Emergency Water and Power supplies for Monrovia"

The Luke plant power supply

An almost total breakdown of electricity production between 5 February and 8 March, poorly motivated White Plains plant operators who had not been paid since June

1990, and the threat of epidemic among the population, impelled the ICRC to become more involved in the rehabilitation of the station and in the production of electricity. With unrest limited to a few skirmishes, the ICRC committed itself to launching a project aimed at rehabilitating the two diesel-powered electrical generators (Luke plant Units 2 and 3, total capacity 27 MW, plus a Mitsubishi unit in fair working condition) and the White Plains WTP. The EC provided funds to the tune of 540,000 ECUs. The objectives of the ICRC were the following:

- Overhaul the two diesel-powered electrical generators at Luke plant that operated on heavy oil, which was available in large quantities, and support the staff with incentives;
- rehabilitate the White Plains station by providing laboratory equipment, tools and incentives for the staff;
- carry out major repairs on the network;

in order to maintain a **minimum production of water, at least 30% of the design capacity** (20,000 m³/day or 5.28 MGD) and distribute it to the town's inhabitants.

The programme started in May and was scheduled to end in October 1991, when it would be handed over to UNICEF. The latter was already involved in maintenance activities that were carried out by one of its engineers, who also prepared a large part of the inventory of spare parts needed to bring the two units back into regular operation. The ICRC programme was meant to speed up the intervention, owing to the emergency situation. UNICEF would take over the programme with the aim of running it in a sustainable manner. At the end of the programme, the following was achieved:

- Units 2 and 3 were operational at up to 7-9 MW each. During the project period power production averaged 6.0 MW. Fifteen per cent of it was used to produce and pump water into the network, which was operating at an average of 46% of design capacity.
- An express power line to White Plains was constructed, reducing the amount of power needed to operate the plant.
- Following the collapse of a sea wall, an emergency intervention saved the seawater pipeline, delivering cooling water to the two units at Luke plant.
- Sixty per cent of the plant was cleaned and degreased to reduce fire hazards.
- The project supported an average of 140 workers (including 125 permanent LEC workers) who received incentives.
- Maintenance tools were provided to the station as well as essential spare parts and lubricating oil.

Figures 5 and 6 show the evolution of power production during the project period. During the first three months, Unit 3 bore the brunt of the production. It took almost three months to bring Unit 2 back into operation, with the Mitsubishi unit used to maintain power above an average of 6 MW. Before the construction of the express line, the circuit that fed the station absorbed 2 MW, with the plant requiring about 1.6 MW to run at full capacity. Thus some 3.6 MW were necessary to operate White Plains. With the completion of the express line, demand was reduced to 1.6 MW and could be

covered with the Mitsubishi unit alone. The entire intervention was beset by one emergency after the other. For instance, the collapse of a sea wall put the whole heat exchange system in danger and the pipelines had to be protected. Oil spillage had to be confined and the whole plant cleaned up. The plant required constant surveillance and regular maintenance. It constantly needed spare parts that were hard to obtain without the regular involvement of an organisation capable of reacting quickly to emergencies.

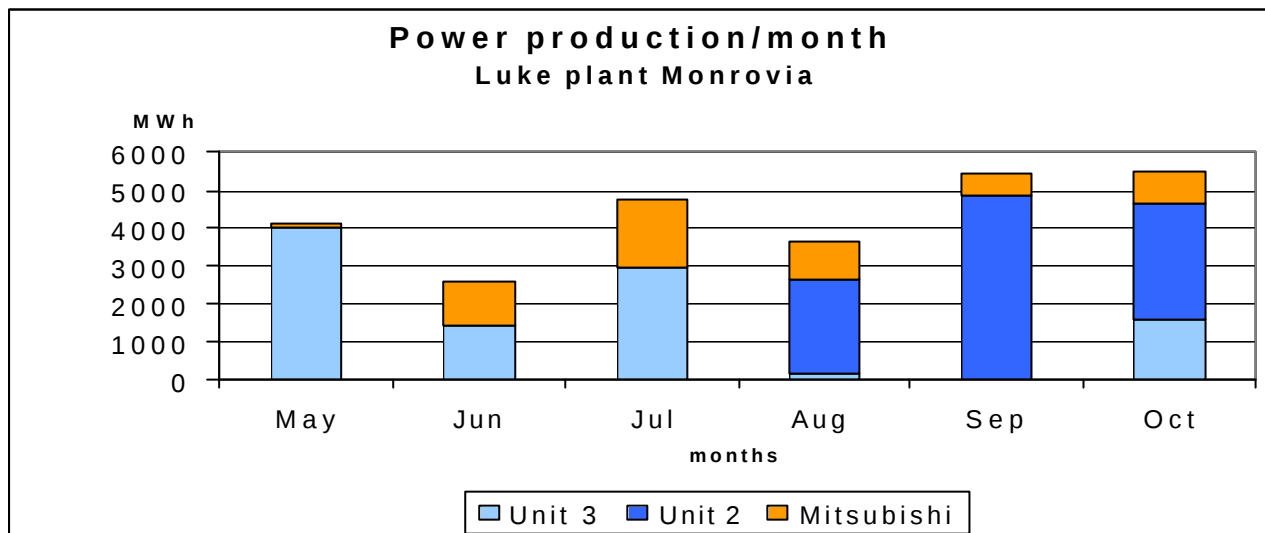


Figure 5
Monthly power production during the duration of the project by unit

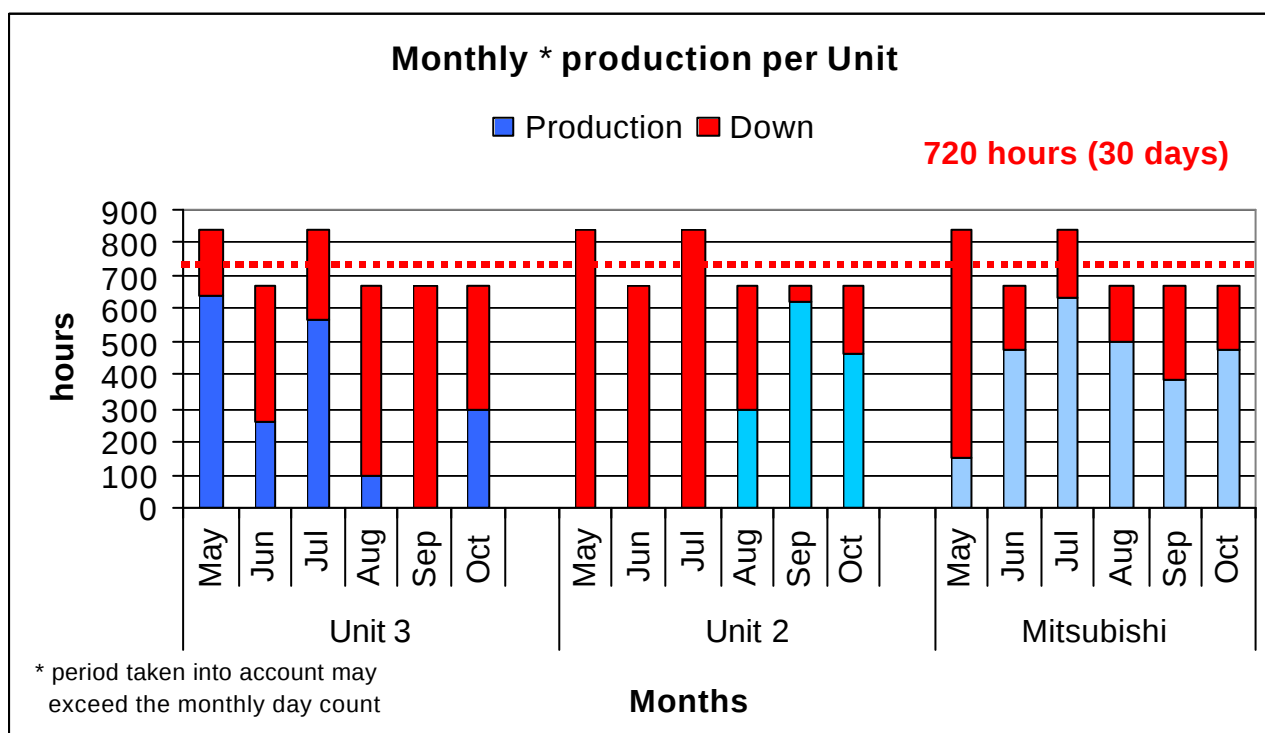


Figure 6
Monthly hours of production of the different units

White Plains WTP

At the WTP level, spare parts were provided to protect the circuits of the low-lift pumps, the flocculation and back-wash systems were rehabilitated, as were the water level and flow monitoring instruments. One hundred and sixty-four MT of Al_2SO_4 and 3.4 MT of chlorine were delivered to the stations and the laboratory was equipped with essential instruments, equipment and reagents to monitor the efficiency of the treatment.

The network

A total of more than 25,000 leaks in the distribution system were plugged (disconnected) and another 15,000 leaks were repaired. It was estimated that about 15,000 of the disconnections involved illegal prewar consumers. Many leaks were due to corroded pipes. The principal line valves on the 36" line were rehabilitated and five protective chambers constructed. Finally, 52 standpipes consisting of six faucets each were constructed in selected areas of Monrovia as substitutes for damaged distribution lines. The location of the stand posts is given in the next figure.



