Analysis of Spring Development and Gravity Flow System to Capture Water for Local Communities

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Abstract. Springs as water sources are relatively inexpensive but highly susceptible to contamination since they are fed by shallow groundwater. Proper spring development helps protect the water from contamination. This study presents an analysis and design of spring development including the type of broncaptering/collecting wall, the dimension for the spring box and the conduction line. In addition, a guideline on "Springwater Construction" published by the Ministry of Public Works has been used in this design. A concentrated spring in Wates, Magelang, Central Java is used as a case study. The design calls for the collection of water from a spring using sets of broncaptering and a spring box, then piping it by gravity a distance of 5.1 kilometers to Van Lith Senior High School. Analysis was done using a manual calculation, which is subsequently compared to the result of HYDROFLO 3 software. Results show that the spring with a flow rate of 0.12 litre/s (manual) and 0.17 litre/s (software) will be collected into a 5 m^3 volume of spring box. The spring box with a +543 m water surface elevation is being supplied to Van Lith +384 m ground elevation using a uniform PVC pipelines with a ¾ inch of diameter.

1 Introduction

Capturing water from springs is a simple yet inexpensive process that has been used since ancient times. Inhabitants of rural mountain villages or underprivileged areas are primarily concerned about the development of springs because of the possibility to obtain pure water from neary sources with easy access at no cost.

In a case study on a concentrated spring in Wates, Magelang, Central Java, the spring is located in the private land of a villager. To clarify the ownership of the chosen spring, some negotiations about an ownership change have been done between a villager and Van Lith Senior High School. So, the ownership was transferred from a privately-owned to a school-owned spring.

Prior to the use of spring water, the school had got the majority of their water from shallow wells, especially for domestic purposes. For other uses, such as to operate a swimming pool, the water was collected from drainage canals. Because of continuous contamination that leads to water quality deterioration, an access to cleaner water sources from the springs was needed.

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A range of studies have been conducted on the spring development and the design of a spring collection system. A study on water supply planning in Taratara village, West Tomohon, North Sulawesi was done by capturing springwater using broncaptering and spring catchment and then distributing the water to public hydrants [6]. In this study, the pipe distribution system was modeled using the EPANET2 software. Another study was done on a pond construction to sustain springs for community use and this has been successfully tested in Kavrepalanchok District, east of Kathmandu, Nepal [9].

This research was conducted to design broncaptering or collecting wall and spring box, as well as to determine the pipelines route and the flow that simulated in two different ways, manual and using HYDROFLO 3 software tool. These two simulations will be used in the comparison of the maximum discharge that occurs in the pipelines, as well as the pipe's type and the pipe diameter with regard to the total pressure drop during internal flow.

2 Literature Review

2.1 Definition and Types of Springs

A spring is a type of groundwater that emerges naturally to the land surface which may flow by gravity from a water table aquifer or by pressure from an artesian aquifer [3]. Springs can be categorised into two types, namely gravity spring and artesian spring. Gravity springs result where the land surface intersects the water table by some cracks or fractures and flows horizontally out of the ground [1]. On the other hand, an artesian spring occurs when water is trapped between impervious layers and is forced to the surface under pressure [4].

A gravity spring can occur at a distinct point as a concentrated spring [3]. It is unhidden and often found along hillsides where groundwater is forced through openings in fracture bedrock. The other type, seepage spring occurs when shallow groundwater seeps from the ground over a large area and has no defined discharge point.

2.2 Spring Development Considerations

2.2.1 Quantity and Quality of Springwater

When considering using a spring as a source of water, it is important to ensure that the flow rate of the spring is reliable during all seasons of the year. The flow rate should be monitored over a year, but it is most critical to have measurements during late summer and fall when the groundwater level at its lowest condition. Water quality is also important to consider because springs may be at risk of contamination from surface run off which infiltrate to the ground.

