

## Issues and Perspectives on the Water Crisis of Metro Manila Cities, Philippines

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**Abstract:** This study delves into one of the most prevalent problems of Metro Manila: Sufficient Water Supply. With its burgeoning population, the Metropolis is an amalgamation of common problems of Asian cities: pollution, traffic jams and the lack of basic necessities such as water. The lack of recycling facilities, reliable water supply, and an uncontrollable wastage of commodities by the populace are just some of the causes of this social malady and economic malaise. If these problems are not addressed properly, these cities will soon experience not only a substantial loss of income but also a loss of lives. This paper will provide a deep perspective on the different issues involved: the history of the problem, the underlying issues, the root causes, the proposal of economic and political gurus and the most plausible alternative to solve it. With potable water always at a critical level, with Angat Dam as its primary source of water, the Metropolis is at the mercy of natural elements such as rain and the summer heat. Its main proposal to tap the Kaliwa River into a dam has met stiff opposition from the local natives in the area and from environmental groups.

Unfortunately, time is running out and soon, the supply of water will soon run out too.

**Keywords:** cities, water supply, issues, dams, problems

**JEL:** Q25, Q28, Q21, Q20, Q29

## 1. Introduction

Metro Manila Cities in the Philippines can be considered as global cities, especially the City of Taguig, where the economic boom has moved from the cities' previous financial center, Makati City. These Philippine cities are tied together by the same transportation system, water system, traffic system, and even the garbage collection system.

This paper seeks to give an overall perspective on the future needs, e.g., water of one of the world's most congested cities, Metro Manila. It focuses on the need for other water sources as Metro cities rely mainly on the water provided by the decades-old Angat Dam. A catastrophic earthquake that could damage the dam will have devastating effects on the chances of survival of its populace. It also addresses the exploitation of the Controversial Kaliwa (Left) Dam as an alternative source of water and the issue of privatization of the water supply during the term of the late President Fidel V. Ramos. It identifies the different causes of the water crisis and the possible solutions and alternatives to address the problem. Finally, it provides the background on the rampant use of water by Filipinos and the need to conserve as an additional step in solving the shortage. Indeed, a globalized city (Renn, 2012) has been defined as a production center of unique financial capabilities and service provider, which can handle the possible management and running of the global economy. Indeed, much of the production of the country is concentrated in the greater Manila area and services such as Business Processing Outsourcing (BPOs) are consistently dotting the skyline.

Many studies were conducted to create a ranking system but accordingly, these (crgsoft.com, n.d.) are the dominant characteristics that a global city should possess and exhibit. These are:

- a) They occupy a large portion of territory with a dense population.
- b) They are a haven of tourists and considered for important venues such as global sports tournaments and economic fora.
- c) They have massive transportation systems and a complex airport system which connects the country to the main commercial routes of the world.
- d) They possess an advance telecommunications system and exhibit an ambience of a unique blend of culture and tradition.
- e) They are active participants in global economic transactions and considered a financial center in the region.

- f) They have a positive image as a migration mecca, attracting people of different cultures and beliefs.

All of these, of course, characterize Metro Manila cities. Some sectors could indeed question this list of items as unreliable and unsatisfactory due to their un-relatedness and off-tangent make-up with perceived traits of a global city. In fact, they measure the capacities of cities as prominent global sites rather than being functional. Nevertheless, this list also has its merits as there are many ways to measure a city's global index. Accordingly, the global city (Charnock, 2013) theory forwards a proposal which may not be acceptable to state-centered political economists as it disembowels cities from their traditional territories and puts them in the periphery of discussions on globalization.

Global cities have more or less similar characteristics because they share similar experiences with other cities and due to technology are more connected with each other. They are usually financial centers and service oriented. Thus, there is a large concentration of workers in their midst, but they also experience inter-racial conflicts and class discriminations. In certain situations, there is a big disparity between a well-entrenched employment sector with secured tenure and just compensation and the lower-class labor group who may not have the necessities of life. Furthermore, this existence of global cities sometimes marginalized those living in rural areas within their national industries.

