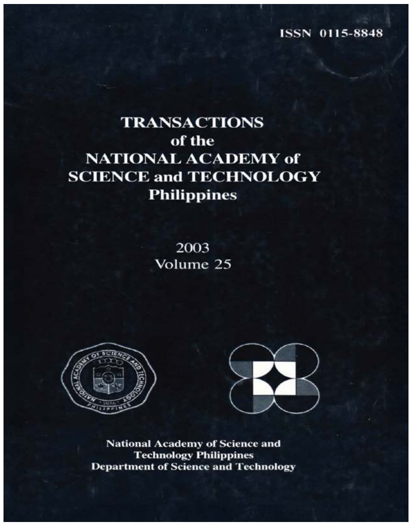
TRANSACTIONSNASTPHL

https://transactions.nast.ph

ISSN 0115-8848 (print)
ISSN 2815-2042 (online)

Vol. 25 Issue No. 2 (2003)
doi.org/10.57043/transnastphl.2003.4749

Transactions NAST PHL, is the official journal of the National Academy of Science and Technology Philippines. It has traditionally published papers presented during the Academy's Annual Scientific Meeting since 1979 to promote science-based policy discussions of and recommendations on timely and relevant national issues as part of its functions as a national science academy. Starting in 2021, this journal has been open to contributions from the global scientific community in all fields of science and technology.



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Citation
van Engelen H. 2003. Water supply in Cebu, Philippines: A case study. Transactions NAST PHL 25(2): 430-449. doi.org/10.57043/transnastphl.2003.4749

Transactions Natl. Acad. Sci. & Tech. Philippines 25 (2): 430-449 (2003)
ISSN 0115-8848

WATER SUPPLY IN CEBU PHILIPPINES: A CASE STUDY

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Abstract

This paper focuses on the water supply of Cebu City and the island because it is a contained supply and consumption system with some historical data. It intends to show that understanding of nature's water supply system is essential for a sound management of a water distribution system. From 1911 until World War II, Cebu relied on surface water (Buhisan dam) and groundwater (Jagobiao) spring for its distribution system. After the war, deep wells were added to the system. From 1974 to the present, substantial foreign input analyzed the local situation and provided possible solutions. This paper further points out what has to be done at the present time to ascertain that Cebu will have potable water for its people.

Key words: water supply, groundwater, surface water, water management, Cebu City, Cebu Island

List of Abbreviations: OWWS, Osmeña Water Works System; MCWD Metro Cebu Water District; WHO, World Health Organization; CDM, Camp, Dresser and Mckee; KKLI, Kampsax, Krueger, Lahmeyer Int.; CC, Cebu Consultants; LWUA, Local Water Utilities Administration; Electrowatt, Electrowatt Engineering Services Ltd.; Bechtel, Bechtel International, Inc.; USAID, United States Agency for International Development; TUD, Technical University of Delft; PCEEM, Philippine-Canada Environmental and Economic Management Project; NAWASA, National Water and Sanitation Administration; MWSS, Metropolitan Water and Sewerage Services.

Introduction

Any human settlement needs fresh water. There are many reasons why a settlement flourishes. Fresh water is of such primordial importance, that scarcity of it becomes a fundamental constraint for an organic development of the settlement.

A tropical climate with no extended dry seasons gives the impression that fresh water is abundant. Volume-wise the supply is abundant. The tropical cloudburst however is no ideal delivery system. Storage is needed to save water for a sunny day. Chemical weathering is fast, given the high temperature and humidity of the climate. Thus in many locations one finds thick layers of sediment protected by a thick green cover. In this way nature has provided a huge, admittedly leaky, storage reservoir. But then again, forests are cut and level areas are developed. This is the common human approach. Stronger erosion, a result of deforestation, removes sediment. Development effectively constructs a roof over the level areas and drains the rainwater as fast as possible. The loss of natural storage (result of erosion) and the reduction of natural recharge (consequence of development) result in batch-type water supply. The phenomenon is well known by its effects: flash floods and dry faucets.

Cebu is no exception on this common script. This paper intends to show that the understanding of nature's water supply system is essential for a sound management of a water distribution system. The focus of the paper is Cebu City with its direct surrounding, because it is a contained supply and consumption system that has some historical data.

From 1911 until World War II Cebu relied on surface water (Buhisan dam) and groundwater (Jagobiao spring) for its distribution system. When the cleanup of the war damage reached Cebu, deep wells were added to the system. The inspiration of the Buhisan dam produced two feasibility studies with plans for two high dams. The growing demand has been followed by a further exploitation of ground water resources by government and private entities. The progressive seawater intrusion proves that the narrow coastal aquifer is under stress. Table 1 shows the historical growth of the population of Cebu. The present population of this area is now more than one million.

Over extraction of ground water from the coastal aquifer does not really lower the water table, because the sea resupplies without limits. The problem is that 1% seawater mixed with 99% fresh water establishes 250 ppm Cl^-, which is the upper limit acceptable according to WHO guidelines. Two percent seawater produces 500 ppm Cl^-, a concentration which the local population does not accept. The sad irony is that Cebu talks about sufficient surface water in its own backyard while it acts to permanently destroy the ground water source that can supply one third of its needs.

The paper consists of three parts. First a description is given of the period 1910 to 1974. During this period a correct and sufficient first step was not sfollowed by the necessary in-depth study. The second part covers the period from 1974 until the present during which substantial foreign input analyzed the local problem and pointed out the solution. During this period much of the science of water (hydrology) was absorbed through local hard labor to the point that "water engineers" can be trained locally. The third part points out what has to be done today to ascertain that Cebu, City and island, will have potable water for its people.

