An Objective Index for Equitable Water Access: a Public Drinking Water Fountain calculation for the City of Vancouver

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Disclaimer

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Executive Summary

Access to safe drinking water is recognized internationally as a human right, emphasized in the Sustainable Development Goal 6 (SDG). Many facilities are required to guarantee safe drinking water access, including conventional treatment and distribution systems, conservation strategies, wastewater facilities and public drinking water fountains (PDWF). Nevertheless, little attention has been given to the planning of PDWF in the previous literature. In this context, this work proposes an objective index to assist the calculation of new PDWF requirements considering a location-based and a population-based indicator. This work was divided into three phases: 1) Content analysis, conducted using a non-systematic method including Google Scholar and Web of Science; 2) Data acquisition and diagnosis, considering data provided by the City of Vancouver as well as online and public data; and 3) Index development, considering three priority levels for the location and population-based indicators. Our results indicate that while the city of Vancouver has a high ratio of public water fountains, over 36/100,000 people, the distribution of the fountains does not encompass all risk-related locations and areas. Furthermore, previous surveys conducted by the City indicate that 88% of the population believes the number of PDWF is inadequate to guarantee water access. Our results indicate the need to install 301 new fountains, encompassing 159 location-based fountains and 142 population-based fountains. These facilities would allow the city to cover sports and youth-related facilities and provide adequate water access to the general and the unhoused population. This work proposes that installing these new facilities be considered a step-by-step process, starting with location-based indicators and moving to population-based ones. These would allow the city to allocate the necessary resources and reevaluate the need for a new PDWF according to stakeholders' feedback.

Introduction

Climate change (Gandolfo-Lucia, 2022), heat waves and water access challenges require alternatives to current drinking water access solutions in urban spaces. These challenges, combined with social-economic factors (Olson & Pauly, 2021), increase the population at risk for heat sickness and the homeless population. Globally, over a billion people do not have access to safe drinking water (Mukheibir, 2010) and in Canada, homeless and Indigenous populations suffer from the lack of alternatives (Olson & Pauly, 2021). These issues led the public authorities to seek new alternatives to the growing water access and heat risk.

Water Access has been recognized as a human right and is encompassed in the Sustainable Development Goals (SDGs). Specifically, SDGs target equitable drinking water and sanitation in SDG 6. However, safe drinking water access is also connected to Good Health and Well-Being (SDG3), Sustainable Cities (SDG 11), Responsible consumption (SDG 12), and climate action (SDG 13) (UN, 2018). SDG 6 can be achieved through individual and public technology development, considering alternatives ranging from water treatment facilities to public drinking water fountains (PDWF).

Drinking water fountains are an important infrastructure for public water access (Gandolfo-Lucia, 2022; Notarian, 2023; O'Donnell & Rice, 2012), and their inclusion in urban water public design is notoriously present throughout the history of many countries and cities (Berdzenishvili, 2019; Lvanov Ba In Architecture, 2009). Nevertheless, these facilities have been neglected in current urban developments due to bottled water public trust and lobbying (Smith, 2020), leading to inequitable water services that favour higher-income populations.

Developing equitable water services requires attention to water intermittency (Grasham et al., 2022). For instance, equitable drinking water fountain access should consider permanent fountains that ensure yearly equity. The expansion of these facilities should not only encompass areas that do not have any facilities but also consider socio-economic vulnerability to determine the number and the placement of these facilities (Grasham et al., 2022).

To my knowledge, few works are available in the literature covering drinking water fountains specifically. Most works aim to provide a guideline for implementation (Cameron et al., 2018;

Notarian, 2023), but they lack a specific index and prioritization to assist municipalities. Other works focus more on diagnosing current drinking water fountains (Avery & Smith, 2018; Gandolfo-Lucia, 2022) and do not provide specific recommendations for installation.

In this context, the present work aims to provide an adaptable index to calculate the amount of drinking water fountains that should be installed in the City of Vancouver. Specific objectives encompass: 1) Literature review to assess currently used indicators, 2) Data acquisition and current state diagnosis, and 3) Index development and guidelines.

Background

Drinking fountains

PDWF have been a part of urban infrastructure since ancient times (Lvanov Ba In Architecture, 2009; Notarian, 2023), counting on public and stakeholder support (Geest & Cocke, 2023). However, these facilities have lost part of their influence in urban environments due to the lack of maintenance, increased bottled water market and the reduction of the number of facilities in urban areas (Geest & Cocke, 2023). This decline results in reduced population access to safe drinking water (Phurisamban & Gleick, 2017).

Multiple users benefit from the installation of PDWF, such as children, commuters, runners, tourists and pets (Phurisamban & Gleick, 2017), as well as the unhoused population (Geest & Cocke, 2023; Notarian, 2023). In this context, the literature proposes multiple strategies to increase the influence of PDWF, including a policy to increase the number of facilities (Phurisamban & Gleick, 2017).

Urban Planning and drinking water fountain placement

While there was no public document covering specific guidelines for water fountain distribution and spacing, different papers and documents considered essential indicators to evaluate drinking fountain access through a diagnosis (Avery & Smith, 2018; Sullivan et al., 2003), as well as highlighting areas for installation (Gandolfo-Lucia, 2022). An essential indicator in the literature is the number of fountains per 100,000 people. For instance, a diagnosis of the Oklahoma state showcased an average of 12.63 fountains/100,000 people (Geest & Cocke, 2023). Other Assessments, on the other hand, point out that most countries have less than one public drinking water fountain per 100.000 people (QS supplies, 2023) and that Montenegro is the country with the highest number of drinking water fountains (over 470 per 100,000 people) and no estimations were found for Canada ratios (Table 1).

Table 1- Fountains/100,000 people ratio in different countries around the world

Country	Ratio (fountains/100,000 people)
Montenegro	472.4
Hungary	135.44
Liechtenstein	118.02
San Marino	76.63
Bulgaria	71.8
Monaco	45.87
Portugal	38.74
Australia	29.88
France	27.64
Moldova	26.95
Iceland	21.69
New Zealand	19.66
United States	5.01
Brazil	0.44
China	0.02

Source: (QS supplies, 2023)

Other indicators identified were race (Avery & Smith, 2018), high-risk populations (e.g.: homeless people, elderly and children) (Geest & Cocke, 2023), economic and social indicators (Sullivan et al., 2003), under-five mortality (Sullivan et al., 2003), location near children-related facilities (O'Donnell & Rice, 2012). At last, a previous study conducted in collaboration with the City of Vancouver highlighted that water mains, vulnerability to heat, density, traffic, and the distance to current water fountains should be considered to prioritize future installation. (Gandolfo-Lucia, 2022). Table 2 shows the leading indicators used in the literature.

Objectives

In this context, this work aims to incorporate technical, spatial, and socio-economic aspects to develop an objective index that calculates the number of permanent PDWF that should be installed in the City of Vancouver. This index aims to consider:

- Risk populations (e.g., unhoused population, elderly and children)
- Current PDWF distribution
- Not only the lack of PDWF, but also locations where these facilities would be needed the most (e.g., sports facilities and playgrounds)

The specific objectives of this work include:

1. Content analysis, considering the current literature covering PDWF.
2. Data Acquisition, considering geographical and statistical data collected with the City of Vancouver and publicly available data.
3. Diagnosis of the current situation, highlighting areas of need and the main issues in PDWF distribution in the City of Vancouver.
4. Development of the objective index, considering a location-based and a population-based indicator.

