

The Water-Energy Nexus: Exploring Options for Davao's Future

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ABSTRACT: This paper analyzes the impending water and energy crisis in Davao City. Three statistical models namely linear, exponential, and cubic were used to predict future water and energy demands. The Tamugan River offers a potential source to address this looming problem, yet, it has become a source of conflict mainly between the Davao City Water District and Hedcor, Inc. The former is bent on harnessing the river which is known to have an abundance of high-quality surface water, while the latter proposes to establish cascaded hydropower plants given the river's immense volume of flowing water. Notwithstanding the sincerity of both parties, the current conflict on who should harness the Tamugan River and how it be harnessed has to be resolved to avoid forestalling Davao City's development.

KEYWORDS: Water, energy, Mindanao grid, Davao grid, Tamugan, Talomo, Lipadas

Introduction

Population growth and economic development have pushed the demand for all forms of resources especially water and energy (Scott et al. 2011; Voinov and Cardwell 2009). The interlink between water and energy needs to be conscientiously looked into as it has a lot of implications for the environment and communities. Water is needed to process and generate energy (Rio Carillo and Frei 2009) while energy is a requirement to extract, treat, and distribute water (Siddiqi and Anadon 2011).

Davao City is purportedly the second largest city in the world, and is situated at the southeastern part of Mindanao, Philippines. There are eight overlapping watersheds flowing into the city and the gulf of Davao (Hearne et al. 2008). Its population in the year 2000 registered at 1,147,116 and is growing at a rate of 2.41 percent annually (National Statistics Coordinating Board [NSCB] 2009a). With the increasing population, more houses, commercial and industrial buildings have been built. Hence, the demand for water and energy has also accelerated.

The watershed of Tamugan River, found to have the highest quality of water (Class AA), is viewed as a potential source to address this increasing demand. The said river, however, has become a source of conflict as to whether it should be used to generate energy or used as a water source. Two organizations, namely Hedcor, Inc., a private developer of run-of-river hydropower plants, and the Davao City Water District (DCWD), a semi-government water utility company, are engaged in this tug-of-war. The former plans to install a set of hydropower plants at the Tamugan River while the latter also intends to use the same river as a source of water for distribution to the people of Davao City. Until 2009, DCWD has ownership rights over the area, but thereafter questions as to who has the right to use the river remains unsettled.

The study was conducted to determine the state of water and power and their interlink in Davao City. Three statistical models, namely linear, exponential, and cubic were employed to predict future water and energy demands. Data published by the Department of Energy (DOE) and DCWD were used in developing the models of these demands. Data obtained from the Davao City government, NSCB, and the National Grid Corporation of the Philippines (NGCP), previously named as Transmission Corporation of the Philippines (TRANSCO), were also used in the analyses.

Framework

Generally, water and energy are interdependent on each other. Water is needed to process and produce energy while energy is required to extract and dispose water. Both resources are crucial to the population and economic growth.

Water extracted from the Dumoy water wells through the use of multiple pumps are directly fed by the DCWD to the residential, commercial and industrial buildings, and other agricultural and manufacturing establishments in the Davao City area. Meanwhile, the NGCP is responsible for feeding the energy produced by the power plants installed at various locations in Mindanao to specific areas. In Davao City, the Davao Light and Power Company (DLPC) distributes electricity to the end users, such as the DCWD which uses the energy in extracting water.

With population growth and improved economic mobility, the supply of water and power is potentially imperiled and could be surpassed by demand. Tamugan River is viewed as a potent source for either water supply (through DCWD) or power generation (via Hedcor, Inc.) or both, providing an option to address the impending water and energy crises. See Figure 1 for the framework used in the study.