In this regard, we may consider Metro Manila cities as global cities as they exhibit the traits and characteristics of such trendy cities. They are also intertwined by the same electrical system and bounded also by the major problem of a constant need: a steady supply of the precious commodity, water.

With its burgeoning population of 14,667,000 (2023 estimate according to [macrotrends.net](https://www.macrotrends.net)), Metro Manila's need for potable water is almost at a tipping point. The next decades present a pressing struggle as Filipino households may no longer have enough water to utilize in their day-to-day activities.

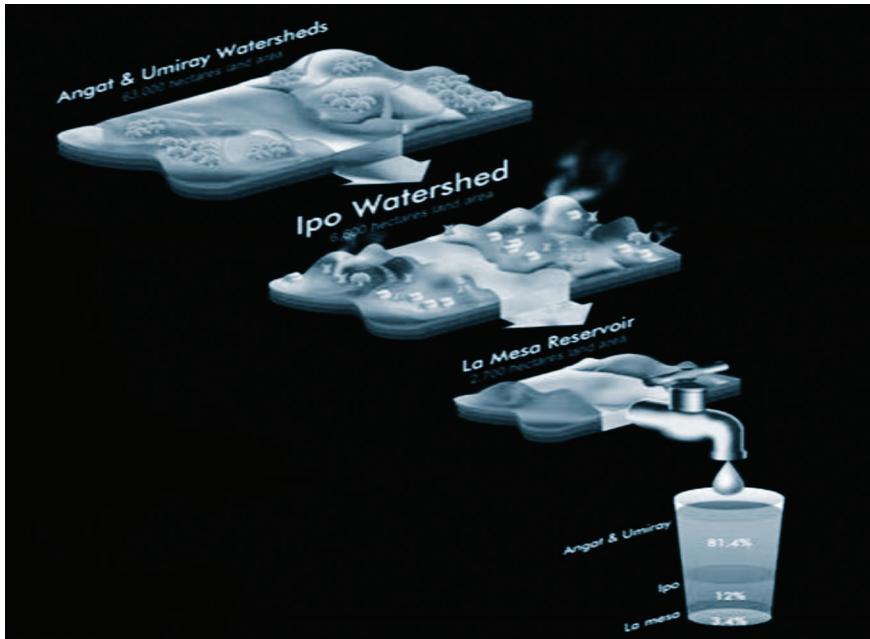
In previous water crises within the Metro where the water levels of dams were at their critical levels; households were informed by the water concessionaires to conserve water and then, rotating water schedules were imposed to make water resources available to everyone. In this regard, the government together with the private sector had been searching for other sources of water supply and had

already privatized its former function of directly supplying water to the residents of the entire Metro Manila.

The data from this research is culled mainly from secondary, literature-based sources buttressed primarily by the experiences and direct observations of the author.

## 2. Water Source

Figure 1. The picture shows the flow of water from Angat Dam in Bulacan to Ipo Dam and finally to the La Mesa Reservoir



Source: Rotor, 2016.

It is unfortunate that there is only one major source of water (81.4 percent) for the water-starved Metropolis: Angat Dam. Constructed in 1961 and opened in 1967, the dam provides potable water to Metro Manila residents and is also rigged to power a hydroelectric plant (Earthquake Impact Reduction Study for Metropolitan Manila in the Republic of the Philippines, 2023). With a normal

high-water level of 210 meters, the dam has three gates with which to release its waters during storms and typhoons when the capacity of the dam is breached. It operates at the normal level of 180 meters and its critical level is at 160 meters. The dam hit a low of 157.56 meters on July 18, 2010 (Lazaro, 2022) which is considered the lowest level that it has attained. It also provides precious irrigation water to around 28,000 hectares of farmland in the provinces of Bulacan and Pampanga and thus, its water storage capability is also critical to farmers in those provinces. The main function of Angat Dam is, however, to supply safe, potable water to the residents of Metro Manila. The dam is engorged with water during the rainy season when the Metro is often battered by storms and thus, during such periods when it is full; it has to open its three flood gates to prevent the water overflow, resulting in the flooding of some major towns in the nearby province of Bulacan. If somehow this water surplus during such times can be contained, then the need of a water supply for Metro Manila residents can be greatly alleviated. However, as of the moment, there is only one downstream dam built which is the IPO Dam (constructed 7.5 kilometers downstream). The IPO Dam's waters spills into the third and final step in the Metro's water supply chain; the reservoir, La Mesa Dam, the water of which is treated and then distributed to the residents of Metro Manila.