Table 2- Indicators used in the literature

Indicator type	Indicator	Used for	Reference
Socio indicators	Race	Diagnosis of water access	(Avery & Smith, 2018; Notarian, 2023)
	Socio-economic status of the population in the area	Diagnosis of water access	
Use related indicators	Foot traffic	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018)
	Sport (racing/biking)	Prediction/calculation of new drinking water fountains	(Notarian, 2023)
Risk-related indicators	Water quality perception	Prediction/calculation of new drinking water fountains	(Berdzenishvili, 2019)
	Homeless population	Diagnosis of water access	(Notarian, 2023)
	Low income communities	Diagnosis of water access	(Notarian, 2023)
	Vulnerable population (children and elderly)	Prediction/calculation of new drinking water fountains	(Notarian, 2023)
Economic indicators	Cost	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018)
Technical indicators	Main water proximity	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018; Gandolfo-Lucia, 2022)
	Design interference	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018)
	Visibility	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018)
	Ratio of drinking fountains per 100,000 people	Diagnosis of water access	(Geest & Cocke, 2023; Wilson et al., 2018)
Spatial indicators	Proximity to children facilities	Prediction/calculation of new drinking water fountains	(Wilson et al., 2018)
	Proximity to food outlets	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018)
	Distance to current drinking water fountains	Prediction/calculation of new drinking water fountains	(Cameron et al., 2018; Gandolfo-Lucia, 2022)
	Location near washrooms	Prediction/calculation of new drinking water fountains	(Notarian, 2023)
	Space in sidewalks	Prediction/calculation of new drinking water fountains	(City of Vancouver, 2021)

Methodology

The current work was conducted in three main stages (**Figure 1**):

I. Content analysis of current indexes, as well as diagnostic analysis of public drinking water access around the world.
II. Geographical and statistical data acquisition, and diagnostic analysis of current access in the City of Vancouver.
III. Creation of the index, considering location and population-based criteria.

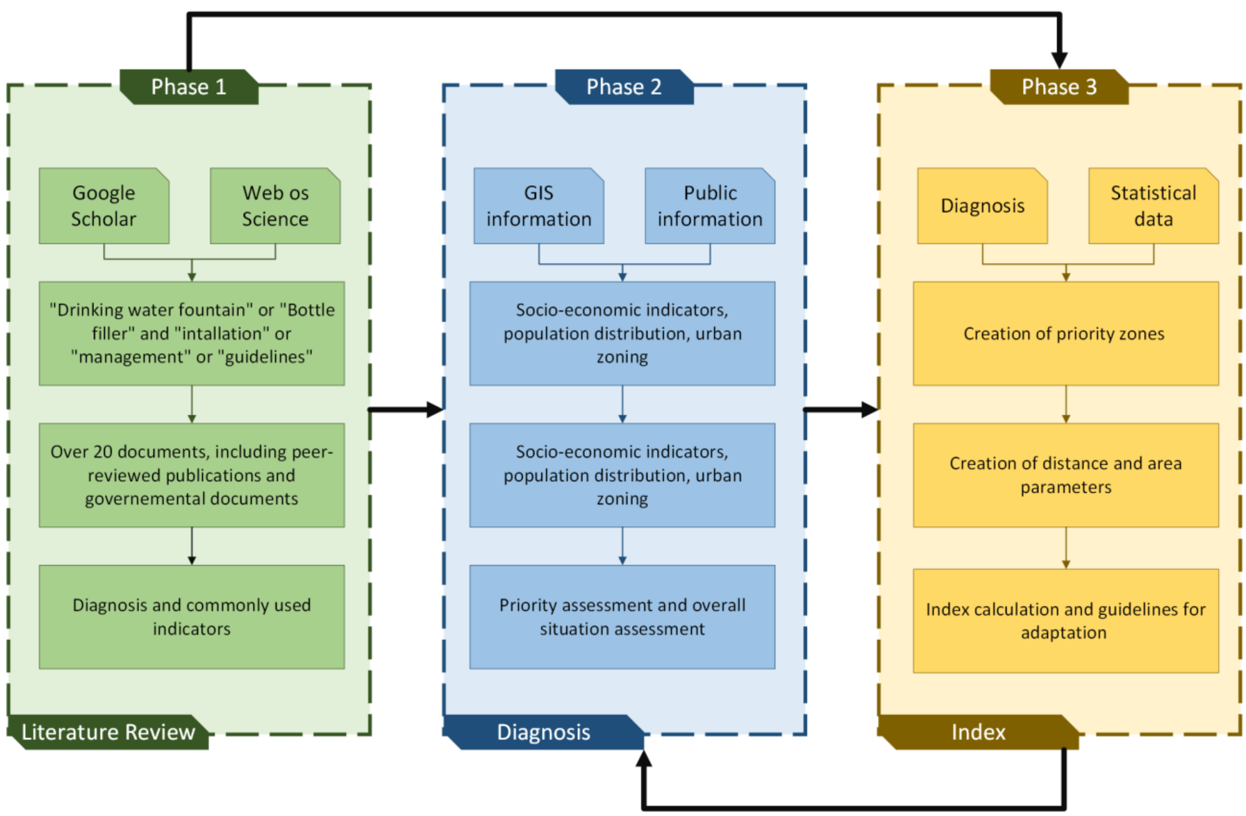

Figure 1- Methodology overview

Content analysis

The content analysis was conducted through a non-systematic review method, due to the scarcity of materials related to public drinking water fountains access and urban planning. Both Google Scholar and Web of Science databases were considered to amplify the reach. Keywords such as "drinking water fountain," "public drinking water fountain," "bottle filling stations," and "urban distribution" were combined, leading to the discovery of more than 20 documents. The research covered both peer-reviewed publications and governmental documents to expand the reach of this research. The documents are covered in the Background session, and they were used as the foundation for the data acquisition requirements, diagnosis and index.

Data acquisition and diagnosis

Data acquisition was performed considering geographical and statistical data made available by the City of Vancouver and acquired manually through websites and other resources. **Table 3** shows the data requirement list sent to the City of Vancouver, as well as the data gathered manually.

Table 3 – Data request

Data requested to the City of Vancouver	
Socio-economic data	**Technical data**
Race distribution	Water mains location
Economic distribution	Location of current permanent drinking water fountains
Current zoning	Location of public washrooms
Population age distribution	Location of public restaurants
Homeless shelters	Sidewalk area
Homeless people concentration	Bike lanes
-	Parks
-	Bus stops
-	Sky train entrances
-	High foot traffic areas
Gathered manually	
Technical data	**Technical data**
School locations[1]	Baseball[2]
Tennis court[2]	Basketball[2]
Volleyball[2]	Jogging[2]
Cricket pitch[2]	Pickleball[2]
Disc golf[2]	Rockey[2]
Football[2]	Running[2]
Lacrosse[2]	Soccer[2]
Rugby[2]	Softball[2]
Lighted fields[2]	Ultimate Fields[2]

*Green: data was successfully acquired, *Yellow: some data was acquired, but not specifically what was needed, *Red: no data was available

[1]VSB Vancouver School Board, 2023

[2]City of Vancouver, [s.d]

After the data acquisition was completed, a diagnosis of the current situation was performed, aiming to discover areas that not only lack drinking water fountains but also the areas that would need these facilities the most. The diagnosis follows a location—and area-based diagnosis, considering specific facilities, urban zoning, and socio-economic aspects.

Location-based analysis evaluated how many of the current facilities are within 50, 100, 500, 1000, 2000, and 3000 m of the installed permanent drinking water fountains. The following facilities were considered in this evaluation:

- Bus stop
- sky train
- restaurants
- Washrooms
- Homeless shelters
- playgrounds
- Schools
- Baseball
- Basketball
- Jogging
- Pickleball
- Rockey
- Schools
- Softball
- Tennis court
- Volleyball
- Cricket pitch
- Disc golf
- Football
- Lacrosse
- Rugby
- Lighted fields
- Ultimate Fields
- Running
- SOCCER

The area-based diagnosis, on the other hand, aimed to strive to identify tendencies related to population age, income and zoning, considering the following aspects:

- Children population above>25%
- Elderly population above 25%
- Children and elderly population > 25%
- Residential, comprehensive development, limited agriculture, historical, industrial, and commercial areas
- Income lower than 50,000
- Income higher than 50,000 and lower than 70,000
- Income higher than 70,000

Both area-based and location-based diagnoses were conducted considering the use of ArcGIS Pro and the use of simple linear regression when applicable.

Index methodology

The index was built considering a combination of a location-based indicator and a population indicator. This strategy was used to ensure access where drinking water fountains are needed the most, considering factors such as population size and the area covered. In this context, this work proposes three levels of location-based infrastructure priority (Table 4) and three areas of priority (Table 5) to facilitate the installation and prioritization of new PDWF by the City Council. This work proposes that high-priority PDWF be installed first, followed by medium and low-priority.

