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# Improving The Understanding of Epanet Software Via Case Studies

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**Abstract :** EPANET is widely used for pipe network analysis. The EPANET manual, although very detailed, still lacks simple case study examples to help students to appreciate its application better. This study is designed to demonstrate the manual calculations and its verification through EPANET for simple pipe flow problems in fluid mechanics course of civil engineering curriculum. The case study examples are solved by involving the students themselves. This has not only created a deeper interest in the course but also helped the students to understand the advantages and limitations of using software.

**Key words:** EPANET, pipe flow, civil engineering, fluid mechanics, case studies.

## 1. Introduction

EPANET, developed by United States Environmental Protection Agency's National Risk Management Research Laboratory, is an open access public domain software which models water distribution pressurized piping system. A typical pipe network consists of pipe, node, pump, storage tank or reservoir. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank etc. It is designed to be used for many different kinds of application in distribution system analysis and has been widely used by researchers to solve complex problems in water distribution system (Ahn et al., 2012; Rasooli and Kang, 2016; Sivapragasam et al., 2015). Considering the importance of pipe flow applications, almost all the university curriculum in Civil Engineering has a mandatory course on the principles of Fluid Mechanics at second year of undergraduate study wherein concepts related to pipe flows and pipe networks are taught. As observed by Zhou and Wang (2016), computer simulation models offer a platform for testing of hypothesis wherein students can use simulation models to test multiple scenarios and arrive at possible outcomes for assessment taking into account assumptions and inputs to the specific scenario under study. An in-depth understanding of the concepts in pipe flow can be imparted to students at undergraduate level using relevant simulation models or software which are increasing being accepted as ideal platforms for imparting higher order learning skills in students (Fiedler et al., 1990, Jong et al., 1999; Sivaselvan, 2014). Turker et al (2016), employed simple experimental set-ups and simulation tools to demonstrate the concepts of load-deflection effect in singe degree of freedom system. Similarly, Khan and Akhter (2015) used simulation experiments to demonstrate a better understanding and visualization of various seismic concepts.

This study aims at illustrating the application of EPANET in solving simple pipe flow and network

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problems which will not only help the students to develop knowledge but also a confidence in looking forward to real world problems with clarity. Although EPANET manual (Rossman, 2000) is very much self explanatory, it still lacks appropriate examples suitable for students at undergraduate level. Some attempts to create example problems using EPANET (Pitt et al., 2004) also do not address the needs of the students appropriately as it focuses directly on complex problems without giving confidence to students through implementation is simpler problems. When a student applies EPANET directly to a complex problem, the output is difficult to be comprehended unless the student gains a strong confidence on the functioning of the EPANET realized through its applications in simple problems. The student should solve pipe flow problems manually and then verify the results through EPANET. Hence, a need was felt to develop simple case study examples to demonstrate basic concepts in pipe flow problems in a simple way involving the students themselves. Since students understand their difficulties much better than others, this study was carried out by undergraduate students as a part of Project based Learning (PBL).

This study first briefly summarizes the system of data input to be done in EPANET taking into account the correct units for different hydraulic parameters. Thereafter, a total of five case study examples are considered viz., (a) flow in a single pipe; (b) flow between two reservoirs connected by a pipe line; (c) a typical three reservoir problem; (d) flow scenario with pump and (e) a simple water supply network system. The main objective of the Fluid Mechanics course is to impart sufficient competence in students to solve pipe flow problems. The third and fourth course outcomes of this course are designed to assess the students' ability to solve simple pipe flow problems to complex pipe network problems. Conventionally, students are taught problems from the text books which are amenable to hand calculations. For the students to solve more complex problems which are not possible by manual or hand calculations, it is necessary that they learn how to solve such problems using software. For this to happen there must exist sample case study examples using the software which illustrates how the software functions. When the students solve the problems by themselves as well validate their answers using the software results, they gain confidence in using the software for solving more complex problems. With this objective in mind, the case studies considered in this study are selected. Hence, the unique feature of this study is that for all these case studies, manual calculations are also done using the principles of fluid mechanics while it is being validated using the software. To demonstrate this to the readers for their clarity, the screen outputs from EPANET are given for each case study along with the corresponding manual calculation. The specific objectives of this study towards improve the learning outcomes of the students are - to understand correct usage of units for various parameters, to experience the differences in head loss computation by different methods, to recognize the need and dependency on simulation software for solving complex problems, to appreciate the need for absolute clarity in the underlying basic principles when using a software and to generate deeper interest in the overall field of pipe flow analysis. Students' feedbacks are taken on their experience in using EPANET and in achievement of the said objectives of this study with respect to the learning outcomes.