Through the years, this 3-tiered water supply system has done its part in supplying ample and clean water to the cities and municipalities of Metro Manila. A major increase in population in the past decades has, however, affected the availability of the precious commodity. Climate change, likewise, accelerated the dearth of water sources as longer periods of drought and the resulting scarcity plagued the previously abundant water supply.

### 3. The Controversial Kaliwa (Left) Dam

The search for additional water resources has resulted in the present proposal to construct a major dam in the Kaliwa River, which is, however, as ancestral lands, home to the indigenous Dumagat and Remontado tribes. The Kaliwa River (ABS-CBN News, 2022) is located in General Nakar, Quezon Province and is considered sacred and central to the indigenous group, Dumagat. It is not only a source of transportation, livelihood, and daily necessities to these indigenous group, it is also a source of livelihood for them. These tribes have put up fierce opposition and stubborn resistance against the construction of the Kaliwa Dam and their fight against dam construction bore fruit when the building of the dam was halted in

2019. However, former President Rodrigo Duterte, during his term (2016–2022), has entered into an agreement with China to provide a US\$235.9 million loan deal for the construction of the dam to continue. The present administration of President Ferdinand “Bongbong” Marcos, Jr. has likewise, given its endorsement to the project. Accordingly, the Kaliwa Dam, when operational, will not only displace the indigenous tribes living in the vicinity but will also affect the viability of the Sierra Madre Mountain Range which protects Luzon inhabitants from storm surges during the typhoon season and likewise, is home to a myriad of animal species, plants, and even fauna.

In relation to this, a prominent lawmaker, Congressman Neri Colmenares (Subingsubing, 2023) of the party-list Bayan Muna, had questioned the propriety of building the said dam, saying: “We question the need for more large dams because they are situated in critical watershed areas” (Subingsubing, 2023).

In support of the position of the Dumagats, the lawmaker added that, indeed, “Large dams aggravate flooding in low lying areas during the onset of typhoon season, causing billions of pesos in damage to agriculture and fisheries, business establishments, properties, and public infrastructure. At worst, lives are lost,” he noted. Thus, Congressman Neri is more open to the construction of smaller but compact dams which have limited impact on the environment and the community; and lessens damage to property.

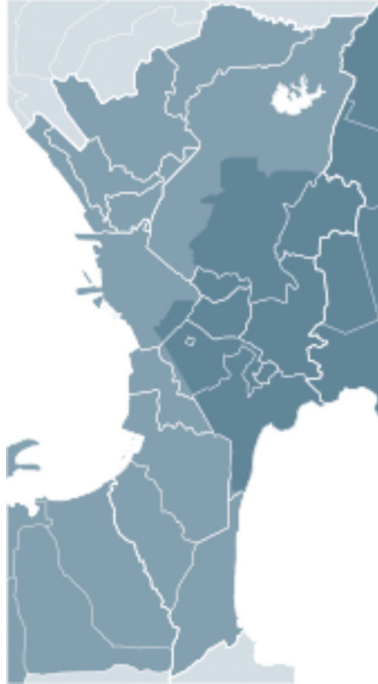
The latest news (Lalu, 2020) accordingly points out to the fact that it seems everything had been ironed out between the tribal leaders and the Metropolitan Waterworks and Sewerage System (MWSS). As of February 2, 2023, it has been agreed that the first phase of the dam construction will now commence and a one-time indemnity fee of 160 million pesos (US\$2,939,258) will be paid to the communities of Rizal and Quezon provinces that will be affected by the project. They will also receive an annual share of the first 25 years of the dam’s operations. The 12.2 billion pesos (US\$224,105,046) Chinese-funded Kaliwa Dam project is supposed to be completed by 2026 and become operational the following year. It is true that the proposed Kaliwa Dam can partially and temporarily solve the impending water crisis as it may be able to produce 600 million liters of water per day when finished. It must, however, overcome the negative tide of public opinion and prove to everyone that it is worth the risk.