Figure 7
Location of the stand posts constructed during the ICRC emergency programme

White Plains Water Treatment Station (16 MGAL/day, 60,000 m³/day)



Backwash tower and sedimentation basin



Low lift pumps



Sedimentation basin and paddles



Diesel powered generators



High lift pump with diesel generator and electrical motor



The next figure shows the outcome of the programme. The mean monthly production was increased to an average of 46% of design capacity (7.6 MG/day, compared to 16 MG/day) almost reaching 12 MG/day in October and November, when the entire project was

put under the supervision of UNICEF. Although average production did increase, daily regularity still depended on the availability of power. The mean daily productions shown in the figure do not take into account days without water, or variations between days.

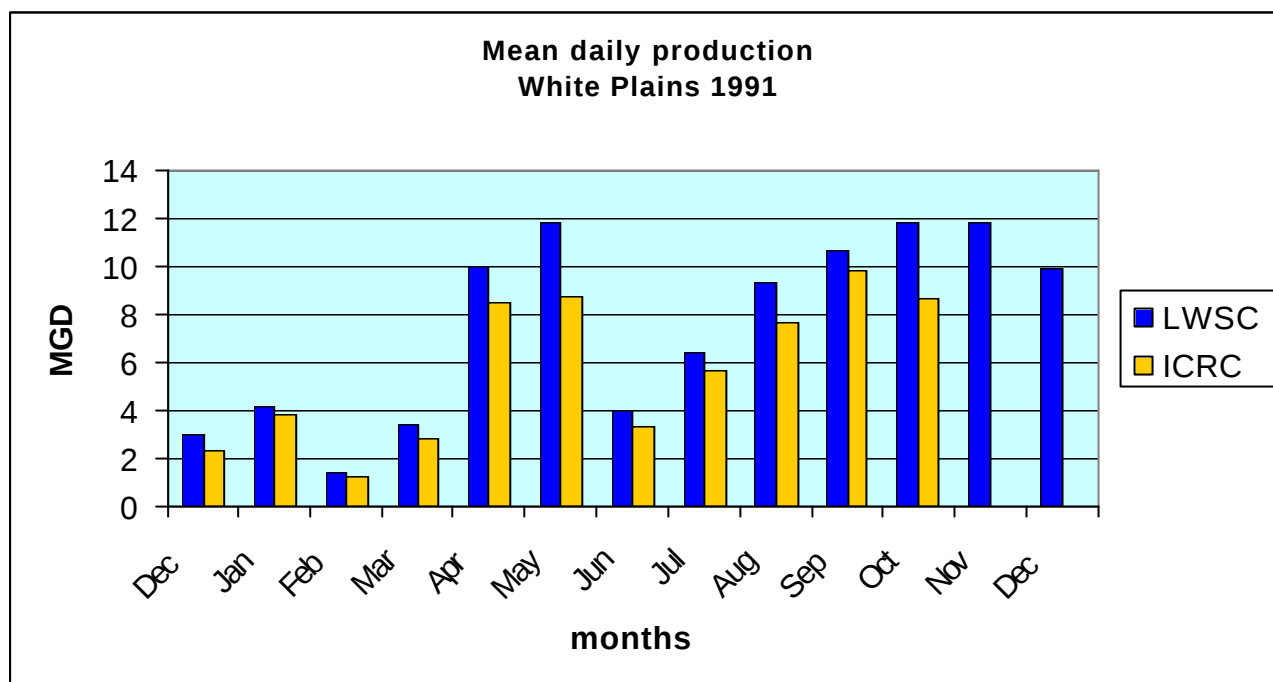


Figure 8
Mean daily production calculated from total monthly production

Precise figures are lacking, but the regularity of the production is probably best appreciated when weekly production hours are plotted (Figure 9). The main reason for fluctuations was power cuts, but also technical problems at the station, which were gradually solved or

improved upon. The main objectives of the project were reached, with a mean daily production considerably over the fixed target of 30% of design capacity, through the improvement of power production at different Luke Plant units.

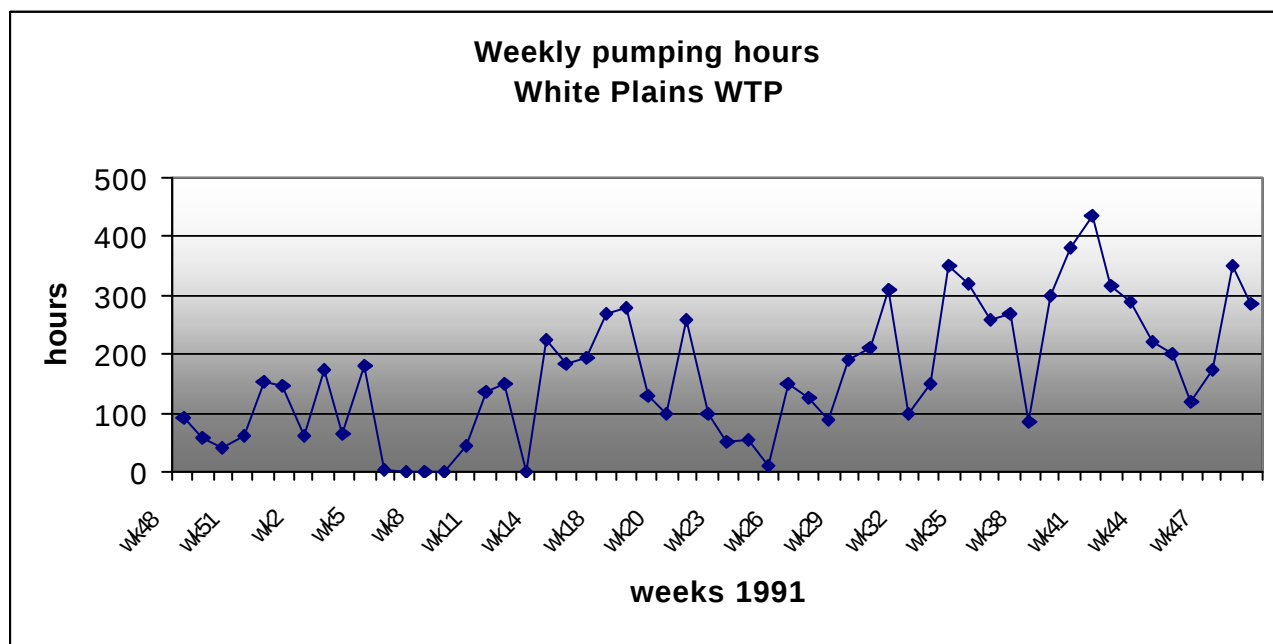


Figure 9
Number of pumping hours per week

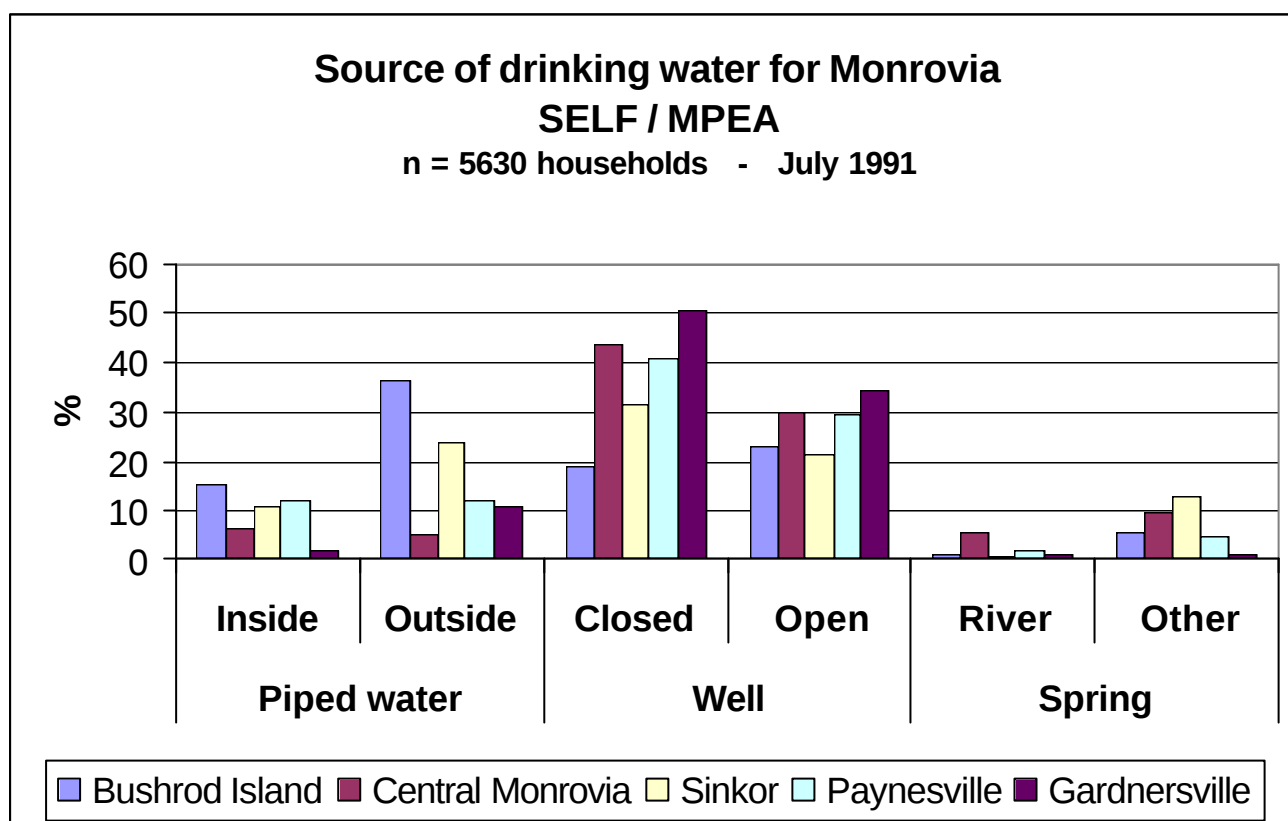


Figure 11
 Origin of water in several areas of Monrovia

By the end of 1991 a total of 51 shallow wells was completed and equipped with hand pumps (Kardia) and about 30 old wells were rehabilitated. The same approach was chosen by UNICEF, with a total of 20 hand-dug wells completed, mainly to supply schools. Five wells were completed by the Lutheran World Service. The approach was adopted by other NGOs and it was expected that the general condition of the wells would be improved. At the end of 1991 LWSC was considered to be in a better position to manage water production and distribution. However, the assistance of an organisation capable of making and enforcing the necessary reforms was still needed in order to make the best use of the meagre resources and adapt production targets to the new situation.