For the location-based indexes, risk-related aspects were also considered, as well as technical aspects. Washrooms, youth sports centers, shelters and playgrounds are considered high-priority locations in the present work. This consideration aims to protect children from heat-related sickness (Agrawal et al., 2024), provide access to the general population near facilities that serve tourists and residents (washrooms), and reach vulnerable populations (shelters). Medium priority considers schools, adult or non-specific sports facilities, as well as sky train access. This consideration aims to cover sports risk for heat sickness (Savioli et al., 2022), as well as provide access to drinking water facilities near high-traffic areas (sky train access and schools). Schools are not considered a high priority as all public schools in Vancouver have PDWF inside the institutions. Last, low priority considers the inclusion of bus stations, due to the number of bus stations in the city as well as the economic feasibility. Restaurants were disregarded in the index due to the lack of sufficient data. Each priority location received a determined maximum distance from a drinking water fountain: 100m (high priority), 500 m (medium priority) and 1000 m for low priority. These distances were based on the time it takes the targeted population to reach the facility (Sviridov et al., 2015) (Table 4).

In the priority zoning distribution, risk factors such as age and income were considered to classify the areas into high, medium and low-priority zones. Income was considered to increase the risk of the population, as it decreases access to cooling technologies and proper housing (Harlan et al., 2006). The population age was also considered for the high and medium priority areas, as the elderly and children are at higher risk of heat sickness (Agrawal et al., 2024; Savioli et al., 2022) (Table 5).

Table 4- Location-based indexes

Priority	Type of facility	Distance (m)	Elderly/children time[1]	Adult[1]
High	Softball youth	100	Around 2 min	Less than 1.5 min
	Shelters	100		
	Soccer youth	100		
	Washrooms	100		
	Playgrounds	100		
Medium	Disc golf	500	Around 10 min	Around 6 min
	Lacrosse	500		
	Cricket pitch	500		
	Pickleball	500		
	Running	500		
	Rugby	500		
	Volleyball	500		
	Football	500		
	Jogging	500		
	Lighted fields	500		
	Ultimate Fields	500		
	Field hockey	500		
	Baseball	500		
	Basketball	500		
	Softball adult	500		
	Tennis court	500		
	Soccer adult	500		
	Sky train	500		
	Schools	500		
Low	Bus stop	10000	Less than 20 min	Less than 13 min

[1](Sviridov et al., 2015)

Table 5 - Priority zone definition

Priority	Definition	Ratio used (population)	Ratio (area)
High	One of the following factors: a) children and elderly> 25%, b) income lower than 50,000CAD$	150 fountains/100,000 people	Radius>=100m
Medium	Areas where children are above 25% of the population and elderly are above 25% of the population	100 fountains/100,000 People	Radius>=200
Low	All other areas	50 fountains/100,000 people	Radius>=300m

All priority for the location based and population-based index were reviewed with the City of Vancouver, and proper adjustments were made during the preliminary results.

Location based indexes

The first step for determining the location-based indicator is to organize the location points in orders of priority (Table 4). The analysis should be considered starting with the high priority locations, moving to medium and low priority locations. After the prioritization, each location-based points should be organized into a simple vector i=(1,2,...,n), in which n describes the number of facilities ranked in that level of priority. In this work, one drinking water fountain per facility is considered, but future studies could change the number according to the need and population using the facility. Initially, the calculation of the indicator in priority level j would be calculated using the following (Equation 1):

$$NPF = \left[F - F_f\right] * \frac{1fountain}{facility} \qquad Equation\ 1$$

Where NPF represents the new permanent fountains, F represents the number of facilities in total and Ff is the number of facilities with a fountain within the specified distance. However, as urban environments are complex and certain facilities tend to be installed in proximity, especially sports-related facilities, this work identified a need to insert in the above-mentioned formula error calculations to remove internal proximity, as well as the intersection between drinking water fountains that could serve multiple facilities at the same time. The goal is to maximize water access and minimize the cost and maintenance requirements throughout the city (Equations 2-4).

$$Error_{internal} = F - F_a \qquad Equation\ 2$$

Where F_a represents the number of facilities within the established distance of each other. For example, playgrounds within 100m of playgrounds would be removed from the final number of new installations.

$$Error_i = \sum_{i=2}^{i=n} NPF_i \cup NPF_{i-1}\,, if\ i \geq 2\ if\ i = 1, Error_i = 0 \quad Equation\ 3$$

$$Error_j = \sum_{j=2}^{j=m} \sum_{i=2}^{i=n} Error_i\,, \qquad if\ j \geq 2, if\ j = 1, \qquad Error_j = 0\ E \quad Equation\ 4$$

Hence, the adjusted location-based number can be calculated by Equation 5.

$$\overline{NPF_{t(J)}} = \sum_{j=1}^{m} \sum_{i=1}^{n} [NPF_i - F_{ai} - \sum_{i=2}^{i=n} NPF_i \cup NPF_{i-1}]$$
$$= \sum_{j=1}^{m} \sum_{i=1}^{n} [F_i - F_{fi}] * \frac{1 fountain}{facility} - F_{ai} - \sum_{i=2}^{i=n} NPF_i \cup NPF_{i-1}],$$
$$Equation\ 5$$

Population-based indicator

The population-based indicator was calculated considering that each priority area would require a different ratio (fountain/100,000 people) for the area according to the heat sickness risk (Table 5). To correct this number, we used an area check, considering that the radius for the total number of fountains in an area (new location-based, new area based and existing fountains) should not exceed 100 m in the high priority, 200m in the medium and 300m in the low. This was considered to avoid having multiple PDWF in the same area, increasing the cost of maintenance and decreasing the efficiency of these facilities. The population ratio was calculated through the following (Equation 6).

$$NPF_l = R_l * P_l - F_l \quad Equation\ 6$$

Where NPF_l represents the number of new permanent fountains to be installed in area l, Rl is the decided ratio (in fountains/100,000 people), Pl is the population in the area l and Fl is the number of permanent fountains installed in the area. However, the installation of fountains in the population-based indicator also requires consideration of the area. For instance, the number of fountains can be low to cover the area, or the number could be high for the area covered. In this context, if the number is not in the same order of magnitude, the area indicator would be considered (Equation 7).

$$NPF_{radius(l)} = \frac{A_l}{a_l} \qquad Equation\ 7$$

In which Al is the total of the area, al represents the influence area of the fountains installed. At last, the area calculation also needs to consider an error calculation (Equation 8):

$$Error_l = \sum_{j=1}^{m} \overline{NPF_{jl}}\ , \qquad Equation\ 8$$

In which the term $\overline{NPF_{jl}}$ represents the number of new fountains calculated for the locations in priority j, inserted in the area l. Notice that multiple location priorities could be contained in a specific priority area. Hence, the final new number of PDWF considering the population indicator is given by Equation 9.

$$\overline{NPF_{t(l)}} = \sum_{l=1}^{o} [R_l * P_l - F_l - \sum_{j=1}^{m} \overline{NPF_{jl}}] \qquad Equation\ 9$$

At last, the total number of new PDWF installed in Vancouver should be given by the sum of the area based indicator (Equation 9) with the total location based indicator (Equation 5). The total number of fountains is given by Equation 10.

$$\overline{NPF_{total}} = \overline{NPF_{t(J)}} + \overline{NPF_{t(l)}} \qquad Equation\ 10$$

Results

Data acquisition

The data acquisition phase gathered data on current drinking water locations, as well as the location of sports centers, homeless shelters and other important points in the city (**Figures 2-9**). The idea behind the data acquisition was to map high-risk areas and locations that would require a drinking water facility installment. In **Figure 2**, the location of the current permanent PDWF is shown. In total 254 fountains are installed in the City of Vancouver, and the current ratio of the city is 36.74 drinking water fountains/100,000 people.