Table 1. Historical growth of Cebu's population.

Year	Cebu City	Mandaue City
1903	45,994	11,078
1918	65,502	21,086
1939	146,817	17,431
1948	167,503	19,068
1960	251,146	29,281
1970	347,116	58,579
1975	413,025	75,904
1980	490,281	110,590

Source: National Census & Statistics Office: 1980 Census of Population & Housing: Cebu; Vol. 1: final report. Manila 1983

The Period of the Osmeña Water Works System (1910 -1974) [1]

Surface Water

Electricity as a general form of energy supply probably had not reached Cebu around 1910. One may suppose that drinking water was taken from hand pumps. The exploitation of a river by means of a dam taller than a church tower must have been perceived as very advanced technology. This is more so because the potable water could be distributed by gravity over the whole area of interest.

In 1911 the Buhisan dam was built. The height of the construction above the riverbed is about 37 meters. The highest church towers at the time were about 20 meters. The surface area of the active storage reservoir was 12 ha in 1978; its volume 200,000 m^3. In 1978 the discharge was 9000 m^3 day^{-1}. This

[1] This section is essentially based on oral communications.

discharge could be handled by the Tisa water treatment plant. A catchment of 560 ha collects some 4 million m^3 $year^{-1}$ (11,000 m^3 day^{-1}). In 1903 the population of Cebu City was 45,994. This must have been the time that the decision to build a dam was made. With 9,000 m^3 day^{-1} as discharge capacity, the demand was thus placed at 0.2 m^3 $head^{-1}$ day^{-1}. However, an active storage of 200,000 m^3 never would have been enough to bridge the dry season gap. History provides an explanation.

In 1912 the dam (or portion of it) collapsed catastrophically. Oral history reports the loss of 22 lives. Apparently the structure retained some functionality, because the same source reports that an iron-and-wood superstructure was frequently washed away until in 1924 the structure was finished as it is now. The present structure consists of a concrete arch resting on a side abuttment and on a rock outcrop in the middle of the gorge. The other opening of the gorge is closed by a gated spillway.

The catchment was locally known as the Osmeña Reforestation, after the local political power, and was totally reforested until the war drove people into the hills after 1941. The combined demand for fire-wood and food did much damage. However, this damage had been restored in 1978, but not before an extremely wet typhoon (1951) had reduced the original storage to 200,000 m^3. The typhoon obstructed the sludge drain in the process. In 1996 this sludge drain was cleared and the storage restored to 250,000 m^3. The active reservoir should be cleaned to 300 000 m^3 following the recommendations of the 1978 study.

In 1978 it was not possible to determine the original bottom of the reservoir. No data were available about design values of active storage, dead storage or discharge. Retro engineering of such values becomes an educated guess under these conditions. But the combination of the facts that the downstream installation of treatment plant and transmission line can handle 9,000 m^3per day at a time that there were no substantial changes made, confirms the opinion that the Buhisan dam was built to supply 9,000 m^3 per day. An active storage of some 350,000 to 400,000 m^3 might have assured a continuous supply in a climate where a period of 40 days without rain is very exceptional. Because rainwater collection was common in the Spanish time, 9,000 m^3 per day may have easily supplied more than 45,000 people.

The raw water and clean water transmission lines needed rehabilitation. The same was true for the treatment plant in Tisa. Following the recommendations by international and local experts, this rehabilitation has been made. The whole installation of 1911 is functional. The investment of 1911 has produced 6 to 9 thousand m^3 water daily. This is more than 200 million m^3, produced by a structure that may cost not more than 10 million dollar at present prices.

Already in 1976 attempts had been made to find operational data about the dam reservoir. Practically nothing has been found. The conclusion seems justified that in the minds of the management of the water system, a dam-with-storage-reservoir did not deserve daily attention. The rainfall had been recorded. At one point the recording stopped, possibly as a result of the war. More important stations retain copies of the collected data. Buhisan was such station. Because the recording had not been resumed, the local copies were discarded as waste paper. This happened a few years before 1976. Daily water levels of the reservoir, figures about released sludge, actual daily discharges to treatment plant or over the spillway would have been a goldmine for hydrologists. Roughly at the same time as the dam was constructed, a synoptic meteorological station started observations in Cebu. The combination of water and weather data over a period of 80 years could even be used to evaluate climate changes. But on a more practical level, an 80-year record could result in the full utilization of the 4 million m^3 per year capacity. At present the MCWD pumps about 4 million m^3 per month using expensive electric energy. Thus the dam still produces a relatively important volume of water.

In 1911 there was inspiration, there was foresight. A good installation was built. Standard maintenance procedures were followed: no population close to the reservoir, erosion control through reforestation and drainage of the unavoidable silt. The war interrupted these procedures, but the tradition was strong enough and the results could be seen, so that after 1945 these procedures were taken up again. In hindsight one sees now that daily rainfall and discharge data could have been used in the evaluation of many other watersheds. Optimal use of our fresh water resources may finally force us to collect such data so that the next generation can use them, for the benefit of the whole island.