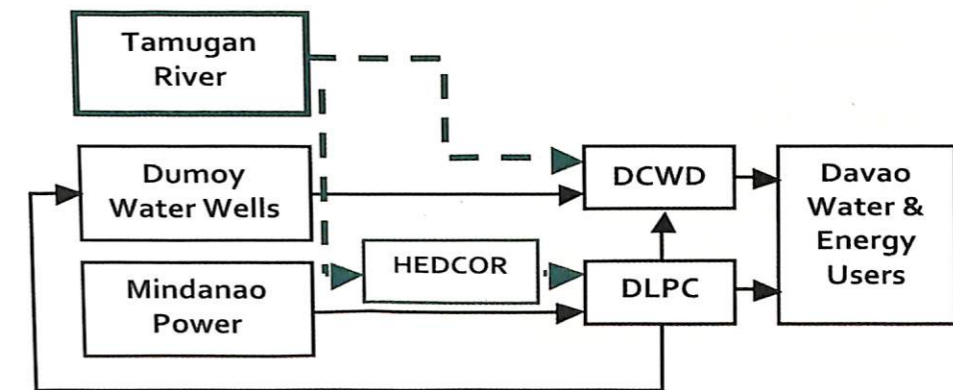


FIGURE 1: Water-energy nexus framework.

On the one hand, Hedcor, Inc. is the largest private developer of run-of-river hydropower plants in the Philippines. It owns and operates fifteen hydropower facilities in Benguet and Davao, with a total capacity of 38.22 MW. Presently, it is working on the 42.50 MW hydropower plant at Sibulan, Davao del Sur. It has developed and constructed twelve mini-hydropower plants within a span of ten years. To increase its hydropower portfolio, Hedcor, Inc. is proposing to develop a 27.5 MW hydropower system at the Tamugan and Panigan rivers. On the other hand, DCWD is a semi-government company that distributes potable water to the people of Davao City for drinking and other purposes. DCWD operates water pumps at the Dumoy area to extract water through its water wells. From 1977 to 1992, forty three water wells were drilled and thirty of these were free-flowing (Lotti 1982). About 90 percent of water distributed by DCWD comes from groundwater sources or the Dumoy aquifer. To increase water production, DCWD plans to use both the Tamugan and Lipadas rivers for water distribution (see Appendix 1). In May of 1997, the National Water Resource Board (NWRB) granted DCWD permit to use water from Tamugan River with the diversion point at Upper Baguio, in Baguio District.

Methodology

The data on water profile and relevant parameters provided by DCWD, data on the state of energy in Mindanao obtained from the DOE and TRANSCO, and the proposal of Hedcor, Inc. to install hydropower plants at Tamugan River were used in the analyses. These data were respectively presented during a roundtable discussion at the Ateneo de Davao University (ADDU) in 2009. Three statistical models namely, linear, exponential, and cubic were used to predict which best fits future water and energy demands.

The linear model can be described by the equation of a straight line $y = mx + b$. Where y (vertical axis) here is the dependent variable representing MW (megawatt) for power and MLD (million liters per day) for water; the m refers to the slope of the line (0° to 360°); the x (horizontal axis) which represents the year; and, b (the y -intercept) is the initial y -value (in MW

or MLD) of the model. If the R^2 of the linear model for the actual data set is about 0.90 to 0.99, the modelled data set resembles the actual data set. Meanwhile, the exponential model is defined by the curve function (concave up) $y = ab^x$. Here y and x represents the vertical (MW or MLD) and horizontal axes (year), respectively. The a here should be greater than 0 ($a > 0$) and b can be of any value. Again the higher the value of R^2 , the higher the reliability of the modelled data set. Finally, the cubic model is a polynomial model with a degree 3 which can be defined by a function $y = ax^3 + bx^2 + cx + d$. Again the y and the x values are the vertical (MW or MLD) and horizontal (year) values. Note, however, that the highest degree of the first term is 3 (ax^3). This would mean that the data set is expected to curve up and to curve down once for all the data in a set. Similar with the linear and the exponential models, the ideal value for R^2 is 1.00 to suitably represent the actual data set.

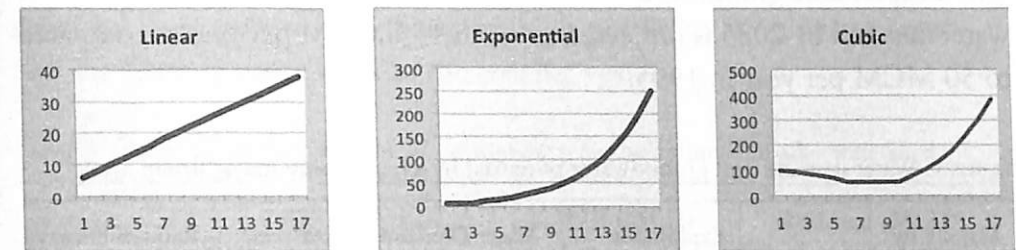


FIGURE 2: Three statistical models namely, a) linear, b) exponential, and c) cubic.