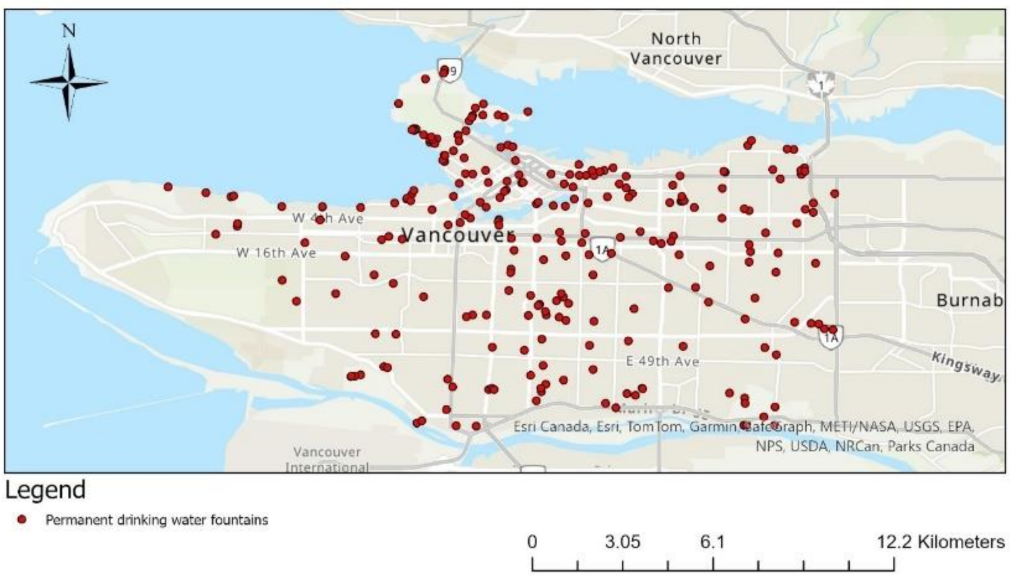

Figure 2- Permanent drinking water fountains

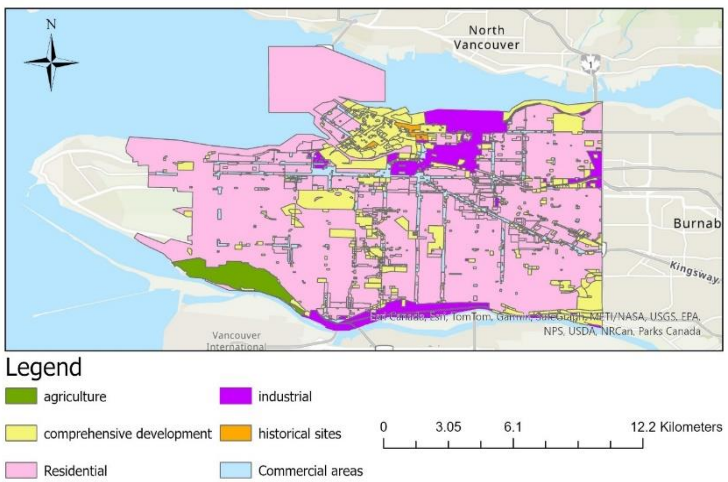

Figure 3- City of Vancouver zoning

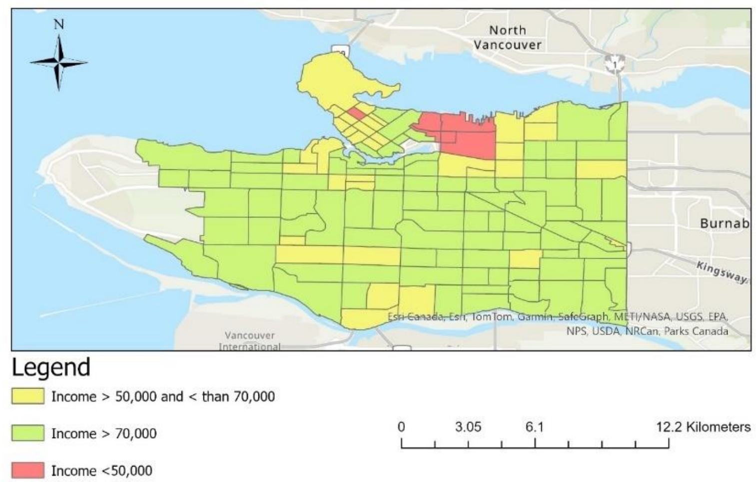

Figure 4- Income zoning

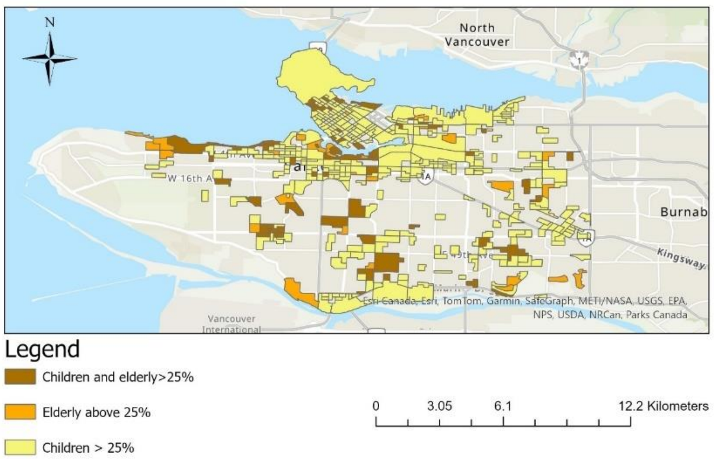

Figure 5- Age zoning

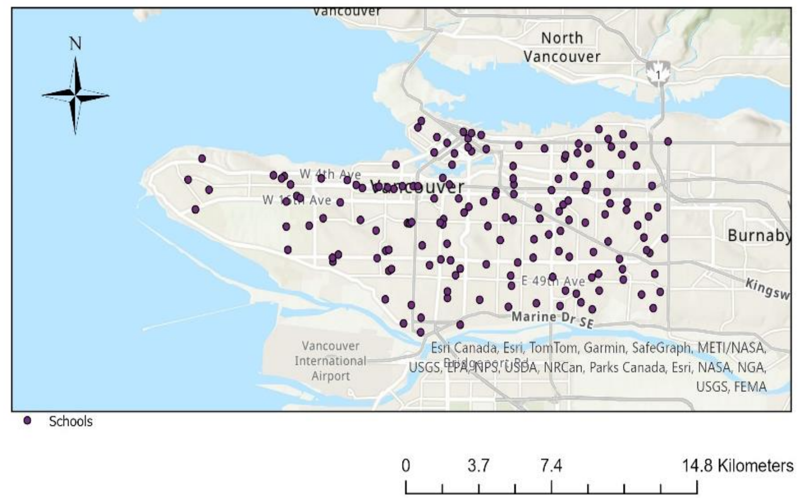

Figure 6- School locations

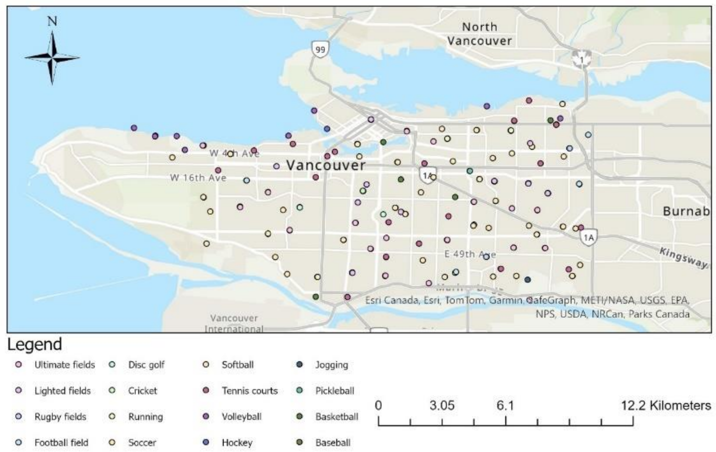

Figure 7- Sport centers location

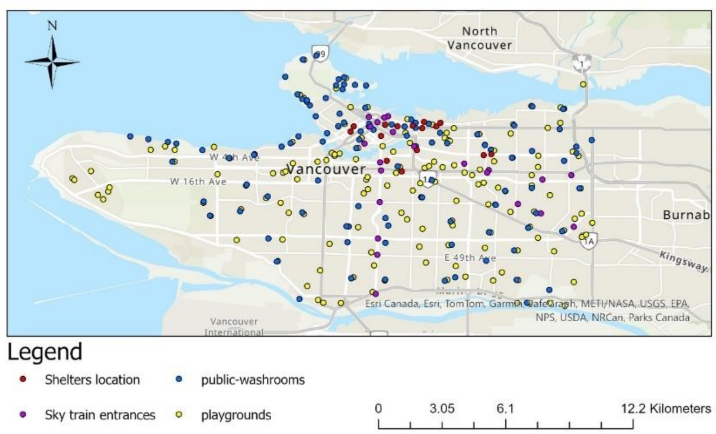

Figure 8- Shelters, sky train, playgrounds and washrooms

Figure 9- Bus stations and restaurants

Figures 3-5 showcase the zoning divisions found in the data acquisition phase. Figure 3 shows the current zoning used by the City Council to showcase the intended use of each area. Figures 4 and 5, on the other hand, were created in the present work to showcase areas with heat sickness at risk populations regarding income and age. At last, Figures 6-9 showcase the location of multiple facilities considered important for drinking water access, such as homeless shelters, sports facilities and children-related facilities (playgrounds, schools and youth sports).