#### 4. A Tale of Two Water Concessionaires: Manila Water Company and Maynilad Services, Incorporated.

The local government units of Metro Manila were formerly supplied with water by the government, specifically, by the agency Metro Manila Waterworks and Sewerage System, the MWSS. The impending water crisis in the 90s led the late President Fidel V. Ramos to privatize the MWSS when he was granted emergency powers with the passage into law of the National Water Crisis Act of 1995. Former President Gloria Macapagal Arroyo further reformed the state-run water supply by providing for local service providers which granted franchises to the two current concessionaires. Some sectors also opined that the water system in the Metropolis which was formerly owned and operated by the government was privatized to promote efficiency and to improve water and sanitation services. There were unsubstantiated reports that the public agency (MWSS) was riddled with an inefficient collection system, graft and corruption, subpar standards in water filtration; and consistently losing money in its operations (Kapunan, 2019). Thus, it was conceded to the two aforementioned companies (Cervantes, 2022). This led to the application of the two giant concessionaires which now supply water to the entire Metropolis: Maynilad and Manila Water. It is ironic that both concessionaires are owned by Philippine tycoons with the former being controlled by the consortium of the Consunji and Pangilinan families while the latter is owned by the Zobel family.

Originally, Maynilad Water Services Inc. was given a 25-year concession in 1997 to provide water services to the 17 cities and municipalities which comprise the Western part of the Metropolis. On December 10, 2021, a new law was passed which gave the company another 25 years to operate and maintain a waterworks system and sewerage and sanitation services in the western section of Metro Manila and in addition, the province of Cavite. On the other hand, Manila Water Company, Inc. was given the authority to operate on the eastern zone plus the province of Rizal. Prior to its entry into the Metro Manila water scene, only 26 percent of the eastern portion's population had 24-hour access to the water supply. This lack of water access was efficiently addressed by said company when it took over the eastern part. In 2021, it was also granted another 25-year license to continue operating the east zone.

Figure 2. Light-colored LGUs are supplied by Maynilad while the Dark-Colored LGUs are supplied by Manila Water



Source: Coconuts.co (2013)

According to a report by Abbey Ruth Gita on Sunstar (2019), the previous administration of Rodrigo Duterte had crafted favorable water contracts for these two concessionaires to operate. This is in line with the former President's vision to make water more affordable to the masses, especially to the informal settlers of Metro Manila. It is said that the Kaliwa Dam project was also revived and specifically designed to support Duterte's "Build, Build, Build" program.

## 5. The Water Crisis

In the past decades, Metro Manila had been hounded not only by the La Niña phenomenon, resulting in floods, but also by dry spells which caused the dams supplying it with water, to drop to very alarming low levels. To combat this climate malady during the dry season, various means and methods were adopted.



In fact, it was the water crisis in 1995 which led to the privatization of the then government owned MWSS and led to the granting of water franchises to the giant concessionaires, Maynilad and Manila Water. In 2019, (Torio, Mendoza and Torres, 2021), just a few years from the international recognition given to the privatization spearheaded by Metro Manila's Concessionaires, a water supply crisis also haunted the Metropolis. The award was based on the exhibition by the two companies of very high operating efficiencies and a vastly improved service level. These improvements were, however, negated by the surge of consumer demand which necessitated the construction of new water infrastructures.