## Primary Components and Pre-Setting in EPANET

Primary components of EPANET are reservoir, node, pipe, tank and pump. The implementation (graphical) of these components is as follows (Rossman, 2000):

### (a) Reservoirs

A reservoir is a natural or artificial lake, storage pond which is used to store water. Reservoirs may be created in river valleys by the construction of a dam or may be built by excavation in the ground. To install the reservoir in EPANET, the reservoir button has to be clicked and put on the map at the required location. Hydraulic head should be given for the reservoir. It should be understood that the 'reservoir' component in EPANET has not output properties as it represents a boundary point.

### (b) Node

Node or junction are points in the network where links join together and where water enters or leaves the network. To install the node, the junction button has to be clicked and put on the map to get the 'node'. The required demand for the junction can be given in the base demand on the node properties along with its elevation details above some reference.

(c) Pipe

Pipes are links that convey water from one point in the network to another. The pipe tool has to be clicked on the toolbar to install a pipeline. EPANET assumes that all pipes run full at all times (and hence for pipes running dry as encountered in rural set-ups sometimes cannot be simulated). The pipe connects two nodes or a reservoir and a node. The length, diameter and roughness coefficient of the pipe can be given in pipe property dialog box.

(d) Tank

Tanks are nodes with storage capacity, where the volume of stored water can vary with time during a simulation. The tank button is to be selected and put on the map. The primary inputs for the tank include bottom elevation (where water level is zero), diameter, initial/ minimum/maximum water levels. Tanks are required to operate within their minimum and maximum level. EPANET stops outflow if a tank is at its minimum level and stops inflow if it is at its maximum level.

Pump

Pumps are links that impart energy to a fluid thereby raising its hydraulic head. The pump tool is to be selected and link the two nodes to introduce the pump. The pump curve is to be selected from data and the major output parameters are flow and head gain.

It is to be noted that while using the software

(a) At least one node is essential to run the EPANET software.

(b) At least one reservoir or tank must be contained in the network.

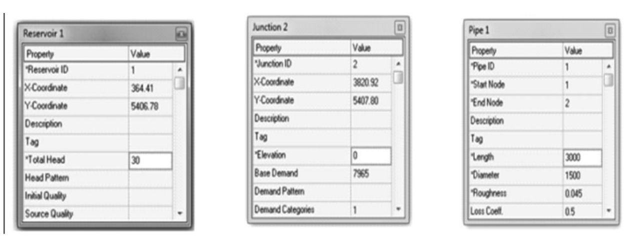


**Fig: 1(a) Input panels of EPANET for case study1**

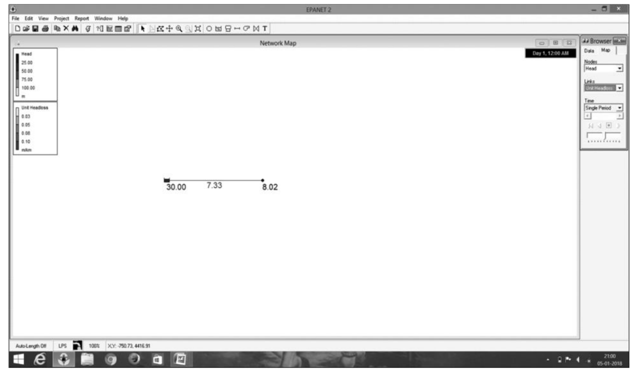


**Fig:1(b)Output panels of EPANET for case study1**

Case Study 1: Flow in a Single Pipe

A reservoir of head 30 m is connecting to a pipe of 1.5m diameter and 3000m length carries a discharge of 7.965m3/s. Calculate the head loss in the pipe. The basic information about the pipe, node demand and reservoir head is given Table 1 respectively.