Results and Discussion

Water is a critical natural resource, and its existence depends largely on how it is being used and how the watershed surrounding it is being protected. With non-existing or limited government policies, and weak law enforcement in managing and protecting the watershed, water quality and quantity may be imperiled (Scott et al. 2011). In Mindanao, water is also being used for power generation. There are other water sources outside Davao City, but the interest to set up both water plants and power plants are centered in the Tamugan River. To understand the water-energy nexus situation in Davao City, the succeeding sections present the facts on water, power generation,

the use of Tamugan River, and the identified points of conflict between Hedcor, Inc. and DCWD.

Water

Davao is one of the most progressive cities in the Philippines. In 2000, it registered a population of 1,147,116. Population is growing at a soaring rate of 2.41 percent annually (NSCB 2009a). However, as reported by NSCB (2009b), economic mobility in Davao region slowed down in 2009. With the growing population and rapid establishment of residential, commercial and industrial infrastructures, Davao City is confronted with a substantial demand for resources, especially water and energy. It is considered by the NWRB (1998) as one of the nine water-critical urbanized areas in the Philippines with exhaustive consumption of water (see Table 1). Davao City's exploitable groundwater is 84 million cubic per meter (MC) per year; water demand by 2025 is projected to reach 153 MCM per year as compared to 50 MCM per year in 1995.

TABLE 1. Water demand and groundwater potential in selected nine major urban areas

Major City	Exploitable Groundwater (MCM ¹ / year)	Water Demand (MCM/year)		Ratio of Demand in 2025 to Demand in 1995
		1995	2025	
Metro Manila	191	1,068	2,883	2.7
Metro Cebu	60	59	342	5.8
Davao City	84	50	153	3.1
Baguio City	15	12	87	7.3
Angeles City	137	11	31	2.8
Bacolod City	103	37	111	3.0
Iloilo City	80	9	47	5.2
Cagayan de Oro City	34	29	98	3.4
Zamboanga City	54	28	203	7.3

Source: NWRB 1998, ¹Million cubic meters (MCM)

The Department of Environment and Natural Resources (DENR) of Region XI and the World Bank (WB) commissioned Asia-Geodyne Corporation to conduct a study to determine the residual volume of groundwater in the Talomo-Lipadas watershed (DCWD 2009). The result of the study showed that the demand for water will most likely surpass supply starting 2011 onwards (see Table 2). Aside from the increasing demand, DCWD (2009) claimed that nine of the water wells in barangay Dumoy already experienced a 3.5-meter drop. This would entail significant reduction in the production of water from the nine water wells. This is a condition that is quite common in China where the water table in some areas was reduced by about 30-35 meters in just thirty years (Voinov and Cardwell 2009). At a decreased water table, saltwater intrusion may happen and may affect the fresh water aquifers, thus affecting the overall quality of water supply (Palanca-Tan and Bautista 2009). In the case of Davao City, the situation may lead us to believe that there is a high possibility of saltwater intrusion into the Dumoy water wells in the coming years.

TABLE 2. Projected residual volume of groundwater in the Talomo-Lipadas watershed

Year	GWR ¹ (MLD)	GWU ² (MLD)	Residual (MLD ³)
1997	280.5	134.61	145.8
2001	280.5	163.68	116.82
2005	280.5	199.03	81.47
2009	280.5	242.03	38.47
2011	280.5	280.50	0.00
2013	280.5	294.30	-13.80
2017	280.5	357.87	-77.37

Source: Asia-Geodyne Corp. in DCWD 2009

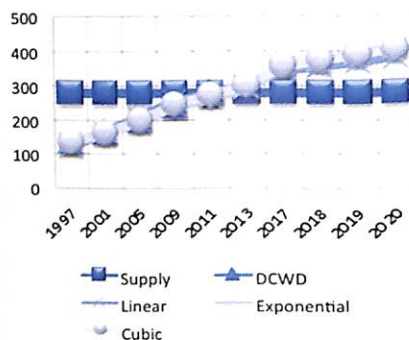
¹Groundwater reserved (GWR), ²Groundwater used (GWU), ³Million liters per day (MLD)