2.2.2 Methods of Spring Development

According to the Directorate General of Human Settlements, Ministry of Public Works, there are three categorizations of spring development [2]. Firstly, based on the spring type, springs can be divided into four types, namely Type 1A (concentrated artesian spring type), Type 1B (seepage artesian spring type), Type 1C (vertical artesian spring type), and Type 1D (gravity contact spring type). The second category is due to the size of spring box, which is one of the main components of spring development, namely Type IIA (volume 4 m^3), Type IIB (volume 8 m^3), and Type IIC (volume 10 m^3). The third category is based on how the springwater will be conveyed, whether by gravity flow or by a pumped system.

2.2.3 The Spring Catchment

The catchment area can be divided into five components as shown in Fig. 1. The intake area includes the area from which the spring is supplied (by infiltration and percolation of rainwater) to the spot where the water comes to the surface. the other components are the catchment, the supply pipe, and the spring chamber or spring box. The typical spring catchment consist of three elements, namely a broncaptering (collecting wall), a permeable construction behind the broncaptering (either in the form of a filter package or as a perforated pipe), and a catchment cover [4].

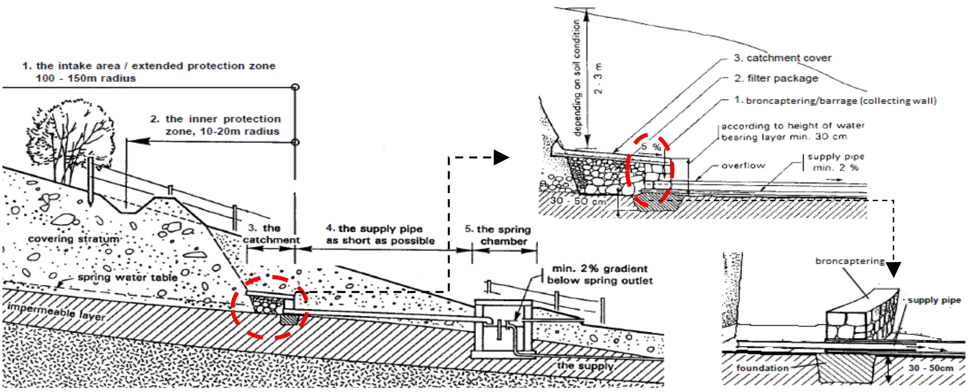

Fig. 1. The five components catchment area of springs (Source: Meuli and Wehrle, 2001)

2.2.4 Spring Box Design

The main components of a spring box consist of six parts, namely inlet pipe from broncaptering, overflow pipe and delivering pipe, cleanout drain, manhole, box valve (operation room), and surface drainage diversion ditch [3, 4, 10]. Table 1 shows the recommended size of water basins for a range of minimum spring yields with coresponding to total users. Water demand is assumed 30-60 litres/day and flowing in 8-12 hours a day.

Table 1. Size of springwater basins

Users/population	**Discharge < 0.5 lt/sec**	**Discharge 0.5-0.8 lt/sec**	**Discharge 0.7-0.8 lt/sec**	**Discharge > 0.8 lt/sec**
200 – 300	5 m^3	2 m^3	2 m^3	2 m^3
300 – 500	10 m^3	10 m^3	5 m^3	2 m^3

2.3 Pipeline Design

2.3.1 Energies of a Flowing Fluid

A fluid particle situated a distance z above datum (measured in unit meter, m) possesses a potential energy. They have energy due to its pressure above datum expressed as the pressure head, $h = p/\gamma$ (m). A body of mass m when flowing possesses a kinetic energy, $KE = ½mV^2$ and for a unit weight it can be written as $V^2/2g$ (m). In real fluid, there is an additional force acting because of fluid friction, namely shear stress (τ). It occurs over the boundary of the element causing a loss of energy (h_f). So, the total energy equation for steady flow of incompressible fluids in a real fluid can be written as [5].

$$z_1 + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + h_f \quad (1)$$

2.3.2 Hydraulic Grade Line and Energy Line

According to Bernoulli's theorem, the quantity z + p/γ refers to the piezometric head, because it shows the level to which liquid will rise in piezometer tube, whose connecting end in a plane parallel to the flow. The line drawn through the liquid surfaces in that tube is called the Hydraulic Grade Line (HGL). The total energy head is measured by a pitot tube which is a small tube with its open end in the flow pointing upstream and will intercept the kinetic energy of the flow. From the piezometer and pitot tube reading, the vertical distance between it indicates the velocity head or $V^2/2g$ [5].