Diagnosis of current drinking water situation in the City of Vancouver

Location-based diagnosis

The initial diagnosis focused on evaluating distances between important city locations that would require water access to the current drinking water fountains. Figure 10 shows the correlation between the water fountain distance and the number of facilities within the specified distance. Figure 11, on the other hand, showcases the correlation between sports facilities and current drinking water fountains.

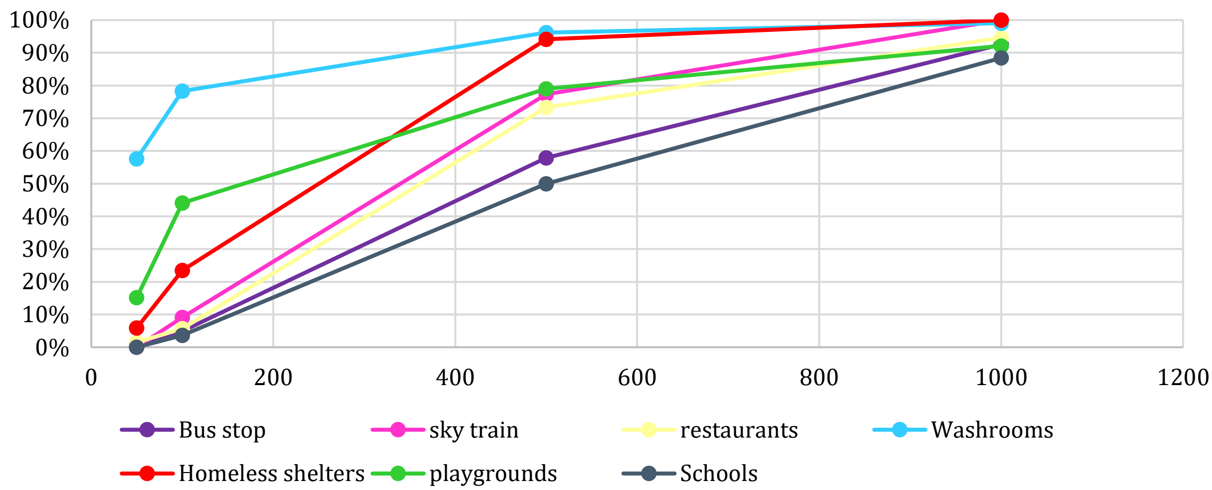

Figure 10- Linear correlation between important facilities and currently installed drinking water fountains

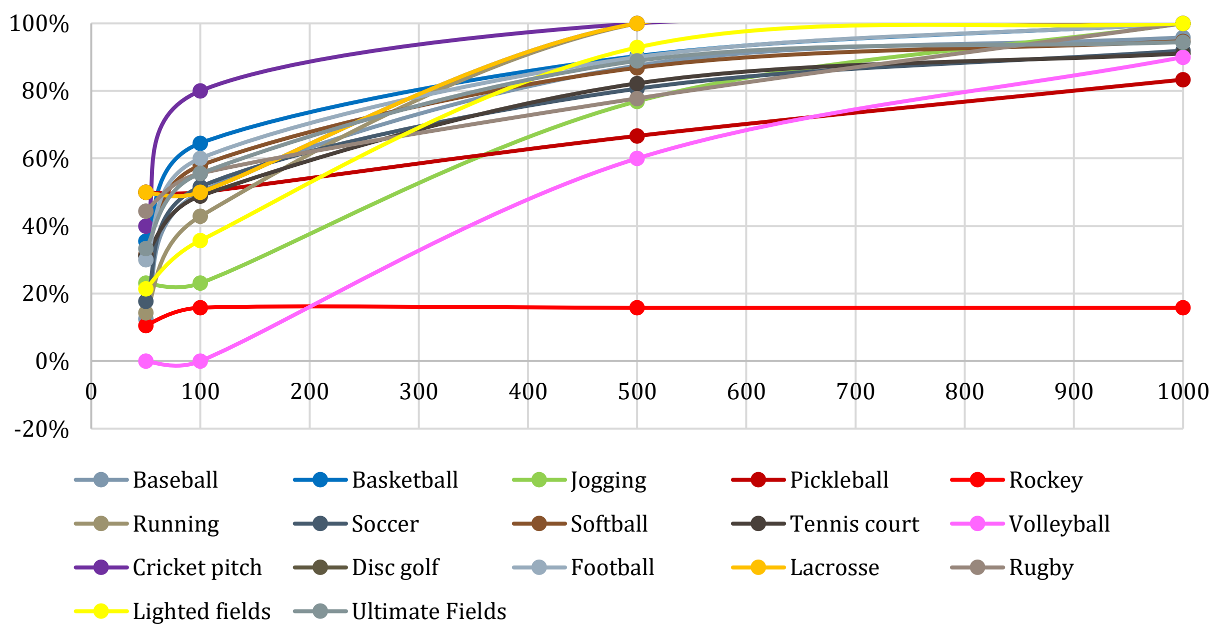

Figure 11- Sports correlation

Areas with high-risk probability populations (children and elderly) have a high correlation with drinking water fountain installation, which shows that the city has considered a risk in previous planning, with particular emphasis on elderly populations (**Figure 12**). A high correlation was also found in the income analysis, and an inversed relationship was discovered: lower-income populations had higher PDWF ratios (**Figure 13**).

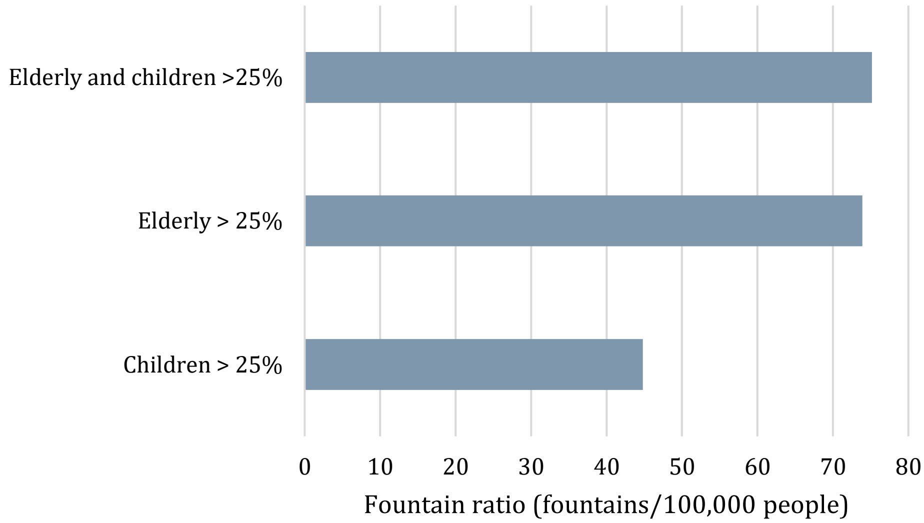

Figure 12- Correlation between drinking water fountain access and risk populations (age)

