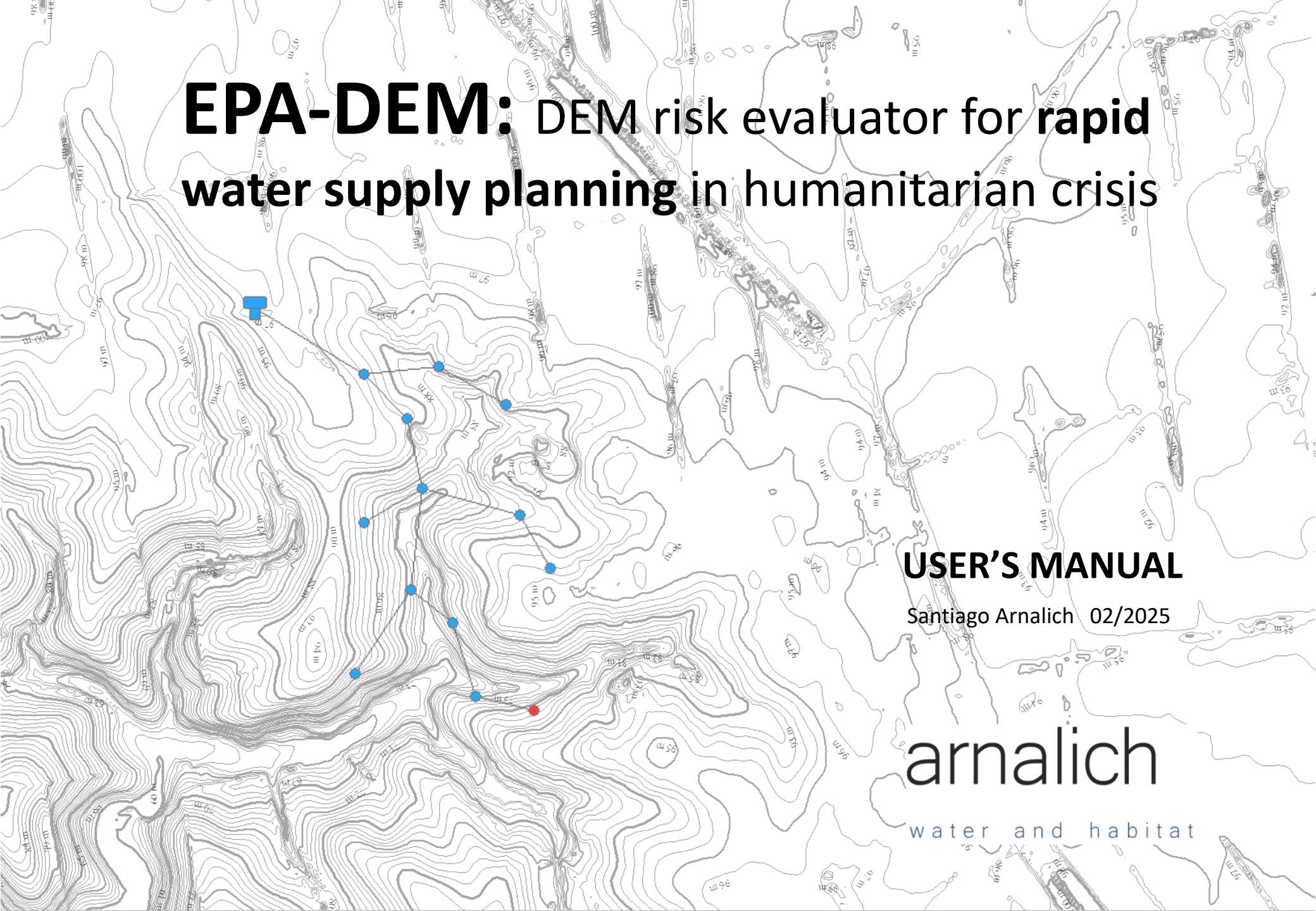
EPA-DEM: DEM risk evaluator for **rapid water supply planning** in humanitarian crisis



USER'S MANUAL

Santiago Arnalich 02/2025

arnalich

water and habitat

About EPA-DEM

EPA-DEM is free and open-source program that enables **rapid water supply planning in humanitarian crises.** It evaluates the risk of using elevations obtained from commonly available digital elevation models (DEM) in hydraulic calculations performed with EPANET.

This can prove vital in **life-saving situations** where alleviating human suffering is key and there is an important **opportunity cost** in delaying water supply operations. Better decisions can be made in almost real time.