3 Methodology

3.1 Study Area

The study was conducted in the area of Wates, Dukun District, Magelang Regency, Central Java which is geographically located at 7º 33' 50.36" LS and 110º 20' 07.76" BT. Wates is one of the villages surrounding Mount Merapi which has contoured or uneven ground. Two locations with three discharge point of springs were discovered in an overgrown area and categorized as fracture/tabular-gravity springs.

3.2 Data Collection

In this study, several field measurements were conducted in order to get necessary data for analysis. A topographic survey was conducted to identify the condition near the springs and trace pipeline route. A discharge measurement for both springs was also conducted on 29th April 2016. According to the head of facilities and infrastructure of Van Lith Senior High School, the springwater was quite good and safe. It was physically clear with no odor and taste,. It also has a low level of dissolved material/metal (Fe^{2+}) to become a source of water supply. As a result, the water quality testing was not carried out in this study.

3.3 Broncaptering and Spring Box Design

A water system to capture the springs consists of broncaptering or collecting wall to hold the water emerges from land surface and a spring box as a temporary storage. The design is based on the "Springwater Construction" guidelines from the Ministry of Public Works.

3.4 Pipeline Flow Analysis: HYDROFLO 3

A pipeline system was built to convey the water from distant springs. Pipelines were installed in series from the spring box to Van Lith Senior High School. Because the location of spring is higher than the school, the flow in pipelines is influenced by gravity. The flow in the pipes was simulated in two different ways: manual and using HYDROFLO 3.

HYDROFLO 3.0.0.4 Academic version from Tahoe Design Software is a fluid conveyance system design tool. In this analysis, the type of fluid conveyance system is categorized to open source and discharge systems driven by gravity.

3.4.1 Supply Element Theory

Supply elements are points of source and discharge at the beginning and end of the main line. In this study, the lines start with open tanks elements and end with discharge to free (open to atmosphere) pressure [7].

3.4.2 Pipe Theory

The Hazen-Williams equation was used for modeling water systems under turbulent flow conditions. A Hazen-Williams friction factor C is determined by empirical test methods.

$$h_f = 0.002083L\left(\frac{100}{C}\right)^{1.85} x\frac{gpm^{1.85}}{d^{4.8655}} \tag{2}$$

where h_f = friction head loss (feet of liquid); L = pipe length (feet); C = Hazen-Williams friction factor; gpm = flow of liquid (US gallons per minute); d = inside diameter (inches)

Minor friction losses through fittings (which include inlets and exits) in water systems were modeled by multiplying this K value by the velocity head, $V^2/2g$. The variations of K value highly depend on the local changes in the pipes, such as an enlargements/contractions, nozzles/orifices, and control valves.

4 Results and Discussions

4.1 Topography Conditions

Fig.2 shows the topographic conditions of the springs and the surrounding which are traced and recorded by GPS. It also shows the proposed pipeline route which spans 5.1 kilometer. This route passes a bark garden and a paddy field, and crosses a river.

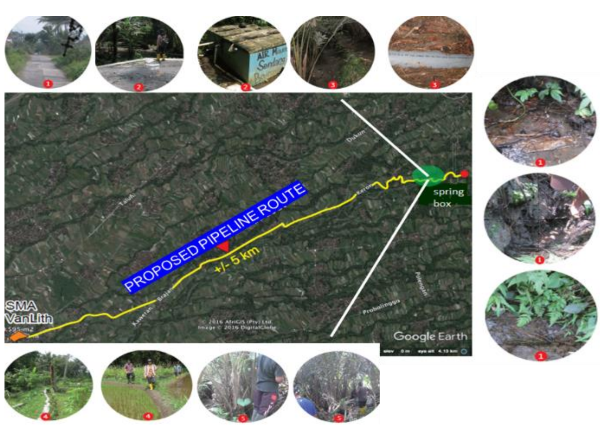

Fig. 2. The proposed pipeline route and the situation in springs (contour map by Google Earth)

