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ACTIVITY/PROJECT SPECIFIC PROCEDURE

SP 9-13
DATA THINNING AND REMOVAL OF BAROMETRIC AND EARTH TIDE EFFECTS FROM WATER-LEVEL DATA
Revision 0

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	(printed name)	(signature)	(date)

1.0 Purpose and Scope

This procedure prescribes the Sandia National Laboratories (SNL) Waste Isolation Pilot Plant (WIPP) process for pressure data management by way of removal of earth tide effects, removal of barometric effects, and data thinning for pressure data obtained at and in close proximity to the Waste Isolation Pilot Plant (WIPP). Pressure data is monitored in these wells in support of WIPP compliance activities to note changes in water level due to natural and impacted causes. Removing earth tides and barometric effects allows us to better identify pressure changes in monitored wells not influenced by these two natural processes. This procedure also details the data thinning process used to selectively thin data for publication. Pressure data is typically recorded hourly, and for wells that have been monitored for several years, it becomes necessary to limit the quantity of data given in a physical report.

Acronyms and definitions for terms used in this procedure may be found in the Glossary located at the Sandia National Laboratories (SNL) WIPP Online Documents web site.

2.0 Implementation Actions

2.1 Removal of Earth Tide and Barometric Effects

Pressure data recorded from Level TROLLs used at the WIPP site are subject to fluctuations caused by changes in barometric and earth tide pressures. To remove these effects, three data sets are required: recorded pressure data for the target well, barometric data recorded in the general proximity of the well over the time frame of the target well pressures, and earth tide pressures generated over the time frame of the target well pressures. The mathematics of the extractions are described in the nSIGHTS Version 2.41a Design Document by Barnhart (2011) in Appendix A. It is important to understand that the removal of earth tides and barometric effects ultimately results in smoother pressure data, but the purpose of barometric and earth tide removal is not as a data smoothing technique. Removal of earth tide and barometric effects should be performed by those with a technical understanding of the physical problem.

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2.2 Data Sources

Well pressures are recorded individually for target wells at the WIPP site using Level TROLLs from In-Situ, Inc. Barometric pressure data is recorded at the Port-a-Camp area just outside the WIPP site fence-line using BaroTROLLs from In-Situ, Inc. Earth Tide data is generated using the TSoft software package by The Royal Observatory of Belgium. The process for generating Earth Tide data is described in the User's Manual for TSoft Version 2.1.0, ERMS #541705.

The inputs to generate the file used in this discussion are based on a centralized latitude and longitude of the WIPP footprint. The difference between earth tides values at the extremes of the WIPP monitoring area were on the order of 10^{-2} which is insignificant to this procedure. For this reason, a single earth tide file, generated at the center of the WIPP site, may be used for all WIPP monitoring wells. The time span coverage of the resulting earth tide data is dependent upon the start time, time increment, and number of points by the relationship of:

Final Time = Start time + (Time increment)(Number of points)*

The time increment of the data should be, at minimum, the same time increment as the barometric data collected. We note that the output file generated by TSoft using these inputs are for Greenwich Mean Time and the time of each earth tide needed to be shifted by seven hours to be appropriate for the Mountain time zone by post-modifying the times generated in the earth-tide file. An earth tide coverage for a time span between 1/1/2004, 00:00:00 and 9/15/07, 20:00:00 centralized on the WIPP site footprint is generated using the values listed in Table 1.

Start time	1/1/2004
Time increment	1800 sec
Number of points	65000
Latitude	32.37
Longitude	-103.79
Elevation	1039 m

Table 1: A list of the inputs used to generate the earth tide file for this document.

2.3 nSIGHTS Barometric Correction Setup

In this section, we detail the creation and object interconnection of pressure data correction for barometric and earth tide pressure in nSIGHTS. As a general description, we will be creating an object structure to read in necessary data, an object structure containing the measure of response of the pressure data to change due to barometric and earth tide pressures, and two plot objects to view data. The creation of these objects will be detailed by grouping in the following instructions.

These objects will provide the three files needed to correct pressure data for barometric and earth tide effects.

<u>Step 1: Open the Program.</u> Open nPre and navigate to *Plots & Data Processing*, *Field Data* tab. The *Default::Data* object already exists by default; this is the data folder object where we will read in data.

