

EVALUATION OF THE SPATIAL DISTRIBUTION OF EVACUATION CENTERS IN METRO MANILA, PHILIPPINES

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ABSTRACT:

In a densely populated and hazard-prone megalopolis like Metro Manila, the ability to execute a rapid evacuation protocol is crucial in saving lives and minimizing the damage during disastrous events. However, there is no centralized database on the location of evacuation centers (ECs) in Metro Manila and the available lists are not up-to-date. This study geotagged the current list of ECs in Metro Manila obtained from different government agencies to evaluate the spatial distribution using Geographical Information System (GIS). This is important since the immediate evacuation of residents depends on the proximity and safe location of the ECs. A total of 870 ECs were geo-tagged and validated using the street view of Google Earth™. EC-to-population ratios were calculated for each of the 16 cities and one municipality of Metro Manila. Values range from ~3,000 to 81,000 persons per EC. Distance analysis using Thiessen Polygon shows that the ECs are not evenly distributed with proximity areas ranging from 0.0009 to 9.5 km². Out of the total number of mapped ECs, 392 (45%) are situated in flood-prone areas while 108 (12%) are within the 1-km buffer hazard zone of an active faultline. Re-evaluation of the locations and the number of ECs per city or municipality is highly recommended to facilitate prompt evacuation when disasters strike.

1. INTRODUCTION

Natural hazards commonly occur in the Philippines. The most frequent type of hydro-meteorological hazards in the country are tropical storms or typhoons that are accompanied by heavy rain and/or strong winds that may result in floods, landslides and storm surges. The susceptibility of the Philippine archipelago to natural hazards, especially in terms of Tropical Cyclones (TCs), is defined by its geographic location and attributes. An annual average of 19 TCs enter the Philippine Area of Responsibility and nine TCs passed the country based on the 1951 to 2013 data (Cinco et al. 2017). The geology of the country also explains the frequency of earthquakes, tsunamis, and landslides.

Metro Manila, also called the National Capital Region of the Philippines, is the country's center of political, economic, and social activities, resulting in a high volume of domestic migrants (UNESCO, UNDP, IOM, and UN-Habitat). However, the region is exposed to hydrometeorological and geologic hazards. It is transected by an active fault line based on combined historical data and studies by the Philippine Institute of Volcanology and Seismology (PHIVOLCS). The country's National Disaster Risk Reduction and Management Council declared that the West Valley Fault may produce a 7.2 magnitude earthquake with Intensity VIII ground shaking (NDRRMC, 2015). This intensity will cause devastating damage in buildings, landslides, and liquefaction and may result in thousands of casualties (estimated 34,000 deaths) to human lives (JICA-MMDA-PHIVOLCS, 2004). Metro Manila is also perennially plagued with floods. The

past flood events indicate that 44 km² of the land area is flood-prone or about 7% of the ~620 km² of the megalopolis (Miranda, 1994). However, in September 2009, when tropical storm Ketsana (local name Ondoy) directly crossed over Central Luzon, ~217 km² (about 34%) of the metropolis was submerged by floodwaters (Rabonza, 2009). The recurrent floods are the effect of two phenomena: the major floods that have a 2 to 10-year return period and the isolated flash floods during the monsoon season. The exposure of Metro Manila to such hazards coupled with rapid population growth (1.68% from 2000-2015), increases vulnerability to disasters.

Pre-impact evacuation of the threatened population is an important management strategy for minimizing potential disastrous events associated with such natural hazards (Perry, 1979). It is crucial to develop a responsive disaster risk reduction and management plan of the region and ensure the availability of established safe evacuation centers (ECs) for emergencies and disasters. A properly implemented evacuation program directly saves lives as well as reduces the loss of property and minimizes disruption of social networks. However, any well-developed emergency response would be futile if EC locations and positioning are not strategically considered relative to disaster risk and if public information on the exact location of ECs is lacking. This study intends to evaluate the susceptibility of ECs to extreme floods and earthquakes. The spatial distribution of the ECs per city or municipality was also examined to determine the proximity area of ECs. In addition, we also calculated the ECs-

to-population ratio to assess the location-allocation problem in each city or municipality in Metro Manila.