4.2 Broncaptering Design

Based on investigations, two sources of springs were discovered and they can categorized as gravity springs. The water emerges from one defined discharge in the earth's surface by fractures or gaps in rock as a concentrated flow. Because these two springs are separated by some distance and different ground levels, the capturing process of both springs will be done using two broncapterings as illustrated in Fig. 3 [8]. According to the Directorate General of Human Settlements, Ministry of Public Works, the springs can be categorized as a concentrated springs (Type 1A) [2]. The detailed design of the spring collection system, the spring box, and the pipe arrangement are shown in Fig. 4.

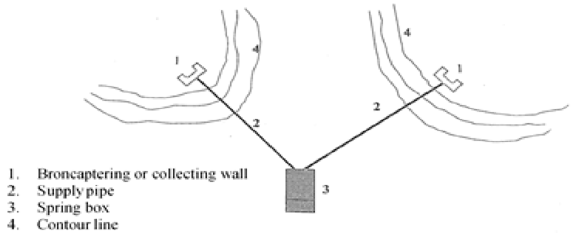

Fig. 3. A set of springwater construction with more than one sources (Source: Lowa, 2016)

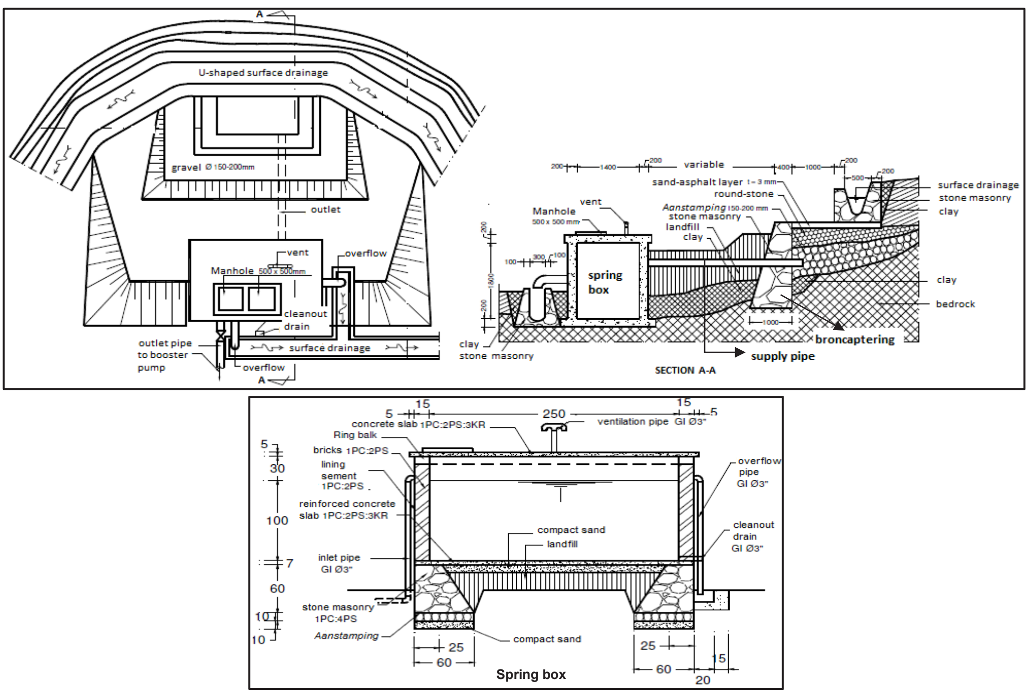

Fig. 4. A plan view and the details of the spring collecting system Type 1A for a concentrated spring (Source: Directorate General of Human Settlements, Ministry of Public Works, 1996)