To determine the production of water in the future, with reference to the Asia-Geodyne Corporation data, three statistical models were used to forecast

future demands, namely a) linear, b) exponential and c) cubic models. For a highly reliable projection, the coefficient determinant or the R² should have a value of 1.00 or 100 percent. Based on the three selected models, the linear model gave an R² of 98.72 percent, the exponential model showed an R² of 98.11 percent, and the cubic model provided an R² of 98.88 percent. From these data, it can be inferred that the most suitable model is the cubic wherein the water demand for 2013 will reach 299.15 MLD. If supply stays at 280.50 MLD, it is possible that water supply will not be enough to supply the demand on or before 2013 (see Table 3). This information indicates that the problem of water supply may happen soon. However, the data shown do not consider additional supply of water derived from other pumps or sources, the impending dropping down or drying up of the water wells due to watershed denudation, over-extraction of water, and the impact of climate change.

TABLE 3. Projected water-supply demand in MLD

Year	Supply	DCWD	Linear	Exponential	Cubic
1997	280.50	134.61	121.20	134.58	134.94
2001	280.50	163.68	165.72	163.25	162.47
2005	280.50	199.03	210.24	198.03	200.07
2009	280.50	242.03	254.76	240.23	246.16
2011	280.50	280.50	277.02	264.59	271.89
2013	280.50	294.32	299.28	291.41	299.15
2017	280.50	357.87	343.80	353.50	357.46
2018	280.50		354.93	370.99	372.69
2019	280.50		366.06	389.34	388.13
2020	280.50		377.19	408.60	403.75



With this foreseen demand for water in the coming years, the DCWD, which was granted permit by NWRB in 1997 to use the Tamugan River, decided to make use of the river for extracting surface water for distribution. The plan can potentially save costs associated with power, since there is no need to install huge water pumps. Water can be allowed to freely flow down to the consumers. However, NWRB sets limits on the use of water to be extracted by DCWD. The latter can only use 4.678 cms (cubic meters per second) during the wet season, and 3.440 cms during the dry season (DCWD

2009). With this permissible level of extraction, DCWD can extract up to a maximum of 404.18 MLD during the wet season, and 297.22 MLD during the dry season. Adding to this extractable water to the current maximum capacity of DCWD at 280.5 MLD, it is possible to extract a total of 684.68 MLD during the wet season and 577.72 MLD during the dry season. Without considering the impact of climate change, watershed denudation, and water wells fatigue, this production is adequate to supply Davao City the needed water even beyond 2020.

Power

The distribution of power in Mindanao is done at a larger scale wherein all power plants are interconnected via transmission lines. These interconnected sources and distribution is known as grid. The NGCP is responsible for managing the transmission of energy from the generating plants. The power grid in Mindanao is subdivided into six districts, namely: Northeastern Mindanao Area (NEMA), Lanao, North Central Mindanao Area (NCMA), Northwestern Mindanao Area (NWMA), Southeastern Mindanao Area (SEMA), and Southwestern Mindanao Area (SWMA). Davao City belongs to the Southeastern Mindanao Area. Distribution of power in the city is accomplished through the DLPC.

The Mindanao power grid is being supplied by hydropower plants (53.55 percent), oil-based power plants (28.44 percent), coal thermal power plants (11.99 percent), geothermal power plants (5.96 percent), and solar power plants (0.06 percent) located in the Mindanao area (TRANSCO 2008). The interconnection of these power plants is being handled and monitored by NGCP. Of the power generated, approximately 75 percent is generated from Northern Mindanao and only about 25 percent is produced in Southern Mindanao and Western Mindanao (see Table 4). All power produced are distributed to three areas, of which Southern Mindanao consumes the most. As shown in Table 4, Southern Mindanao needs 236 MW more than what it is currently generating at 373 MW in order to meet its demand. Moreover, transmitting power from Northern Mindanao to Southern Mindanao entails cost due to transmission losses and installation costs of transmission systems.