2. STUDY SITE

Metro Manila is composed of 16 highly urbanized cities (autonomous local government units that have a minimum population of 200,000 and an annual income of at least USD 100,000) and one municipality, encompassing a total land area of ~620 km². (Figure 1, Table 1). Based on the 2015 census of population, ~12.9 M people reside in the region, equivalent to ~13% of the country's population. It is the second most populated region in the Philippines and the second most densely populated with 20,785 persons/km² (PSA, 2015). The United Nations reported that of the world's megacities in 2018, Metro Manila ranked 17th, the largest of the three Southeast Asian megacities, the other two are Jakarta and Bangkok (UN, 2018).

The climate of Metro Manila is divided into two distinct seasons based on rainfall normal values from 1981 to 2010 from three stations: wet from June to October, with rainfall above 200 mm, and dry from November to May. The wettest month is August, with mean rainfall reaching up to ~500 mm. The average annual rainfall totals ~2150 mm. From 1948 to 2018, a total of 18 tropical cyclones have crossed Metro Manila, 11 of which has maximum sustained winds of 120–220 km/h (PAGASA, 2019).

The region is bounded by Manila Bay in the west and Laguna Lake in the southeast (Figure 1). Connecting these two water bodies is the 25 km long Pasig River, with the main channel flowing through the cities of Manila, Mandaluyong, Makati, Pasig, and Taguig. Northeast of Metro Manila lies the western flank of the Sierra Madre Mountain Range. The presence of this mountain range slows down the movement of a tropical cyclone, allowing more time for rainfall to form (Racoma *et al.*, 2016). In the northwestern coastal area, flooding due to excessive groundwater extraction has been reported (Rodolfo and Siringan, 2006). This area is experiencing land subsidence by several centimeters to more than a decimeter per year, which worsens flooding particularly during storms and high tide events.

An active major fault (Marikina Valley Fault System) transects the eastern portion of Metro Manila for ~135 km (PHIVOLCS, 1999) (Figure 1). Earthquakes with M6–7 on this fault system is estimated to have recurrence intervals of roughly 400–600 years (Nelson *et al.*, 2000). The soft Quaternary layers with a maximum thickness of ~50m covering the coastal area along Manila Bay (Daligdig and Besana, 1993), is expected to amplify high-frequency ground motion (Yamanaka *et al.*, 2011).

3. METHODOLOGY

3.1 Data Collection and Mapping of ECs

Several lists of evacuation centers were gathered from national government agencies and local government units through correspondence and official requests for information. Some lists were available as downloadable information from official websites. Out of the total 973 identified ECs from the gathered lists, 870 were located on either Google Earth or Google Maps and geotagged for identification of the coordinates. Google Maps' Street View feature helped locate some ECs with missing location details. However, a total of 103 ECs listed were not mapped due to insufficient information regarding the address and location details. Also, a number of identified ECs were identified as duplicate entries on the lists.



Figure 1. Location of the study area.

GIS hazard maps for flood-prone areas (LiDAR generated) and the West Valley Fault (PHIVOLCS) were extracted and overlaid with the ECs locations using ArcGIS. The flood hazard map (Figure 4) used a 100-year rainfall return period with 10-m resolution obtained from the Department of Science and Technology-University of the Philippines Disaster Risk and Exposure Assessment for Mitigation and Phil-LiDAR Program (<https://lipad.dream.upd.edu.ph/>, July 16, 2019). Secondary data for population and the land area of the city/municipality were obtained from a 2015 Philippine Statistics Authority census. These were used to calculate the ratios of ECs to both population and land area (Table 1).

3.2 Spatial Analysis

The Thiessen Polygon (Voronoi Polygon) apportioned each EC within a city into proximal polygons. Perpendicular bisectors are drawn to the lines joining each measured ECs relative to surrounding ECs. These bisectors formed a series of polygons; each polygon contained one evacuation center. The area of proximity to an EC is identified by calculating the area of each polygon. Any possible location within each polygon is the nearest distance to its given data point (EC) relative to the neighboring ECs. This analysis identified the nearest EC within a neighborhood. The polygons provided information on the ECs proximity (mean, minimum and maximum distance), accessibility and relative distribution (Okabe *et al.*, 2000).

Buffer analysis was used to determine the number of ECs that lie within the 1-km buffer zone of the West Valley Fault. Each EC within the buffer zone was identified as having higher vulnerability in the incidence of fault movement. A 100-year rainfall return flood map was overlaid to the EC points to

determine the number of ECs that lie within the flood hazard zone.