**Table 1: Basic Information Of Case Study 1**

| Components | Length (m) | Diameter (mm) | Roughness (mm) | Demand (lps) | Head (m) |
|---|---|---|---|---|---|
| Pipe | 3000 | 1500 | 0.045 | - | - |
| Node | - | - | - | 7965 | - |
| Reservoir | - | - | - | - | 30 |

Manual Calculation

$$Q = 7.965\,m^3/\text{sec}$$
$$D = 1.5m$$
$$A = \frac{\pi D^2}{4} = \frac{\pi(1.5)^2}{4} = 1.767\,m^2$$
$$V = \frac{Q}{A} = \frac{7.965}{1.767} = 4.507\,m/s$$

$$R_e = \frac{VD\rho}{\mu} = \frac{4.507*1.5*1000}{0.001371} = 5.1720*10^6$$
$$\frac{k}{D} = \frac{4.5*10^{-5}}{1.5} = 3*10^{-5}$$

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log\left[\frac{k}{D} + \frac{21.25}{R_e^{0.9}}\right]$$
$$f = 0.01$$
$$h_f = \frac{fLV^2}{2gD} = \frac{0.01*3000*(4.507)^2}{2*9.81*1.5} = 21.6m$$

EPANET is run and the result is shown in Figure 1(a) and 1(b).As seen from the figure, balance head available at the node is 8.02 after a friction loss of about 22 m (7.33 m/km length).This is close to the manually obtained head loss due to friction values.

Case Study 2: Flow between two Reservoirs

Two reservoirs placed at a distance of 3200m apart carries a discharge of 0.27m3/s. The water surface elevation difference between the two reservoirs is 6m. Determine the diameter of the pipe to carry the required discharge. The basic information about the pipe, node demand and reservoir head is given in Table 2 respectively.

**Table 2: Basic Information of Case Study 2**

| Components | Length (m) | Diameter (mm) | Roughness (mm) | Demand (lps) | Head (m) |
|---|---|---|---|---|---|
| Pipe 1 | 3200 | 562.5 | 0.225 | - | - |
| Pipe 2 | 0.801 | 2500 | 0.225 | - | - |
| Node | - | - | - | 270 | - |
| Reservoir 1 | - | - | - | - | 30 (assumed) |
| Reservoir 2 | - | - | - | - | 24 (assumed) |

It is to be noted that since there is no output possible from the "reservoir" component in EPANET, in order for the flow to happen, a node is introduced with node demand. The pipe component between the node and the second reservoir is introduced for running the software, and as such this pipe segment has no practical significance. Hence, the diameter of the pipe is kept is very large and length very small when compared to the original pipe so that head loss in this segment is negligible.

Manual Calculation

Since it is a design problem we have to find the diameter value using trial and error method. [Note: even to solve this problem in software, one has to determine the diameter using trial error and compare the discharge value with the given value].

Step 1: assume f (in the range 0.010 – 0.021) and find D using head loss formula

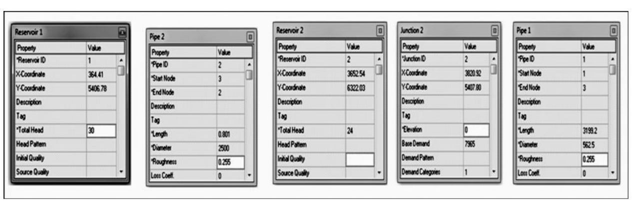

**Fig: 2(a) Input panels of EPANET for case study2**

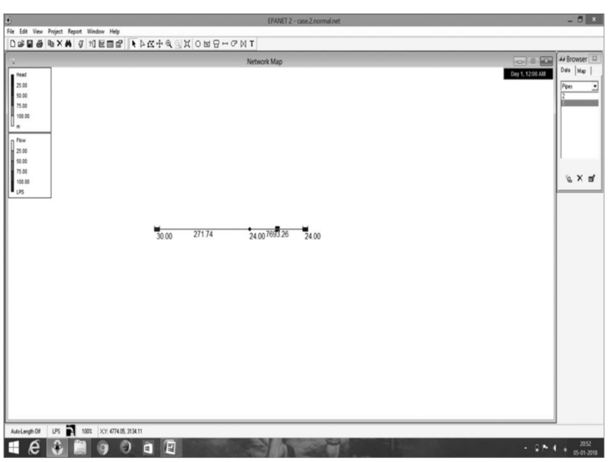

**Fig: 2(b) Output panels of EPANET for case study 2**

Step 2: using the D as obtained above, calculate the f value using friction factor formula.