TABLE 4. Capacity in Northern, Southern and Western Mindanao

Area	Installed Capacity		Dependable Capacity		Peak Demand		Reserve
	MW	%	MW	%	MW	%	
Northern Mindanao	1448	74.87	1259	74.85	464	38.57	795
Southern Mindanao	373	19.29	323	19.20	559	46.47	-236
Western Mindanao	113	5.84	100	5.95	180	14.96	-80
Total	1934		1682		1203		

Source: Department of Energy 2009

The DOE in 2009 projected that the peak demand for power will exceed the installed capacity starting the year 2014 (see Table 5). Nonetheless, if the reserved margin would be included in the peak demand, or that the required capacity is used as the basis for projection, then the required capacity has already exceeded installed capacity since 2010. Reserved margin is the required capacity to be maintained to ensure continuous supply of power in case one of the plants breaks up at any given time, ensuring power systems availability. As shown in Table 5, a 21 percent reserved margin was used by the DOE. In the first quarter of 2010, Mindanao experienced an energy crisis (Senate of the Philippines 2010). Hydropower plants, both at the Lanao and Pulangi areas, generated outputs of less than 50 percent of their expected capacities. As a result, power curtailment was implemented.

TABLE 5. Mindanao power supply outlook in MW (2008-2017)

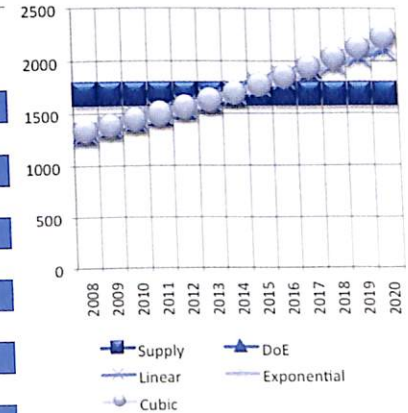
Particular	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Installed Capacity	1682	1682	1682	1682	1682	1682	1682	1682	1682	1682
Required Reserved Margin	278	288	301	313	326	340	354	370	387	406
Percent of Peak Demand	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Peak Demand	1325	1372	1431	1488	1552	1618	1688	1763	1844	1932
Required Capacity	1603	1660	1732	1801	1878	1958	2042	2133	2231	2338

Source: Department of Energy 2009

On the basis of the data published by the DoE, three statistical models were used to predict energy demand. All statistical models showed high level of determination: The linear model produced a coefficient determination (R^2) of 99.33 percent, the exponential model 99.91 percent, and the cubic model 1.00 or 100.00 percent. Using the cubic model, it was found that the demand for power in 2014 would reach 1688 MW which is about the same as the installed capacity of 1682 MW. The projection shows that starting 2014 or even before 2014, that is, presupposing that the power plants do not work on their designed capacity, it is highly probable the problem on energy may happen (see Table 6). This would further mean then that there is a need to install new energy capacities. Forecasted power here does not consider the reserved margin.

TABLE 6. Mindanao power supply-demand in MW

Year	Supply	DoE	Linear	Exponential	Cubic
2008	1682	1325	1299	1316	1323
2009	1682	1372	1366	1371	1375
2010	1682	1431	1433	1429	1430
2011	1682	1488	1500	1489	1488
2012	1682	1552	1568	1551	1551
2013	1682	1618	1635	1617	1617
2014	1682	1688	1702	1684	1688
2015	1682	1763	1769	1755	1764
2016	1682	1844	1837	1829	1845
2017	1682	1932	1904	1906	1931
2018	1682		1971	1986	2023
2019	1682		2038	2069	2121
2020	1682		2106	2156	2226



Among all the districts in Mindanao, SEMA, which also includes Tagum City and General Santos City, consumes more power than any other district (see Table 7). While no data on the distribution of power to Davao consumers are available to date, it is presumed that, due to the evident development of Davao City, its demand constitutes majority of the power consumption as reflected under SEMA. Distribution of power in the city is as follows:

Residential buildings (33.64 percent); commercial buildings (13.6 percent); industrial buildings (50.58 percent); and other purposes (2.17 percent). At present, more subdivisions and big establishments are being constructed in the city. As shown in Table 4, Davao City relied heavily on its source of power from Northern Mindanao. With the growth of other neighboring cities, the establishment of more companies, and the threat of climate change, Davao City's development may be hampered by insufficient power to meet its present and future needs.