Ground Water

1. Spring

Around the island of Cebu one finds several large springs just above sea level. These springs are very popular and intensively used. Cebu has its own seaside spring in Jagobiao on the boundary between Mandaue and Consolacion. The spring is close to the North road, so it is understandable that the growing city tapped this spring in 1934. The population had passed the 100,000 mark, the maximum population that reasonably can be served by 9,000 m^3day^{-1}. The capacity of the spring has not been documented. It seems that no meters were used: the production was derived from pump specification and hours of operation. Pumps were needed to bring the water to the center of Cebu. The pipeline used the right of way of Northroad and railroad track, by-passing Mandaue City. The spring had one obvious defect: in periods of very intense rain its water got turbid. The managerial response to this problem was simple: monitor closely in times of intense rain and stop pumping when turbidity becomes visible. The implied health risk of the intermittent turbidity had been recognized in a peculiar way. In 1945 one attempted to close a sinkhole in Talamban by blasting, "to prevent remaining Japanese soldiers from poisoning the Jagobiao spring"[2]. That through this sinkhole, or through any other surface contact human waste could be a continuous health risk for the spring, was only in the late 1970s considered as sufficient reason to abandon a source that produced not more that 5,000 $m^3 day^{-1}$.

This decision was made by MCWD, the successor of OWWS, at a time that the pumping station required an expensive rehabilitation.

Also from a purely hydrologic viewpoint the decision was correct. A spring that shows a clear surface contact during heavy rains indicates at the same time that its water regularly may be in contact with human waste. Such spring deserves to be treated as "surface water." The permanent absence of *E. coli* as observed by frequent analysis, is no guarantee that the "50-days-no-contact" rule for surface water is maintained. This rule has been used in Europe already in the 1930s. In 1985 it was also introduced in the USA.

The basic facts about springs are known. Rainwater becomes acidic when it passes soil. Acids dissolve limestone. Consequently, solution channels are created, sometimes with dimensions of real underground rivers and grottos. Such rivers can feed really substantial springs. And here lays the catch: river currents are measured in kilometers per hour. This is in sharp contrast with ground water flows that are measured in meters per day, several thousand times slower than river flows. Consequently, large springs in karstic formations may have to be treated as surface water. In Cebu surface water reaches the sea in much less time than 50 days.

Contamination by human waste can spoil potable water by its microbial content (bacteria, viruses, etc). Illness-causing bacteria do not usually survive longer than a few days outside the human body. Nature, however, needs much more time to destroy viruses. Studies show that a reduction of 99% often requires 50 days. That last 1% can then be sufficiently reduced by chlorine. And by the combined action the water is safe. A big spring, however, that is sometimes turbid, is fed by an underground river that has surface contacts close by. The water was only a few days earlier at the surface where it could be contaminated by human waste. In 1934 very few people were living in the recharge area of the Jagobiao spring. Thus the chances of contamination were small enough to justify the use of the spring. This was still the situation in the 1960s. But around 1980 many subdivisions, private housing developments, were developed. And the spring water became slowly unacceptable for drinking purposes, because it may have been in contact with human waste a few days earlier. The rule of 50-days-no-contact with human waste is not maintained in the Jagobiao case.

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[2] A vague oral tradition states that the connection between sinkhole and spring had been established by a tracer, but no documentation has been found.

2. Wells

The population of Cebu grew fast beyond the 9,000 m^3day^{-1} capacity of the Buhisan dam. The Jagobiao spring added water, but its addition was more a reaction to popular demand than pro-active planning: 9,000 m^3day^{-1} is definitely not enough for more than 100,000 people in the down-town area. Add to this shortage the relative ease by which a private well could be constructed and one has an explanation of the popularity of the private well. A survey made in 1977 found more than 7000 wells in the service area of MCWD. About one half of these wells were known to be drilled between 1964 and 1976. A couple of hundred wells probably date back until the 1930s; 78 wells were definitely dated to the pre-war period.

The war damaged much of Cebu's infrastructure, so it is no surprise that repair and extension of the water distribution network showed much patchwork. Even today the MCWD does not guarantee that all privately installed connections of the period 1945-1950 have been accounted for. With no additional sources for the OWWS, private wells proliferated. The City installed handpumps in squatter areas. Homeowners drilled own wells, eventually at 10 meters intervals. Business placed transmission lines of 1 to 2 km between private well and hotel or factory. But still the water supply was inadequate.

To remedy the emergency situation, expatriate experts recommended the construction of a dozen deep wells in the distribution area. These wells pumped directly into the network, were provided with check valves, but not with watermeters. This was done in the early 1960s. The wells alleviated the shortage, but could not provide a constant pressure. Private storage that was filled during periods of sufficient pressure was a common installation. The fire brigade resorted to its own elevated storage tanks and sometimes used sea water (although its equipment was not made for it). Emergency measures have a tendency to become permanent until the point of total breakdown of the temporary measure. In the early 1980s the last of these emergency wells was abandoned.

As the production was not monitored and maintenance was limited to repair of reported failures only, at least one well was found in 1974 to act as a sink. Its impellor was totally corroded and its check valve stuck in the "open" position. During the few hours of the day when that part of the system had a positive pressure, the water flowed down the well. Its production was still in the books, as "design capacity times hours of operation"; the first factor was printed on the folder of the salesman, the second factor was derived from the electric bill. Notwithstanding this type of management, the City treasurer found it necessary to publish his objections against the organization of a Water District. His reason: the OWWS contributed P1,000,000 net per year to the city's income. OWWS yearly budget was some P6,000,000 at the time.

For all practical purposes the population that depended on a public water service, was unknowingly taxed, with 16% on its water bill. This money moved beyond the standard and controlled channels. The public reaction on this revelation was very subdued. Everybody experienced that the distribution system did not distribute much more than air (as the saying went). But the admission that the system managed to make some 16% profit, did not result in the mass resignation of the responsible political body. No elective official was sent home by the electorate. Even today water supply is considered to be profitable business by some municipalities.