Step3: if the assumed and calculated f values are same then the trial and error process terminates

$$\text{assume } f = 0.0173$$

$$h_f = \frac{fLQ^2 16}{2g\pi^2 D^5}$$

$$6 = \frac{0.0173 * 3199.2 * (0.27)^2 * 16}{2 * 9.81 * \pi^2 * D^5}$$

$$D = 0.56m$$

$$\text{substitute } D = 0.56m$$

$$R_e = \frac{VD\rho}{\mu}$$

$$= \frac{1.089 * 0.562 * 1000}{0.001117525}$$

$$= 547.36 * 10^3$$

$$\frac{K}{D} = \frac{2.55 * 10^{-4}}{0.562} = 4.539 * 10^{-4}$$

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log\left[\frac{k}{D} + \frac{21.25}{R_e^{0.9}}\right]$$

$$f = 0.0173$$

The trial runs in the EPANET are shown in Figure 2(a) and 2(b). And it is seen that when the diameter of the pipe is taken as 0.562m, the discharge matches with the expected discharge.

Case Study 3: Three Reservoir Problem

Three reservoirs A, B and C have water surface elevations as 100m, 80m and 60m respectively. The three pipes connecting the reservoir meet at junction J. The pipe AJ is 900m long, BJ is 800m long and CJ is 700 m long. The diameters of all the pipe are 850 mm. Find the direction and magnitude of flow in each pipe. Take roughness of the pipe as 0.26mm. The basic information about the pipe, node demand and reservoir head is given in Table 3(a) respectively.

Manual Calculation

This problem has to be solved using trial and error approach by assuming a suitable head at the junction of the three pipes (see Table 3(b)). The final trial calculation is shown here:

**Table 3(a): Basic Information of Case Study 3**

| Components | Length (m) | Diameter (mm) | Roughness (mm) | Head (m) |
|---|---|---|---|---|
| Pipe 1 | 900 | 850 | 0.26 | - |
| Pipe 2 | 800 | 850 | 0.26 | - |
| Pipe 3 | 700 | 850 | 0.26 | - |
| Reservoir 1 | - | - | - | 100 |
| Reservoir 2 | - | - | - | 80 |
| Reservoir 3 | - | - | - | 60 |

**Table 3(b): Trial And Error Result For Case Study 3**

| $Z_P$ (m) | $Q_1$ ($m^3$/sec) | $Q_2$ ($m^3$/sec) | $Q_3$ ($m^3$/sec) | $Q_1$-($Q_2$+$Q_3$) ($m^3$/sec) |
|---|---|---|---|---|
| 74 | 3.215 | 1.638 | 2.675 | -1.098 |
| 73 | 3.277 | 1.769 | 2.578 | -1.07 |
| 77 | 3.024 | 1.158 | 2.948 | -1.082 |
| 79 | 2.89 | 0.668 | 3.177 | 0.895 |
| 79.75 | 2.838 | 0.334 | 3.178 | 0.674 |

$$assume\ z_p = 79.75m$$
$$Z_1 - Z_p = h_{f1}$$
$$100 - 79.75 = 20.25$$
$$h_{f1} = \frac{f_1 L_1 Q_1^2 16}{2gD_1^5\pi^2}$$
$$20.25 = \frac{0.015*900*Q_1^2*16}{2*9.81*\pi^2*(0.85)^5}$$
$$Q_1 = 2.838m^3/\sec$$
$$= 2838LPS$$

$$Z_2 - Z_p = h_{f2}$$
$$80 - 79.75 = 0.25$$
$$h_{f2} = \frac{f_2 L_2 Q_2^2 16}{2gD_2^5\pi^2}$$
$$0.25 = \frac{0.015*800*Q_2^2*16}{2*9.81*\pi^2*(0.85)^5}$$
$$Q_2 = 0.334m^3/\sec$$
$$= 334LPS$$

$$Z_p - Z_3 = h_{f3}$$
$$79.75 - 60 = 19.75$$
$$h_{f3} = \frac{f_3 L_3 Q_3^2 16}{2gD_3^5\pi^2}$$
$$19.75 = \frac{0.015*700*Q_3^2*16}{2*9.81*\pi^2*(0.85)^5}$$
$$Q_3 = 3.178m^3/\sec$$
$$= 3178LPS$$

