AZRED 2.0 USERS MANUAL

A.1 What is AZRED?

AZRED is an extended version of EPANET, which is the most widely used software program for modeling urban water distribution systems. AZRED was developed at the University of Arizona, and its name derives from 'AZ,' the Postal Service's abbreviation for Arizona, and 'RED', which is a Spanish word for network. AZRED adds two new features to the water quality solver component of EPANET: the capacity to include the effects produced by axial dispersion in pipes with low flow, and a module for calculating the effects of incomplete mixing at various types of four-way junctions, such as crosses, double-tees, and wye connectors.

A.2 How to install AZRED?

AZRED consists of three files: (1) a main core, named "epanet2.dll," which is a Microsoft Dynamic Link Library (DLL) that replaces the simulation engine of EPANET, (2) a graphic shell, named "Epanet2w," which substitutes for the graphical user interface (GUI) of EPANET, and (3) a text file, called "AZparameters.txt," which contains the input data exclusive of AZRED. To install these three files, first install a copy of EPANET, which can be downloaded from the Environmental Protection Agency website: http://www.epa.gov/nrmrl/wswrd/dw/epanet.html, and then drop the aforementioned files to the folder titled "C:\Program Files\EPANET2\" A message will appear asking if you want to replace "Epanet2w" and "epanet2.dll" (see Figure 1). Confirm.

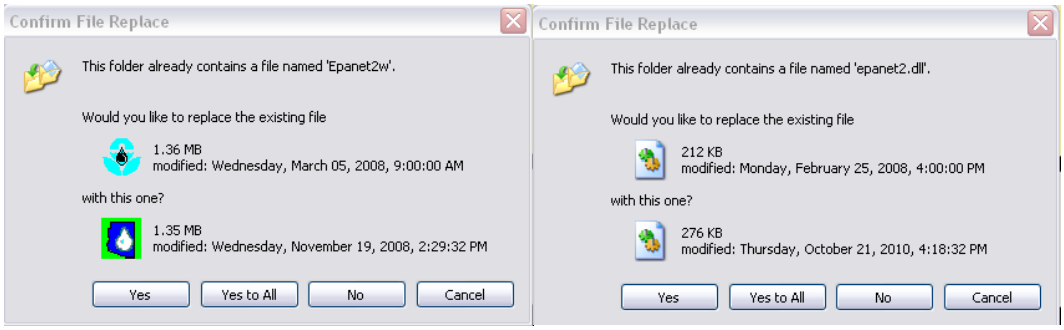

Figure 1: Confirm replacement of "Epanet2w" and "epanet2.dll" file

A.3 How to use AZRED?

AZRED was designed to be fully compatible with EPANET. Anyone experienced in the use of the latter can learn the use of the former with a minimum of effort. AZRED mainly differs from EPANET in that it includes on a text file containing the parameters to be used for the simulation.

Modifying "AZparameters.txt"

AZRED takes its input data from a text file, located in the path "C:\Program Files\EPANET2\AZparameters.txt," with the following content:

```
AZRED's parameters
-----------------------------------------------
1. Use incomplete mixing?                  =yes;
2. Use dispersion?                         =yes;
3. Dispersion Coefficient (1, 2, or 3)     =3;
4. Initial Backward Dispersion Coeff       =0.01;
5. Initial Forward Dispersion Coeff        =0.012;
-----------------------------------------------
```

AZRED has two main components: the incomplete mixing module (IM), and the axial dispersion module (ADM), and both were conceived as autonomous tools that could be used together or independently. The first two parameters determine which module(s) AZRED will use for the simulation; if none is applied, the outcomes will be identical to those obtained using EPANET. The last three parameters are applied only if axial dispersion is included in the simulation (ADM is turned on). The third line determines the dispersion rate coefficient to be used; the user can choose from three expressions that describe steady laminar flow: the classic formula developed by Taylor (1953) for steady dispersion, and two formulas proposed by Lee (2004) and Romero-Gomez (2010) for unsteady dispersion. The last expression is a direction-dependent approach that requires initial backward and forward dispersion rates, which are the fourth and fifth options, respectively.