4. RESULTS AND DISCUSSION

4.1 Spatial Distribution of Evacuation Centers

The ECs sprawled either sparingly or densely over the whole of Metro Manila (Figure 2). The spatial distribution is influenced primarily by the location of various government-owned facilities. Hence, EC location is not evenly distributed across any of the cities or municipality. Least number of ECs were observed in areas such as forest reserves, exclusive gated communities, commercial centers, and ports. There is an observed absence of ECs in the northeastern part of the study area. It is home to the La Mesa Watershed - a protected area of rainforest which provides potable water to people of Metro Manila. There are smaller segments within Makati, where gated residential communities, high-rise office buildings, and commercial centers are situated, that have very few identified ECs. This pattern is also observable in the neighboring cities of Taguig and Pasig, the surrounding areas near the national penitentiary in Muntinlupa, and the reclaimed areas near the coast, west of Metro Manila.

Table 1. Land area, population, evacuation centers (ECs), and ECs-to-population ratio per city/municipality in Metro Manila. Land area and population data are from the Philippine Statistics Authority (2015).

City / Municipality	Land Area (km ²)	Population	ECs		ECs Mapped	ECs Mapped: Population Ratio
			Number	Source		
Caloocan	55.8	1,583,978	21	1	21	1: 75,400
Las Piñas	32.7	588,894	70	1	69	1: 8,500
Makati	21.6	582,602	106	2	106	1: 5,500
Malabon	15.7	365,525	71	2	71	1: 5,200
Mandaluyong	9.3	386,276	34	3	34	1:11,400
Manila	25.0	1,780,148	22	3	22	1:81,000
Marikina	21.5	450,741	17	2	17	1:26,500
Muntinlupa	39.8	504,509	26	3	26	1:19,400
Navotas	8.9	249,463	12	3	12	1:20,800
Paranaque	46.6	665,822	83	1	83	1:8,000
Pasay	14.0	416,522	18	1	18	1:23,100
Pasig	48.5	755,300	129	1	116	1:6,500
Pateros	10.4	63,840	5	4	5	1:12,800
Quezon	171.7	2,936,116	242	5	155	1:19,000
San Juan	6.0	122,180	37	1	37	1:3,300
Taguig	45.2	804,915	30	3	28	1:28,700
Valenzuela	47.0	620,422	50	3	50	1:12,400
TOTAL	619.5	12,877,253	973		870	

- 1- Department of Interior and Local Government-Central Office Disaster Information Coordinating Center
- 2- Department of Social Welfare and Development-Disaster Response Operations Monitoring and Information Center
- 3 - Department of Interior and Local Government-Central Office Disaster Information Coordinating Center / Department of Social Welfare and Development
- 4 -Municipal Social Welfare and Development Office of Pateros
- 5 -Quezon City Disaster Risk Reduction and Management Office

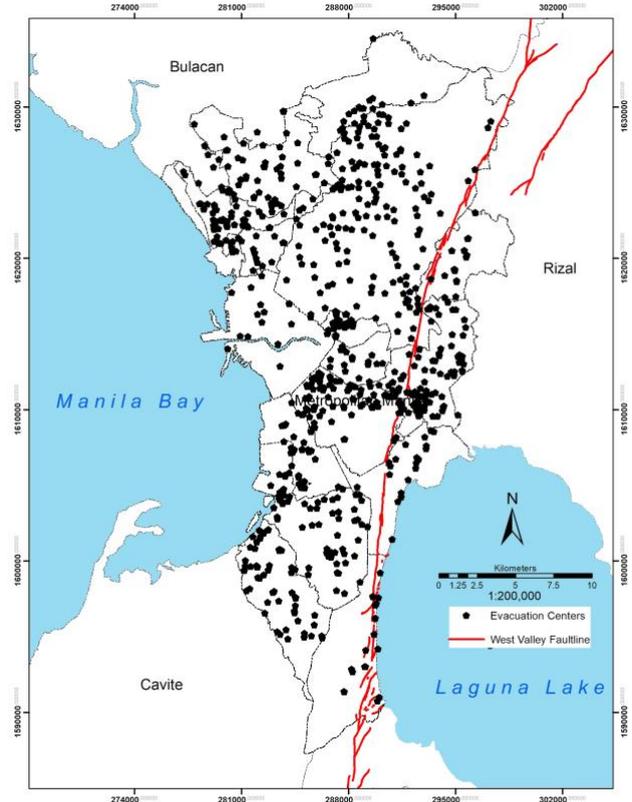


Figure 2. Distribution of evacuation centers in Metro Manila. Table 1 lists the data sources.

