

PAPER • OPEN ACCESS

## Design and simulation of an alternative aqueduct network for urban population

To cite this article: M S Orjuela Abril *et al* 2019 *J. Phys.: Conf. Ser.* **1386** 012129

View the [article online](#) for updates and enhancements.

You may also like

- [Experimental Study on Structure Water Support Interaction of Large Aqueduct](#)  
Chunlei Li, Lijun Zhao and Haibo Wang
- [Application of Digital Technology in Safety Evaluation of Dabeishan Aqueduct](#)  
W L Chen, X L Chen, W D Wu et al.
- [Hydraulic Study of the Water Supply to the City of Seville through Its Aqueduct between the 17th and 19th Centuries](#)  
Candela Bandrés, María Dolores Robador and Antonio Albaronedo



The Electrochemical Society  
Advancing solid state & electrochemical science & technology

### 241st ECS Meeting

May 29 – June 2, 2022 Vancouver • BC • Canada

Abstract submission deadline: Dec 3, 2021

Connect. Engage. Champion. Empower. Accelerate.  
**We move science forward**



**Submit your abstract**



# Design and simulation of an alternative aqueduct network for urban population

M S Orjuela Abril<sup>1</sup>, J P Rojas Suárez<sup>1</sup>, and G C Prada Botia<sup>1</sup>

<sup>1</sup> Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: gaudycarolinapb@ufps.edu.co

**Abstract.** Aqueduct systems help to record water consumption, being a connection between nature and the population, allowing water to be transported continuously; a good design of aqueduct networks is necessary to meet the purpose of providing the community with a technical report that can serve as a starting point to carry out a construction of the aqueduct for the public battery. This research presents the simulation of an aqueduct system by means of the epanet software according to the daily maximum flow, pressure, velocities of the distribution network, pumping time, with respect to the different pressures and diameters, diagnosing the routes, nodes, forms of access, restrictions and limitations that may affect the proper functioning of the system; In this way, the advantages and the magnitude of beneficiaries who will have this new access and improved service to meet the needs of the inhabitants are evident, according to the technical requirements of drinking water and sanitation of the technical regulation of the drinking water and basic sanitation sector, where it can be implemented by any public company in the country.

## 1. Introduction

Internationally shared, or transboundary, groundwater resources have long played an important role in sustaining human needs for water, e.g. agriculture and other uses, and natural ecosystems [1]. The best example in the history of city planning and administration is ancient Rome; because of its scale, the water supply system of ancient Rome is considered an outstanding achievement of hydraulic and civil engineers [2]. Approximately 43% of the world's irrigation water consumption is groundwater and groundwater is the main source of drinking water for some 2 billion people worldwide [3].

One of the biggest difficulties are the concrete cracks, mainly the temperature cracks on the surface or through the body of the aqueduct, adding the mechanism of damage and fracture of the concrete material, the temperature load during construction is very complicated and must be treated carefully and properly [4]. For this reason, some technical aspects that are needed in the aqueduct are the capacity, pressure and speed, being relevant for the safety level of the pipe, because it is high due to the influence of the pressure in the pipe [5].

In early 2018, Cape Town faced a potential water supply disaster, partly associated with a long-term drought, but also caused by population growth and lack of foresight in planning water supply infrastructure [6]. In the United States, 50% of the 39,000 hydraulically fractured wells that consumed 100 billion gallons of water are found in areas of high or extremely high water stress, i.e., semi-arid regions or regions with low precipitation [7].

In Colombia, in spite of having abundant hydraulic sources, its population faces increasing difficulties in accessing potable water, to the point that it is estimated that by 2025, 69% of the population could face a severe liquid shortage; approximately 22 million Colombians consume water



of poor quality, unsuitable [8]. The country's aqueduct systems present difficulties to reach each case due to the low investment and maintenance of the pipes and instruments of the aqueduct system, so this research would be available to the country's public service.

This article presents the design of an aqueduct system for the urban settlement in the municipality of San José de Cúcuta, Norte de Santander, Colombia, in the Antonia Santos neighborhood, through the epanet 2.0 simulation program to provide the community with a technical report for the construction of the aqueduct, this should be a worldwide approach, to make drinking water more accessible to those regions lacking this vital liquid.