Rainfall collection

Average yearly rainfall in Monrovia is close to 4,500 mm. Collection of run-off from zinc roofs in buckets, drums and cisterns is widely practised and, in addition to the wells, permitted the survival of the population of the city from the end of June until November 1990, when distribution ceased completely. In principle, and with proper storage, rainfall would be sufficient to meet the needs of the city during the dry season. Water should be stored in large quantities to allow for consumption between rains.

Health problems and water-related diseases

In early February a survey carried out by MSF-Belgium among 302 households representing 4,191 people (3,432 adults and 759 children under five years of age) showed that the mortality rate was roughly 40/1000/year (confidence limits 18 to 62), almost twice the prewar figure of 17/1000/year (available for 1986 from the Liberia Demographic and Health Survey statistics), but obviously less than the rate observed during the civil war. Twenty per cent of people interviewed mentioned diarrhoea as a cause of death. Pathologies diagnosed in seven health clinics that carried out from 5 to 8,000 consultations per week, from 28.12.1990 until beginning of February, did not show high morbidity patterns for diarrhoea. The latter represented about 10% of the total number of consultations, malaria being one of the commonest diseases observed, at between 30 and 35%.

A slight increase in diarrhoeal diseases, up to 16% of cases, was observed in week 6, but data are lacking for the following period. Diarrhoea with blood represented between 4 and 4.6% of reported cases.

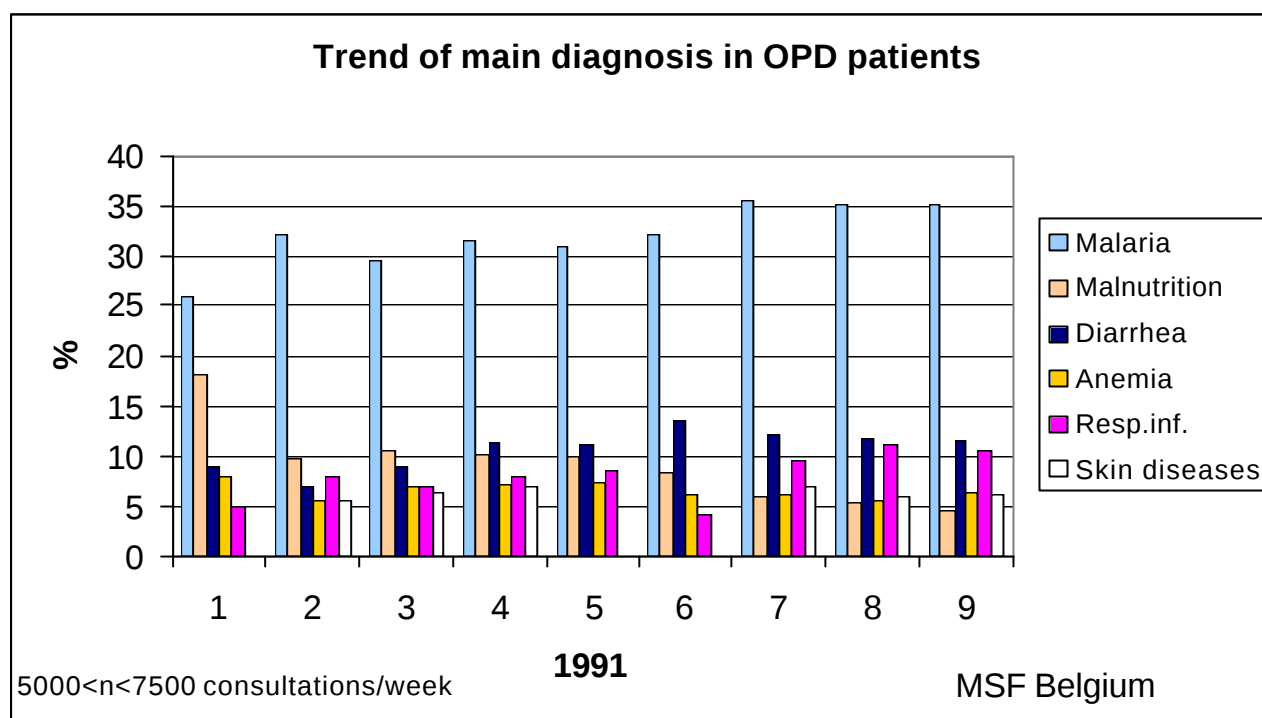


Figure 12

Trend of main diagnosis in seven health clinics just after the resumption of water distribution from White Plains

The 1992 water emergency and the beginning of the water trucking period

When the ICRC emergency project ceased, the mean daily production of water distributed to the town fluctuated between 6 and 10 MGD. At the end of October LWSC took delivery of 205 MT of aluminium sulphate purchased by the interim government, sufficient to cover consumption for at least six months. The production figures were maintained throughout 1992, with UNICEF providing technical support and equipment. At the same time, several programmes were started to construct or rehabilitate shallow wells within the city, following the earlier ICRC approach. Besides UNICEF, several organisations such as AICF (*Action Internationale Contre la Faim*), LWF (Lutheran World Federation) and other private agencies were also active in this field. Following the resumption of hostilities, the White Plains WTP was again damaged and stopped production on 19 October. Access to the station was considered too dangerous for normal and regular operation. The city was left with shallow wells as its only source of potable water and many of them would dry up at the onset of the dry season.

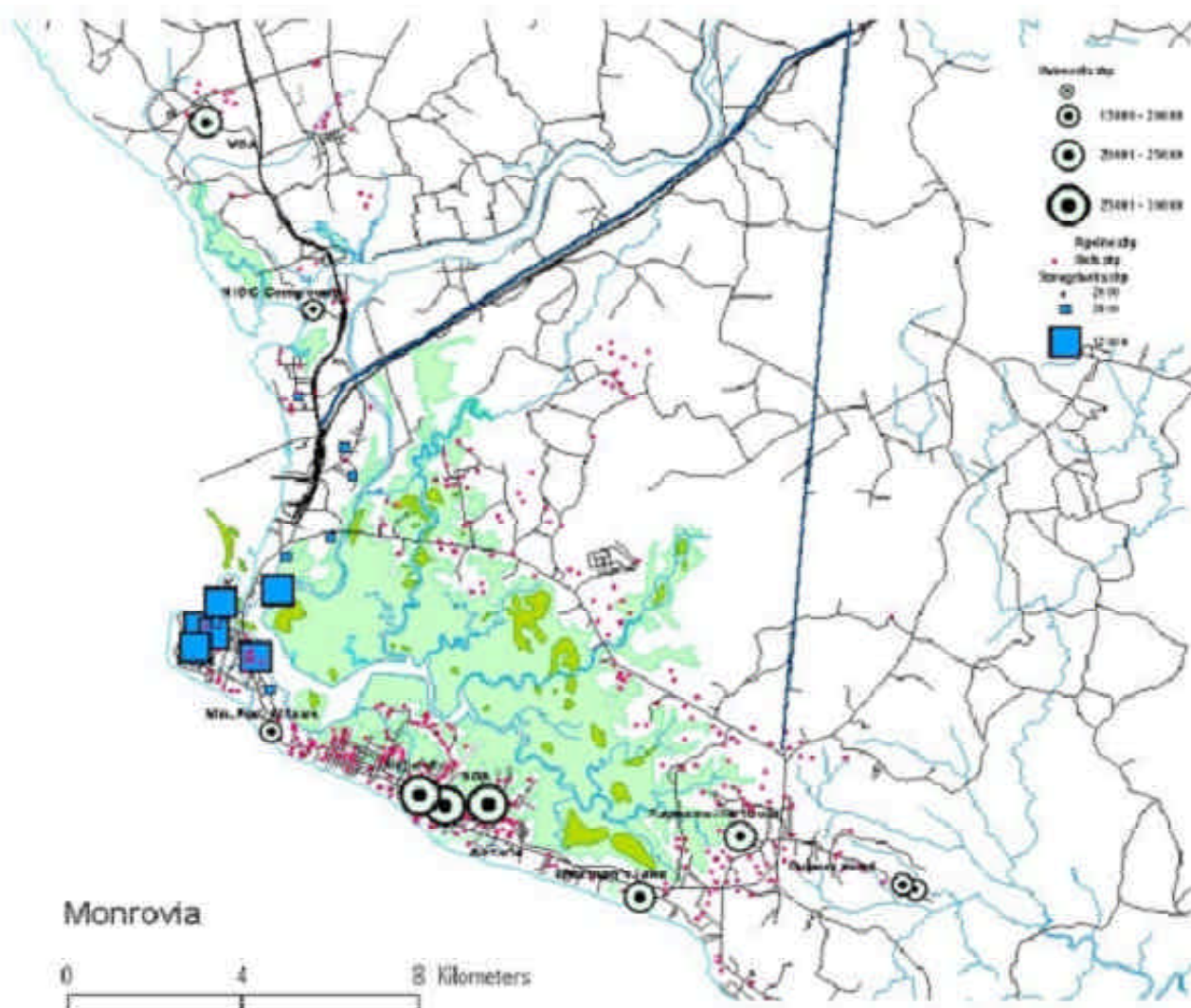
Unable to carry out specific damage assessment, and bearing in mind the needs of the inhabitants and the possible outbreak of communicable diseases linked with the lack of water, LWSC and UNICEF decided to launch an emergency water trucking programme. Several technical options were considered:⁶