4.3 Spring Box Design

The first spring has a flow rate of 0.04 litre/s, while the second spring has a double rate of 0.08 litre/s. To store the water for both springs, a total flow rate of 0.12 litre/s must be considered. In Table 1, the size of spring box was determined by two parameters: the discharge of the springwater and the number of population. It was assumed that the total population was about 200-300 people, because the spring development was done primarily to operate a swimming pool. Based on the requirements with a discharge of less than 0.5 litre/s and a population of 200-300 people, the recommended size of the spring box is 5 m^3 of volume or with a detail dimensions of length 2 m, width 2 m, and height 1.25 m.

4.4 Pipeline Flow Calculation

The first spring is located in +543 m of elevation, while the second spring is located higher at elevation +545 m. So that the spring box was put in the same elevation of the first spring to avoid flow change in another direction if the spring box is higher than the spring's location. The water surface elevation at the spring box is +543 m and the ground elevation in Van Lith Senior High School is +384 m. The total static head is therefore 159 m.

The distribution pipelines were arranged in series with uniform cross sections of pipes. The losses that were taken into account were the head loss due to friction (major losses) and the losses at the entrance as the spring box enters the pipe, as well as the losses by the bends. The last two losses were considered as minor losses. A manual calculation was done with an initial assumption of the pipe diameter until it meets the total head loss is less than the available total head and the remainder pressure head is not negative. The pipelines calculation was divided into several segments as tabulated in Table 2. It was divided into 13 pipes in series where the first pipe was located in elevation +542 m.

Table 2. The trial result of pipe diameter (manual calculation)

pipe	elevation (m)		angle of bends	angle of α	length of pipe (m)	diameter of pipe (m)	major losses hf (m)	minor losses		HGL (m of liquid)	∑ head loss hL
	begin	end						kb, koef of bends	hb (m)		
1	542	540			77	0.019	1.317				
			125	55				0.305	0.003	541.667	1.333
2	540	539			67	0.019	1.146				
			95	85				0.800	0.007	540.514	2.486
3	539	534			115.5	0.019	1.975				
			140	40				0.140	0.001	538.537	4.463
4	534	529			106	0.019	1.813				
			138	42				0.162	0.001	536.723	6.277
5	529	528			53	0.019	0.906				
			142	38				0.131	0.001	535.816	7.184
6	528	518			163.5	0.019	2.796				
			157	23				0.064	0.001	533.019	9.981
7	518	516			200	0.019	3.420				
			124	56				0.316	0.003	529.596	13.404
8	516	509			172.5	0.019	2.950				
			136	44				0.184	0.002	526.645	16.355
9	509	505			112	0.019	1.915				
			148	32				0.104	0.001	524.728	18.272
10	505	485			586	0.019	10.021				
			-	0				0.000	0.000	514.707	28.293
11	485	458			737	0.019	12.603				
			168	12				0.030	0.000	502.103	40.897
12	458	422			1265	0.019	21.633				
			162	18				0.045	0.000	480.470	62.530
13	422	384			1405	0.019	24.027				
								0	0	456.443	86.557

total length of pipe 5059.5 m

total head loss 86.557 m
the remainder of the pressure head 72.443 m
Total head 159 m
CEK : feasible

According to Bernoulli's theorem, if the velocity head is constant as a uniform diameter, the drop in the hydraulic grade line (HGL) between any two points is equal to the loss of head in it. Table 2 shows the optimum diameter of pipe of 0.75 inch so that the total head loss (86.557 m) does not exceed the available total static head (159 m). The total static head is obtained from the difference between elevation of spring box water surface (+543 m) and the pool line (+384 m). Additionally, the remainder of the pressure head at the end of the system is more than zero (72.443 m) so the water will be able to flow without any blockage.

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A pipe flow simulation using HYDROFLO was done to verify the result from the first method (manual calculation) and to provide more detailed results including the pressure head graphics. The first step is set up the plot plan of the proposed system as depicted in Fig. 5.