This model performs simulations of the extended period of the hydraulic response of the system, forecasting the evolution of flows and velocities inside the pipes, the variations in pressure at the points of demand, the levels in the tanks, including the proportion of concentration of any circumstance at any point in the network over time and determining the time the water remains in the network as its point of origin from the different points of supply [9].

## 2. Methodology

The project was carried out in the municipality of San José de Cúcuta, Norte de Santander, Colombia, community of Antonia Santos, beginning with the collection of information from a census conducted for public services [10], knowing the capacity that the system must have to design and the scope of the number of beneficiaries; in addition, aqueduct design information was collected: pressures, velocities in the distribution network, pumping time, adding to this a design alternative in the epanet simulation program for a future population of 5% of the current population 7959 inhabitants, with the design parameter of the maximum daily flow; according to the indications of the manuals with norms for the development of the project: RAS (technical regulation of the potable water and basic sanitation sector) 2000 [11].

## 3. Result and discussion

### 3.1 Design flow rate

The maximum daily flow (QMD) corresponds to the maximum consumption recorded over 24 hours over a period of one year represented in Equation (1), where QMD is the average daily flow by the maximum daily consumption coefficient; for this case, pumping is to a 24-hour storage tank as in the case of this research article, resulting in 22.11 liters/second.

$$QMD = Qmd * K1 \quad (1)$$

### 3.2 Pressures

Table 1 illustrates the minimum pressures in the distribution network, in this case the minimum pressures for the high level of complexity that is handled for the city of San José de Cúcuta, Norte de Santander, Colombia, should be 15 mwc and the maximum should be 50 mwc but due to the topographic conditions of the settlement, to guarantee the service to the inhabitants of the highest part of the settlement, the inhabitants of the lowest part of the settlement are affected, due to the fact that there are pressures higher than the maximum allowed, which is why it is necessary to have pressure reducing valves in these areas.

**Table 1.** Minimum pressures in the distribution network [12].

Level of complexity	Minimum pressure (kPa)	Minimum pressure (m)
Low	98.1	10
Medium	98.1	10
Medium high	147.2	15
High	147.2	15

### 3.3 Speeds in the distribution network

The speeds of the distribution network in this project are limited to the values established in SAR 2000[11], where the maximum speed is 1.5 m/s to 2 m/s and the minimum speed is 0.5 m/s. It must be taken into account that, if some velocities give less than 0.5 m/s, these pipelines will be able to meet future demands.

**Table 2.** Network-Nodes.

ID Node	Height (m)	Base Demand (LPS)	Demand (LPS)	Height (m)	Pressure (m)
Connection 2	347.25	0.00	0.00	369.66	22.41
Connection 3	341.77	0.64	0.64	367.32	25.55
Connection 4	305.00	0.47	0.47	367.23	62.23
Connection 5	348.31	0.66	0.66	367.26	18.95
Connection 6	343.11	1.80	1.80	366.55	23.44
Connection 7	310.59	0.20	0.20	357.14	46.55
Connection 8	282.22	0.45	0.45	356.27	74.05
Connection 9	272.07	0.56	0.56	356.10	84.03
Connection 10	283.1	2.35	2.35	356.09	72.99
Connection 11	275.09	0.55	0.55	356.07	80.98
Connection 12	281.62	0.62	0.62	355.94	74.32
Connection 13	303.35	0.88	0.88	356.83	53.48
Connection 14	316.39	0.20	0.20	357.13	40.74
Connection 15	322.43	0.77	0.77	358.21	35.78
Connection 16	325.60	0.20	0.20	358.24	32.64
Connection 17	309.26	3.42	3.42	356.99	47.73
Connection 18	333.07	0.26	0.26	359.55	26.48
Connection 19	323.86	0.31	0.31	359.30	35.44
Connection 20	330.26	0.91	0.91	363.22	32.96
Connection 21	338.82	1.32	1.32	363.21	24.39
Connection 22	352.06	1.21	1.21	365.44	13.38
Connection 23	352.13	0.70	0.70	365.45	13.32
Connection 24	341.48	1.07	1.07	362.90	21.42
Connection 25	323.40	0.57	0.57	364.96	41.56
Connection 26	314.69	0.24	0.24	364.87	50.18
Connection 27	301.95	0.77	0.77	364.67	62.72
Connection 28	288.49	0.56	0.56	356.23	67.74
Connection 29	323.24	0.27	0.27	362.33	39.09
Connection 31	270.00	0.00	0.00	304.91	34.91
Connection 32	270.00	0.00	0.00	305.00	35.00
Connection 33	270.00	0.00	0.00	371.56	101.56
Connection 34	270.00	0.00	0.00	370.68	100.68
Connection 35	270.00	0.00	0.00	370.68	100.68
Reservoir 1	370.00	NA	-20.95	370.00	0.00
Reservoir 30	305.00	NA	-1.01	305.00	0.00