- Identification of the main sources of water available in large quantities
- Identification of all water tankers available
- Organisation of a trucking operation
- Construction of deep water wells/boreholes
- Resumption of White Plains water production

The Interim Government of National Unity was approached to obtain formal approval from the Presidency for the requisition of all the water trucks available in the town, in order to start the water trucking operation. The latter was scheduled to last at least six months, the amount of time considered necessary to resume any activity at the station, given the extent of the repairs needed and the delivery time for supplies from abroad.

A preliminary survey identified the large-diameter wells capable of delivering water in sufficient quantities to fill up the tankers in a reasonably short time (less than 30 minutes for a 6,000 gallon tanker). During the first two weeks, when it was difficult to operate outside Central Monrovia, water was mainly pumped from the well located within the Ministry of Foreign Affairs and then gradually from other locations. The mean output of the seven wells in use was between 15 and 20,000 gal/day (56-75,000 litres). Limits were set on the output yields to avoid salt intrusion, and to take into account the effects of the dry season. The location of these wells is given in figure 13, together with the position of the main storage tanks to be filled by the tankers and from which the water would then be distributed to the public. The

⁶ UNICEF, Emergency Water Supply Operations for Monrovia, Present status and plans of action, December 1992



Attributes of Storage tank shp					Attributes of Storage tank shp				
Shape	ID	Type	Location	Cap. Gallons	Shape	ID	Type	Location	Cap. Gallons
Point	1	Tower No. 1	Broad Street	12000	Point	1	Tower No. 1	Broad Street	12000
Point	2	Tower No. 2	Benson Street	12000	Point	2	Tower No. 2	Benson Street	12000
Point	3	Tower No. 3	Mamba Point	12000	Point	3	Tower No. 3	Mamba Point	12000
Point	4	Tower No. 4	Benson Street	12000	Point	4	Tower No. 4	Benson Street	12000
Point	5	Tower No. 5	Soni el School	12000	Point	5	Tower No. 5	Soni el School	12000
Point	6	Tower No. 6	LEC Compd.	12000	Point	6	Tower No. 6	LEC Compd.	12000
Point	7	Oxlam 01	UN Drive	2500	Point	7	Oxlam 01	UN Drive	2500
Point	8	Oxlam 02	SDA Compd.	2500	Point	8	Oxlam 02	SDA Compd.	2500
Point	9	Oxlam 03	Clara Town	2500	Point	9	Oxlam 03	Clara Town	2500
Point	10	Oxlam 04	Logan town	2500	Point	10	Oxlam 04	Logan town	2500
Point	11	Oxlam 05	Jamaica Rd.	2500	Point	11	Oxlam 05	Jamaica Rd.	2500
Point	12	Oxlam 06	SKD Comm.	2500	Point	12	Oxlam 06	SKD Comm.	2500
Point	13	Oxlam 07	New Kou Town	2500	Point	13	Oxlam 07	New Kou Town	2500
Point	14	Metalic tower	West Point clini	2000	Point	14	Metalic tower	West Point clini	2000

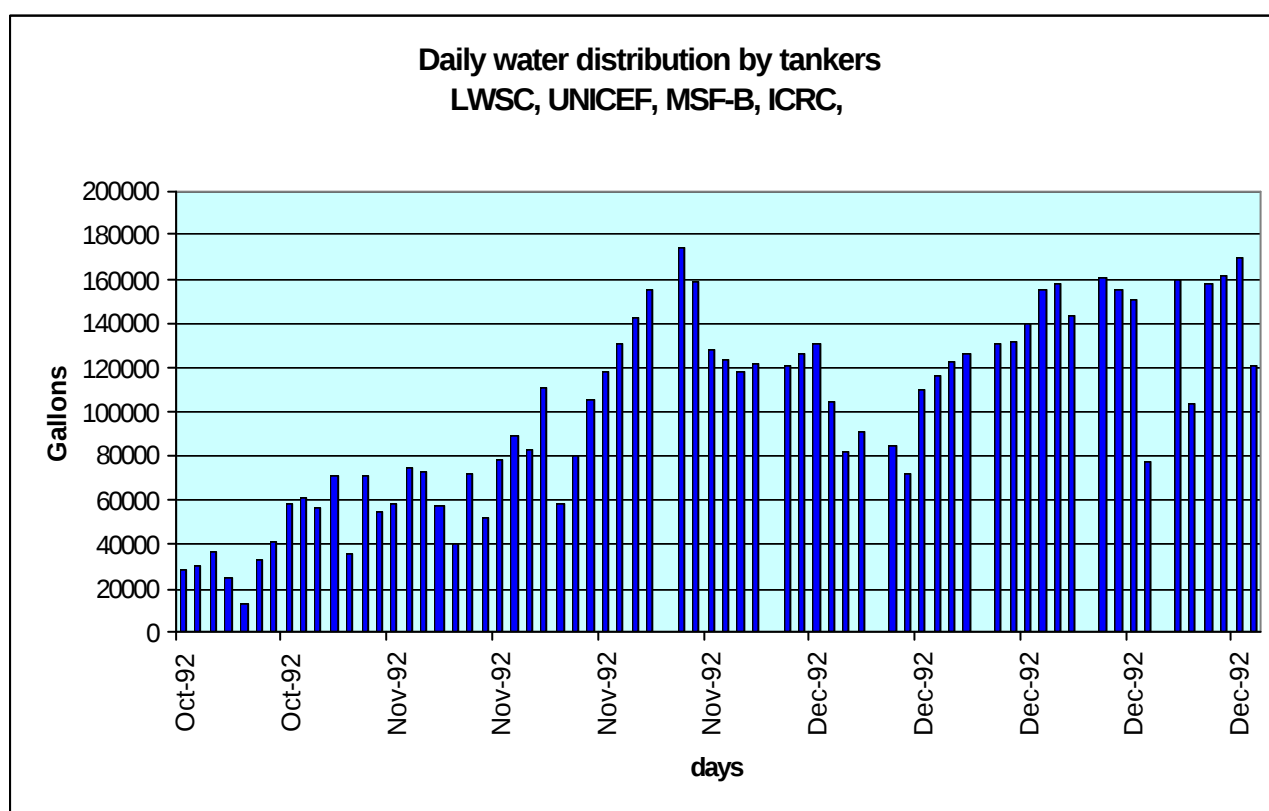
Figure 13
The main large-diameter wells and storage tanks used for emergency water distribution

total capacity of the water towers and storage tanks was close to 90,000 gallons (330,000 litres) and would increase with the construction of several others at various locations, such as hospitals or clinics.

Plans were also made to drill deeper wells in locations where boreholes were showing promising results, as in Paynesville or in the area close to the brewery, where a borehole was already in operation. MSF-Belgium was given responsibility for this project and for the selection of the contractor, but the final selection of the site was left to the Ministry of Land, Mines and Energy. A local contractor was hired immediately to speed up operations and the first borehole was scheduled to be operational by end of January 1993. Twenty trucks were immediately available for the operation, with a total capacity of about 60,000 gallons per trip, later increased to 71,250 gallons with the rental of four new trucks. Pumping teams were equipped with transfer pumps, chlorination devices and vehicles. The quality of the water was monitored by UNICEF, which was responsible for the training of the disinfection teams.

The operation started on 21 October. An initial target was set of over 100,000 gal/day, to be increased gradually up to 160,000 gal/day (600,000 litres), which was considered sufficient for the neediest areas, i.e. those depending almost entirely on piped water and without any easy access to shallow well water. Twenty-five per cent of the water would be delivered to shelters, about 10% to hospitals and clinics and the public would receive the remainder. The quantities delivered are given in the next figure (*Figure 14*).

It took about one month to reach the target of 160,000 gal/day (600,000 litres/day), which dropped to an average of between 120,000 and 140,000 gal/day, when the decision was made to stop distribution on Sundays. On average, 120,000 people were supplied with five litres of potable water per day. According to the above-mentioned survey, these people are probably those entirely dependent on piped water, who live on Bushrod Island, in Sinkor and also in some areas of Central Monrovia. The large majority of the population was still dependent on traditional sources.