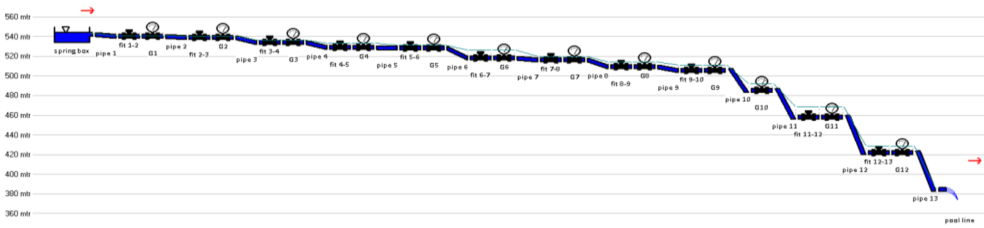

Fig. 5. Plot of main line in HYDROFLO 3

In the HYDROFLO simulation, the primary use of a gauge element is to obtain a gauge pressure reading at a particular point. The gauge was placed immediately after a fitting (See Fig. 5). According to the 1st attempt simulation result with 0.75 inch of uniform pipe's diameter, a negative pressure was found at gauge G2 (-5.40 kPa). It was probably due to the size of pipe 2 and fitting 2-3. A fitting in this system accommodates the flow through the bends in particular a pipe elbow. The fitting 2-3 is a 85° pipe elbow which is the largest bend angle in the pipelines route that located between pipe 2 and 3.

A smaller diameter will cause a higher velocity and a higher head loss. On the other hands, the effect of the flow through a pipe elbow is a large increase in pressure losses as compared to the straight pipe of equivalent length. As such, the location G2 displays a negative pressure reading. The HGL at gauge G2 is under the pipe, so the flow will be blocked. Increasing the pipe diameter is one of the solutions to deal with negative pressure, so the diameter of pipe 2 and fitting 2-3 have been changed from 0.75 inch to 1.00 inch. The further results show that the pressure at gauge G2 becomes 9.77 kPa (see Table 3).

Table 3. The gauge pressure reading comparison for the 1st attempt and 2nd attempt simulations

				1st attempt		2nd attempt	
Gauges: ID		Elevation (mtrs)	Demand (L/s)	Pressure (Kpa)	HGL (mtrs)	Pressure (Kpa)	HGL (mtrs)
G1	at the beginning of pipe 2	540.00	0.00	5.45	540.56	5.21	540.54
G2	at the beginning of pipe 3	539.00	0.00	-5.40	538.44	9.77	540.01
G3	at the beginning of pipe 4	534.00	0.00	7.87	534.81	22.69	536.34
G4	at the beginning of pipe 5	529.00	0.00	24.03	531.48	38.52	532.97
G5	at the beginning of pipe 6	528.00	0.00	17.56	529.81	31.89	531.29
G6	at the beginning of pipe 7	518.00	0.00	64.69	524.67	78.51	526.10
G7	at the beginning of pipe 8	516.00	0.00	23.13	518.39	36.32	519.75
G8	at the beginning of pipe 9	509.00	0.00	38.42	512.96	51.08	514.27
G9	at the beginning of pipe 10	505.00	0.00	43.07	509.44	55.39	510.71
G10	at the beginning of pipe 11	485.00	0.00	58.48	491.03	68.99	492.12
G11	at the beginning of pipe 12	458.00	0.00	95.76	467.88	104.00	468.73
G12	at the beginning of pipe 13	422.00	0.00	59.50	428.14	63.83	428.59

The first simulation was completed using uniform diameter of PVC pipelines, but there was a negative pressure. The second simulation attempt (after changing diameter) in Table 4 gives information about the changing HGL (m) in sequence of elements. There is no residual head left at the end of the segment and the optimum flow that may occur is 0.17 litre/s, which is more than the flow rate of the springs (0.12 litre/s).