NA: Not available; m: meter, l: liter; s: second; mwc: meter of water column.

### 3.4 Pumping time

As stated in Ras 2000 title B.8.1 (Scope of pumping stations) [12], the capacity of the pumping station must be QMD if pumping is performed 24 hours. For this case, the pumping time used was 24 hours, for this time the model proposed in epanet complies.

**Table 3.** Network and lines.

ID Line	Length (m)	Diameter (mm)	Roughness (mm)	Flow (LPS)	Speed (m/s)	Unitary loss (m/km)	Friction factor	Condition
Pipe 1	174.00	203.2	0.0015	21.96	0.68	1.94	0.017	Open
Pipe 10	155.18	76.2	0.0015	1.11	0.24	1.05	0.026	Open
Pipe 17	92.98	76.2	0.0015	1.34	0.29	1.46	0.025	Open
Pipe 20	1000.00	76.2	0.0015	0.18	0.04	0.03	0.032	Open
Pipe 22	1000.00	76.2	0.0015	-2.03	0.45	3.03	0.023	Open
Pipe 33	99.46	76.2	0.0015	1.01	0.22	0.88	0.027	Open
Pipe 34	107.00	76.2	0.0015	0.00	0.000	0.00	0.000	Open
Pipe 37	100.00	76.2	0.0015	1.01	0.22	0.88	0.027	Open
Pipe 38	100.00	76.2	0.0015	0.00	0.00	0.00	0.000	Open
Pipe 39	764.43	76.2	0.0015	1.01	0.22	0.88	0.027	Open
Pipe 40	121.47	203.2	0.0015	21.96	0.68	1.94	0.017	Open
Pipe 41	349.81	76.2	0.0015	0.47	0.10	0.24	0.033	Open
Pipe 42	218.54	304.8	0.0015	20.85	0.29	0.25	0.019	Open
Pipe 43	124.44	76.2	0.0015	4.90	1.08	14.54	0.019	Open
Pipe 44	124.44	76.2	0.0015	4.90	1.08	14.54	0.019	Open
Pipe 45	182.61	254	0.0015	-5.95	0.12	0.06	0.024	Open
Pipe 46	246.14	76.2	0.0015	1.58	0.35	1.95	0.024	Open
Pipe 47	98.19	76.2	0.0015	1.01	0.22	0.89	0.027	Open
Pipe 48	353.38	76.2	0.0015	-0.77	0.17	0.56	0.029	Open
Pipe 49	355.12	152.4	0.0015	10.38	0.57	2.01	0.019	Open
Pipe 50	965.63	76.2	0.0015	3.92	0.86	9.74	0.020	Open
Pipe 51	455.61	76.2	0.0015	1.56	0.34	1.91	0.024	Open
Pipe 52	336.74	76.2	0.0015	3.16	0.69	6.63	0.021	Open
Pipe 53	338.15	76.2	0.0015	3.16	0.69	6.64	0.021	Open
Pipe 54	324.58	76.2	0.0015	-1.07	0.23	0.98	0.027	Open
Pipe 55	92.96	76.2	0.0015	-0.39	0.08	0.17	0.035	Open
Pipe 56	249.72	76.2	0.0015	4.67	1.02	13.31	0.019	Open
Pipe 57	236.17	76.2	0.0015	2.3	0.50	3.78	0.022	Open
Pipe 58	212.65	76.2	0.0015	5.38	1.18	17.19	0.018	Open
Pipe 59	102.33	76.2	0.0015	-1.82	0.40	2.49	0.023	Open
Pipe 60	182.06	76.2	0.0015	3.30	0.72	7.19	0.020	Open
Pipe 61	134.10	76.2	0.0015	3.54	0.78	8.12	0.020	Open
Pipe 62	207.77	76.2	0.0015	2.95	0.65	5.86	0.021	Open
Pipe 63	192.86	76.2	0.0015	2.93	0.64	5.79	0.021	Open
Pipe 64	190.31	76.2	0.0015	1.39	0.30	1.55	0.025	Open
Pipe 65	233.15	76.2	0.0015	0.87	0.19	0.68	0.028	Open
Pipe 66	398.20	76.2	0.0015	1.37	0.30	1.52	0.025	Open
Pipe 67	258.27	76.2	0.0015	0.81	0.18	0.61	0.029	Open
Pipe 68	323.93	76.2	0.0015	-0.62	0.14	0.38	0.031	Open
Pipe 69	245.27	76.2	0.0015	-0.36	0.08	0.15	0.036	Open
Pipe 70	309.45	76.2	0.0015	2.16	0.47	3.38	0.023	Open
Pipe 71	313.36	76.2	0.0015	-0.19	0.04	0.04	0.035	Open
Pump 35	NA	NA	NA	1.01	0.00	-66.65	0.000	Open
Pump 36	NA	NA	NA	0.00	0.00	0.00	0.000	Closed