The impact of the drilled boreholes and the rehabilitation of the WTP

Following UNICEF's recommendations, two boreholes were drilled in Paynesville under the supervision of MSF-Belgium. At the same time GTZ became involved in the rehabilitation of the White Plains treatment station. The express line built by the ICRC during the 1991 emergency project had been dismantled and power had to be provided by diesel-powered generators to operate the low- and high-lift pumps and to provide power for the station's essential functions. For reasons of economy and because of the huge leaks in the 36" pipeline, LWSC and GTZ decided to operate only the 16" pipeline. Two Nijhois (Holland) high-lift pumps (592 m³/h at 85 metres of water column) were installed and operated alternatively for 12-14 hours/day with the aim of delivering about 1.8-2 MG/day (7,100-7,500 m³/day), representing only 12% of the design capacity of the plant. Water was delivered to Bushrod Island, supplying its network, including the brewery, and an elevated

tank from which water was then delivered to the other areas of the town by means of water tankers. Borehole No.1 at Paynesville was also used for that purpose, with Borehole No. 2 specifically devoted to supplying the soft drinks factory, with some water distributed to the public. The whole operation was supported by emergency funds provided by ECHO (European Commission Humanitarian Office) until 1995.

Data from a survey carried out over a period of four months to monitor the whole operation showed a slight decrease in the quantities delivered to the population, as compared to the figures at the end of 1992. An average amount varying between 72,000 and 75,000 gal/day (280,000 litres) was delivered and distributed from the various elevated or ground-level storage tanks. In fact, strictly humanitarian deliveries to hospitals or institutions were a small part of the whole operation, representing about 17% of the monthly amounts delivered, with the remainder delivered to public water tanks. *Figure 15* shows the results of the survey.

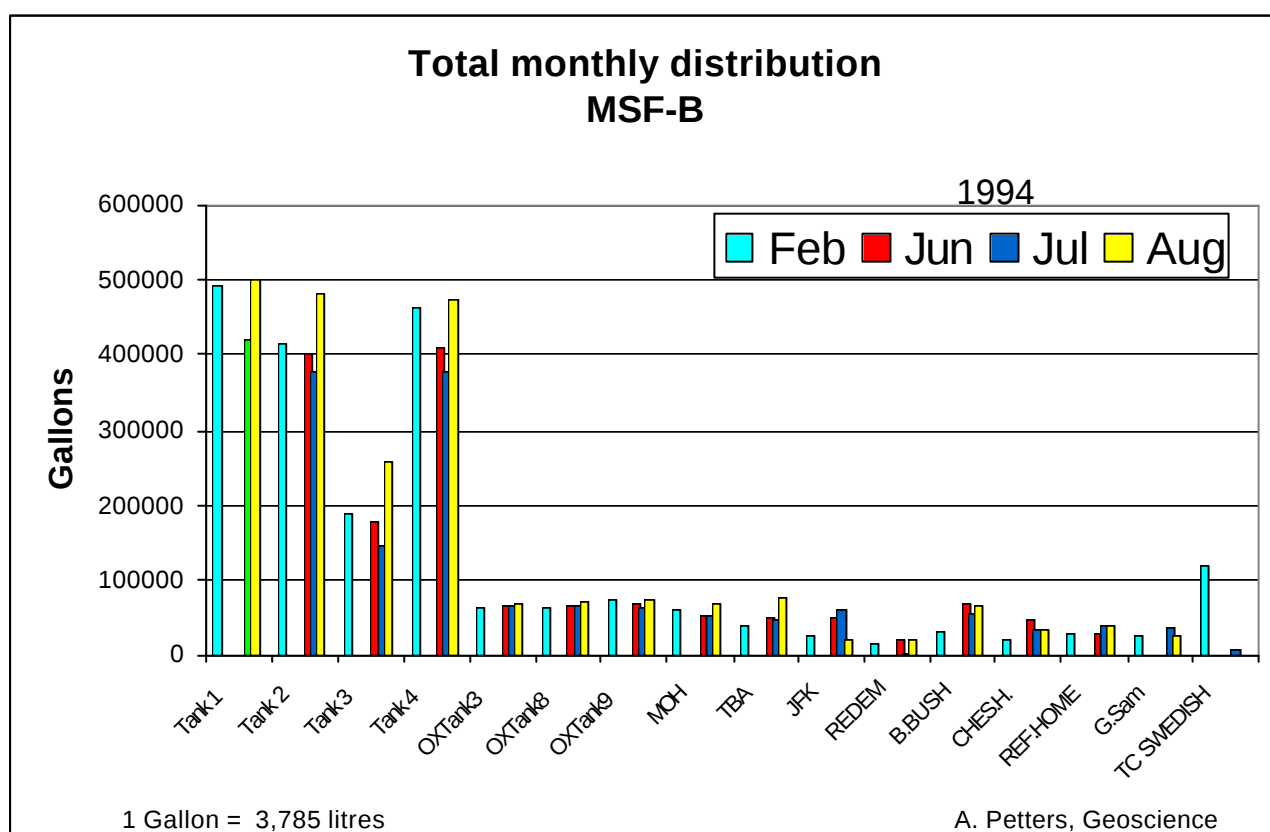


Figure 15
Total monthly distribution to storage tanks and to hospitals and institutions

The survey also showed significant discrepancies between the records kept at the filling stations (at the gantry at Logan Town close to LEC and at Paynesville Borehole No. 1) and the amount delivered to the public

from the elevated storage tanks, underscoring the need for better management and monitoring of the operation. Until 1995 water was delivered to the public free of charge.

The UNICEF / LWSC well-chlorination programme⁷

UNICEF began mass disinfection of wells in 1995. The campaign was linked to the well-digging programme that initially focused on improving the access to water of the displaced people in the town, estimated at about 270,000 living in 35 organised shelters, and was meant to enhance its impact. The target was then extended to the other communities using water from about 400 protected wells. It was preceded by a community-based or house-to-house dissemination campaign, to teach basic health

education principles. Practical demonstrations on how to prepare safe drinking water using household bleach, how to prepare and use oral rehydration solution (ORS) and sugar salt solution (SSS) were repeated at regular intervals, generally before an expected increase in diarrhoeal diseases, in February-March, May-June and August-September, according to analyses of prewar data.

Data from reference 7 are plotted in the next figure (Figure 16).

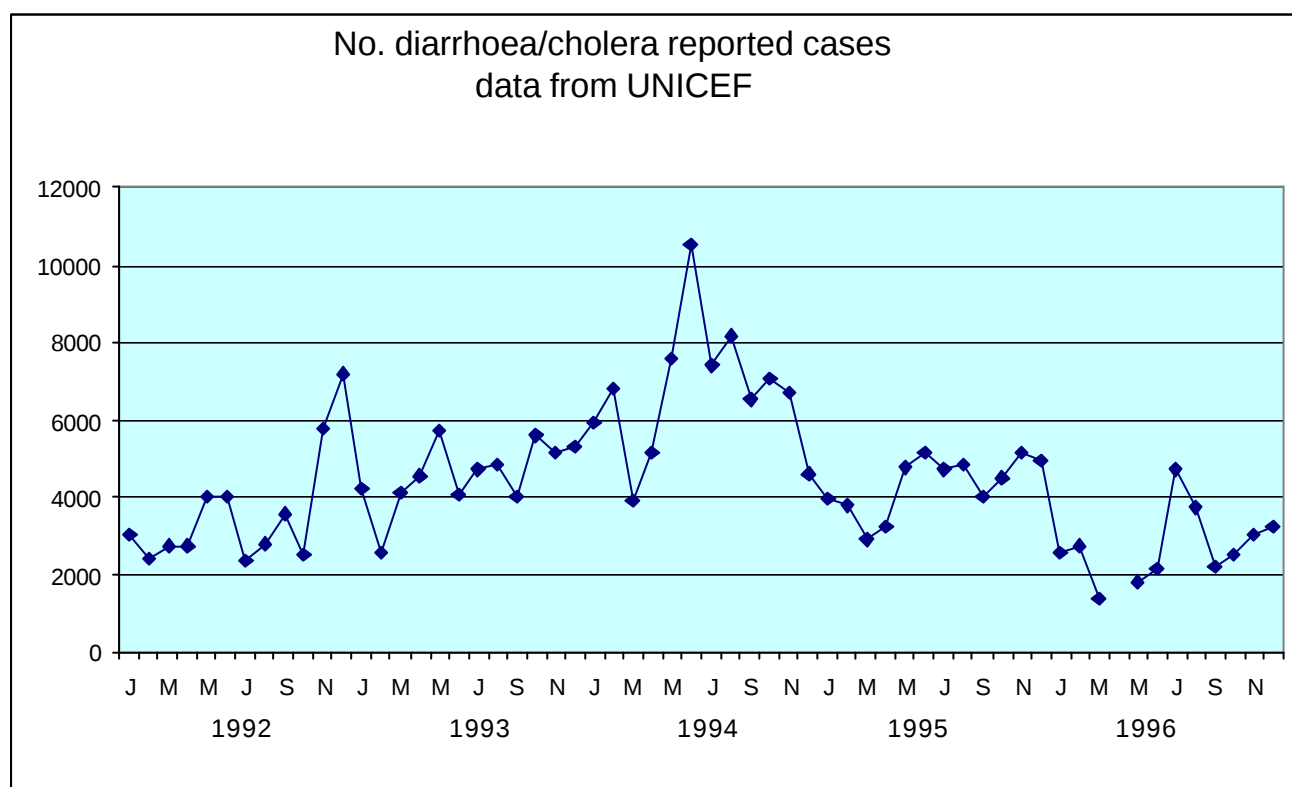


Figure 16

The evolution of the number of diarrhoea/cholera cases reported at the health centres in Monrovia between 1992 and 1996 (UNICEF)

The increase in the number of cases in November 1992 has been linked to the outbreak of hostilities in October, which resulted in the interruption of water production and distribution from White Plains. In fact, water distribution from the station was quite regular throughout the year, reaching an average of 5-7 MGal/day, as a result of the ICRC project and UNICEF involvement as of the end of 1991. During the same period the number of cases being reported was under the threshold of 145 cases/day set by the Ministry of Health as indicative of an epidemic. The increase in November/December is significant, and may be linked to the fact that people had to adapt to new sources of water, the trucking programme being still in its early stages. The station was repaired in early 1993

and the distribution programme was run at its normal pace, apparently with a decrease in the number of cases observed. The same applies to the 1996 crisis, where similar patterns were observed and distribution was also perturbed. The data for 1994 were explained by the poor performance of the WTP production, and by a deteriorating and leaking distribution network. But the outbreak can be linked to many different factors and, of course, access to safe water is one of them. In fact, only an estimated 30% of the population were using "piped" water and 40% were relying on underground water, with rainwater collection high during the rainy season.