TABLE 7. Mindanao grid districts

District	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NEMA	157	170	176	185	195	205	215	226	239	252	266
LANAO	190	208	220	228	234	240	246	254	262	272	282
NCMA	199	208	215	225	234	243	252	263	275	287	301
NWMA	124	133	138	144	150	156	163	170	178	187	197
SEMA	372	392	403	419	436	453	471	491	513	536	561
SWMA	199	214	220	229	239	256	271	283	296	310	325
Total	1241	1325	1372	1430	1488	1553	1618	1687	1763	1844	1932

Source: TRANSCO 2008

Tamugan River exploration and contesting parties

With the looming water and energy crisis, explorations had been done to locate a potent source of water that possesses acceptable water quality and sufficient water volume to meet Davao City's future needs. High quality surface water is necessary for drinking purposes, while a large volume is relevant for power generation and other uses. Evaluated rivers include Lipadas, Talomo, Davao, Tagulaya, Sibulan, Tamugan and Panigan. Tamugan River, which was found to have the highest quality of water (Class AA) and lying within the jurisdiction of Davao City, was identified as the top choice. The water resource of the Tamugan River is viewed as a solution to issues related to water distribution and availability of power.

Figure 3 shows the proposed architecture of the hydropower plant of Hedcor, Inc. to be installed at the Tamugan and Panigan rivers (Hedcor, Inc. 2009). It can be noted that a diversion weir is installed at the Talomo River. Diverted water coming from Talomo will be used to supply the 7.5 MW Panigan hydropower plant. Water output from Panigan will be used as a supplementary water supply to the 20.0 MW Tamugan hydropower plant.



FIGURE 3. Hedcor, Inc. proposed hydropower plant. Source: Hedcor, Inc. 2009, meters above sea level (MASL)

According to the DCWD, the installation of the diversion weir at the Talomo River will potentially affect the lower part of the river. During the dry season, it is highly possible that the diversion weir will be closed to divert water to the Panigan hydropower plant. However, during the roundtable discussion at the ADDU in 2009, Hedcor, Inc. promised not to block the flow of water in the Talomo River in times of drought. Further, the Talomo River provides a significant contribution to the extraction of water at the Dumoy plants. As claimed by DCWD (2009), the Dumoy aquifer is composed of 40 percent rain water while 48 percent (80 percent of 60 percent) is derived from Talomo River (see Table 8). Hedcor, Inc. contested these data. Table 8 shows other points of disagreement between DCWD and Hedcor., Inc.

TABLE 8. DCWD and Hedcor, Inc. data comparison

DCWD	Hedcor, Inc.
Direct infiltration accounts for 40 percent of recharge.	Direct infiltration accounts for 40 percent of aquifer recharging in lower levels.
River soaking accounts for 60 percent of recharge.	River soaking accounts for 60 percent of aquifer recharging below 300 masl.
Talomo River	
Talomo River accounts for 80 percent (of the 60 percent) of the recharge of the aquifer.	Talomo River accounts for possibly 70 percent of the recharge of the aquifer.
Diversion will affect the aquifer and reduce the groundwater available to the pumping wells.	Lipadas system is also a likely major contributor to recharge.
Tamugan River	
Tamugan River accounts for 20 percent of the recharge of the aquifer.	Tamugan River accounts for 0 percent of the recharge of the Talomo aquifer.
Recharge between 600-400m (the Hedcor project affects the aquifer).	Recharge below 300m of Davao River aquifer (thus the Hedcor project does not affect the Talomo aquifer).

Source: Hedcor, Inc. 2009

Moreover, the management of DCWD declined more proposals from Hedcor, Inc. just so that the operation of the hydropower plant in Tamugan River can start. These include the proposal to use the waters of Tamugan and Panigan rivers to roll the turbines of the 27.5 MW hydropower plants (1 unit, 7.5 MW; 2 units, 10 MW). Hydropower plants are cascaded to optimize the harvesting of water. DCWD was offered to use the water as a commodity to be directly distributed to consumers for drinking and other purposes. However, based on the study by Lotti in 2000 and Hedcor, Inc. in 2007, if Hedcor will be allowed to use the water at Tamugan River, DCWD can make use of only 0.12 cms, that is, if DCWD will not use the Hedcor water outflow, while Talomo River will be left with only 0.21 cms if the weir will be closed (see Table 9). DCWD did not give in to Hedcor, Inc.