On the other hand, the water crisis in 2019 was primarily caused by a drought that was greatly enhanced by the El Niño phenomenon. Due to the lack of rains, the critical level of the Angat Dam fell below the 160 meters warning threshold. Thus, the government had to make drastic measures again such as rationing water to the populace and imposing moratorium on the supply of water to the farms. The water crisis is further exacerbated by the migration of Filipinos living in the rural areas outside the cities. Attracted by the allure of employment opportunities, high educational standards and the fast life of the city, the needs of these rural dwellers add more burden to the already strained water supply. Migrant Muslims (Reza, 2018) from the war-torn South (Mindanao) have also been pouring into Metro Manila cities, establishing exclusive Muslim-controlled areas such as the Culiati Compound in Quezon City.

Another use of the water from Angat Dam is irrigation. Surplus water during the rainy season is usually diverted to the farms to meet the farmers' needs. This, however, presupposes that there is an oversupply of dam water which is around the normal level of 210 meters. Once water levels reach the critical level of 160 meters, water supply to Metro Manila is reduced. If water from rains is still scant, then the water supply for irrigation is also curtailed.

## 6. Solving the Water Crisis

The water problem has to be tackled soon, otherwise potential climate change effects and the increasing Metro Manila population will wreak havoc on an already meager supply. It is unfortunate that government leaders had been shortsighted in addressing the recurring problem; relying on decades-old dams and the ample supply of water in previous years was a fatal mistake which they have a difficult time coping with. One way to solve the water crisis is the use of Desalination

plants. These plants can be a major source of fresh water in the Philippines as the country is basically surrounded by water. The issue, however, is on the cost of harnessing energy resources (Gorjian and Ghobadian, 2015) to produce drinkable water under this method and the harmful effects it emits on the environment. One forwarded solution by water management experts is tapping into the unlimited resources provided by the ocean (Rahman, Kumar and Dominguez, 2022). This is very much applicable to the Philippines since it is an archipelago and thus, its islands as we have said, are surrounded by bodies of water. It is also very proximate to the largest body of water on the planet, the Pacific Ocean. While desalination already adopts such technology; it has environmental side effects as it uses substantial energy and produces a by-product, concentrated Brine which is difficult to dispose of. The capture of humid air over the ocean's proposal is more viable and less costly and can also withstand the effects of climate change. It basically consists of "capturing water vapor from the atmosphere just above the ocean surface and transporting the moisture-laden air to proximal land where its condensation can provide fresh water" (Rahman, Kumar and Dominguez, 2022). Indeed, this method if pursued by the authorities, can constantly provide fresh water to areas which have a dearth in water supply. Another option being considered is cloud seeding (Lazaro, 2022); which was also given a trial by the Philippine government but was not that successful. This project was spearheaded by the National Disaster Risk Reduction and Management Council (NDRRMC) which released 18.3 million pesos (US\$336,140) to the Department of Agriculture for cloud seeding operations with the Philippine Air Force as implementor. According to the NDRRMC, a cloud-seeding operation is a process of combining chemical agents with existing cloud formations to thicken them and thus, increase the chance of rain. Gude, Gadhamshetty and Ramanitharan (2020) for their part, have put forward the idea that water re-use is the most viable solution to solve a water crisis. While water treatment under this process also has its questionable practices that could harm the environment and the human body, it has been adopted by major cities like Barcelona. If done properly and in the right conditions, water re-use can be a major solution to a water crisis while focusing on the role of water as a finite resource which needs to be enhanced time and again to prevent its demise.

Another viable solution to the water problem is finding a way to contain the water flow of dams like the Angat Dam during the rainy season. These waters, instead of flooding and wasting the farms of the nearby province of Bulacan can be contained, stored, and harnessed to supply the cities of Metro Manila during the lean months of summer. A water viaduct or a tunnel could be dug near the rim of the

Angat Dam and thus, instead of overflowing, the extra water will be re-directed to these water-carrying structures which will carry the latter to giant water tanks or reservoirs, which contents will be tapped only during extreme emergencies when water supply is meager.