⁷ Diarrhoea, Cholera and Disinfection of Wells in Monrovia, Liberia, Bronislav Jekic, UNICEF, WATERfront, Issue 11, August 1998

The number of wells with a water layer of less than one metre or for which information is lacking is still quite high (red dots), up to 212, from a total of 366 wells included in the database. Many of these wells have been rehabilitated recently but they must be maintained and even improved, owing to their importance to the entire city. The area of Bushrod Island, limited by Stockton Creek, a natural channel connecting the Mesurado River to the Saint Paul River, does not rely on shallow wells as its aquifer is too close to the surface and too shallow to be used, being subject to salt intrusion and to surface contamination.

More than a hundred of these wells have been equipped with hand pumps, mainly Kardia, Consallen and different types of Vergnet pumps. In 1990 the ICRC started to

equip the wells dug in the framework of its programme with Kardia pumps put at its disposal by the European Community. Local teams had already been trained since 1991 in the servicing of these pumps, at least the first two models, and some of these technicians were still part of the servicing teams at the beginning of 2000. Many of these pumps would need to be replaced with new ones but the majority can be repaired at minimal cost. Despite the efforts made by UNICEF to involve the community in the maintenance of the wells and the hand pumps, the problem of real community participation remains unsolved. The ability or willingness of the community to pay for a well or for the installation of a new pump still needs to be strengthened and may only be envisaged when the economic situation improves. The next figure shows the type of pumps equipping the wells, based on data obtained from UNICEF's chlorination programme.

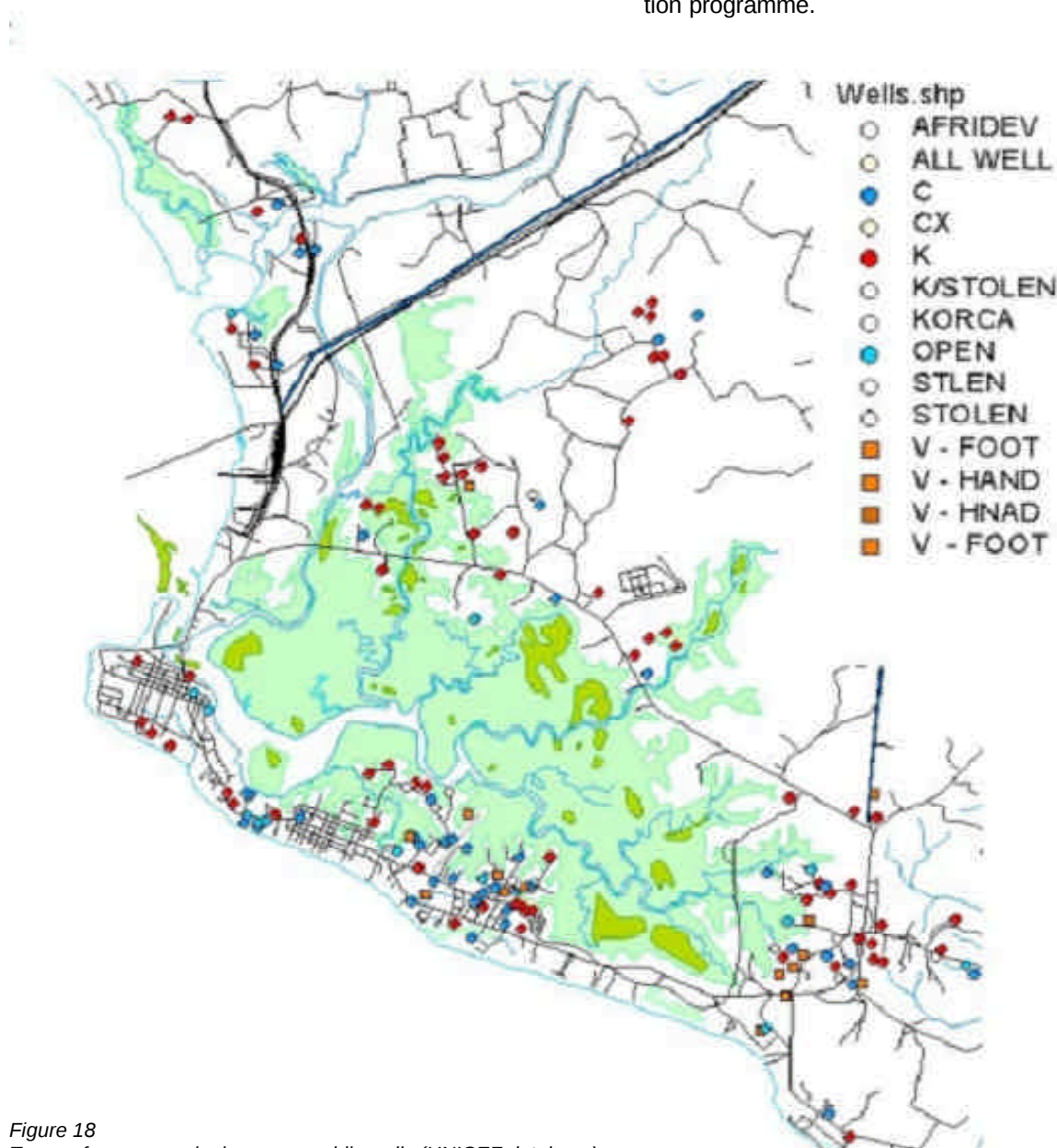


Figure 18
Types of pumps equipping some public wells (UNICEF database)

From emergency to development?

In the aftermath of the civil war of 1991 all the NGOs and organisations operating in Monrovia were funded solely with humanitarian emergency funds. Too often, funds earmarked for emergency are no longer available once the hostilities stop or when a cease-fire has been signed. Although the emergency is considered over, no provision has been made for the proper use of other funds destined for development aid. Some organisations have extended their interventions to cover this gap. Monrovia is a particular case, as the EC recognised at the beginning of 1995 that by deploying funds from its development budgets it could link emergency humanitarian operations with longer-term rehabilitation and institutional development. In actual fact, the situation of the city's water supply and of the LWSC was in a continuous decline and drastic remedies had to be applied in order to provide vital continuity of the utility. While addressing the basic needs of the population of the town, conditional investments were a way of measuring the capacity of the utility to absorb new concepts in the field of tariffs, financial control, performance targets and overstaffing. They were also a measure of the capacity of the government to promote sustainable development and eventually to clear the way to a possible privatisation of the utility.

Private water trucking

One of the first measures taken to achieve a more sustainable programme that would enable the utility to reorganise its management of the whole water supply operation was to cut the funds for commercial trucking. The latter was delivering an average of 72-75,000 Gal/day to about 100 paying customers representing about 43% of the total amount delivered in the town, but for only a small number of people (about 10,000). Comparison with the impact of civil trucking, which supplied about 100,000 people, led to the perception that operators were in fact taking advantage of a subsidised operation, and discriminating in their deliveries. Despite the considerable revenue for the LWSC, up to an average of USD 20,000/month, progressive withdrawal from commercial trucking had to be initiated, with the fleet to be used for purely donor-subsidised civic distribution.

The applied tariff since 1998 was USD 20 per 1000 gallons (Figure 19), with USD 6 for the water, equal to the tariff applied to the public, and USD 14 for transport. Water trucking became an important business at the end of 1992, when it was launched as an emergency programme to cope with the damage suffered by the White Plains station. The independent survey carried out in 1994 identified a discrepancy between the amounts delivered at the filling station and those



Figure 19
Applied tariff advertised at the filling stations

accounted for at the distribution points. In 1995 accountability was improved, with freely accessible and cross-checkable records of water withdrawal, truck movement and financial receipts and expenditures. Maintained by the EDF (European Development Fund) project as a temporary measure in 1995, it went on smoothly until 1999, when it was felt that withdrawal was necessary for the above-mentioned reasons. Eventually, the withdrawal became effective only in July 2000, with the hope that the private sector would seize the business opportunity, which it did not. Sales at the overhead tanks supplying the population increased by some 15%, and a few minor businesses were started. On the other hand, about a third of the 30 private vendors selling water from small street tanks disappeared, as the tankers' private operators probably felt it was uneconomical to supply them.