Table 1 summarizes the data expected by each of the five parameters. To modify any of the data or the parameters, simply change the values between the equal sign and semicolon in the text file.

Table 1. Description of parameters required by AZRED

Parameter	**Description**	**Data expected**
1. Use incomplete mixing?	'yes' use incomplete mixing at cross-junctions 'no' use complete mixing for all junctions	String of characters
2. Use dispersion?	'yes' include axial dispersion in calculations 'no' neglect axial dispersion	String of characters
3. Dispersion Coefficient	'1' Taylor (1953) '2' Lee (2004) '3' Romero-Gomez (2010)	Integer
4. Initial Backward Dispersion Coeff	Initial backward dispersion coefficient (only if '3' is used for the third parameter)	Positive real number
5. Initial Forward Dispersion Coeff	Initial forward dispersion coefficient (only if '3' is used for the third parameter)	Positive real number

Using AZRED with a Graphical User Interface (GUI)

AZRED utilizes the Graphical User Interface (GUI) of EPANET with a slight modification: the legend "2.00.12 Coord Enabled" appears in the lower right part of the main window frame, as depicted in Figure 2. The incomplete mixing module requires this adjustment in order to determine the coordinates of nodes at runtime. To open AZRED, double click the file "C:\Program Files\EPANET2\Epanet2w."

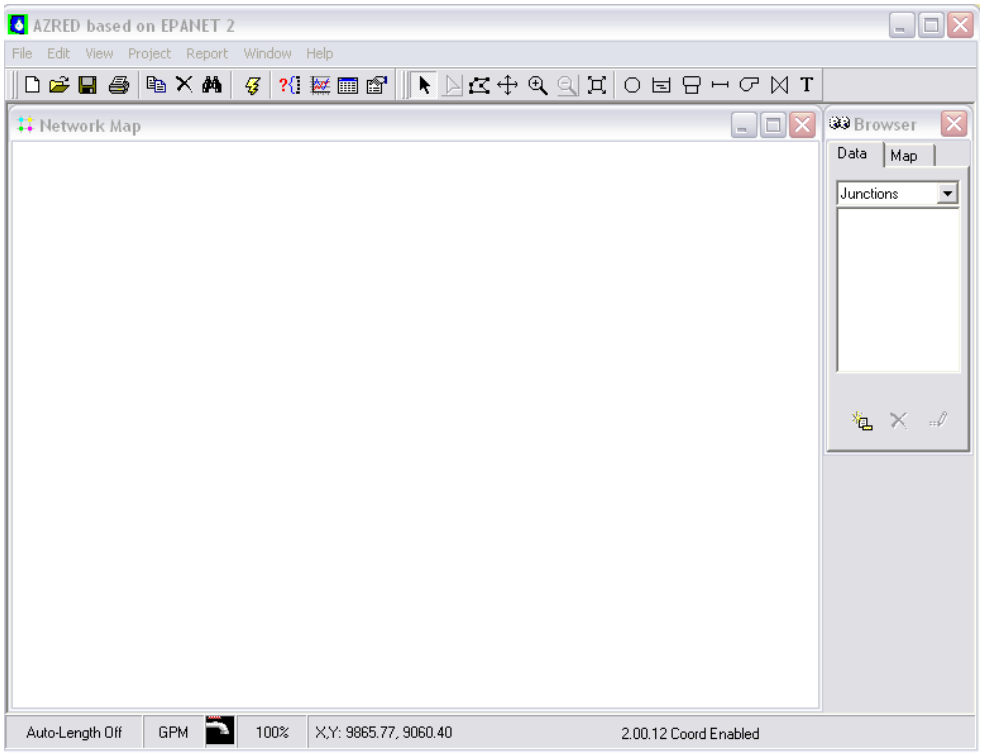

Figure 2 AZRED executed with a Graphical User Interface (GUI)

To open a water distribution network, choose any input file compatible with EPANET (*.net and *.inp). For instance, Figure 3 displays AZRED opening the second example network of EPANET, "Net2.net." Before running a simulation, modify the file "AZparameters.txt" by inputting the desired values. This file can be modified without closing the analyzed network because AZRED will read it prior to each simulation.