NA: Not available

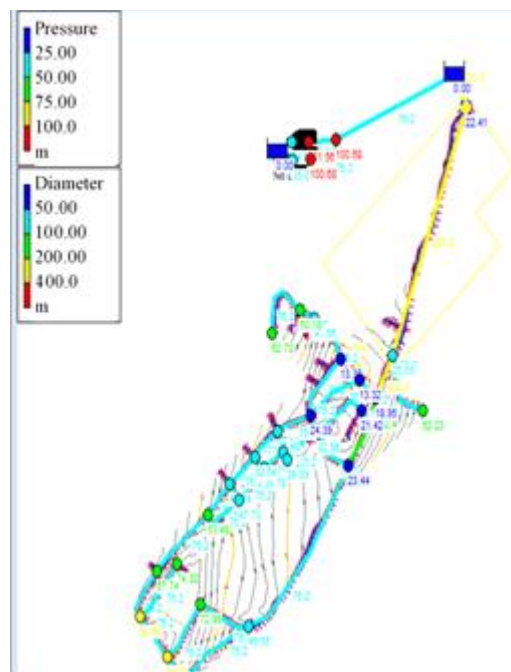
### 3.5 Design alternative

The tank located in the neighborhood of Antonia Santos, city of San José de Cúcuta, Norte de Santander, Colombia. does not work, that is, it does not have the necessary water supply to supply the inhabitants of the subnormal settlement of Brisas del Mirador that is located in the neighborhood of Antonia Santos, city of San José de Cúcuta, Norte de Santander, Colombia. The company providing the service has a long-term project that consists of putting a network of 36 inches from where it simulated in epanet in order to supply the service to the inhabitants of the sector. The future conditions are simulated; in the modeling a reservoir is located, the height of the site, plus the pressure of the service, in the epanet program the reservoir is an inexhaustible source of water, in this way the condition is set to the program that in this place there will be one that will guarantee the water supply.

According to Table 2, a pressure reducing valve must be installed to reduce the pressures in the 4, 8, 9, 10, 11, 12, 13, 27 and 28 nodes, since they exceed a pressure of 53 m and the maximum condition was 50 mwc due to the level of complexity of the sector, while in Table 3, for the flow and wall coefficients, reaction speed and quality gave a value of zero, but some pipes have a velocity between 0 m/s and 1.18 m/s, not complying with the minimum permitted velocities of 0.45 m/s and maximum of 5 m/s.

### 3.6 Simulation

Figure 1 illustrates the simulation of the new aqueduct design for the Antonia Santos neighborhood in the city of San José de Cúcuta, Norte de Santander, Colombia, according to the pressure, diameter, nets and knots previously determined.