The ECs in Metro Manila are structures which are not originally designed to be ECs. These are barangay halls, multipurpose halls, public school buildings, covered basketball courts and public gymnasiums which are converted into evacuation centers when the need arises (Figure 3). Thus, locations of these evacuation centers are not determined by factors concerning disaster risk reduction and management but rather primarily dependent on the location of existing available facilities. The location and proximity of the ECs are important components of an assessment as these dictate the distribution pattern for each city or municipality and the capacity of each evacuation facility.

The linear distances (Euclidean distances) among ECs are fundamental properties to describe their spatial patterns throughout Metro Manila. The mean, minimum, and maximum area of proximity signify the spatial distribution (i.e. uniformly distributed or clumped) and the accessibility of each ECs to the evacuees (Table 2). Distance analysis using Thiessen Polygon shows that the ECs are not evenly distributed with proximity areas ranging from 0.0009 to 9.5 km². The area of proximity can be used to identify the actual number of constituents that the particular EC will serve by identifying the individual EC jurisdiction. Further, this information helps identify areas that need additional ECs (Boots and Getis, 1988; Masuya *et al.*, 2015).

4.2 Susceptibility to Flood and Earthquakes

Out of the total number of mapped ECs, 392 (45%) are situated in flood-prone areas while 108 (12%) are within the 1-km buffer hazard zone of the active West Valley faultline (Figures 2 & 4, Table 3). The cities of Marikina and Pasay were identified as having >80% of their ECs within the flood hazard zone. The

cities of Caloocan, Malabon, Manila and Pasig have >50% (but less than 80%) of ECs within the flood hazard zone. Navotas is at the bottom of the list with only 1 out of 12 ECs (8.3%) located in identified flood-prone areas.

All five geotagged ECs of the municipality of Pateros lie within the 1-km buffer zone of the West Valley Fault. Muntinlupa City is also highly vulnerable to earthquakes with >80% of its ECs (21 out of 26) within the 1-km buffer zone whereas 20% to 40% of ECs in Taguig, Marikina and Pasig fall within the highly vulnerable area. In Quezon City, and in the cities of Paranaque and Makati, <20% of ECs fall within the West Valley Fault 1-km buffer zone. ECs outside of the 1-km buffer zone are those located in Caloocan, Las Piñas, Malabon, Mandaluyong, Manila, Navotas, Pasay, San Juan, and Valenzuela.

Basketball Court, Branches St., Brgy. Sangandaan, Quezon City (bottom two photos).

Table 2. Proximity distance (neighborhood) of evacuation centers in Metro Manila.

City / Municipality	ECs Density (per km ²)	Area of Proximity (km ²) of ECs		
		Mean	Min	Max
Caloocan	0.38	0.54	0.0009	2.7
Las Pinas	2.11	1.24	0.041	8.53
Makati	4.91	0.37	0.011	3.86
Malabon	4.52	0.25	0.007	1.03
Mandaluyong	3.66	0.57	0.068	2.36
Manila	0.88	2.45	0.11	7.97
Marikina	0.79	1.3	0.24	6.57
Muntinlupa	0.65	2.14	0.058	9.5
Navotas	1.34	2.62	0.74	4.52
Paranaque	1.78	0.67	0.073	2.75
Pasay	1.29	0.72	0.01	3.21
Pasig	2.39	0.31	0.004	1.24
Pateros	0.48	0.24	0.09	0.38
Quezon	0.9	0.93	0.032	6.02
San Juan	6.22	0.19	0.007	2.02
Taguig	0.62	1.38	0.097	3.86
Valenzuela	1.06	0.81	0.009	3.33

As a risk reduction measure, evacuation centers which are identified to be susceptible to flood and/or earthquake need to be evaluated in terms of its location. The construction of ECs must also conform to the Philippines' National Building Code, i.e. withstand strong winds (300 km/hr) and earthquakes that can register 8.0 M on the Richter scale. Responding to this mandate would require long-term planning and logistics. The strategic decision-making in upgrading the system requires a corresponding resource allocation (Xie *et al.*, 2010). Since extreme natural events in the Philippines often result to calamities, evacuation planning is crucial to prevent loss of lives and minimize damage to properties. The communities should invest in strengthening preparedness measures (Lim *et al.*, 2013). These preparedness measures should have started in 2010 when the Philippine Republic Act No. 10121 mandated local governments to set aside not less than 5% of their estimated revenue from regular sources for their disaster councils. The allocation should cover the establishment of early warning systems and recovery activities for immediate delivery of food, shelter, and medication.