<u>Step 2: Read-In Pressure Data.</u> Right click the *Default::DataPgDesc* object and use the dropdown menu to select ***Use Object→New→XY Data Processing→Read XY Data***. Change *Object ID* to "Well Pressure Head" and use the *Browse* button to find the pressure data you wish to correct. Once

the file is found, select it, hit *Open* which should return you to the *Read XY* data object, and then hit *Apply*. This process will be generally repeated to read the barometric and earth tide data sets.

Step 3: Read-In Barometric Data. Right click the *Default::DataPgDesc* object and use the dropdown menu to select ***Use Object→New→XY Data Processing→Read XY Data***. Change *Object ID* to "Baro Data", and use *Browse* to find the barometric pressure data file you wish to use for correction. Once the file is found, select it, hit *Open* which should return you to the *Read XY* data object, and then hit *Apply*.

Step 4: Read-In Earth Tide Data. Right click the *Default::DataPgDesc* object and use the dropdown menu to choose ***Use Object→New→XY Data Processing→Read XY Data***. Change *Object ID* to "ET Data", and use browse to find the earth tide data you wish to use for correction. Once the file is found, select it, hit *Open* which should return you to the *Read XY* data object, and then hit *Apply*.

Now that we have read in the data, it is necessary to visualize the pressure data for use in later sections.

Step 5: Create 2-D Plot. Right-click on *Default::Data* and select ***Page→New 2D XY Data Plot***. This will generate a graph that you can visualize in a separate window and can manipulate its contents in the plot object.

Step 6: Name the Plot. Select the *2D-XY* object, change the *Object ID* to "Well Pressure Heads" and hit *Apply*.

Step 7: Format Plot Area. Select the *2DPlotAnno* object and check the *Axis labels* box, type "Time" for the *X axis* and "Pressure" for the *Y axis*, change the *Label Font* and *Increment Font* size to 16, click *Apply*.

Step 8: Incorporate Data to Graph. Right-click the *Well Pressure Heads::XY* object and choose ***New→Data: XY Series***. In the *Data: XY Series* object, check the top left box to activate the first data series, select *Well Pressure Head* in its dropdown menu, hit *Apply*.

Step 9: Visualize the Data. Selecting the graph window, right-click in the plot area and choose *Axis→Data Limits* to display your pressure data.

We will now create the objects that handle the barometric and earth tide correction calculations.

Step 10: Create a New Data Page. Right click the *Default::DataPgDesc* object and select ***Page→New Data***, change *Object ID* to "Correction" and hit *Apply*.

Step 11: Extract a Data Range. Right click the *Correction::DataPgDesc* object and use the dropdown menu to choose ***Object→New→XY Data Processing→Extract Range***. Change the *Object ID* to "Baseline Well Pressure Head", and use the *XY Input Data* dropdown and choose the *Well Pressure Head* data. Select the *A and B* option in *Operation*, set *A Value* and *B Value* to represent a stable pressure time span displayed in the pressure data graph created in the last section, and hit *Apply*. It is recommended that the stable pressure time span (i.e. a pressure span without testing effects, nearby drillings, etc.) be, at minimum, several months. The *A Operation* and *B Operation* default to *Greater Equal* and *Less Equal*, respectively, and should be left as such.

Step 12: Create a Barometric and Earth Tide Response Function. Right-click the *Correction::DataPgDesc* object and choose ***Object→New→Well Test Analysis →Create BP/ET***

Response Function, in the three drop down menus, choose *Well Pressure Head* for *P(t) Data to Compensate*; *Baro Data* for the *Barometric Pressure* and *ET Data* for the *Earth Tide Effects*. Set the *Maximum Time Delay Value* to 0.25 days, and *Specific Time Spacing Value* to the general time increment of the barometric/earth tide data frequency (in days), hit *Apply*. We note this object also contains the capability to convert pressure data from psig (gauge) to psia (atmospheric) and vice versa.

Step 13: Create Barometric and Earth Tide Compensation. Right-click the *Correction::DataPgDesc* object and choose ***Object→New→Well Test Analysis→P(t) BP/ET Compensation***. In the four dropdown menus, select "Well Pressure Head" for *P(t)Data to Compensate*, "Response function Create BP/ET Response Function Fld:\Correction" for the *Response Function*, "Baro Data" for the *Barometric P(t) Data*, and "ET Data" for the *Earth Tide Data*; click *Apply*.