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Table 4. The report elements in sequence after adjusting the diameter of pipe and fitting

Open Source/Discharge System

Source Elev:	
Source Pressure:	
Source HGL:	543.00 mtr
Discharge Elev:	384.00 mtr
Discharge Pressure:	0.00 Kpa
Discharge HGL:	384.00 mtr
Total Static Head:	-159.00 mtr

System Information

Pipe Head Loss Eq.: Hazen-Williams
Flow Tolerance: 0.00063 ltr/s
Atmospheric Press: 101.00 Kpa
Total Elements: 38 (approx)
Total Branches: 0 (used in solution)

Liquid Properties

Water,Saturated at 80 deg F
Temperature: 26.70 C
Specific Gravity: 0.99
Viscosity: 1.13E-06 m2/s
Vapor Pressure: 3.52 Kpa (abs)
Specific Heat: 1.00 Cal/grC

Element Data by type...

Supplys:

ID	Type	Pressure (Kpa)	Elev (mtrs)	Flow (L/s)	In/Out	HGL (mtrs)
spring box	reservoir/tank (open)	0.00	543.00	0.17	out	543.00
	Inlet/Exit: pipe inlet-inward projec, Elev=542.00 mtrs, dia=0.750 in, hl=0.13 Kpa					
	one storing system for two springwater					
pool line	free discharge	0.00	384.00	0.17	in	384.00
	the distributed line to the pool					

Elements in sequence

ID	Type	Desc	Pressure (mtlq)	Elev (mtrs)	Head Change (mtlq)	HGL (mtlq)
Start of Main Line - source side...						
spring box	Supply	reservoir/tank (open)	0.00	543.00		543.00
		Inlet/Exit: Type=pipe inlet-inward projecting			-0.01	542.97
		one storing system for two springwater				
pipe 1	Pipe	PVC Sched 40			-2.44	540.54
fit 1-2	Fitt	Custom Fitting			-0.01	540.54
		55 degree of bend				
G1	Gauge	at the beginning of pipe 2	0.54	540.00		540.54
		at the beginning of pipe 2				
pipe 2	Pipe	PVC Sched 40			-0.52	540.01
fit 2-3	Fitt	Custom Fitting			0.00	540.01
		85 degree of bend				
G2	Gauge	at the beginning of pipe 3	1.01	539.00		540.01
		at the beginning of pipe 3				
pipe 3	Pipe	PVC Sched 40			-3.67	536.34
fit 3-4	Fitt	Custom Fitting			0.00	536.34
		40 degree of bend				
G3	Gauge	at the beginning of pipe 4	2.34	534.00		536.34
		at the beginning of pipe 4				
pipe 4	Pipe	PVC Sched 40			-3.36	532.98
fit 4-5	Fitt	Custom Fitting			0.00	532.97
		42 degree of bend				
G4	Gauge	at the beginning of pipe 5	3.97	529.00		532.97
		at the beginning of pipe 5				
pipe 5	Pipe	PVC Sched 40			-1.68	531.29
fit 5-6	Fitt	Custom Fitting			0.00	531.29
		38 degree of bend				
G5	Gauge	at the beginning of pipe 6	3.29	528.00		531.29
		at the beginning of pipe 6				
pipe 6	Pipe	PVC Sched 40			-5.19	526.10
fit 6-7	Fitt	Custom Fitting			0.00	526.10
		23 degree of bend				
G6	Gauge	at the beginning of pipe 7	8.10	518.00		526.10
		at the beginning of pipe 7				
pipe 7	Pipe	PVC Sched 40			-6.35	519.75
fit 7-8	Fitt	Custom Fitting			-0.01	519.75
		56 degree of bend				
G7	Gauge	at the beginning of pipe 8	3.75	516.00		519.75
		at the beginning of pipe 8				
pipe 7	Pipe	PVC Sched 40			-6.35	519.75
fit 7-8	Fitt	Custom Fitting			-0.01	519.75
		56 degree of bend				
G7	Gauge	at the beginning of pipe 8	3.75	516.00		519.75
		at the beginning of pipe 8				
pipe 8	Pipe	PVC Sched 40			-5.47	514.27
fit 8-9	Fitt	Custom Fitting			0.00	514.27
		44 degree of bend				
G8	Gauge	at the beginning of pipe 9	5.27	509.00		514.27
		at the beginning of pipe 9				
pipe 9	Pipe	PVC Sched 40			-3.55	510.72
fit 9-10	Fitt	Custom Fitting			0.00	510.71
		32 degree of bend				
G9	Gauge	at the beginning of pipe 10	5.71	505.00		510.71
		at the beginning of pipe 10				
pipe 10	Pipe	PVC Sched 40			-18.60	492.12
G10	Gauge	at the beginning of pipe 11	7.12	485.00		492.12
		at the beginning of pipe 11				
pipe 11	Pipe	PVC Sched 40			-23.39	468.73
fit 11-12	Fitt	Custom Fitting			0.00	468.73
		12 degree of bend				
G11	Gauge	at the beginning of pipe 12	10.73	458.00		468.73
		at the beginning of pipe 12				
pipe 12	Pipe	PVC Sched 40			-40.14	428.59
fit 12-13	Fitt	Custom Fitting			0.00	428.59
		18 degree of bend				
G12	Gauge	at the beginning of pipe 13	6.59	422.00		428.59
		at the beginning of pipe 13				
pipe 13	Pipe	PVC Sched 40			-44.59	384.00
pool line	Supply	free discharge	0.00	384.00		384.00
		the distributed line to the pool				