$$Z_p = 79.75m$$
$$Q_1 - (Q_2 + Q_3) = 0.674m^3/\sec$$

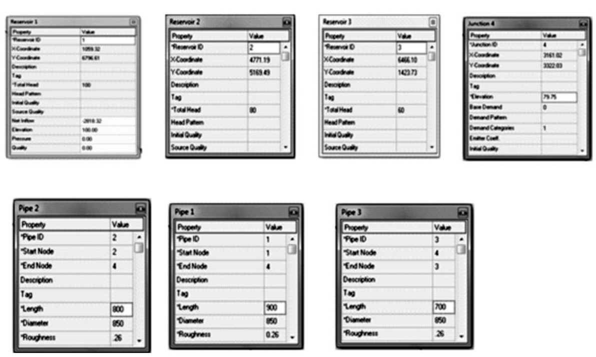

**Fig. 3(a) Input panels of EPANET for case study 3**

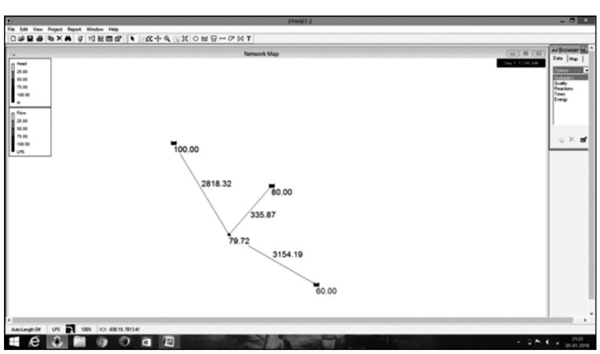


**Fig. 3(b) Output panels of EPANET for case study**

However, the implementation in EPANET doesn't need a trial-error (unlike the design problem as discussed in Case Study 2). The EPANET solution is shown in Figure 3(a) and 3(b) respectively.

The manually calculated discharge values vary only slightly when compared to that given by EPANET. This may be due to difference in friction factor used in the manual calculation and as used by EPANET.

Case Study 4: Pumping of Water

A pump lifting water through a 100mm diameter and 100m long ductile iron pipe from a lower to an upper reservoir. The suction side of the pump is of 100mm diameter and 4m long ductile iron pipe. The difference in reservoir free surface elevation is 10m. The pump performance curve is given as hp =15 - 0.1Q2. Estimate the flow rate. The basic information about the pipe and pump are given in Table 4(a) respectively.

**Table 4(a): Basic Information of Case Study 4**

| Components | Length (m) | Diameter (mm) | Roughness (mm) | Head (m) |
|---|---|---|---|---|
| Pipe 1 (suction) | 4 | 100 | 0.26 | - |
| Pipe 2 (delivery) | 96 | 100 | 0.26 | - |
| Reservoir 1 | - | - | - | 10 |
| Reservoir 2 | - | - | - | 20 |

**Table 4(b): Trial And Error Result For Case Study 4**

| Trail no. | Q ($m^3$/sec) | $h_{fs}$ (m) | $h_{fd}$ (m) | $Vd^2/2g$ | $H_{mano}$ (m) | Q (lps) |
|---|---|---|---|---|---|---|
| Trail 1 | 0.005 | 0.0223 | 0.5354 | 0.0206 | 10.578 | 6.63 |
| Trail 2 | 0.0055 | 0.0269 | 0.647 | 0.0249 | 10.698 | 6.55 |
| Trail 3 | 0.00639 | 0.0364 | 0.8744 | 0.0337 | 10.944 | 6.36 |

Manual Calculation

The details of trail calculation are shown in Table 4(b). For the final trial, the manual calculations are shown below:

$$H_{mano} = (h_{fs} + h_{fd}) + (h_s + h_d) + \frac{V_d^2}{2g}$$
$$given\ that\ h_s + h_d = 10m$$
$$assume, Q = 6.39*10^{-3}m^3/\sec$$
$$h_{fs} = \frac{f_1 L_1 V_1^2}{2gD_1}$$
$$= \frac{0.027*4*(6.39*10^{-3})^2*16}{2*9.81*\pi^2*(0.1)^2}$$
$$= 0.0364$$
$$\frac{V_d^2}{2g} = \frac{(0.8136)^2}{2*9.81}$$
$$= 0.0337m$$
$$H_{mano} = 10 + 0.0364 + 0.8744 + 0.0337$$
$$= 10.944m$$

$$h_{fd} = \frac{f_2 L_2 V_2^2}{2gD_2}$$
$$= \frac{0.027*96*(6.39*10^{-3})^2*16}{2*9.81*\pi^2*(0.1)^5}$$
$$= 0.8744$$
$$V_d = \frac{Q}{A}$$
$$= \frac{6.39*10^{-3}}{\frac{\pi*(0.1)^2}{4}} = 0.8136m/\sec$$