Step 14: Correct the Pressure Data. Right-click the *Correction::DataPgDesc* object and choose ***Object→New→XY Data Processing →Write XY File***. Change the *Object ID* to "Corrected Data Output", and in the *XY Data Source* dropdown menu, select *BP/ET Compensation BP/ET Compensation Fld:\Correction*. Use the *Browse* button to locate and label a folder and file name in which you wish to write the corrected data. Hit *Apply* to write the output corrected pressure data file.

Step 15: Visualize the Corrected Data. In the *Well Pressure Heads::XY* plot object, select XY Data Series object and check a second box on the left (below the Well Pressure Head data already selected), and in the dropdown menu, select *BP/ET Compensation*; hit *Apply*. This will plot the corrected data in the same graph as the original pressure data for comparison and evaluation.

We will now create a diagnostic response plot for our data correction called a step response function as described by Toll and Rasmussen (2005) and revisit/update the well head pressure graph previously created. The step response function is useful for diagnosing the confined or unconfined nature of an aquifer whereas an unconfined aquifer has a signature that decreases to an asymptote with respect to time and a confined aquifer has a signature that increases to an asymptote with respect to time.

Step 16: Create a 2-D Plot. Right-click on *Default::DataPgDesc* and choose ***Page→New 2D XY Data Plot***

Step 17: Rename the Plot. In the *2D-XY* object, change the *Object ID* to "Response Plot", and hit *Apply*.

Step 18: Format the Plot Area. Select *2DPlotAnno* and check the *Axis labels* box. Type "Time Increments" for the *X axis* and "Step Response" for the *Y axis*, change the *Label Font* and *Increment Font* size to 16, click *Apply*.

Step 19: Select Data to Plot. Right-click in the *Response Plot::XY* object and choose ***New→Data: XY Series***.

Step 20: Plot the Function. In the *Data: XY Series* object, check the top left box to activate the first data series; select *Response function* in its dropdown menu and hit *Apply*.

Step 21: Visualize the Function. Selecting the graph window, right-click in the plot area and choose *Axis→Data Limits* to display your response function.

Figures 1 and 2 show an example of corrected pressure data and the final nSIGHTS object structure, respectively.

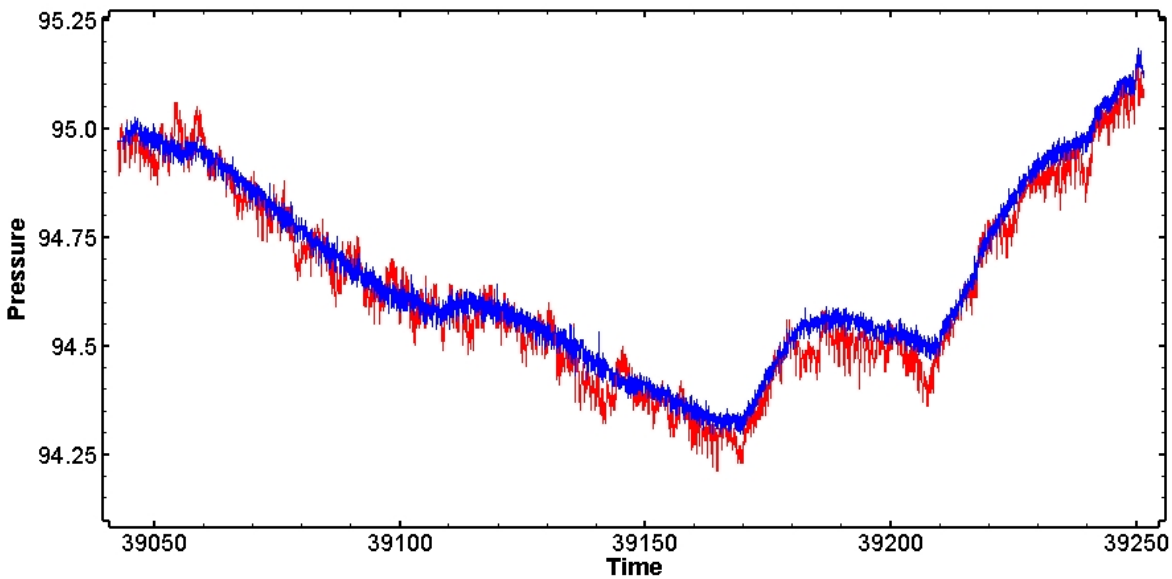

Figure 1: An example of corrected pressure data (blue) versus the recorded data (red) that contains barometric and earth tide fluctuations.