Traditionally, by the mid-20th century, the main source of water in the Philippines is groundwater. Water is directly pumped from the ground by the use of water pumps and were consumed by the populace as drinking water; it was also used in washing and bathing and cooking to name a few. A United Nations' Report (Lazaro, 2022), however, stated that ground water is overexploited and diminishing fast as its renewability is extremely slow. Even rainwater itself can also be a major source of water in Metro Manila. Before the onset of modernization, this was the most constant and reliable source of water not only in the cities, but also in the rural areas and different provinces of the country.

Usually, ancestral houses have water tanks made of cement on the side of the house as storage for the rain from the roofs. These water tanks were equipped with faucets but were, however, later demolished when water supply was provided by the water concessionaires e.g., Maynilad and Manila Water. The best option (Practical Engineering, 2019), however, was put forward by the Global Utilities Development Company (GUDC) of Osaka, Japan. It would still involve the construction of dams like the Kaliwa Dam but on a much smaller scale. These proposed smaller dams are called weirs. A weir is a small barrier across a river, it would still change the river's flow and increases its level but not to the extent that a big dam would. The idea was proposed to the MWSS by the GUDC in 2009 via a Memorandum of Understanding. The proposed Kaliwa River Weir would only be seven meters in height, attached with a 16-kilometer-long tunnel and embedded with a water treatment plant. Japan actually proposed the construction of a weir as an alternative to the Kaliwa Dam but it was shelved in favor of the Chinese-funded dam proposal.

While these water source alternatives have their merits and disadvantages; it is ideal that the most plausible alternative will be adopted by the government (MWSS) or the two concessionaires in terms of costs, political and people's acceptance, efficiency, effectiveness, etc. All stakeholders need to be consulted and convinced on the viability of the project. For example, the benefits need to outweigh the costs. Presently, the two most advantageous water sources are the construction of weirs and water re-use. These sources are less costly and more acceptable to the community and less harmful to the environment. Their

implementation can also be fast-tracked, and these projects do not require much technological know-how and expertise.

## 7. Filipinos' Consumption of Water

Most Filipinos are huge consumers of water. Water is part and parcel of their daily existence. They practically use water in every move, whether for drinking purposes or for other necessities; water is a commodity they cannot live without.

Filipinos cannot simply live without large volumes of water. Aside from drinking, it is a major need in terms of taking a shower, cooking, comfort room necessities, cleaning, washing, etc. With a big bulk of the population living in squalor conditions as informal settlers; these needs are further magnified and enhanced. Indeed, Filipinos consume large volumes of water because of the country's tropical climate; with a mean average temperature of 26.60 Centigrade (Philippine Atmospheric, Geophysical and Astronomical Services Administration, n.d.) and even hotter climate during summers. This leads to Filipinos taking a bath at least twice a day (Halili, 2020) and a large number even take a shower three (3) or more times a day. Some spend at least an hour in the showers and one can only imagine the huge amount of water used during these long periods of bathing. Another major use of water consumption in the Metropolis is unrepaired leaks and car washing. Leaks are most common in places where there is an abundance of squatters which make a living on illegal connections. Car wash shops are also a common sight in the Metro as those who have cars are very particular with how their vehicles are being perceived by other people. A number of these water guzzlers are sprinkled in the major thoroughfares of Metro Manila, and they put a lot of strain on the precious water supply. Pilferage or illegal connections have also been a bane in the neck for the two concessionaires (Supreme Court E-Library, 2019). Like the supply of electricity, water is one other precious commodity which is "hacked" by informal settlers who lack the means to apply for legal water connections with the suppliers.

## 8. Water Conservation

A constant solution to water shortages adopted by the two concessionaires is, of course, water rationing which is often done during periods where water is hard to come by. During these periods, household water is only available at a certain time. A major concern in water conservation is household leaks which are common in

dilapidated housing programs, old houses and in the houses of informal settlers. Strict implementation of plumbing measures can drastically reduce water consumption as studies (Agarwal et al., 2022) would show that plumbing improvements generate long-lasting effects on water conservation.

A strong educational system which emphasizes the need to conserve natural resources such as water has also been in place in the primary level of schools via such subjects as Science, and Technology and Livelihood Education (TLE) by the Department of Education. Hopefully, such subjects will inculcate in the minds of the Filipino youth the need to conserve water.