**Figure 1.** Simulation

## 4. Conclusions

The supply of water available to all is a benefit that many countries and urban areas do not have, due to the poor design and construction of its aqueduct, causing it to be unaffordable or unfit for human consumption, an issue that occurs in the neighborhood of Antonia Santos, San Jose de Cucuta, Norte de Santander, Colombia, which has a population of 7959 inhabitants in this settlement area; There is a problem concerning the need for water supply that has affected them for years, living indignantly, even when a service is provided provisionally in a distribution network.

The scientific study yielded results by means of a census of the population, inspection of the terrain, and needs of the population, solid data for the design of the aqueduct of the Antonia Santos settlement, San José de Cúcuta, Norte de Santander, Colombia, obtaining that the maximum daily flow is 22.11 l/s, maximum design speed of the aqueduct is 1.5 m/s to 2 m/s and minimum speed of 0.5 m/s, using a pumping time of 24 hours. The minimum pressure level of 15 mwc and maximum of 50 mwc, but depending on the topographical conditions of the settlement we find high and low areas, which have more flow pressure than ideal, for this reason it is recommended to install pressure reducing valves in nine connections that have pressures greater than 50 mwc.

It is estimated that the future population will be 7959 inhabitants and 1896 dwellings, with an average daily flow of 18.42 l/s, a minimum daily flow of 11.05 l/s, a maximum daily flow of 22.11 l/s, a minimum hourly flow of 33.16 l/s, i.e. an estimated 200 l/inhabitant/day and a low density of 100 dwellings/hectare/inhabitant. With this simulation, it is expected to have information that contributes to the improvement of the living conditions of inhabitants of different sectors, being the basis of studies for public or private sector projects.

### References

- [1] Wada Y and Heinrich L 2013 Assessment of transboundary aquifers of the world-vulnerability arising from human water use *Environmental Research Letters* **8** 2
- [2] Stroia L, Georgescu S C and Georgescu A M 2010 Antiquity versus modern times in hydraulics – a case study *IOP Conference Series: Earth and Environmental Science* **12** 012097
- [3] Gleeson T and Wada Y 2013 Assessing regional groundwater stress for nations using multiple data sources with the groundwater footprint *Environmental Research Letters* **8** 4
- [4] Zhang X G, Wang T, Sun J P, Zhang Q, Song Z P and Wang J J 2018 numerical simulation analysis of temperature control of large volume concrete aqueduct *IOP Conference Series: Earth and Environmental Science* **199** 3
- [5] Suyono T, Pranoto W A and Irawan A P 2019 Hydraulic analysis of drinking water pipeline inter island *IOP Conference Series: Materials Science and Engineering* **508** 012035
- [6] Hughes D A 2019 Facing a future water resources management crisis in sub-Saharan Africa *Journal of Hydrology: Regional Studies* **23** 100600
- [7] Scanlon B R, Reedy R C and Nicot J P 2014 Will water scarcity in semiarid regions limit hydraulic fracturing of shale plays? *Environmental Research Letters* **9** 12
- [8] Pineda C 2008 *Agua y vida en Colombia: apuntes y conclusiones foro Paipa 2007* (Colombia: Politécnico Granacolombiano) 56
- [9] Iglesias-Rey P L, Martínez-Solano F J and Ribelles-Aquilar J V 2017 Extending epanet capabilities with add-in tools *Procedia Engineering* **186** 626
- [10] Zapata D V and Cordero M A 2017 Diseño de las redes de acueducto y alcantarillado de la parte baja del asentamiento humano Brisas del mirador, San José de Cúcuta, Norte de Santander, Colombia (Colombia Universidad Francisco de Paula Santander)
- [11] Ministerio de Desarrollo Económico 2000 *Documentación técnico normativa del sector de agua potable y saneamiento básico, Título A* (Colombia: Ministerio de Desarrollo Económico)
- [12] Ministerio de Desarrollo Económico 2000 *Documentación técnico normativa del sector de agua potable y saneamiento básico, Título B* (Colombia: Ministerio de Desarrollo Económico)