The emergency wells also had a negative hydrological effect: acceleration of the seawater intrusion. The majority of these wells were situated in the downtown area where the water was badly needed. From a hydrologic standpoint the sites were relatively good: close to the major natural drains of Lahug and Guadalupe rivers. The inaccurate information on the volume extracted by private wells may have caused a far too optimistic estimate of the safe extraction rate[1].

Evaluation

After an imaginative start in 1911 the OWWS seems to have chosen for a reactive management. It took until 1934 and a 100% increase of the population before an additional source was tapped. The third substantial, although short-lived, additional input came in the 1960s. And this time the population stood at 250,000. The turbulent years of the war are an excuse. The case by which individual households could drill for water, took some pressure away from OWWS. These are facts, but no justification of a "laissez fair" attitude. Questions may be asked. Was the Buhisan dam an achievement of such perplexing magnitude, that it numbed the Cebuano community to a deadly complacency? It was a great achievement, even construction and reconstruction was done by expatriate (Japanese) labor. The fact that no correlation between rainfall and discharge was preserved (or possibly never made), points in a similar direction of not-comprehending the magnitude of the achievement.

The vulnerability of a coastal aquifer was not realized, witnessing the carelessness in registering the extraction of OWWS and private wells. There were warning signs. In the early 1960s a German chemist of USC warned about his findings: analyses showed clear signs of sea water intrusion. Sea water intrusion was a well-known hazard internationally. But in the country the agencies responsible for the water supply did not react. Was it only the very limited knowledge? Or was it also the sluggishness of the bureaucracy? For water supply one would love to see the professionality and agility of the private

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[1] A private experience of inaccurate information may illustrate its danger and underline the statement that no information is better than wrong information. In the mid 1970s I twice received information from the appropriate government offices that "about 60% had been registered; of course, not everybody registers as required" The first time I took this information on the face value. The 700 registered wells ("about 60%") turned out to be more than 4,000 wells. The second time when that same expression was used, I smiled and thought Let us check it.

enterprise, but then without the greed that eventually moves to ever increasing profits. Would a closed economic system like a cooperative be the answer? A system in which the user knows what it takes to collect the product and bring it to the house? A system in which the user also knows how nature provides fresh water?

The Period of the Metro Cebu Water District (1974 to present)

The Beginning of External Input, the CDM and KKLI Projects.

Around 1970 some larger constructions were started by the OWWS. An open reservoir, 3,000 to 4,000 m^3, was constructed on an elevated location in Lahug. About 2 km 8" steel pipe with a thin butimen coating was placed along the Cadre Talamban road. A "concerned citizen" wondered if it was another of those "election water systems," that appear with the same frequency as elections. In vote-rich areas, handpumps and GI pipes were distributed. Reservoirs were constructed. But too often those items never saw any water.

The national answer to a very weak water supply system nation-wide was the creation of the Local Water Utilities Administration. The local result was the creation of MCWD, a government corporation with the task to provide Metro Cebu with potable water (9 May 1974). The OWWS was absorbed in MCWD. Most of the municipalities belonging to Metro Cebu joined.

On 14 October 1974 a contract was signed between LWUA and Camp Dresser and McKee about a Feasibility Study for Water Supply - MCWD. Oral information has it that USAID was the source of the funds. In the same information it was stated that the terms of reference were inadequate with respect to the problem. One line of the Introduction to the Final Report of CDM, February 1976, may be sufficient justification of the hurry: "The MCWD water supply is generally inadequate and unsafe." This line speaks about the water supply of more than 446,000 people. At least 25% of this population had MCWD as its only supplier of potable water.

An Interim Report had been submitted on 26 August 1975 "for early review by LWUA, the Water District and the Asian Development Bank." Apparently there was some frenzied activity, understandable because one was dealing with "inadequate and unsafe" water for half a million people.

The Cebu business community had realized the seriousness of the failing water supply in Cebu. It contacted USC in April 1974 where it found a response. This response found a solid echo in Nederland where the Technical University of Delft offered to "transfer technology," as it was formulated during discussions in Nederland in August 1974. The combination of local financial and intellectual resources with urgent demand received professional input from the Dutch Development Assistance and resulted in the formation of the University of San Carlos - Water Resources Center, May 1975. A 4-year assistance contract became active in January 1976 between TUD and USC. This particular contact is still alive, but at present as a part of a much more solid interaction. The questions that are formulated at the end of 1.3 were not raised at this time, but the general feeling was strong that water supply must be supported by local understanding and know-how.

Independent, but parallel and mutually beneficial, activities in Manila resulted in a much larger assistance to the MCWD. On 1 Aug 1975 Kampsax, Krueger, Lahmeyer International started a project that involved the feasibility of the Lusaran dam, the evaluation of the capacity of the coastal aquifer and the improvement of the distribution network. Although in a later stage "education" was added, the professional development of the MCWD staff in the basics of hydrology received little attention. This omission is understandable. Training was a very small item on the initial contract. Further, expatriate engineers are not teachers by choice. Finally, in a culture where a Bachelor diploma is considered as the de-facto final diploma, too few candidates have been prepared to improve their personal knowledge in sufficient depth.