5 Conclusions

From the calculation and analysis, it can be concluded that: (1) the type of spring development can be categorized as Type 1A, which is a concentrated spring; (2) the recommended size of the spring box is 5 m^3 with a length of 2.00 m, a width of 2.00 m, and a height of 1.25 m; (3) from the manual calculation, the diameter of the PVC pipe should be 0.75 or ¾ inch to convey the flow of 0.12 litre/s, while the system that modeled by HYDROFLO will convey more with a flow rate of 0.17 litre/s; (4) from the first HYDROFLO simulation, with the same diameter (0.75 inch) and material (PVC with Hazen-William coefficient, C_{HW} = 130), a negative pressure was read at gauge G2; (5) the negative pressure is caused by both the size of pipe 2 (too small) and the condition of the bend between pipe 2 and 3 (too large of the bend angle) that lead to enlarged pressure losses; (6) a proposed solution to overcome the negative pressure is by increasing the diameter of the pipe and fitting.

References

1. U.S. Department of Agriculture*, Springs and Wells*, chapter **12**, eDirectives of NRCS, (1983)

2. Directorate General of Human Settlements, Ministry of Public Works, *A Practical Guide of Spring Development and Construction*, module **2.1** (1996)

3. G.D. Jennings, *Water Quality and Waste Management: Protecting Water Supply Springs*, North Carolina Cooperative Extension Service, AG 473-15, (1996)

4. C. Meuli, K. Wehrle, *Spring Catchment – Series of Manuals on Drinking Water Supply*, SKAT, Vol.**4**, (2001)

5. E.J.Finnemore, J.B. Franzini, *Fluid Mechanics with Engineering Applications*, (2009)

6. M.C. Hajia, A. Binilang, E.M. Wuisan, *Planning of Water Supply System in Taratara Village West Tomohon*, TEKNO, Vol.**13**, No.**64**, (2015)

7. Taho Design Software, *HYDROFLO User Guide*, (2015)

8. A. Lowa, Water *Supply Pipe Networks by Gravity Flow System*, (2016)

9. B. Sharma, S. Nepal, D. Gyawali, G.S. Pokharel, S.M. Wahid, A. Mukherji, S. Acharya, A.B. Shrestha, *Springs, Storage Towers, and Water Conservation in the Midhills of Nepal*, ICIMOD Working Paper **2016/3**, (2016)

10. Penn State College of Agricultural Sciences Research and Extension Program, The Pennsylvania State University, *Spring Development and Protection*, **XH0024**, (2017)