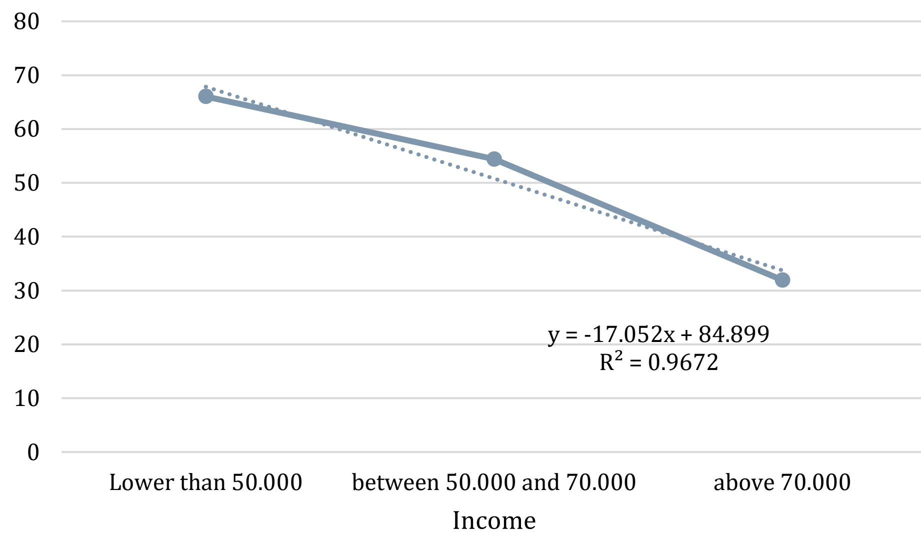

Figure 13 – Correlation between drinking water fountain access and income

Regarding the zoning areas, the correlation was not connected to important habitation and walking areas, and agricultural areas had a substantially higher ratio of drinking water fountains (**Figure 14**). These results demonstrate that the City of Vancouver requires more strategic planning regarding the location of new drinking water fountains.

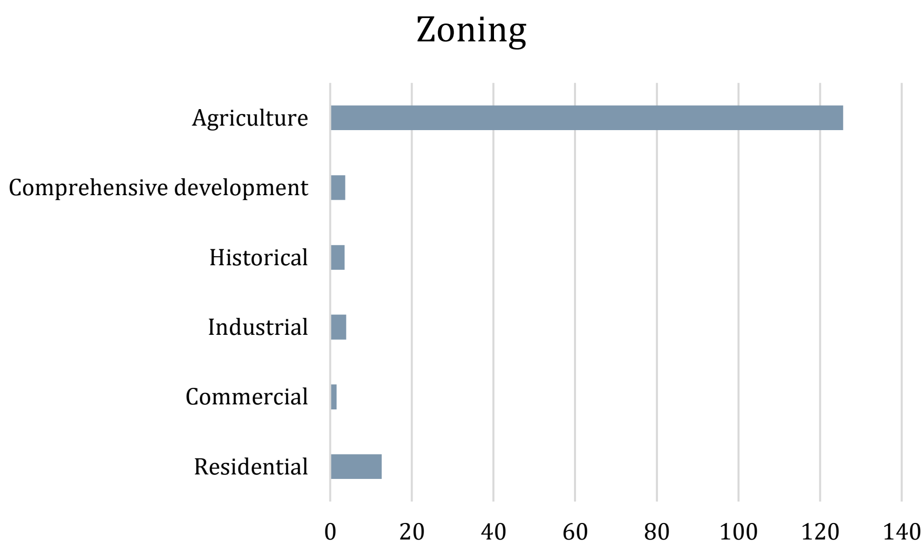

Figure 14- Drinking water fountain ratio to each zoning area

General distribution assessment

Current PDWF in the City of Vancouver is distributed in a way that the use of the city is disregarded, as well as multiple locations missing these facilities. In general, considering that the area of influence of a drinking water fountain would be 500m or 1000m, the city has multiple blank spots that would require the installation of new PDWF (**Figure 15 and Figure 16**).

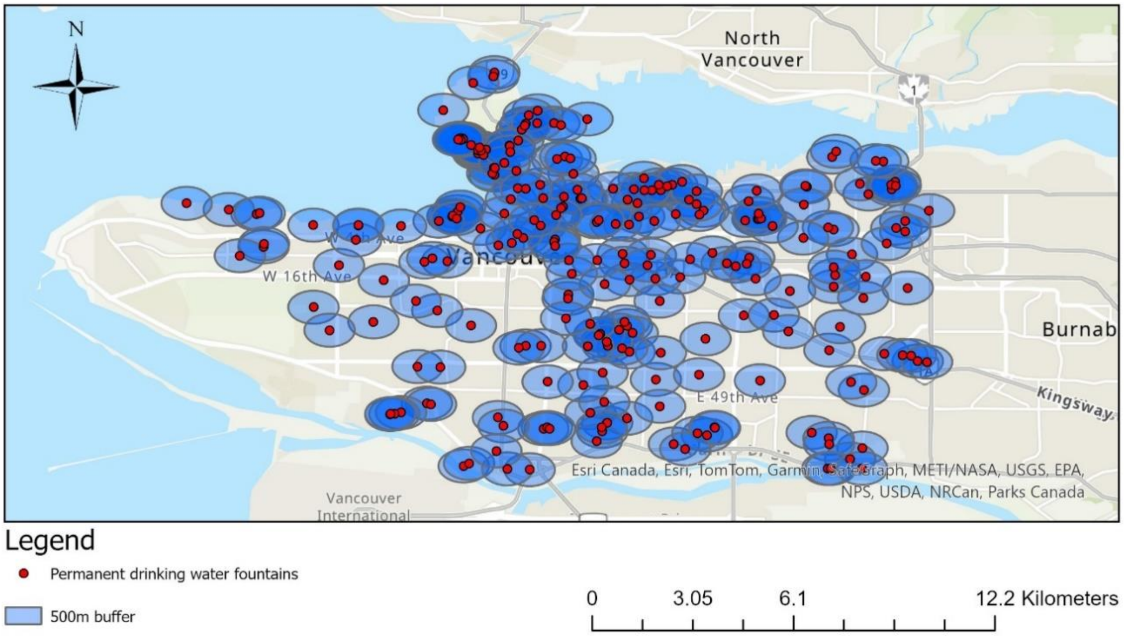

Figure 15- Area analysis, considering a 500m buffer

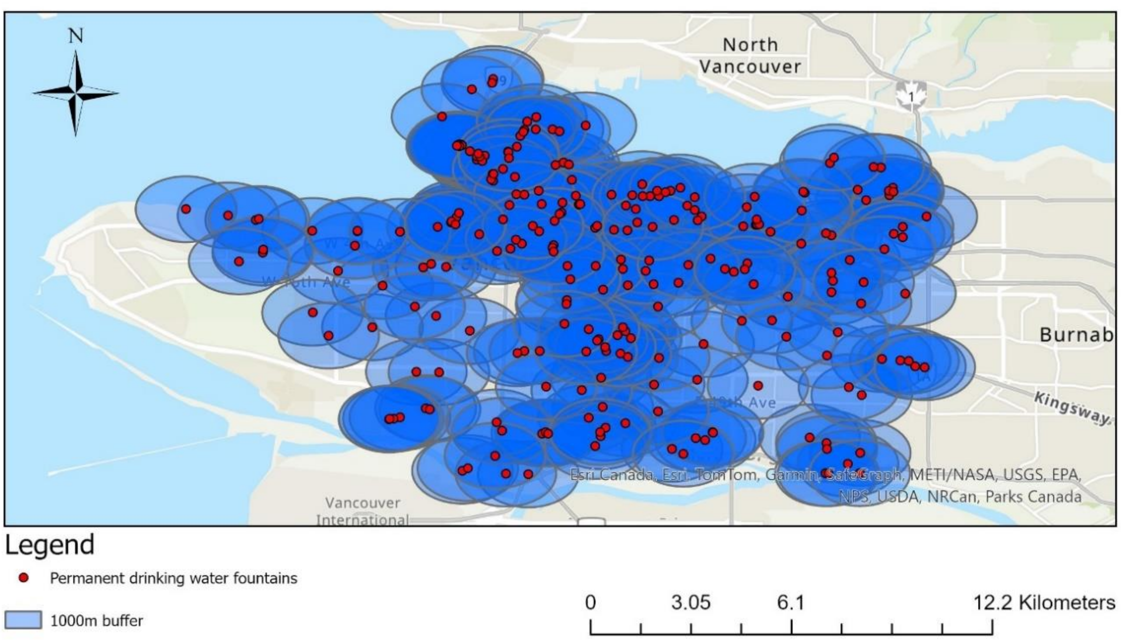

Figure 16 - Area analysis, considering a 1000m buffer

Index calculation

Location-based indexes

As the diagnosis shows, there are areas in the city without drinking water fountains, but the decision to locate a new fountain should consider the need as well as the lack of drinking water fountains. **Table 6** shows the results for each type of facility considered high, medium, and low priority. **Figure 17** shows the approximate location for installing the new location-based water fountains.