## 9. Conclusion

The impending Metro Manila water crisis would have been averted if government planners had been more intuitive and foresightful about the future of the Metro's water supply. The construction of more strategically located and environment-friendly dams in the last two decades or so would have been major developments in addressing and solving the issue.

Strict water conservation measures are also important components in solving the Metropolis' water needs. People simply lack the awareness and duty to conserve water, especially in times of dry spells. Unrepaired leaks and car wash shops are also gigantic consumers of the precious commodity. While there are various ways to produce drinking water such as desalination, capturing humid air over the ocean, water pumps, water re-use and tapping rainwater, to name a few, these may not be enough to solve the problem as the country still lacks the requisite technology and infrastructure to make desalination and humid air capture work. These are just stopgap measures and not long-term solutions.

Potential water projects such as the Kaliwa Dam have been restrained by stiff resistance from environmental groups and indigenous tribes, making it difficult for them to be operational soon. At the most, downstream dams such as the IPO dam can be of great help in solving the worsening water crisis. The construction of smaller dams such as weirs can also be studied as an alternative to the building of big dams such as the proposed Kaliwa Dam. Weirs incur much smaller costs, do not fully inundate large tracts of land and can be easily maintained. Meanwhile, Metro Manila cities along with other local government units of the country will just have to rely on the chance that dry spells called the El Nino phenomenon will

no longer visit the country, otherwise the nation and Metro Manila's dwindling water supply is doomed.

On a final note, the Philippines must take advantage of the latest technologies and engineering feats that are available in today's world. Indeed, many companies have the "latest tools and techniques to meet engineering challenges over dwindling natural resources" (Brandt et al., 2016).

## References

ABS-CBN News (2022) *Stop Kaliwa Dam, Groups Call Anew on Save Sierra Madre Day*. Available at: <https://news.abs-cbn.com/news/09/27/22/stop-kaliwa-dam-groups-call-anew-on-save-sierra-madre-day> (Accessed: 4 February 2023).

Agarwal, S., Araral, E., Fan, M., Qin, Y. and Zheng, H. (2022) 'Water Conservation through Plumbing and Nudging', *Nature Human Behaviour*. 2022 Jun, 6(6), pp. 858–867. Available at: <http://dx.doi.org/10.2139/ssrn.3815431>

Brandt, M., Elphinston, A.J., Ratnayaka, D. and Michael Johnson, K. (2016) *Twort's Water Supply*. 7th edition. Oxford: Butterworth-Heinemann.

Cervantes F. M. (2022) *PRRD Inks Laws Granting Maynilad, Manila Water 25-year Franchises*. Available at: <https://www.pna.gov.ph/articles/1164865> (Accessed: 6 February 2023).

Charnock, G. (2013) 'Global City', *Encyclopedia Britannica*. Available at: <https://www.britannica.com/topic/global-city>. (Accessed: 2 February 2023).

Coconuts.co (2013) *Maynilad to replace 30-year-old pipes in Fairview*. Available at: <https://coconuts.co/manila/news/maynilad-replace-30-year-old-pipes-fairview/> (Accessed: 2 February 2023).

Crygsoft.com (s.a.) *10 Characteristics of Global City, its Classification, Types, Features and Examples*. Available at: <https://crgsoft.com/global-city-what-is-it-types-characteristics-and-examples/>. (Accessed: 22 March 2023).

Earthquake Impact Reduction Study for Metropolitan Manila in the Republic of the Philippines, Final Report (2023) Available at: [https://openjicareport.jica.go.jp/pdf/11763752\\_03.pdf](https://openjicareport.jica.go.jp/pdf/11763752_03.pdf) (Accessed: 5 June 2023)

Gita A. R. (2019) *Duterte Orders Review of Contracts with Water Concessionaires*. Available at: <https://www.sunstar.com.ph/article/1799697/Manila/Local-News/Duterte-wants-removal-of-onerous-provisions-of-contracts-with-water-concessionaires>. (Accessed: 2 February 2023).