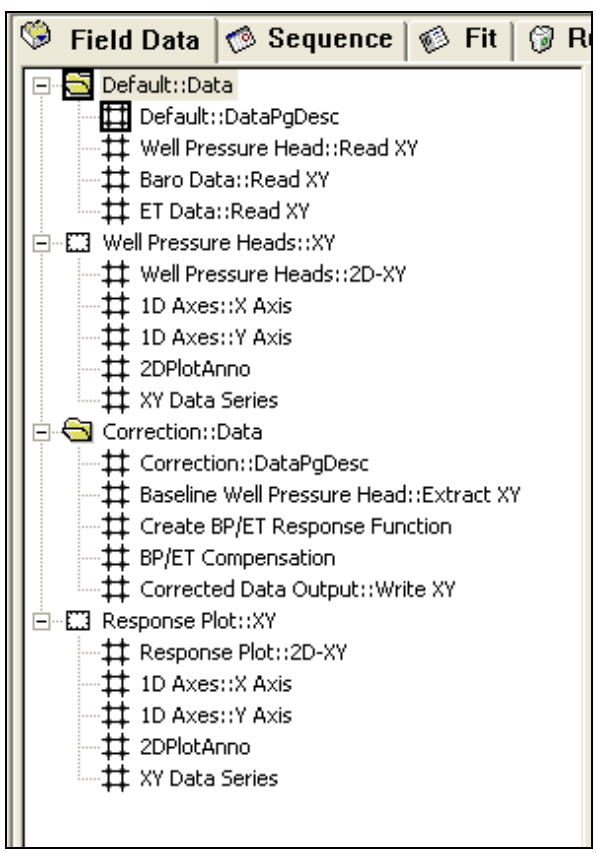

Figure 2: The nSIGHTS object structure used for barometric and earth tide correction.

2.4 Correction Acceptance

A data set will be considered corrected if:

1) The barometric data span covers that of the corrected pressure data.

2) The earth-tide data span covers that of the corrected pressure data and is generated for the location in which the pressure data was collected.

3) The *Maximum Time Delay Value* provides a corrected data set that minimizes pressure fluctuations due to barometric and earth-tide effects and provides a corrected data set that rests on the mean of the uncorrected data set.

4) The *Maximum Time Delay Value* has been adjusted to a value that is realistic for the aquifer in which the pressure data is being recorded. Toll and Rasmussen (2007) generally recommend a period of 12 to 24 hours for most confined aquifers. They note that for unconfined and some deep confined aquifer systems have exhibited considerably longer time delays. In practice, it is best to start at a small time delay (2-6 hours) and gradually increase the time delay until an adequate removal of earth tide and barometric effects is achieved; "adequate" being determined by the user.

2.5 nSIGHTS Data Thinning Setup

Data thinning is a common practice for long-term data collection of pressure data for monitored wells at the WIPP site. In some cases, the wells are monitored for several years. Data thinning allows for the pressure to be placed in a more manageable form. The data thinning process for our pressure data will be done using the nSIGHTS software package. The prescribed approach for data thinning for data at the WIPP site is the reduction of data where minimal activity (i.e. hydraulic testing) exists at the target well.

<u>Step 1: Open the Program.</u> Open nPre and navigate to *Plots & Data Processing*, *Field Data* tab. The *Default::Data* object already exists by default; this is the data folder object where we will read in data.

<u>Step 2: Read in Pressure Data.</u> Right click the *Default::DataPgDesc* object and use the dropdown menu to select ***Object→New→XY Data Processing→Read XY Data***. Change *Object ID* to "Pressure Data" and use the *Browse* button to find the pressure data you wish to thin. Once the file is found, select it, hit *Open* which should return you to the *Read XY* data object, and then hit *Apply*.

<u>Step 3: Reduce Data.</u> Right click the *Default::DataPgDesc* object and use the dropdown menu to select ***Object→New→XY Data Processing→Reduction***. In the *XY Reduction* dropdown menu, select *PDAT Pressure Data Fld:\Default* to point the reduction object at your target pressure data you will thin. This object will thin the data by amount and specification supplied by the user. The specifics of each method will be described later in this section.