Table 9. Water Flow at Tamugan and Talomo rivers

A. Tamugan River (estimated flow)	
Total flow of Tamugan and Panigan rivers at the confluence	= 11.00 cms
Requirements of Hedcor	= 10.88 cms
Remaining flow for DCWD	= 0.12 cms
B. Talomo River (mean annual flow)	
Total flow of Upper Talomo River at Hedcor's property diversion tunnel	= 2.58 cms
Proposed diverted water	= 2.37 cms
Remaining flow	= 0.21 cms

Sources: Lotti 2000; Hedcor, Inc. 2009

Conclusion

The projection that the demand both for water and power will surpass the available supply in the nearest future is a challenge that confronts the entire island of Mindanao, particularly Davao City. One way to address this is to encourage people to seriously conserve the use of water and energy. Another is to develop and implement local and national policies to protect the watershed both for water and energy use. Establishing and maintaining an open communication and close coordination between concerned agencies—public and private—to discuss ways to achieve sustainable development for Davao City is also a positive step. In the case of the tug-of-war between the DCWD and Hedcor, Inc. on the question of who should operate and use the water resource of Tamugan River, the third solution is obviously absent. As a result, the city's development is left hanging in a balance. Indeed, while water is a very important natural resource because it supports the lives of animals, plants, and human beings, and considering the fact that it is used to produce electricity, deciding on its proper purpose could prove to be a difficult and challenging task. And yet it is a concern that must be urgently addressed for the sake of the future of Davao City.

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Appendix 1

Talomo-Lipadas Watershed¹

The Talomo-Lipadas watershed is a vital location for the city of Davao. It is believed to contain recharge areas and is the source of aquifers for the Davao City Water District (DCWD) Dumoy water wells and pumping stations. At the same time, it provides agro-economic opportunities and settlement areas for migrants within the vicinity. To ensure high quality of water, aquifers require clean surroundings which are devoid of contaminants to surface water.

Groundwater, however, is often vulnerable to contamination. Agricultural production, manufacturing operations, and settlements may produce pollutants that could affect the aquifer. As pointed by Prantilla (2008), it takes at least thirty years for the water from recharge points to reach the aquifer of Dumoy. Moreover, some of the contaminants and perturbations that most likely affect the groundwater are: Geological-lithological (formation of infiltration and percolation zones); morphological (surface form); geochemical (binding conditions of soil, composition of pollutants); physical (adhesive and cohesive forces in soils); and hydrogeological (surface and subterranean flows, flow direction and velocity) characteristics of the watershed area supplying water to the aquifer and above the aquifer (Prantilla 2008). In addition to the contamination and disturbance of the groundwater, the increasing population and weak legislation to protect watershed areas can contribute to the vulnerability of the Tamugan River.

The Talomo-Lipadas River extends to five districts of Davao City, which has forty-seven barangays. In 1980, the population in the covered area was estimated to reach 261,572; and, in just twenty years, it reached a population level of 552,767. This increase translates to a rate of 3.74 percent annually. With the current rate, it is most likely that population would reach one million in less than two decades. High population growth rates in the five districts would mean expanded use of land area and, therefore, increased disturbance to water and reduced production of water.

Two identified elements that heavily affected watershed areas are urbanization and increased agricultural activities in the area, and excessive deforestation of the forest cover. A study conducted by the Geosciences Division of Mines and Geosciences Bureau (MGB) XI showed that land utilization within the Talomo-Lipadas watershed rests primarily on urbanization and various agricultural activities.

¹ Most of the information in this section was extracted from the presentation of Dr. Prantilla (2008).

Barangays Calinan, Tugbok and Toril demonstrate highly urbanized characteristics where hospitals, universities, churches, markets, and high-density residential areas, industries, among others, can be found. Agricultural lands are used to grow root crops, tree crops, rice, corn, vegetables and other plants. Meanwhile, it was estimated in 1987 that the closed forest cover of Talomo-Lipadas watershed was 6,170 hectares. In just fifteen years, the forest cover has been significantly reduced to 2,593 hectares, which is 42.03 percent, compared to the 1987 forest cover (Philippine Council for Energy and Environmental Management [PCEEM] 2006). The reduction of forest cover may have an impact on the capacity of the watershed to recharge its aquifers: This may cause accelerated erosion of soil and may potentially increase the occurrence of floods.