The trial and error will stop if the assumed discharge and the estimated discharge using the pump curve are same as shown in Figure 4(a) and the solution of EPANET is as shown in Figure 4(b).

$$H = 15 - 0.1^2$$
$$0.1Q^2 = 15 - 10.944$$
$$Q = \sqrt{\frac{(15 - 10.944)}{0.1}}$$
$$Q = 6.36LPS$$

It can be noted that for pipe flows involving pumps, a pump curve is required which represents the head and flow rate relationship.

Case Study 5: A simple pipe network system

The water supply network consist of constant head elevated storage tanks at A and C of 75m and 70m respectively with an inflow and outflow at B and D of 0.2 m3/s .The network is on a flat terrain with node elevations equal to 50 m. Compute the inflow and outflow to the storage tank. The basic information about the pipe network is shown in Table 5.

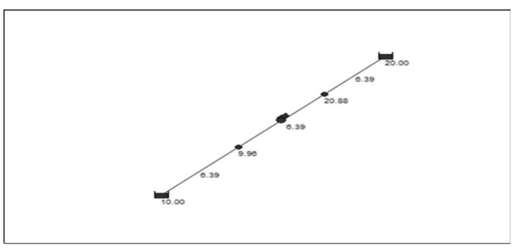


**Fig. 4(a) Input panels of EPANET for case study 4**

Manual calculation

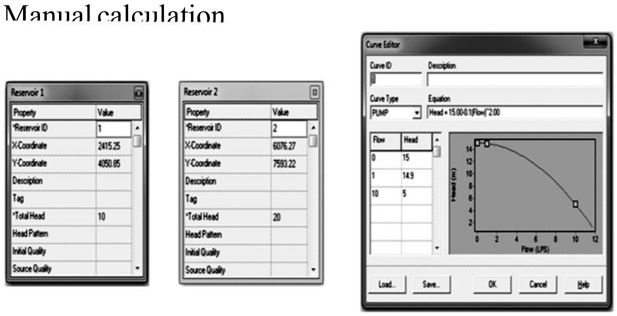

**Fig. 4(b) Output panels of EPANET for case study 4**

**Table.5: Basic Information of Case Study 5**

| Pipe | Length (m) | Diameter (mm) | Roughness (mm) |
|---|---|---|---|
| AB | 700 | 250 | 0.26 |
| AD | 1000 | 400 | 0.26 |
| DC | 1200 | 350 | 0.26 |
| CB | 800 | 300 | 0.26 |

$$h_f = \frac{f_1 L_1 (Q_1 - Q_3)^2 16}{2g\pi^2 D_1^5} + \frac{f_2 L_2 (0.2Q_3 + Q_1)^2 16}{2g\pi^2 D_2^5}$$
$$h_f = \frac{f_3 L_3 Q_2^2 16}{2g\pi^2 D_3^5} + \frac{f_4 L_4 (Q_2 - 0.2)^2 16}{2g\pi^2 D_4^5}$$
$$5 = \frac{16}{2g\pi^2}\left(\frac{f_3 L_3 Q_2^2}{D_3^5} + \frac{f_4 L_4 (Q_2 - 0.2)^2}{D_4^5}\right)$$
$$5 = \frac{16}{2*9.81*\pi^2}\left(\frac{0.019*1000*Q_2^2}{(0.4)^5} + \frac{0.023*1200*(Q_2 - 0.2)^2}{(0.35)^5}\right)$$
$$Q_2 = 0.176m^3/\sec$$

$$Q_1 + Q_2 = (0.2 + Q_1 - 2Q_3) + (Q_2 - 0.2)$$
$$= Q_1 + Q_2 - 2Q_3$$
$$Q_3 = 0$$
$$5 = \frac{0.021*700*Q_1^2}{(0.25)^5} + \frac{0.02*800*(0.2 + Q_1)^2}{(0.3)^5}$$
$$Q_1 = -0.06m^3/\sec$$

The manually calculated discharge values are nearly equal to the discharge calculated using the software as shown in Figure 5(a) and 5(b) respectively.