Figure 3. Identified ECs: Manotok Subdivision Covered Court, Marangal Street, Brgy. Baesa, Quezon City (upper two photos); Mendoza Village Covered

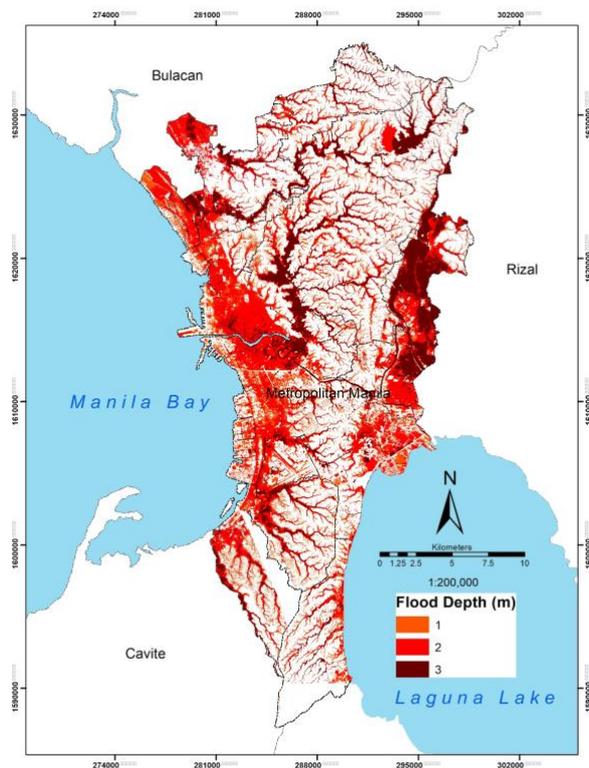


Figure 4. The 100-year return flood hazard map of Metro Manila (Data from LiPAD - LiDAR Portal for Archiving and Distribution).

Table 3. Evacuation centers situated within the flood-prone areas and in the 1 km buffer of the West Valley Fault.

City/ Municipality	Number of ECs Mapped	Number of ECs Susceptible to Flood	% ECs Susceptible to Flood	Number of ECs within 1 km buffer of fault	% ECs within the 1 km buffer
Caloocan	21	13	61.90%	0	0
Las Pinas	69	24	34.80%	0	0
Makati	106	45	42.50%	11	10.40%
Malabon	71	43	60.60%	0	0
Mandaluyong	34	9	26.50%	0	0
Manila	22	15	68.20%	0	0
Marikina	17	16	94.10%	4	23.50%
Muntinlupa	26	9	34.60%	21	80.80%
Navotas	12	1	8.30%	0	0
Paranaque	83	35	42.20%	2	2.40%
Pasay	18	16	88.90%	0	0
Pasig	116	68	58.60%	42	36.20%
Pateros	5	2	40.00%	5	100.00%
Quezon	155	63	40.60%	17	11.00%
San Juan	37	13	35.10%	0	0
Taguig	28	9	32.10%	6	21.40%
Valenzuela	50	11	22.00%	0	0
Total	870	392	45.10%	108	12.40%

4.3 Ratio of Evacuation Center to Population per City/Municipality

The results identified the City of Manila as having the highest EC-to-population ratio at 1:81,000 followed by Caloocan City (1:75,400) and Taguig City with 1 EC for every 28,700 people (Table 1). Based on the experience in the aftermath of Typhoon Haiyan, 10 families, with an average of five members per family, overcrowded a standard classroom (Ramos *et al.*, 2015).