This program performs a **Monte Carlo risk analysis** on an EPANET file. It generates numerous derived files by randomly adjusting elevations in the original file according to a calibrated normal distribution. Then, it runs simulations of each file to identify those that would fail (pressure below a set threshold) and **returns the success rate**.

The software is provided "as is“, **without warranty of any kind**, either expressed or implied[1].

Santiago Arnalich, February 2025

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ACRONYMS

DEM: Digital Elevation Model
EPANET: https://www.epa.gov/water-research/epanet
INP: native format for an EPANET file
n: number of simulations
σ: Standard deviation

Downloading

EPADEM can be downloaded using the following link:

www.arnalich.com/dwnl/epadem.zip

Installation

EPADEM **does not require installation**. Just unzip the downloaded file in the location of your choice.

Four files and folders will appear beside this user's manual, with the following content:

- **release:** this is where the program files live
- **src**: contains the source code in case you want to make changes to this open source program.
- **Report section.txt** contains the text you will have to copy and paste into the INP EPANET file.
- **README.md** file is just that, a readme file.

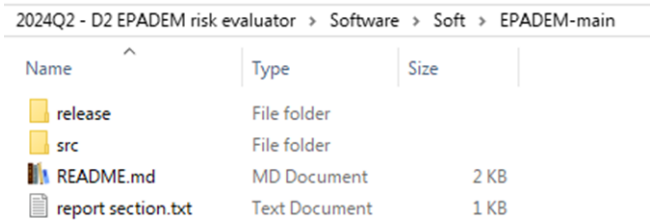

Figure 1. EPADEM's unzip file structure. The program is in the release folder.

Starting EPA-DEM

To start the program, open the release folder and click on the file called **EPADEM.exe**

Suggested user cases

The program can be used for:

1. **Evaluating the risk** of a particular design to elevation inaccuracy.
2. **Reducing the risk** of designs by seeing the effect of design modifications on risk scores.
3. **Stress test designs** using elevation as a proxy for other risks, for example, data inaccuracy.

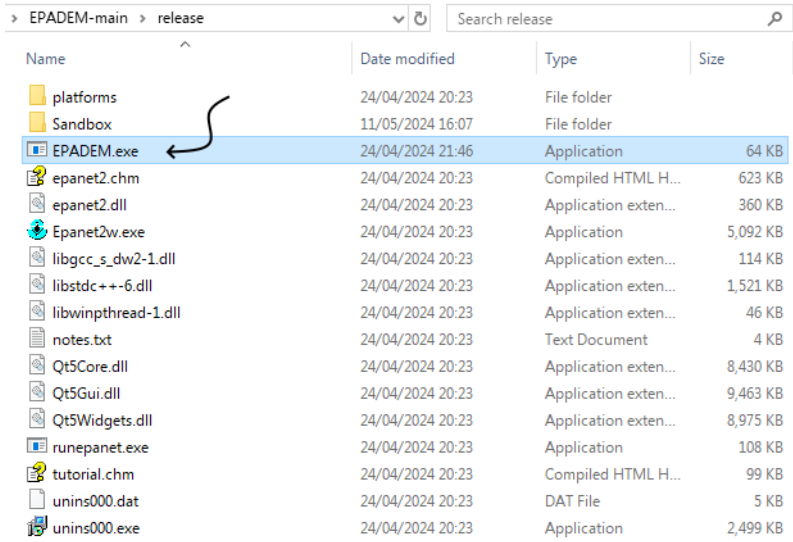

Figure 2. EPADEM.exe file is located inside the release folder.

Interface: analysis options

All the options available are displayed in a single dialogue box:

- **CPU core to use**: selecting a higher number from 1 to 4 speeds up the calculation process.
- **Number of simulations to run**: The more simulations, the more precise the result will be. More complicated files may take very long to evaluate. A minimum of 1000 simulations is recommended.
- **DEM standard deviation:** This is where the precision DEM used is introduced and can change with the geographic location, the topography and the presence absence of trees. To see charted values of different DEMs and recommendations on which one to use, visit: www.arnalich.com/EPADEM.html
- **Min. pressure value, m.** This is the threshold value below which a simulation has failed. You can start using 0m and modifying your value to get a better sense of what your risk is. For example, values below 0m may just indicate no flow at all (water does not go uphill), or just a reduction in the expected flow.
- **Path to INP file**: Location of the INP file to analyze.
- **Don't delete temp files**: Temporary files can be kept in the release/Sandbox folder for inspection.