The outcomes obtained by AZRED when its tools are turned off are the same as the outcomes obtained by EPANET. Figure 4 exhibits the time series plot obtained for fluoride concentration at node 36 in "Net2.net," with the following parameters:

```
AZRED's parameters
-------------------------------------------------
1. Use incomplete mixing?                 =no;
2. Use dispersion?                        =no;
3. Dispersion Coefficient (1, 2, or 3)    =;
4. Initial Backward Dispersion Coeff      =;
5. Initial Forward Dispersion Coeff       =;
-------------------------------------------------
```

However, when the tools of AZRED are turned on, the effects produced by the incomplete mixing and axial dispersion modules are perceivable. The additional calculations performed by AZRED will increase the simulation time, for example, but the most evident distinction arises with respect to water quality predictions. Figure 5 presents the time series graph, generated by AZRED, for fluoride concentration at node 36. Note how, for "Net2.net," a differential transport of mass (dispersion) augments the residual mass in the system; this in turn reduces the abrupt changes in concentration produced by a model that neglects axial dispersion (Figure 4). The parameters sent to AZRED are as follows:

```
AZRED's parameters
-------------------------------------------------
1. Use incomplete mixing?                  =yes;
2. Use dispersion?                         =yes;
3. Dispersion Coefficient (1, 2, or 3)     =3;
4. Initial Backward Dispersion Coeff       =0.00;
5. Initial Forward Dispersion Coeff        =0.00;
-------------------------------------------------
```