Looking back at the activities in Manila one feels strong competition in a field that was not yet really established, as LWUA was only established after 1972. Was it a concept that had thoroughly been discussed already? The MCWD was formally established on 9 May 1974. On 14 October 1974 funds had been raised and a contract signed with a substantial expatriate man-power contingent. The Interim Report was produced by CDM on 26 August 1975 for the ADB. 15 March 1976 was the deadline of the bidding that ultimately sent KKLI to Cebu on 1 Aug. 1976 under a World Bank funded contract. Along the way CDM received a "yellow card", 3-year elimination from competitive bidding in the Philippines. This verdict may have been legally correct. But was CDM morally to be blamed for accepting an inadequate TOR? Who outside the country knew that an official "60% of the actual" was the local way of saying "I have no idea" about how closely the given number approaches the real situation? One may hope that the reliability of the data has improved. And then it may also be advisable to make agency and individual accountable for mis-information.

In hindsight all elements to push hard for transfer of technology were on the table at this point in time: the generally inadequate and unsafe supply of the second city of the country; the lackluster response of the Water Works System; the glaring difference between local and foreign engineers (representative samples for both parties); the scope of professions from cartographers to anthropologists, from geologists to hydraulic specialists. Those facts were recognized; a search for cause and remedy was not initiated on government level.

Resources

1. Surface Water

The presence of a large group of expatriates, in 1978 the number during a short period reached 40, took much pressure away from the technical staff of MCWD. This was particularly noticeably in one area: hydrometry, an at-the-time for Cebu esoteric subject. Data on rain fall, rain intensity, evapotranspiration and river run-off are far removed from water meter readings, but hydrometry in the end measures the supply of a Water District. In the same context the Buhisan dam was left to the TUD-WRC cooperation. The results of these studies have been mentioned already. It took more than a decade before recommendations were implemented. For an outsider the reasons are obvious. First the dam was still productive. The seriousness of the reduced storage capacity never had been translated into lost business opportunity; otherwise the opening of the sludge drain would have been a fact in 1975. Second the visible actors were "only students". As mentioned already, a full-time MS-student is locally not well known. However, West-European Master of Science students are the product of a very demanding 12-year secondary/ tertiary program and a Master Thesis is the product of at least a full-year study with much technical support and strict supervision. Finally, any report costs money. The thesis, covering the Buhisan dam, did not cost a single peso, as all expenses were payed by Dutch sources. Locally, even very costly reports, paid by World Bank loans, are often relegated to the shelves. But the fact remains that hydrometry is even today insufficiently appreciated as the basic measurement of fresh water resources.

The KKLI group produced a feasibility study for the Lusaran valley that reached the level of a pre-engineering report for the implementation. The capacity was placed at 150,000 m^3day^{-1}. The structure might have produced water from 1987 on. At that time the relation between Manila and Cebu was best described as the stereotypical relation between a colonial capital and an outpost of the colony. Not only a strong intellectual and economic drain flowed towards Manila. But also initiatives had to originate in Manila in order to have a chance for implementation. It was the existing leftover of colonial times administration reinforced by a dictator who had to settle personal accounts.

A kind of pacifier was found in the feasibility study of the Mananga dam. One expected that the construction would be less costly. It turned out that for less money one receives less water.

A different combination of the KKLI companies, now working under the name Cebu Consultants, evaluated the feasibility of a dam. The complexity of a feasible dam-site combined with the presence of a sizable population cluster, an existing road connection and a large natural reservoir produced a two-phase development plan (1985). Phase I taps the natural reservoir at 25,000 to 35,000 m^3day^{-1} by means of 15 wells. This has been developed at a cost of several hundred million pesos by means of a loan that was provided by LWUA at an interest rate that lays a few percentage points below the commercial rates at that time. Objectively it was a political fine imposed on Cebu, because the money was part donated, part acquired by soft loans.

Phase II is a high dam that can produce 70,000 m^3day^{-1}. It has been the object of three feasibility studies respectively by CC with a revision by Electrowatt, by PCEEM and recently by Bechtel International, Inc. The different consultants agree on the technical viability. The financing is the last hurdle.

The hurdle is serious. Existing laws and regulations make it impossible that the national government finances a dam for Cebu. It is against the devolution of power. But if Cebu avails of a soft loan, the national government adds charges for handling and securing so that a 2.5% soft loan becomes a 13% commercial hard dollar loan. A logical, not-colonial approach would be: let Cebu be responsible for the whole package, inclusive of some risk of a dam that not always performs as expected. In the case of the Mananga dam Cebu can take the risk of not being allowed to use a hose to clean the family car in times of exceptional drought. This is namely the practical translation of accepting a 95% confidence rate on 70,000 m^3 daily (21.6 million m^3 yearly).

It should be mentioned that discharge and corresponding confidence rates are calculated by means of statistics over a 25-years period. These calculations do not account for a recent development: the predictability of below-average dry years (El Niño events). The last three events have been correctly predicted with a lead-time of five to six months. Very interestingly for Cebu, the first warnings were given a few months before the beginning of the rainy season. Consequently, in wet years without El Niño warning more than 70,000 m^3 could be used per day. The increased risk of non-performance (the El Niño is predicted by the weatherman) can be absorbed by a buffer pumping capacity of the MCWD. In this way the overall production of the dam might be increased by one or two percentage points, while "loss of water" due to overtopping is nearly totally prevented.

2. Groundwater

The KKLI staff realized that the construction of a dam would take several years. In the mean time well fields were developed to serve the pressing needs. With the well fields came storage reservoirs of 5000 m^3 in 1978-1980. The purpose of these reservoirs is primarily to serve as buffer, thus as pressure regulator, for peak hours. The other advantage is that the pumps in the wells always work against the same head, so that the pumps can be designed for maximum efficiency. Once the dam would be on-stream, the reservoirs would function as pressure regulators and the wells would bridge supply gaps during droughts.