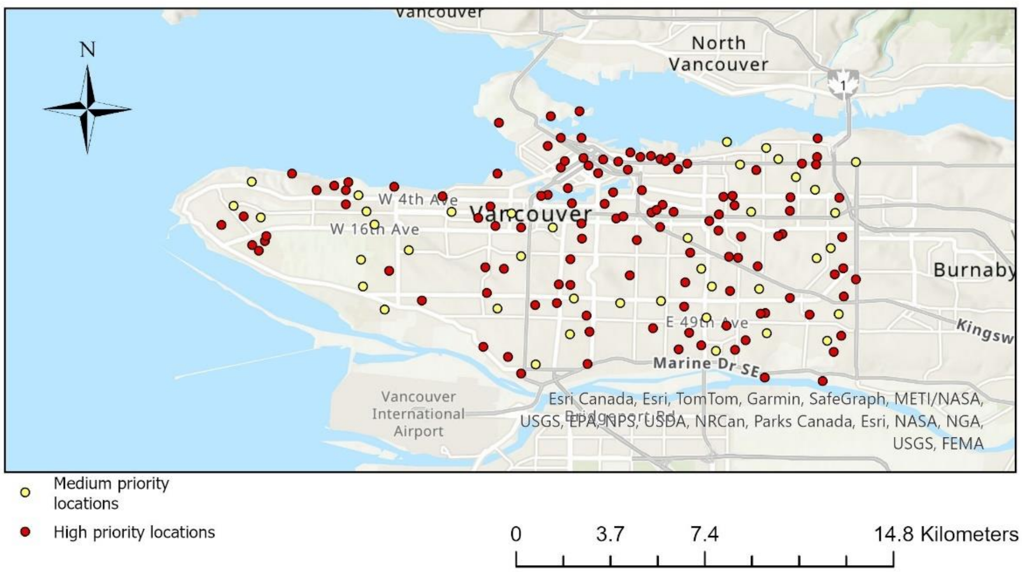

Figure 17- Location-based installation spots

Table 6- Location-based indexes

Priority	Type of facility	distance	number	within the determined distance	NPF	Error calculation	Install	internal error	Install
High	Shelters	100	17	4	13	0	13	2	119
	Washrooms	100	106	83	23	0	23		
	high priority sports	100	28	17	11	2	9		
	Playgrounds	100	151	67	84	8	76		
Medium	Disc golf	500	2	2	0	0	0	11	40
	Lacrosse	500	2	2	0	0	0		
	Cricket pitch	500	5	5	0	0	0		
	Pickleball	500	6	4	2	2	0		
	Running	500	7	7	0	0	0		
	Rugby	500	9	7	2	2	0		
	Volleyball	500	10	6	4	1	3		
	Football	500	10	9	1	1	0		
	Jogging	500	10	7	3	3	0		
	Lighted fields	500	14	13	1	1	0		
	Ultimate Fields	500	18	16	2	2	0		
	Hockey	500	13	12	1	1	0		
	Baseball	500	24	21	3	3	0		
	Basketball	500	31	28	3	3	0		
	Softball adult	500	31	26	5	4	1		
	Tennis court	500	43	37	6	5	1		
	Soccer adult	500	43	35	8	7	1		
	School	500	164	82	82	37	45		
	sky train	500	22	17	5	5	0		
Low	Bus stop	10000	1897	1756	141	141	0	0	0

Population based indicator

To develop the population-based indicator, the areas in the city of Vancouver were initially divided into three areas of priority: high, medium and low priority, considering the risk of the population to heat-events (**Figure 18**).

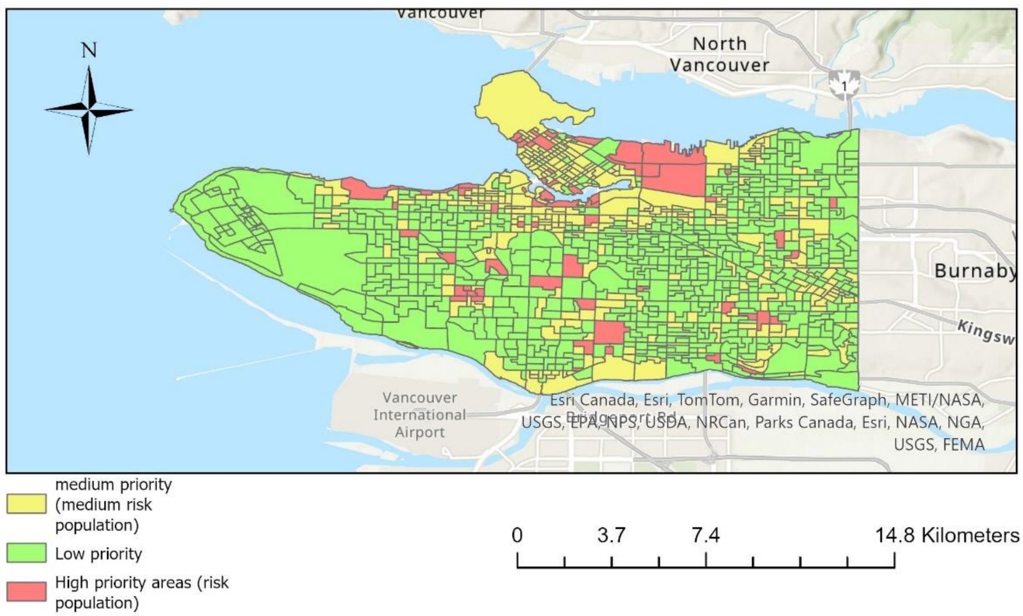

Figure 18- High, medium and low priority areas

The index was calculated considering different ratios for each area, considering the risk zone each area was classified into. Then, an area-check was conducted to avoid installing drinking water fountains within 100m of each other (high risk), 200m (medium risk) and 300m (low risk), while also ensuring drinking water access and Vancouver insertion as one of the global leaders in drinking water access through fountains and public services. **Table 7** shows the calculations for the population based indicators.

The total number of new PDWF is given by:

$$\overline{NPF_{total}} = \overline{NPF_{t(J)}} + \overline{NPF_{t(l)}} = 159 + 142 = 301\ new\ fountains$$

Table 7- Population based indicators

Priority	Area (km^2)	Population	ratio	total fountains (ratio)	current fountains	error	Install	Influence area (km^2)	radius (m) - check	Total fountains (final)
High	10.58	63035	150	94.5525	45	28	21	0.031415927	189.28	21
Medium	32.94	258275	100	258.275	106	40	112	0.785398163	201.59	112
Low	88.11	370125	55	203.56875	103	91	9	3.141592654	371.70	9

How to modify the index

The following are the steps to modify the index according to new populations/ratios and distances (Figure 19):

1- Start by modifying the distances in the location-based indicator, considering the new errors and the new threshold for the proximity to existing water fountains.
2- Review the number of the population, as well as the area distribution, according to the high, medium and low-risk groups.
3- Create new ratios or maintain the current ratio changing solely the population
4- Conduct the radius check, considering the new number of fountains and the tolerated distance.