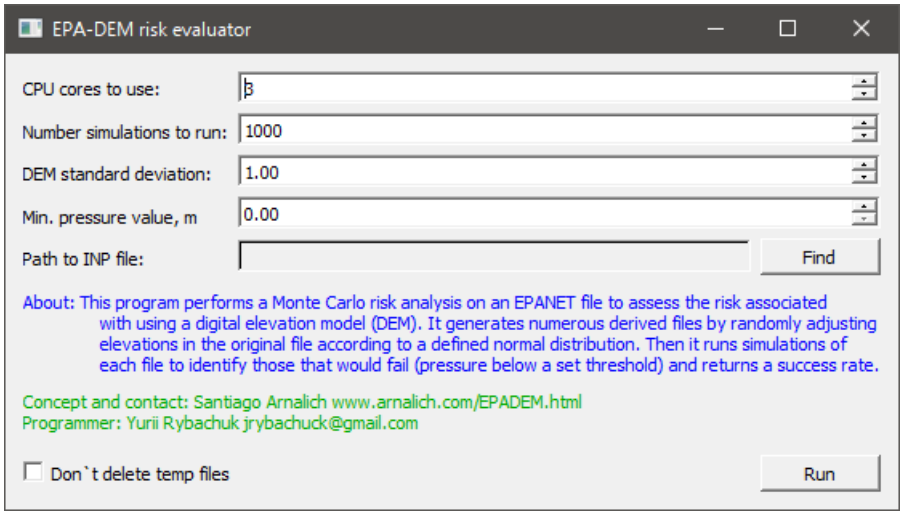

Figure 3. EPADEM's interface. Analysis options.

Exporting an INP in EPANET

After creating a model of the water network in EPANET using elevations obtained from a particular DEM and sizing all the components, it is time to export the file for the analysis.

In EPANET, go to File > Export > Network (see image 4) to export the EPANET input file (INP) needed for the simulations.

A dialogue box similar to that of any other program will prompt you to choose a name and a file location. That would be the location that you need to navigate to in the **Path to INP file** option.

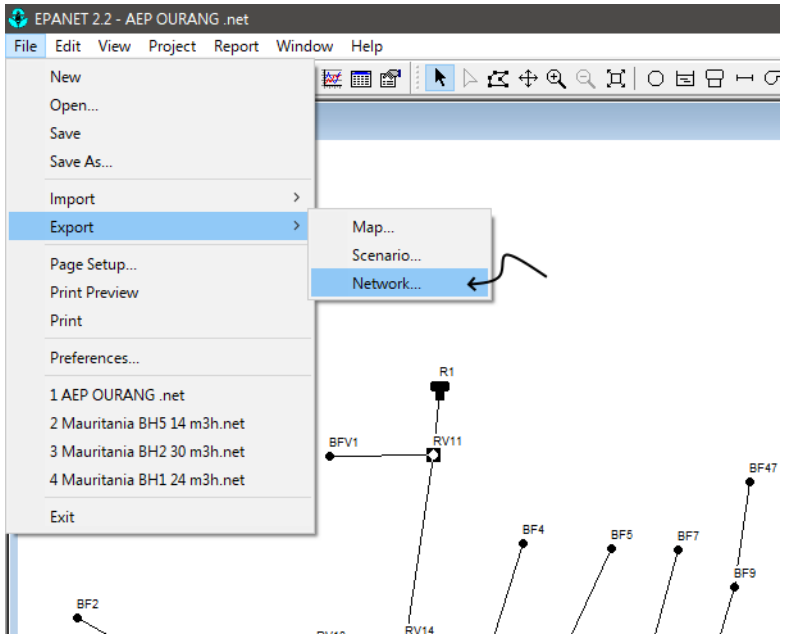

Figure 4. Exporting the EPANET file to INP format.

Preparing the INP file

You need to open the INP with a text editor, such as Notepad in windows, and copy paste the text below into it. You can also find this text in the file *report section.txt* in the main folder.