The wells that were constructed in the period 1978-1985 were actually designed as a stopgap measure during the construction of the Lusaran dam. The increased risk of seawater intrusion in the coastal zone was accepted, because most of the small private wells in that zone should be phased out as too close to septic tanks. The informal discussions of the KKLI staff placed the full-utilization of the Mananga potentials at around 1995 to 2000, 15 to 20 years in the future. The wells of 1978-1985 surely would be needed again. The geologists had indicated potential dam sites in the Mananga basin, the hydrologists agreed on the need to tap the Kotkot basin. Geology and topography indicated that wells in the cone of debris might be a way to harvest the Kotkot water. And some part of the 1978-1985 wells capacity would again be very welcome in the period before the full utilization of the Kotkot potentials was realized.

During the KKLI project a backbone transmission line was constructed just at the foot of the hills from Talamban to Tabunok. It was designed to receive 150,000 $m^{-3}day^{-1}$ from a future treatment plant at the location of MCWD's shop in Talamban. The Lusaran dam was to supply the raw water through a transmission line tunneled underneath the Kotkot valley. At the Tabunok end it was expected to receive water from the Mananga valley.

The expansion of MCWD was clearly expected to be to the North. In Casili, Liloan and Compostela sites for well fields were found and developed. A combination of terrain and right-of-way problems led to drop the hill-side backbone concept in favor of a transmission line along the North road. Around the existing distribution system many kilometers of new distribution lines were laid.

The use of groundwater presently is essential for Cebu. But it is also a risky affair when people live on top of the groundwater reservoir. The risks are two-fold. When the extracted quantity is too high, seawater will contaminate the aquifer permanently. When the wellhead is insufficiently protected, microbial (or chemical) elements may create a health hazard.

The risk of over-extraction has been recognized since the late 1960s. The spot checks of that period have been expanded to more than 130 sampling points that have been sampled once every year since the late 1970s. The construction of exclusive observation wells, as opposed to production wells, has been done in less than 10 instances. Too few suitable sites can be found. Operational wells may not give the detailed information about the salinity gradient-with-depth of the aquifer. But a larger number of observation points produce sufficient information over time. The seawater intrusion is advancing inland. The logical conclusion, less extraction, cannot be implemented because the MCWD does not have a sufficient volume of water to distribute. MCWD supplies 135,000 m^3day^{-1} and estimates that this is 50% of the demand. Measuring extraction rates of private wells would require the installation of several thousands of water meters under technically and operationally difficult circumstances. MCWD has chosen to concentrate its energy on finding other sources to replace the over-extraction. Once MCWD can supply sufficient water, the small private wells are to be eliminated. Large installations might be retained, but extraction rates must be monitored.

MCWD operates 100 wells at present. More than 60 of these wells are situated close to or in residential areas. These locations, combined with a partly karstic aquifer, make it difficult to establish an adequate wellhead protection. Potential contaminants are chemical or bacterial in nature. Contamination by heavy metals, waste of nickel-plating, has been reduced and most probably will not find its way to the potable water source. Leaks and waste from gasoline stations has not been a subject of a systematic survey. Hydrocarbons become a serious health hazard when heavy chlorination is required to eliminate bacterial contamination. Septic tanks and drains are the source of the bacterial contamination. Wells with deep-sited screens and small draw-down do not exaggerate vertical mixing. Thus the danger of bacterial contamination is reduced, but not excluded. Wells that pump directly into the distribution lines, are usually sited in less protected locations. These direct supply wells constitute 30% of the number of MCWD wells, luckily not 30% of the volume of water. Chlorination reduces the number of microbes, but reduction is measured in percentages. The remaining risk may still be higher than desired. The acute danger of this contamination can be reduced by reliably functioning chlorinators. Bacterial contamination. however, also contains viruses and prions. Some of these viruses have a long dormant life in or outside the human body. Prions could act as triggers of dormant infections like ALS and BES. Thus this type of contamination could well be a time bomb. In the case of direct-supply wells chances are that the contaminating human being would become the contaminated person: waste water that seeps into the ground close to such well, may well be recycled into the water distribution of the site. The risk is small but real. Complacency is not acceptable.

The general lowering of the water table is an established fact. In the Tabunok area the level of the water table has been lowered by 5 m between 1948 and 1980. In the Cabadiangan area a difference of 0.7 m has been observed between 1976 and 1996. The cause is the extraction of construction material from the riverbed. The destruction of the highway bridge in Tabunok has been acknowledged as one result. That the natural storage of ground water above sea level was reduced by millions of cubic meters has not yet sunk into the minds of most engineers, definitely not into the minds of the small and large contractors that are still digging.

During the KKLI project a known concept, communal faucets, was translated to practical application in Cebu. Squatters are by definition illegal occupants. No "building permit" exists. Consequently, MCWD cannot legally connect a water pipe to such dwelling. The Social Services of the municipality provided public hand pumps and took care of the maintenance. Local politics, as it is, sometimes used the maintenance as campaign material during election time. Nature, by its seawater intrusion, puts another constraint on these hand pumps. Finally, the bacterial quality of these wells is difficult to control as hand pumps normally take water from the contaminated upper layer of the aquifer. The health risk is obvious because pit-privies are common. A central "watering-point" that is fed by MCWD is the obvious solution, from a technical standpoint. To make the solution viable, a social infrastructure is essential. Thus the communal faucet was introduced. Starting with an existing, or new, community organization, MCWD entered into contracts that defined modes of maintenance, collection of fees, payment of water bills. The practice works in more than 200 locations that serve between 20 and 50 households each. On a much wider horizon, the communal faucet is one illustration of the Dublin Statement (Rio de Janeiro 1992) that potable water systems should be managed by their users.