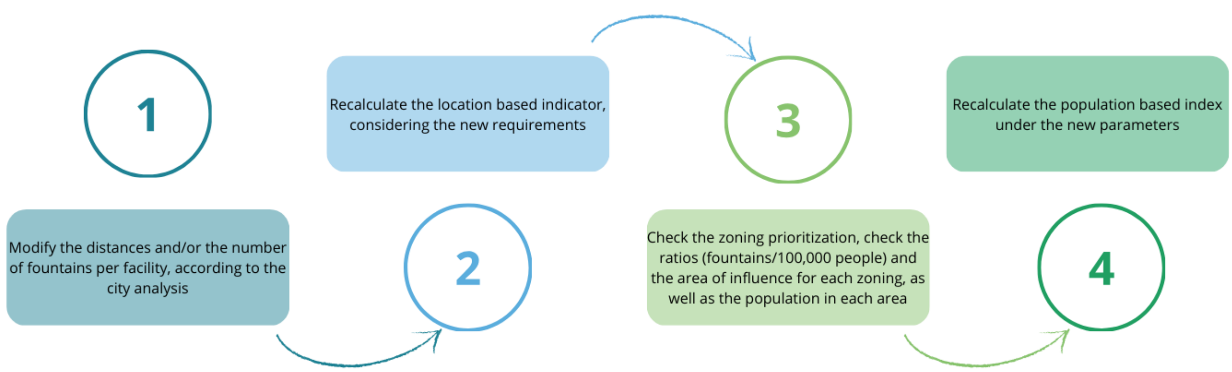

Figure 19 – Index modification steps

Conclusions

In summary, this work identified the need to install 301 new drinking water fountains in the City of Vancouver, considering the specified ratios and distances. This new number would bring the total to 555 drinking water fountains in the City, with a ratio of over 80 fountains/100,000 people. The new ratio would place the City of Vancouver as one of the world leaders in drinking water fountain access, but it would also require extensive work in maintenance, as well as public education.

The installation process should follow the priority order, considering the installation of the location-based facilities first to avoid the repetition of facilities in nearby areas. The population-based water fountains should be installed considering the proposed areas of influence and the minimum distance of 100m, 200m, and 300m for high, medium and low priority areas, respectively.

Recommendations

While this work strived to exhaust the indicators relevant to drinking water fountain use and classify the areas and locations into a high, medium, and low priority system to assist the installment and prioritization of new drinking water fountains, a few limitations are found in this work.

1- Due to time constraints, a public consultation was not carried out, and future works should strive to consider population organizations, risk-related organizations and the City council for future adjustments in the calculations proposed here.

2- As shown in the literature, drinking water fountain use is not only connected to the availability of these fountains but also to the maintenance of these facilities. Hence, future management plans should include detailed cleaning, inspection, and maintenance plans, considering costs and population requirements.

3- Future works should also include further data acquisition considering other facilities that might require the installation of drinking water fountains.

References

Agrawal, A., Agrawal, R., & Professor, A. (2024). *An analysis of heat-related illnesses in children due to immoderate temperatures*.

Avery, D. C., & Smith, C. D. (2018). Access to public drinking water fountains in Berkeley, California: A geospatial analysis. *BMC Public Health*, *18*(1). https://doi.org/10.1186/s12889-018-5087-4

Berdzenishvili, R. (2019). *Rediscovery of drinking water fountains in Stockholm*.

Cameron, S., Chung, E., Mun, N., Pillai, I., & Tan, B. (2018). *Investigating the Optimal Locations for Outdoor Drinking Water Fountains in UBC*.

City of Vancouver. (2021). *City of Vancouver Engineering Requirements for the Installation of Public Drinking Fountains*.

Gandolfo-Lucia, N. (2022). *Accessible and Equitable Drinking Fountain Placement Strategy*.

Geest, E., & Cocke, T. (2023). Ensuring the Future Accessibility of Drinking Fountains in Oklahoma and Beyond. *Journal of Science Policy & Governance*, *23*(1). https://doi.org/10.38126/jspg230102

Grasham, C. F., Hoque, S. F., Korzenevica, M., Fuente, D., Goyol, K., Verstraete, L., Mueze, K., Tsadik, M., Zeleke, G., & Charles, K. J. (2022). Equitable urban water security: beyond connections on premises. *Environmental Research: Infrastructure and Sustainability*, *2*(4). https://doi.org/10.1088/2634-4505/ac9c8d

Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. *Social Science and Medicine*, *63*(11), 2847–2863. https://doi.org/10.1016/j.socscimed.2006.07.030

Lvanov Ba In Architecture, J. (2009). *Drinking Fountains: The Past and Future of Free Public Water in the United States ARCHVES Signature redacted OD bepartment of Urb Signature redacted*.

Mukheibir, P. (2010). Water access, water scarcity, and climate change. In *Environmental Management* (Vol. 45, Issue 5, pp. 1027–1039). https://doi.org/10.1007/s00267-010-9474-6

Notarian, M. (2023). A Spatial Network Analysis of Water Distribution from Public Fountains in Pompeii. *American Journal of Archaeology*, *127*(1), 85–118. https://doi.org/10.1086/722233

O'Donnell, C., & Rice, R. E. (2012). A communication approach to campus bottled water campaigns. *Social Marketing Quarterly*, *18*(4), 255–273. https://doi.org/10.1177/1524500412466075

Olson, N., & Pauly, B. (2021). Homeless encampments: connecting public health and human rights. *Canadian Journal of Public Health*, *112*(6), 988–991. https://doi.org/10.17269/s41997-021-00581-w

Phurisamban, R., & Gleick, P. (2017). *Drinking Fountains and Public Health Improving National Water Infrastructure to Rebuild Trust and Ensure Access*. www.pacinst.org.

Savioli, G., Zanza, C., Longhitano, Y., Nardone, A., Varesi, A., Ceresa, I. F., Manetti, A. C., Volonnino, G., Maiese, A., & La Russa, R. (2022). Heat-Related Illness in Emergency and Critical Care: Recommendations for Recognition and Management with Medico-Legal Considerations. In *Biomedicines* (Vol. 10, Issue 10). MDPI. https://doi.org/10.3390/biomedicines10102542

Smith, C. B. (2020). *THE DECLINE OF PUBLIC DRINKING WATER FOUNTAINS IN AMERICAN CITIES: REASONS AND CONSEQUENCES A THESIS SUBMITTED IN PARTIAL FULFILLMENT*

OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN URBAN AND ENVIRONMENTAL POLICY AND PLANNING.

Sullivan, C. A., Meigh, J. R., Giacomello, A. M., Fediw, T., Lawrence, P., Samad, M., Mlote, S., Hutton, C., Allan, J. A., Schulze, R. E., Dlamini, D. J. M., Cosgrove, W., Delli Priscoli, J., Gleick, P., Smout, I., Cobbing, J., Calow, R., Hunt, C., Hussain, A., … Steyl, I. (2003). The water poverty index: Development and application at the community scale. *Natural Resources Forum*, *27*(3), 189–199. https://doi.org/10.1111/1477-8947.00054

Sviridov, A. V., Shushkova, T. V., Ermakova, I. T., Ivanova, E. V., Epiktetov, D. O., & Leontievsky, A. A. (2015). Microbial degradation of glyphosate herbicides (review). *Applied Biochemistry and Microbiology*, *51*(2), 188–195. https://doi.org/10.1134/S0003683815020209

United Nations. (2018). SDG6 Synthesis Report 2018. In *United Nations* (1st ed.). United Nations. https://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018-on-water-and-sanitation/

Wilson, N., Signal, L., & Thomson, G. (2018). Surveying all public drinking water fountains in a city: outdoor field observations and Google Street View. *Australian and New Zealand Journal of Public Health*, *42*(1), 83–85. https://doi.org/10.1111/1753-6405.12730

Online references

City of Vancouver. [s.d]. Fields, courts and diamonds. Available on <https://vancouver.ca/parks-recreation-culture/fields-and-courts.aspx>. Access on July 30th, 2024.

QS supplies. 2023. Which Countries and Cities Have the Most Water Fountains? Available on < https://www.qssupplies.co.uk/countries-and-cities-have-the-most-water-fountains.html> . Access on July 30th, 2024.

VSB. Vancouver School Board. 2023. Our Schools. Available on <https://www.vsb.bc.ca/page/27772/school-directory-and-map>. Access on July 30th, 2024k

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