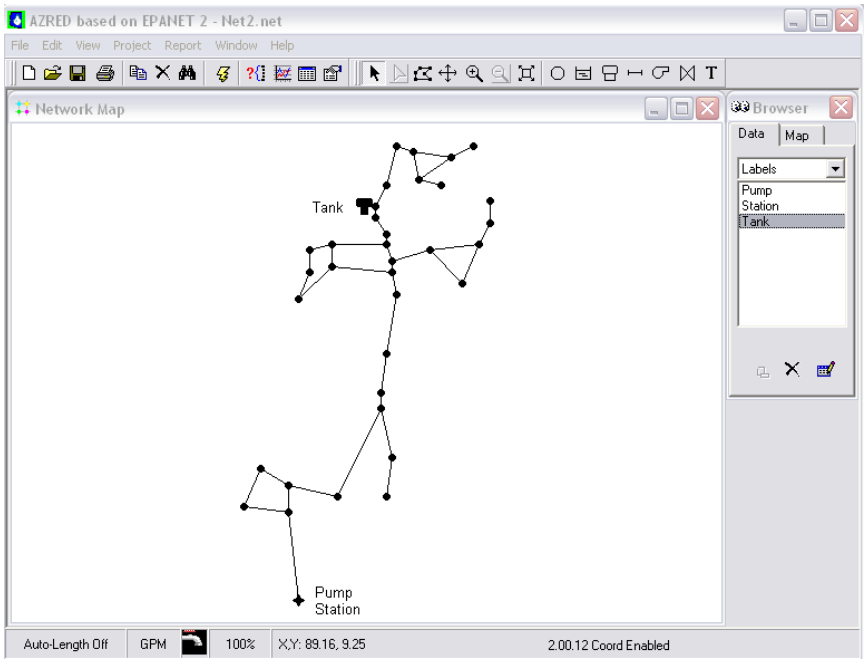

Figure 3. EPANET's "Net2.net" opened with AZRED

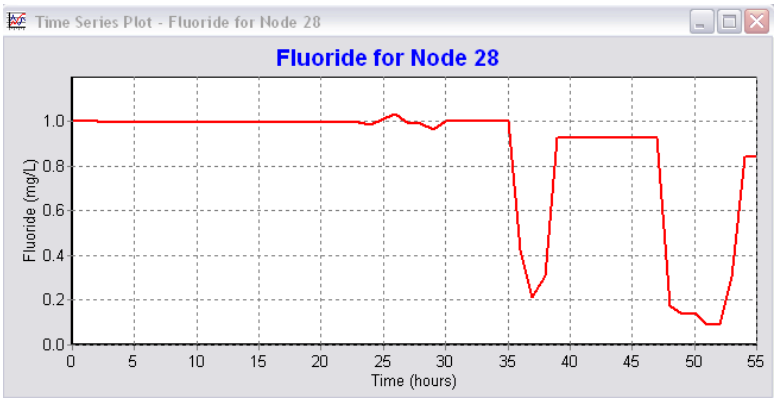

Figure 4. EPANET time series plot for fluoride concentration (mg/L) at node 28 of "Net2.net"

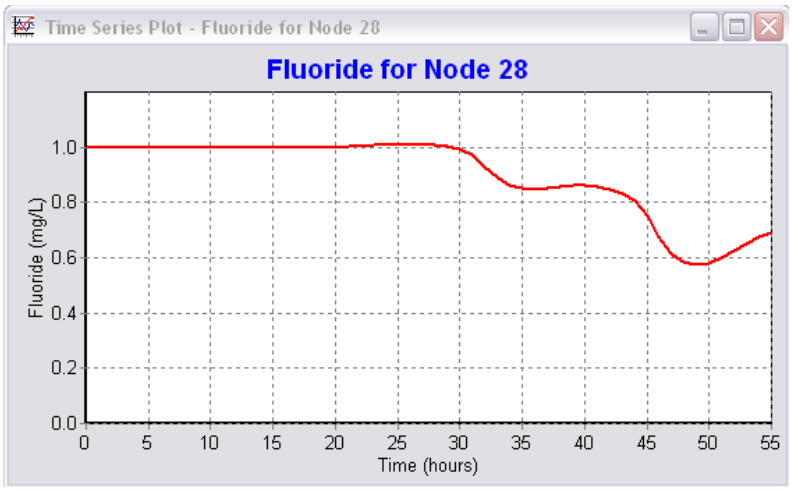

Figure 5. AZRED time series plot for fluoride concentration (mg/L) at node 28 of "Net2.net"

A.4 Receiving feedback from AZRED

After each execution, AZRED creates a text file called "AZreport.txt" which is located in the folder "C:\Program Files\EPANET2\" AZRED uses this file to notify the user of the results of the simulation. If there is a mistake in the "AZparameters.txt" file, AZRED will indicate where the problem is, as described in

Table 2, and will abort the use of the specific tool associated with the problem. For example, if the third line in “AZparameters.txt” had a value of 4, the axial dispersion module couldn’t be executed because no valid expression would have been selected for the rate of dispersion; in this case AZRED would use the water quality model of EPANET that ignores dispersion, and “AZreport.txt” would then contain the following message: ‘Invalid dispersion coefficient. Water Quality calculated without dispersion.’

Table 2. Error messages in "AZreport.txt"

Error in parameter	**Printed message**
1. Use incomplete mixing?	Using complete mixing
2. Use dispersion?	Dispersion neglected
3. Dispersion coefficient	Invalid dispersion coefficient. Water quality calculated without dispersion
4. Initial dispersion coefficient	Invalid backward dispersion coefficient Water quality calculated without dispersion
5. Initial forward dispersion coefficient	Invalid forward dispersion coefficient Water quality calculated without dispersion