Evaluation

1.Distribution

Since 1974 the improvement of the water distribution has been enormous: about 50% of the present population in the services area of MCWD receives good drinking water in a reliable way from the Water District. A small (estimated at 15,000 to 20,000 people) segment carries its drinking water from communal faucet to residence. This adds a contamination risk, but it can be controlled by the user. MCWD charges PhP 22.00 per m^3 on the average, P18.00 for the communal faucet client.

The other 50% partly relies on private distribution systems in sub-divisions. These usually are in good shape. Then there are a few thousand private wells with electric pumps serving up to 100 households each. The quality varies from perfect to doubtful. The same remark can be made about the hundreds of handpumps, private or public. The costs of water for these groups vary from a few pesos per cubic meter to some thirty pesos. However, the cost calculation is in many cases very vague.

Water vendors are a completely different group of suppliers that caters to the non-MCWD clients. There are those who have several tank trucks on the road. They supply inter-island vessels, commercial buildings and subdivisions. Quality is acceptable to good. Prices vary from P20.00 to P100.00 per m^3. One has also vendors who have only a pushcart on the road. They deliver water to "forgotten" corners in containers of 20 liters. Prices start at P100.00 per m^3 and reach up to P400.00 per m^3.

Detailed quantification of all these groups would require a house-to-house survey. The simple existence of so different ways of water supply in a city shows that the coverage of the MCWD must be expanded, although at present everybody has access to sufficient water. The main constraint is however the insufficiency of the present source: the coastal aquifer.

The losses in the distribution system are monitored as cubic meters that are not accounted for. The method is clear: The production is metered, the sales are metered and charged, the ratio "charged" over "produced" is the system's performance. The system's loss (1-performace) is about 36% at present. Uncertainties of meter readings account for few percentage points on the system's loss. Leaks are probably the main cause together with unregistered connections, still possible in the down-town area, and outright theft by manipulation of meters. The expectation is that segmenting the down-town area will eliminate the unregistered connections, reduce theft and assist in finding invisible leaks.

The re-introduction of the direct-injection wells is essentially an emergency measure with several risks. The projections of the Internal Rate of Return were favorable. Reports of Actual Rate of Return do not reach the Board. The extra volume provided by these wells is needed without doubt. Are the costs commensurate with the health risks?

MCWD has identified additional sources that it can exploit without external support. The constraints are mainly political in nature. The costs are acceptable. The identified volume is about 60,000 m^3 per day.

2. Chemical Water Quality

The coastal aquifer is under stress: more fresh water is extracted than nature resupplies. The indicator that is used, is the concentration in parts per million (ppm) of chlorine ions (Cl^-). In the period from 1960 to 1980 the Chemistry Department of the University of San Carlos analyzed many water and rock samples as exercise in analytical chemistry. Cl^- concentrations were measured by color change during titration. Based on a couple of hundred analyses it was observed that away from the sea, no fresh water contained more than 30 ppm Cl^-. Based on this observation the conclusion was made that a concentration of more than 30 ppm Cl^- indicates the presence of seawater[4]. It is regrettable that no formal publication was made. As a practical guideline 50 ppm Cl^- was chosen as the first signal of the presence of seawater in the fresh water aquifer. The steady move inland of the 50 ppm Cl^- isoline gives the population a serious warning to either find substantially additional sources or to prepare to live with a substantially lower volume of fresh water.

In rich countries storage tanks of gasoline stations are double walled with indicators that show when hydrocarbons collect in the void between the two walls. Spills of oil change and other maintenance works have to be collected according to strict procedures. This is prescribed to prevent contamination of the environment. The arrangement warns when leaks develop before contamination enters the soil. The penalty on contamination easily exceeds the

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[4] 25ppm Cl^- is equivalent with one liter sea water mixed with 1000 liter fresh water, if sea water is the exclusive source of Cl^-. This is of course negligible in the context of potability.

real estate value. Simple observations during a change of the car engine oil make clear that in Cebu much oil is directly discharged in the rain/dirty water drain. And is the storage tank double-walled? And is the penalty proportional? One should not forget that the chlorination of hydrocarbons-containing-water produces carcinogenic substances.

3. Microbial Water Quality

The wells drilled during the KKLI presence (until 1985) are located sufficiently far inland to avoid serious risks of up coning of salt water. Thus it became feasible to penetrate 20, or more, meters into the groundwater reservoir. Contaminants that seep down from the surface, normally do not affect the lower layers. A clever well design combines a deep screen with a small draw down and thus prevents these contaminants to be sucked into the well. This approach was forced upon the designers, by the topography of the location. It worked well: all these wells are free from bacteria.

At the discharge of the buffer reservoirs, chlorinators inject chlorine into the distribution line as an extra safety. The combination of small leaks and low pressure does not lead to disaster because of the presence of free chlorine.

However, since the early 1990s some 30 "direct-supply wells" have been added to the system. Most of these wells are situated in the built-up area. These wells are provided with individual chlorinators. It is an open question if the added risks of higher contamination have been balanced against the advantage of the added volume of water.

The danger of microbial contamination has been underlined by the discovery in the 1990s of prions. Prions are pre-proteins that are normally present in live cells in folded, resp. stretched shape. They are suspected to trigger dormant infections as Amyotrophic Lateral Sclerosis (Gehrings disease) or Bovine Encephalitic Syndrome. The destruction of bacteria by chlorine is quite efficient, more efficient than the destruction of virus, a less complicated structure. Does chlorine destroy prions? The potential danger can be minimized by preventing positive feedback: contaminated water should never reach the source of the contamination. However, water from a direct-injection well is probably consumed in the surrounding of the well. Only medical statistics can give the answers after 15 to 20 years.