Gorjian, S. and Ghobadian, B. (2015) 'Solar Desalination: A Sustainable Solution to Water Crisis in Iran', *Renewable and Sustainable Energy Reviews*. August 2015, 48. pp. 571–584. <https://doi.org/10.1016/j.rser.2015.04.009>

Gude, V.G., Gadhamshetty, V., and Ramanitharan, K. (eds.) (2020) *Sustainable Water: Resources, Management and Challenges*. New York, NY, USA: Nova Science Publishers.

Halili N. (2020) *How Often Should You Really Shower*. Available at: <https://multisport.ph/37762/how-often-should-you-really-shower/> (Accessed: 4 February 2023).

Kapunan R. (2019) *The privatization of MWSS*. Available at: <https://manilastandard.net/opinion/columns/backbencher-by-rod-kapunan/290170/the-privatization-of-mwss.html> (Accessed: 1 February 2023).

Lalu G.P. (2020) *MWSS Should Pursue Alternatives to Kaliwa Dam-BayanMuna*. Available at: <https://newsinfo.inquirer.net/1209350/group-says-mwss-should-pursue-alternatives-to-kaliwa-dam> (Accessed: 2 February 2023).

Lazaro R.E. (2022) *PAG-ASA Confirms Cloud-Seeding Over Angat*. Available at: <https://www.philstar.com/headlines/2022/04/02/2171622/pagasa-confirms-cloud-seeding-over-angat>. (Accessed: 3 February 2023).

Macrotrends.net (2023) *Philippines Population 1950-2023*. Available at: <https://www.macrotrends.net/countries/PHL/philippines/population>. (Accessed: 1 February 2023).

Philippine Atmospheric, Geophysical and Astronomical Services Administration (n.d.) *Climate of the Philippines*. Available at: <https://www.pagasa.dost.gov.ph/information/climate-philippines> (Accessed: 5 February 2023).

Practical Engineering (2019) *What is a Weir*. Available at: <https://practical.engineering/blog/2019/3/9/what-is-a-weir>. (Accessed: 3 February 2023).

Rahman, A., Kumar, P., and Dominguez, F. (2022) 'Increasing Fresh Water Supply to Sustainably Address global Water Security at Scale'. *Scientific Report*. 12(1), 20262. Available at: <https://doi.org/10.1038/s41598-022-24314-2>

Renn, A. M. (2012) *What is a Global City*. Available at: <http://www.newgeography.com/content/003292-what-is-a-global-city> (Accessed: 2 January 2023).



Reza, A. (2018) 'Migration, Diaspora, Muslim Transnational Communities and Education' in H. Daun and A. Reza (eds.) *Handbook of Islamic Education*. Sweden: Springer Publication. pp. 415–434. Available at: [https://doi.org/10.1007/978-3-319-53620-0\\_20-1](https://doi.org/10.1007/978-3-319-53620-0_20-1)

Rotor A.V. (2016) *La Mesa Dam - Heart of the Angat-Ipo-La Mesa Water System*. Available at: <http://avrotor.blogspot.com/2016/02/la-mesa-dam-heart-of-angat-ipo-la-mesa.html> (Accessed: 2 February 2023)

Subingsubing K. (2023) *Kaliwa Dam Project gets Tribes' Nod: Tunneling in Progress-MWSS*. Available at: <https://newsinfo.inquirer.net/1724264/mwss-kaliwa-dam-project-gets-tribes-nod-tunneling-in-progress>. (Accessed: 1 February 2023)

Supreme Court E-Library (2019) *Supreme Court E-library*. Available at: <https://elibrary.judiciary.gov.ph/#>. (Accessed: 2 February 2023).

Torio, P., Mendoza, R. and Torres, A. (2021) 'The Metro Manila 2019 Water Crisis: Of Efficiency Traps and Dry Taps', *World Water Policy*; 7(2), p. 15, pp. 151–165. Available at: <https://doi.org/10.1002/wwp2.12060>