Classrooms are common makeshift evacuation facilities and are usually maximized during extreme events. Actual evacuation operations should comply with the recommended ratio of 1:1.5 (person to sq.m. floor area) for short-term occupancy and 1:3.5 (person to sq.m. floor area) for the long-term shelter to minimize adverse impact on the health and well-being of the people (Vanuatu Ministry of Climate Change Adaptation, 2016). The problem of congestion in ECs has become a common scenario during evacuation and relief operations in the event of disasters. Insufficient health and sanitation facilities in the designated ECs complicate the problem of congestion and increases the vulnerability of evacuees to post-typhoon diseases.

In the past flood events, as the floods brought about by Typhoon Ketsana in 2009, flood-stricken areas in Metro Manila had to rely on their coping mechanisms and adaptation strategies in response to extreme events (Porio, 2011). This ability is common to groups and individuals exposed to external stresses and disturbances such as typhoons and floods (Adger, 2000) and mostly observed in developing countries (Blaikie *et al.*, 1994).

4.4 Implication for evacuation strategies by local government units

4.4.1 Access to information. The country's Freedom of Information Law provides the right of the individual to access any public information. A joint memorandum circular of the national government agencies also states that the identification and listing of ECs as temporary shelters during disasters should be made available to the public including additional information like size, capacity, and susceptibility to hazards. However, a comprehensive list of ECs for Metro Manila is unavailable or missing. Information obtained from official websites and government agencies is in fragments. The acquisition of official documents demands a written request which had to be approved by the head of the corresponding government agency. Whenever information is made available, the location of ECs is described by street names and barangay names and/or numbers. Majority of these ECs have not been geotagged, mapped, nor archived into a standardized list to be made available for public information. With this realization, the accessibility of updated information regarding ECs was the primary problem encountered in this study. This study compiled all gathered information obtained from different government agencies to generate a master list of identified evacuation centers for each city and municipality. The data on the list may be updated regularly. The master list can be used to develop a centralized database for Metro Manila risk reduction and management along with other information and details (e.g. distance, capacity, amenities) of the ECs that can be made accessible online for the consumption of the general public.

4.4.2 Designation of permanent evacuation centers. Even distribution of ECs provides easy access to people in times of disaster (Masuya *et al.* 2015). The Republic Act 10121 allocates 5% from local revenue for Local Disaster Risk Reduction Management Fund, of which 30% is allocated for the Quick Response Fund and 70% for disaster prevention and mitigation, preparedness, response, rehabilitation and recovery, including the construction of evacuation centers. In the current setup, the spatial distribution of ECs depends primarily on the location and availability of the government facilities that are used as ECs when the need arises. For the ECs to become evenly and strategically distributed throughout Metro Manila, the local governments of these cities and municipality will need to acquire additional properties for the intention of constructing facilities that are dedicated for evacuation operations and disaster

management. In 2018, the Philippines' Department of Interior and Local Government (DILG) have revised the guidelines in strengthening the evacuation systems. It is now in the hands of the local government units to implement these guidelines.

5. CONCLUSION

The goals of establishing a responsive and effective disaster risk reduction and management plan are to save lives and minimize the damage when disasters strike. With the intensification of typhoons occurring in the Philippines and increasing population, evacuation is an essential life-saving measure. Thus, safe and sufficient evacuation centers coupled with an effective evacuation protocol are crucial in achieving these goals. The disaster risk reduction management plan for Metro Manila is at a developing stage with fragments scattered among its 16 component cities and 1 municipality. There is an urgent need for the consolidation of information starting with a comprehensive and up-to-date list of evacuation centers. This study has been able to put together all gathered lists of evacuation centers and geotagged information was added. However, each component list has to be reviewed to include additions and updates. Government policies regarding evacuation centers must be revisited to confirm the existence of the problem of implementation. The spatial analysis of EC distribution in Metro Manila revealed weaknesses particularly on the number of ECs to population ratio for all 17 component study areas. Among the calculated ratios, the best EC-to-population ratio is at 1:3,300 (San Juan City) which still needs a lot of improvement. Proper location of ECs, considering population density of an area and analyzing flood and earthquake susceptibility, not only help solve the problem of congestion but also reduces the risk of loss of lives and damage to property. While most, if not all, of the identified ECs are makeshift shelters which are government buildings or public spaces (i.e. schools, barangay halls, gymnasiums, etc.) by design, it is recommended that future construction and development of additional ECs be based on the DILG guidelines and that location identification be based on spatial distribution and capacity requirements.

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