Where to?

More than 2000 years ago the same question was asked, be it in another language: "quo vadis?" And each future case study will end with the same question. Does there exist an answer for Cebu?

The study shows a great progress from an initial <u>public supply</u> of 9000 m^3 day^{-1} to 135,000 m^3 day^{-1}. But the population, served or to be served, increased to

1.3 million at present. The supply does not anticipate the demand. The supply follows the demand.

The distribution network has been expanded and improved. The ratio between extracted volume and billed volume is slowly improving. But the break-up of one distribution block covering some 70% of the total volume is very slow in coming. The Board of the Water District provides incentives to improve the recovery rate. One feels a lack of understanding of the process by which this improvement can be made. Every month time is spent to discuss fluctuations in the performance of some 10 sections that consume only less than 30%, while no mention is made about progress of breaking up the single 70% block.

The quality of the water receives much attention. Regular microbial analyses are made. But the prevention of contamination, the wellhead protection, does not stretch farther than a few square meters around the well. Information about leaking septic tanks and gray-water drains does not elicit serious reactions. Inspection of newly constructed septic tanks is apparently not considered as a task of the Water District, although traditionally the sewerage is the domain of the water supplies; witness the names NAWASA, respectively MWSS, which include the Sewerage. The Charter of the Water Districts extends their responsibility over the sewerage. Information about new developments, as EPA guidelines or the discovery of new types of pollutants, seems not to make any impression.

The collection of hydrometric data, the fundamental supply side information, is contracted-out. The data are faithfully received. The pumping data of the Jaclupan well field are collected through a wireless system, capable of storing daily figures. Are these figures correlated with the Mananga river hydrometric information? This correlation might reveal the speed of the underground flow from river to wells. Are the Jaclupan wells pumping fast-filtered surface water? The 50-days retention time of surface water as required by USA and EU directives has been discussed extensively. It was mentioned as a serious negative constraint in a specific BOT. It was discussed in connection with the operation of the infiltration field of the Jaclupan wells. But seemingly nobody asked the question how many days pass before the river water that goes underground 2 km upstream of the well field, is extracted by the wells. Admittedly no changes can be made at present, but risks must be acknowledged and evaluated where possible.

Notwithstanding the presence of computers with sufficient CAD software, requests for approval of extensions of the distribution lines are never accompanied by schematic or design drawings that show the location with flows and pressures in the area. Is not one picture worth a thousand words? Everybody agrees that visualizations are great means to clarify situations. Do people realize that a deep understanding of the situation is essential to produce good visualizations?

There must be an underlying reason why so many questions are unanswered, questions, which can be answered by abstractions or generalizations. One suspects that the answer must be sought in the educational system. After all, the staff of the MCWD is a product of this system. It has often been said that the system stresses rote learning. It definitely does not encourage independent exploration. Analysis of problems followed by a synthesis of solutions is not a clear strength of college graduates. Add to this the observation that under the present formative environment of comics and television the abstractive power of the mind is developed at the age of 20 only. The present university graduate has learned what to think. At least a portion should learn how to think. The conclusion is clear: more young people must have a chance to add two to three years of full-time study. In the sector of the applied sciences the student must learn to recognize the theory beneath the observed facts and final applicable solutions based on the theory[5]. It is a difficult task, but the reward will be the much-needed local scientific force for development.

Postscript

This Case Study does not include the pricing of water, because economics is not the realm of a physicist. The terminology shows the difference between economics and physics. Economics deals with "speculation" (on the stock market) and "games" (of mergers). Such terms are not part of physics. Diversion of cash, generated by the service of distributing potable water, is not governed by scientific laws. The transgression of rules, physical or financial, can be catastrophic. But remedies in the physical sector, if they exist, may take eons. In the financial sector corrections can be made in a number of years.

On the micro-economic level pricing of water is an absolute mystery, in the eyes of a physicist. In Cebu, people faithfully pay an average of P22.00 per m^3 (1,000 liters). In Manila, people complain when charged P9.00 per m^3 (for its distribution only, the collection and treatment of water was paid by the national government). Again in Cebu one can buy cold water at some traffic lights for P10.00 per 0.3 liter. And "ice-water" is available down town along the sidewalk for P0.50. The plastic bag contains an estimated 0.1 liter. Admittedly one consumes "at one's own risk." The price increase in Manila to some P30.00 in this year, is supposed to pay for the cost of collecting and treating surface water. A recent (2002) cost calculation of a dam construction with the necessary accessories shows that raw water may cost some P16.00 per cubic meter when a

[5] In the present Bachelor's programs the absolute reliance on facts and formulas should be trimmed in favor of the underlying general principles. An illustration can be given in Ohm's Law and Darcy's Law that basically state that speed is proportional to force, what is in blunt contradiction to Newton's Law who in the 2nd half of the 17th century stated that acceleration and force are proportional. Such empirical laws are practical and can be used automatically but IN THE LIMITS OF APPLICABILITY. Once and engineer has been wondering why pre-Newton formulations can safely be used (because the physics behind them shows limits), he has learned to ask questions.

soft loan (2.5 % over 25 years) is utilized properly. After 25 years the P16.00 (amortization costs) are reduced to essentially lower maintenance costs. Cebu's Buhisan dam shows that a 100-year useful life is clearly possible for a dam. P14.00 per cubic meter seems to be a very reasonable price for distribution, when the system is in good shape.

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