Several other customers are essential to the financial sustainability of the utility: the brewery, the soda and soft drinks factory, deliveries to family customers and distribution to the public from the overhead tanks. Metered customers are restricted to Bushrod Island, which was still supplied from White Plains. The proportions of the different revenues vary according to the season. Private trucking is very important during the three or four months of the dry season, as can be seen from the following figures, where revenues from private trucking and from overhead tank distribution are given. Although much criticised, this activity has probably more than covered its costs, helping LCWS to support other sectors (Figures 20, 21).

Water vendors at Mamba point



Elevated tank in Central Monrovia



Ground distribution tank Central Monrovia



Individual collection at Paynesville borehole



Elevated distribution tank at Logan bridge



Central Monrovia



Water collection at a shallow well



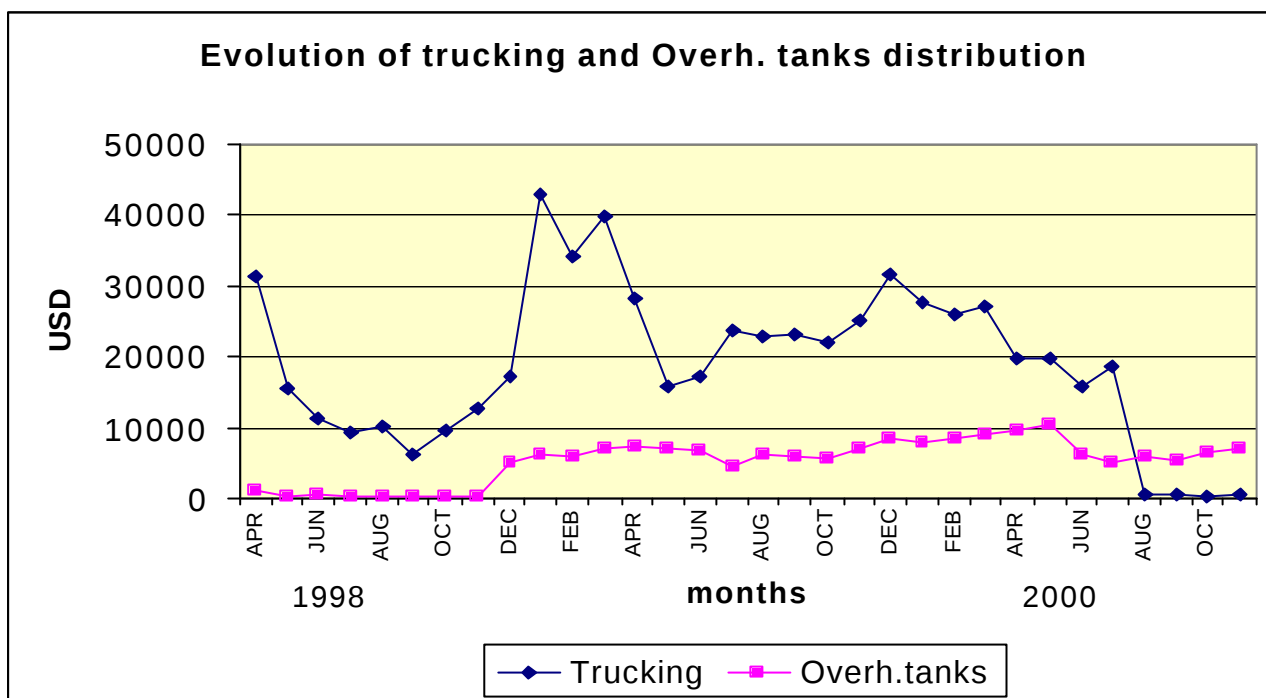


Figure 20
Monthly evolution of trucking and overhead tank distribution since April 1998

During the rainy season the proportion of revenue from private water trucking was still high, up to 25-28% of total revenue, and of the same magnitude as the combined revenues of the brewery and the soft drinks factory. Despite criticism, the utility should reconsider its involvement in this sector, which could represent an important part of its regular budget and would at the same time enhance its preparedness in case of an event at the White Plains station.

The Paynesville boreholes

The two boreholes were drilled in 1993 under the supervision of MSF-Belgium to provide alternative water sources for the emergency trucking operation, with financing from the EU Commission. They have been maintained and progressively equipped with new sub-

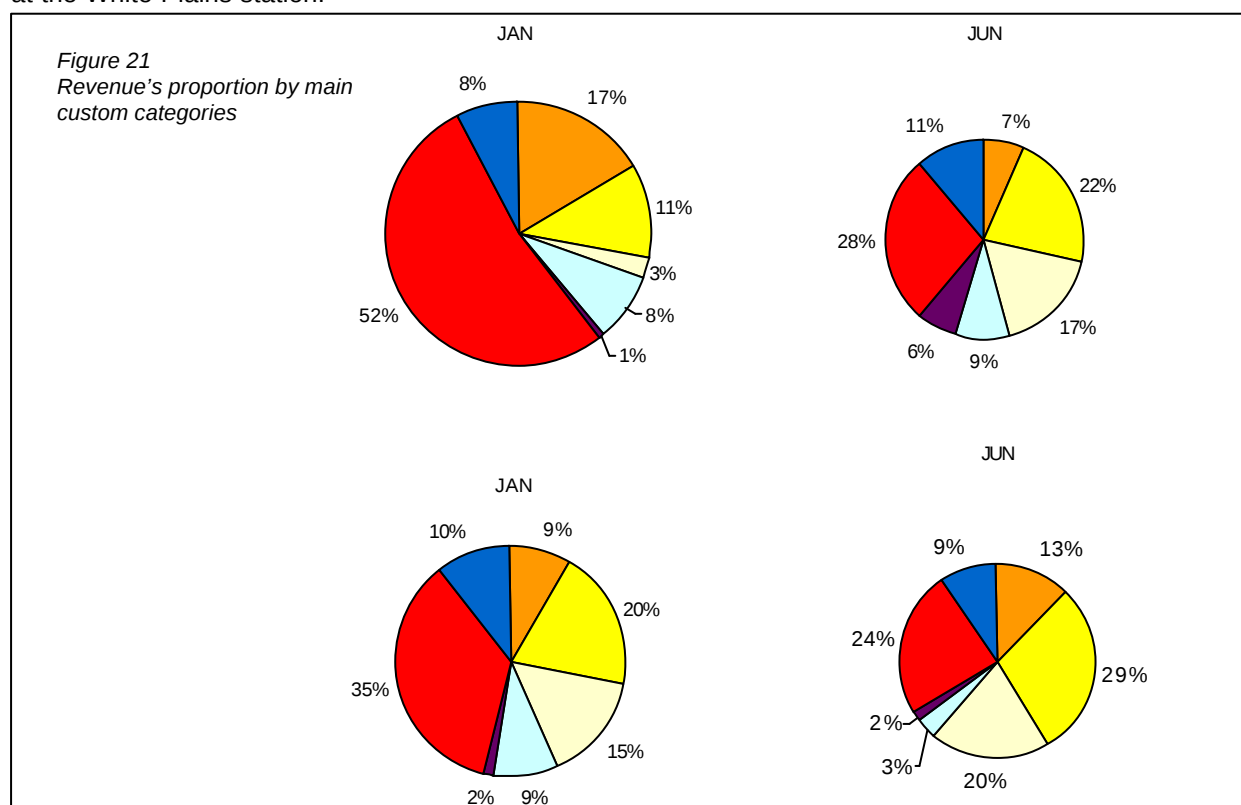


Figure 21
Revenue's proportion by main custom categories

mersible pumps and with elevated storage capacities. Borehole No.1 is located just outside the locality of Paynesville. At the beginning of 2000, at this borehole, the pump delivered roughly 25 m³/h during 12 to 14 hours, for an average output of about 250-300 m³/day, mainly to fill tankers.

Small quantities were also distributed directly to the public. Precise records were kept. The type, the number of trucks, their destination and the amounts delivered to the public were monitored. An example of these records, collected between February and March 2000, is given in Figure 22.