It is to be noted that in this network the values of inflow at junction B should be given as negative and the values of outflow at junction D should be given as positive. This is because EPANET takes the inflow as negative and outflow as positive.

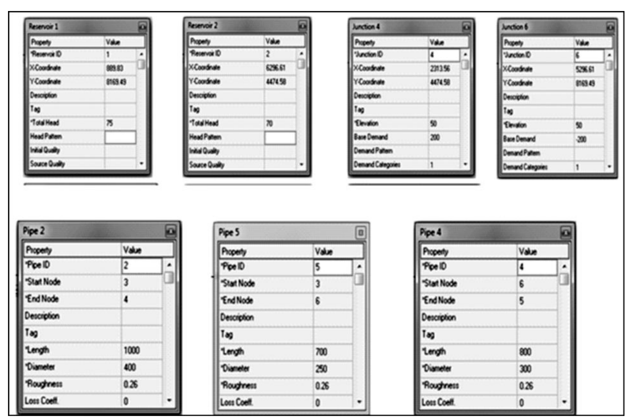

**Fig. 5(a) Input panels of EPANET for case study 5**

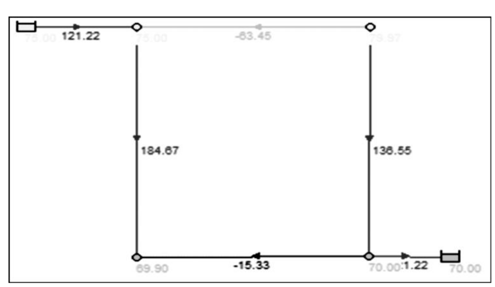


**Fig. 5(b) Output panels of EPANET for case study 5**

Feedback of Students on the experience

A class of 60 students was considered for this study consisting of students with different learning abilities. Most students were not exposed to any software simulation experience. The experience on software was given after the topics were taught to the students in the conventional way. Table 6 shows the students data who participated in this exercise:

**Table 6: Student details**

| Student Strength | % of Fast Learners | % of Medium Learners | % of Slow Learners |
|---|---|---|---|
| 60 | 20% | 40% | 40% |

At the outset almost all the students made mistakes in entering the correct units for the various parameters in the EPANET and the simulation results were found to be incorrect even for the simplest case study. A feedback was obtained from the students based on this exercise. The feedback template is given in Table 7 along with students' response (% of students).

**Table 7: Student details**

| S. No. | Question | Fully Agree | Partially Agree | Disagree |
|---|---|---|---|---|
| 1. | I have previous experience with use of simulation software | 10% | 10% | 80% |
| 2. | I find EPANET software manual needs to be supplemented with case study examples for better understanding | 80% | 20% | - |
| 3. | The case study examples developed are very useful for the understanding of EPANET software | 80% | 10% | 10% |
| 4. | I am able to appreciate the importance of using correct units in EPANET | 100% | - | - |
| 5. | I am able to clearly and quickly understand the difference in the head loss calculated using different methods | 80% | 10% | 10% |
| 6. | I find that it is much easier to solve c omplex problems with simulation software | 90% | - | 10% |
| 7. | The experience with EPANET has invoked a deeper interest in me in the topics of pipe flow | 70% | 20% | 10% |
| 8. | I understand that for applying any simulation software correctly, it is necessary to have very clear understanding of the basic principles | 100% | - | - |
| 9. | I would not have understood these topics depth without experience in using EPANET with case studies | 90% | 10% | - |
| 10. | I would like to do project work using EPANET | 50% | 20% | 30% |