Paste it as shown in image 5, just below the [TITLE] section and save the file and exit

```
[REPORT]
Status No
Summary No
NODES All
LINKS All
FLOW PRECISION 4
ELEVATION PRECISION 4
HEAD PRECISION 4
PRESSURE PRECISION 4
Page 0
```

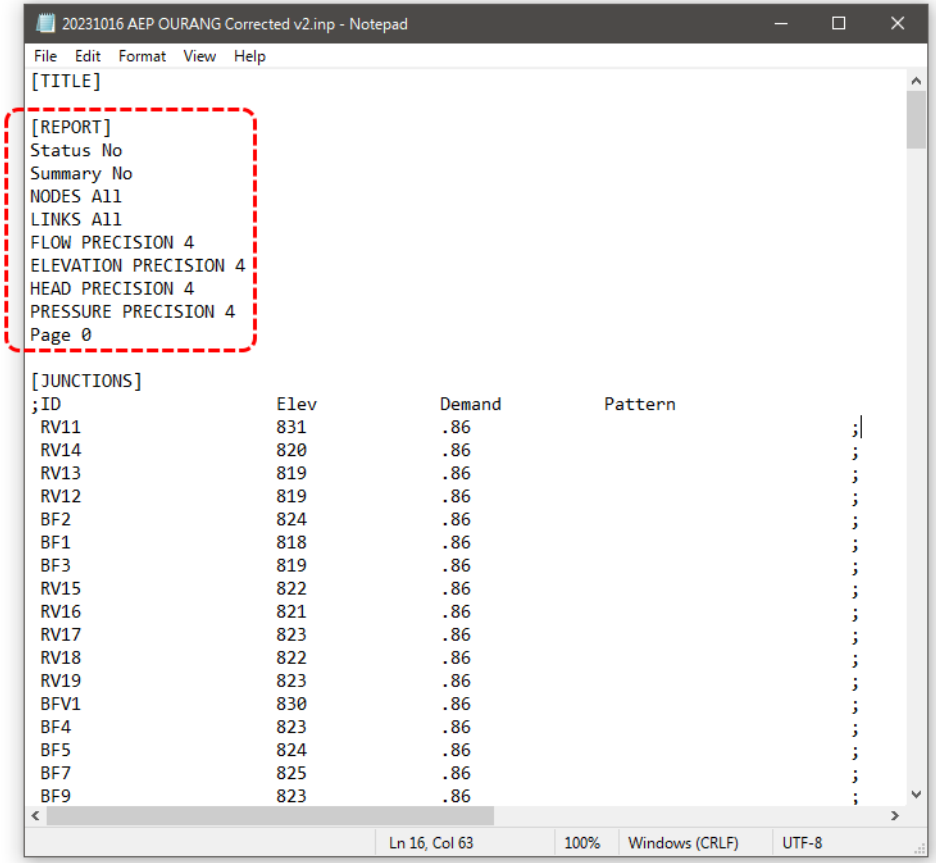

Figure 4. Add the [REPORT] section in red.

Running a simulation

Once you have selected the options in the dialogue, click run and wait for the program to finish. Depending on the complexity of the water network and the number of simulations chosen, this can take several minutes.

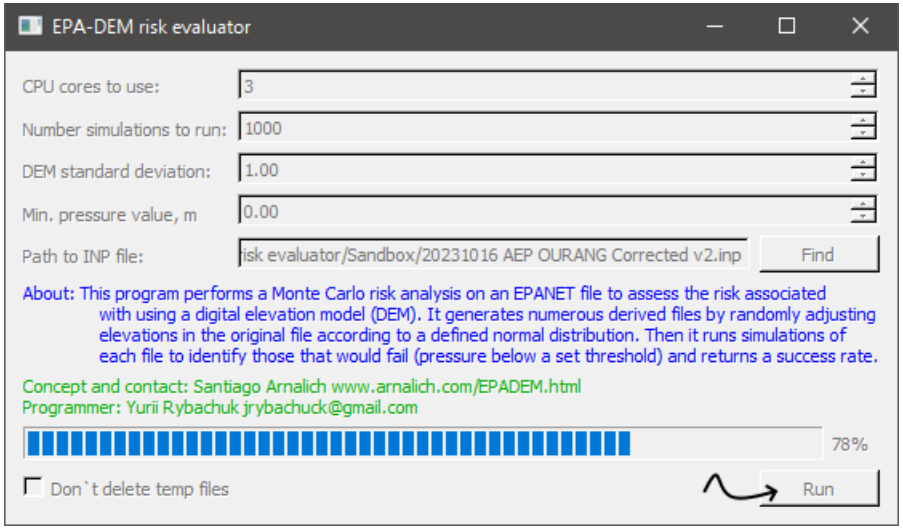

Figure 5. EPA-DEM running the simulations.