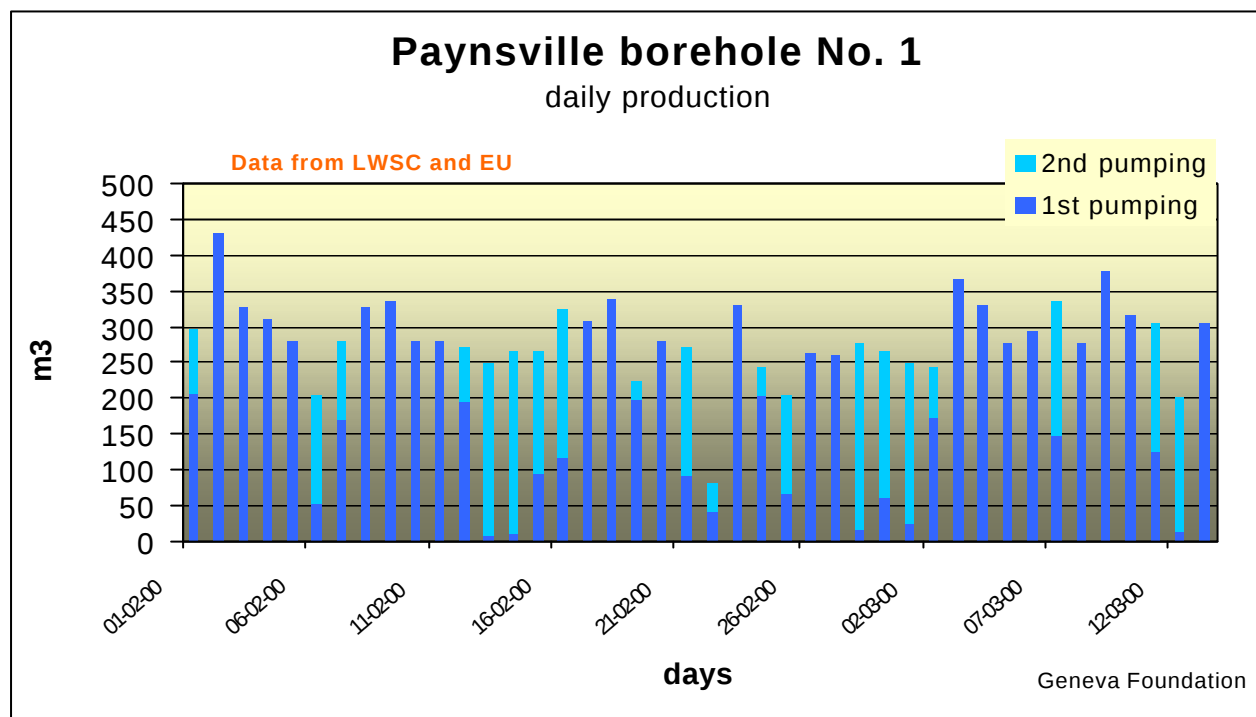


Figure 22
Daily production at Paynesville Borehole No. 1 (collected at the pumping station)

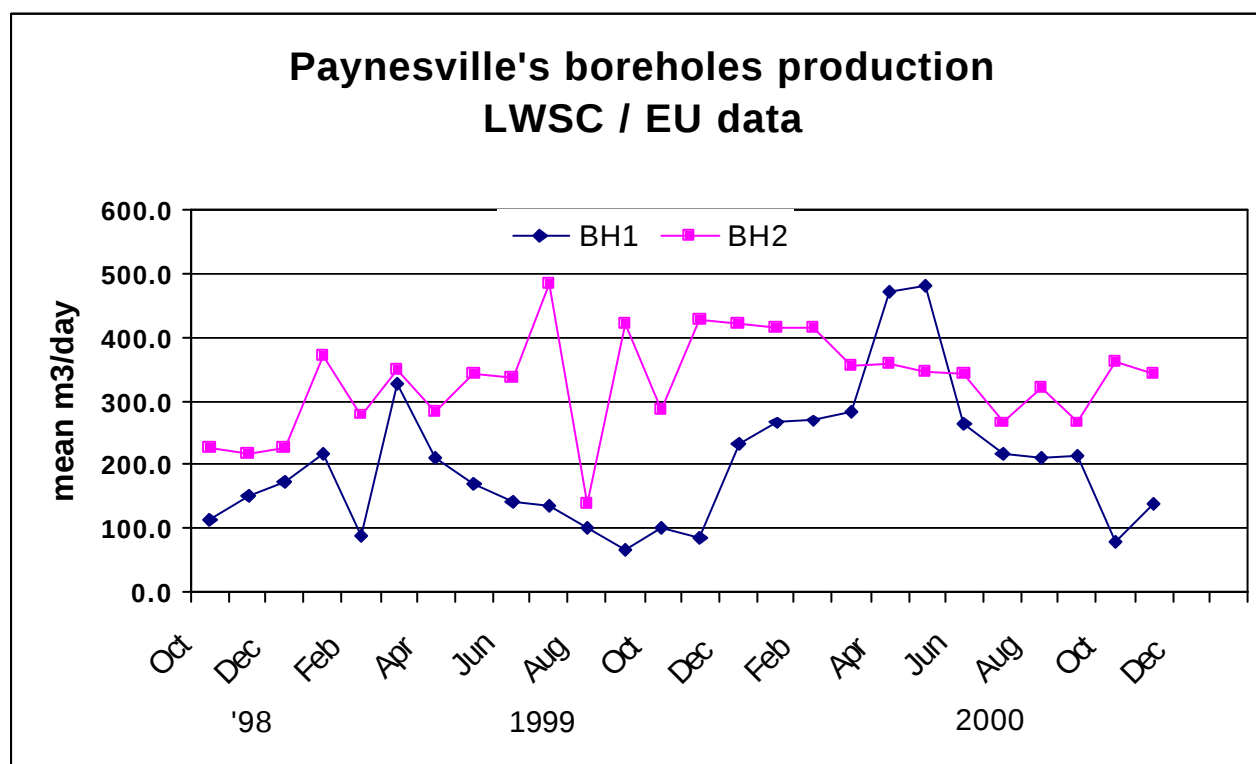


Figure 23
Mean daily production of boreholes at Paynesville from October 1998 to end of 2000

Average daily production during these two months was between 250-300 m³ but fluctuates according to the seasons between an average of 100 m³/day during the wet months and the above amount. Figure 22 gives the mean daily production in m³, computed from total monthly figures. Borehole No. 2 is used mainly to supply the soft drinks factory and its output is over 300 m³/day, reaching an average of 400 m³/day. The higher production figures for Borehole No.1 in April and May 2000 reflect increased needs due to the problems with the lift pumps at White Plains (see below). The operation of both boreholes was essential as they provided more than 40% of total revenues from all water sales. When private trucks were being filled, this proportion was higher, but even afterwards it represented, together with the brewery, a crucial source of revenue. The operation of the boreholes, drilled to face an emergency in 1993, has become one the utility's trump cards in view of its future viability.

The situation at the White Plains water treatment station

The station has never been operated at its prewar capacity in the last five years. Recent data from LWSC and EU show that the plant was operated at 10-12% of its design capacity until April 2000, when production at the plant stopped for about one month. *Figure 24* gives the mean daily amounts pumped into the 16" pipeline, computed from the monthly totals. The production at the station stopped from 12 April to end of May due to the failure of the remaining low-lift pump. It was resumed at a lower level, up to 4,000 m³/day (about 1 MG/day), when it was recognised that the needs of the operation at the Bong Mines gantry and of Bushrod Island could be met with less water, and at lesser cost for pumping, treatment chemicals etc.

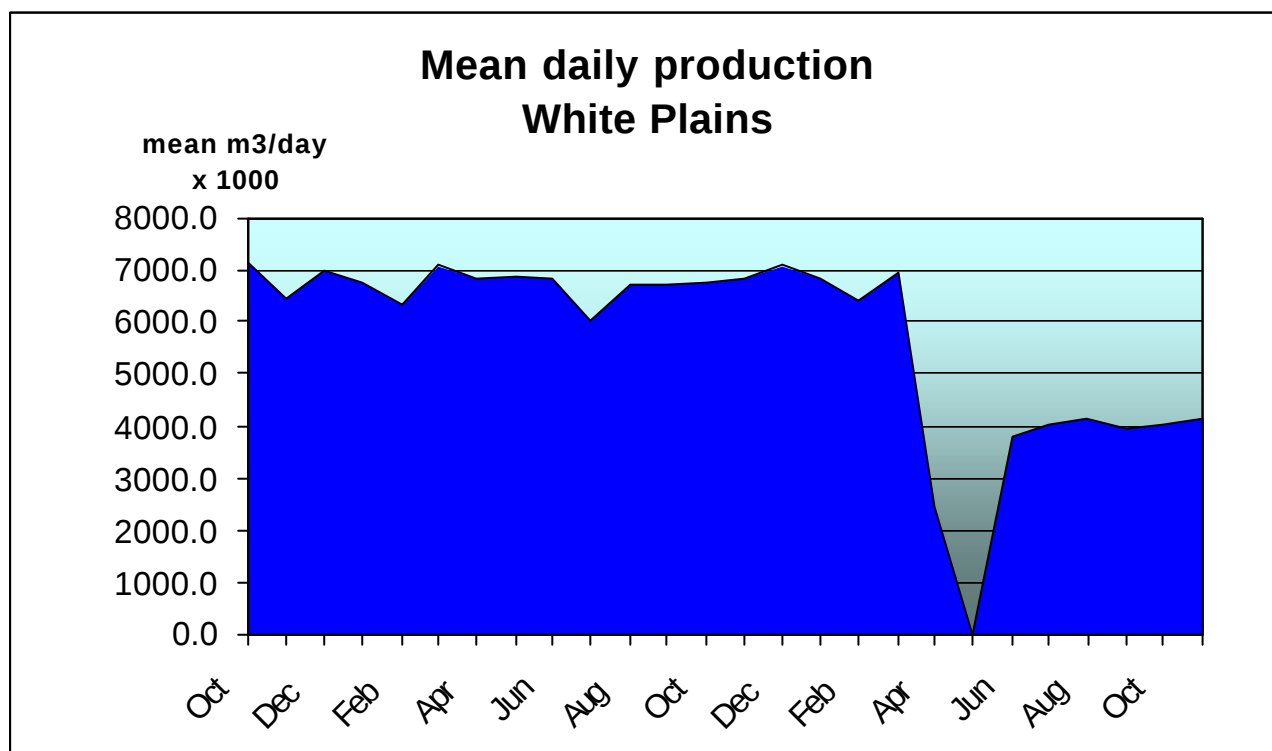


Figure 24
Mean daily production at White Plains water treatment station. Output estimated on the basis of the pump yields and probably lower than what is indicated