About 80% students found it difficult to study the existing EPANET manual on their own and apply it. The 20% of fast learners who were good in basic analytical and reasoning skills agree that with some effort can they can manage with the existing manual directly. Most students agreed that the case studies developed are really very useful to them and they found it thrilling to verify the results with manual calculations. They found it more like a 'real time' experience than a virtual experience in using the software. Most students found it easy to appreciate in just one click of a button the difference in head loss estimation using two different methods namely the Hazen-Williams equation and Darcy -Weisbach equation. When it was it was analytically discussed it class, the understanding was not very deep. Students were given one exercise to solve complex pipe flow problem which has a solved solution in the text book. Most students could get to the answer in no time and could also appreciate how software could have arrived at that solution because of their experience in manual calculation when solving simple problems and validating with the EPANET. 70% students fully agreed that the experience has invoked a deeper interest in the pipe flow problems. Fluid Mechanics is one of the toughest courses in the UG curriculum in Civil Engineering. Moreover, the pipe flow concepts are very important for any civil engineer. It is commendable that 70% students find deeper interest in these topics. The remaining students felt that they need more experience in using the software. All the students were in full agreement that it is necessary to understand the basic concepts thoroughly in order for them to interpret the results of simulation meaningfully, and towards this aim, the design of these case studies and their solution both manually as well as using EPANET has tremendously helped them. About 50% of students were very eager to take up their major projects using EPANET. In fact, a set of students have done a very good project integrating EPANET with an optimization tool for a real time pipe network problem and published as a paper in a Scopus indexed journal. The remaining students, who were more interested in other specialization of civil engineering like structural engineering etc, also had shown interest in taking up minor projects in EPANET at the later stage. The whole attempt was very successful not only for the course on Fluid Mechanics but also invoking students' interest in learning other simulation tools as well as they progress to higher years of their study. In fact, the number of software based projects is in increase in the department as an outcome of this endeavour.

## Conclusions

Based on this study, it is concluded that for gaining deeper interest and confidence in use of simulation software, the students, particularly in the early years of their undergraduation, should be involved in solving simple to medium complexity problems both manually and through the relevant software. This ensures that not only the students learn the topics better but also they develop a long lasting interest in the topics and its applications in the real life. It also helps the students to better understand the advantages and disadvantages of the software being used and thus exercise caution in its usage. More specifically, the example case studies developed by the students for using EPANET will be very much useful for all the budding engineers in civil engineering who wish to use EPANET for their work.

The experience in working with a software beyond just running it with some set of data to actually feel how it is performing by verifying the results obtained through manual calculation has enhanced the performance of the students in the course in Fluid Mechanics. It has also motivated the students to take up projects not only in the use of EPANET, but also embrace more software based learning approach in their other courses as well. Students desire to understand fundamental concepts have also increased through this exercise. Most of the employers during recruitment feel that the fundamental concepts of students are not upto the mark. Such exercises will help students develop more interest in learning the fundamental concepts which forms the core of any engineering graduate.

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**References**

[1] Ahn, J C., Lee, S W., Choy K Y., and Koo, J Y.(2012) Application of EPANET for determination of chlorine dose and predictions of THMs in a water distribution system, Sustainable Environmental Research, 22(1), 31-38.

[2] De Jong, T., Martin,E., Zamarro, J., Esquembre, F.,Swaak,J., Van Joolingen,W.(1999) The integration of computer simulation and learning support: An example from the physics domain of collisions. Journal of Research in Science Teaching 36 , 597–615.

[3] Friedler, y., Nachmia,R., and Linn, M., (1990) Learning scientific reasoning skills in microcomputer-based laboratories. Journal of Research in Science Teaching 27 173–191.

[4] Khan, K A., and Akhter, G.(2015) Computer-based experiments for learning seismic signal processing concept. International Journal of Computer Applications in Engineering Education 23, 959-966.

[5] Pitt, R., Clark, S., and Maestre A.(2004) A step-by-step guide to EPANET 2.0 simulations (2004).

[6] Rasooli, A., Kang,D.,(2016) Design of hydraulically balanced water distribution network based on GIS and EPANET, International Journal of Advanced Computer Science and Applications, 7(2), 118-125.

[7] Rossman, L A. (2000) EPANET2 User Manual. U.S. Environmental Protection Agency.

[8] Sivapragasam, C., Aishwarya,S., Uma, R., Karthik, G., and Kannabiran,K.(2015) Genetic programming based simple decision support system for pipe network operation. International Journal of Earth Science and Engineering, 8(1), 302-306.

[9] Sivaselvan, M.V (2014)Failure analysis of engineering structures in undergraduate courses using optimization. International Journal of Computer Applications in Engineering Education 22 , 297–308.

[10]Turker, H T., Coskun, H., and Mertayak, C.(2016) Innovative experimental model and simulation method for structural dynamics concept. International Journal of Computer Applications in Engineering Education 24, 421-427.

[11]Zhou, X-L., Wang. J-H.(2016) Interactive computer for teaching biot poroelasticity modeling in civil engineering. International Journal of Computer Applications in Engineering