Interpreting the result

We cannot eliminate uncertainty or risk completely. It is key to understand that we are trying to reduce the uncertainty in a cost-effective way. While it depends a lot on the appetite for risk, as guidance:

Success values of **95% and higher are low risk**. There are very likely when the original network has a lot of nodes (>100). There may be still some actions that can be taken, specially for networks with a small number of nodes. It is usually possible and simple to get to 100%. Even if your success rate is 100% it may be worth stress testing the design by increasing the Min. pressure value.

Values below 95% are risky, it is advisable **to return to the EPANET** file and try to make improvements on the original design.

Note that repeating the same analysis will yield slightly different results, especially when the number or simulations is low (<1000). This is completely normal.

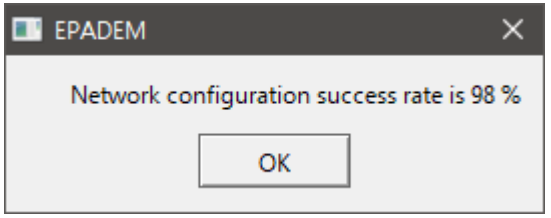

Figure 6. EPA-DEM showing the result.

Concepts involved

The error between the real elevation and that of a DEM **follows a normal distribution** (see image on the right). This is the same distribution that describes variables in the real world, for example, a person's height. In this case, the mean describes the difference between the relative and the absolute elevations. The behavior of a water system depends on the difference in elevations, not their absolute value, so this parameter is not important for us.

What is key is the precision of the measurements, that is how different they are from the mean. This is measured with the **standard deviation, σ**. 68% of the points will fall between the values of 1σ, 95% between 2σ and 99.7% between 3σ. The Monte Carlo analysis calculates the probability of an event by repeating the experiment a large number of times. . For example, a spin of the casino's roulette, and hence the name. The larger this number, say 100000, the more the expected chance of success will be trustworthy.

EPA-DEM changes the elevations in an EPANET file randomly but following the probability function of a normal distribution creating a derived file. It repeats the process to create a large number of derived files. It then runs the simulation in EPANET to see if any point has a pressure below a certain threshold value deemed problematic. EPA-DEM plays in the Monte Carlo casino automatically to see the chances of success.

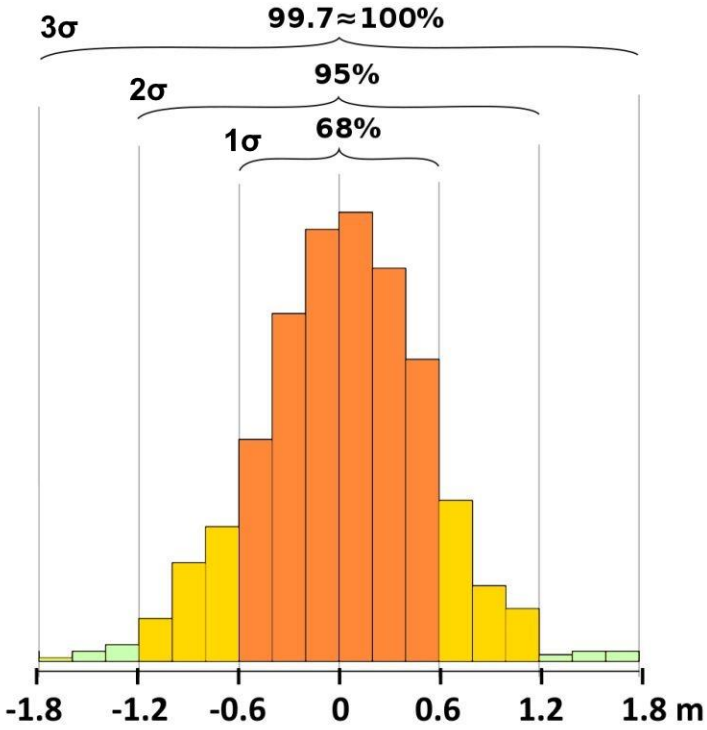

Figure 7. FABDEM 1.2 vs. total station error for Azraq, Jordan. The chances of a point having more than 1.8 error are very low, 0.003%.

Acknowledgements

Nosakhare Boadi for sparking the discussion and organizing a small-scale comparison of survey methods in Malawi.

Yurii Rybachuk for his invaluable programming skills.

Andrea Cippá for his help in comparing over 40,000 total station points against several DEMs to obtain their statistical parameters.

All those who have shared topographic surveys to calibrate the DEMs.

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