<u>Step 4: Write Thinned Data File.</u> Right-click the *Correction::Data* object and choose ***Object→New→XY Data Processing →Write XY File***. Change the *Object ID* to "Thinned Data Output". In the *XY Data Source* dropdown menu, select *Reduction*, hit *Apply*. Use the *Browse* button to locate and label a folder and file name in which you wish to write the thinned data. Hitting *Apply* again will write the output thinned pressure data file.

Now that we have read in the data, it is necessary to visualize the pressure data.

Step 5: Create Data Plot. Right-click on *Default::Data* and select ***Page→New 2D XY Data Plot***. This will generate a graph that you can visualize in a separate window and can manipulate its contents in the plot object.

Step 6: Rename the Data Plot. Select the *2D-XY* object, change the *Object ID* to "Pressure Data Graph" and hit *Apply*.

Step 7: Format the Plot. Select the *2DPlotAnno* object and check the *Axis labels* box, type "Time" for the *X axis* and "Pressure" for the *Y axis*, change the *Label Font* and *Increment Font* size to 16, click *Apply*.

Step 8: Plot the Data. Right-click the *Well Pressure Heads::XY* object and choose ***New→Data: XY Series***. In the *Data: XY Series* object, check the top left box to activate the first data series, select *Pressure Data* in its dropdown menu, hit *Apply*.

Step 10: Visualize the Data. Selecting the graph window, right-click in the plot area and choose *Axis→Data Limits* to display your pressure data.

The data now displayed is the baseline data for our data thinning process.

Data thinning, as described in Step 3, in nSIGHTS can be done using three different *Data Reduction Operations*: *Skip*, *Maximum Change*, or *Both*. To select an operation, use the *Data Reduction Operation* dropdown menu and select a method. The *Skip* function thins data by removing points in a repetitive sequence as described by the value entered in the *Point Skip Interval*. As an example, if the *Point Skip Interval* is 1, every-other point will be selected. Figure 3 illustrates the result of using *Point Skip Intervals* of 1 and 2.

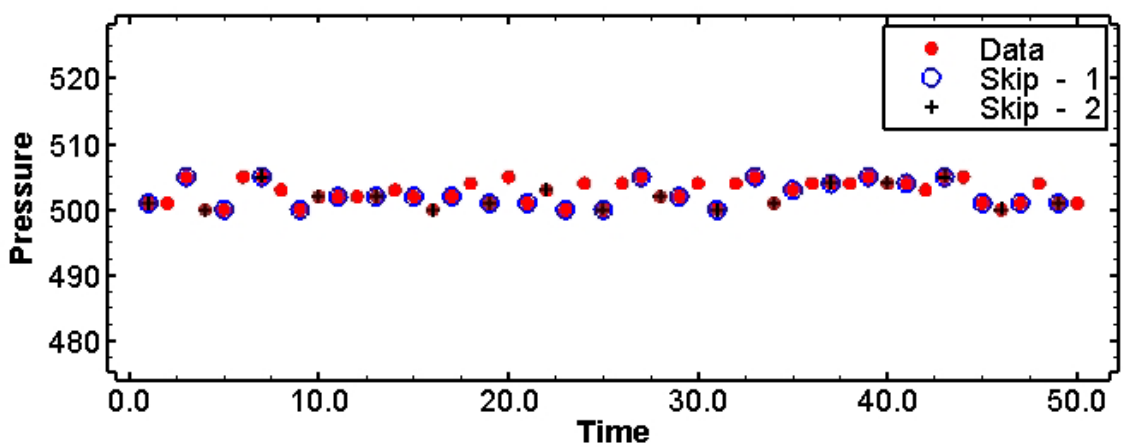

Figure 3: The *Data Reduction Operation* applied to pressure data (red) using a *Point Skip Interval* of 1 (blue) and 2 (black).

The *Maximum Change* function thins data by removing points that exceed an X or Y value change. As an example for a data set with points ΔX = 1 and ΔY varying between 0 and 5, if the *Maximum X Change* (MXC) is 5, and the *Maximum Y Change* (MYC) is 10 every-fifth point will be selected. In this case, every fifth point exceeds the *Maximum X Change* but none exceed the *Maximum Y Change* inside the 0 to 5 ΔY.

In the event where both MXC and MYC are both applicable to the pressure data set, the *Data Reduction Operation* will measure all point for their relation to their neighboring points and select them

for the thinned data set if they exceed the ΔX or ΔY limits entered. It is important to note that ΔX or ΔY qualifications are based on the last point selected. Figure 4 illustrates the result of using two different MXC/MYC value sets.

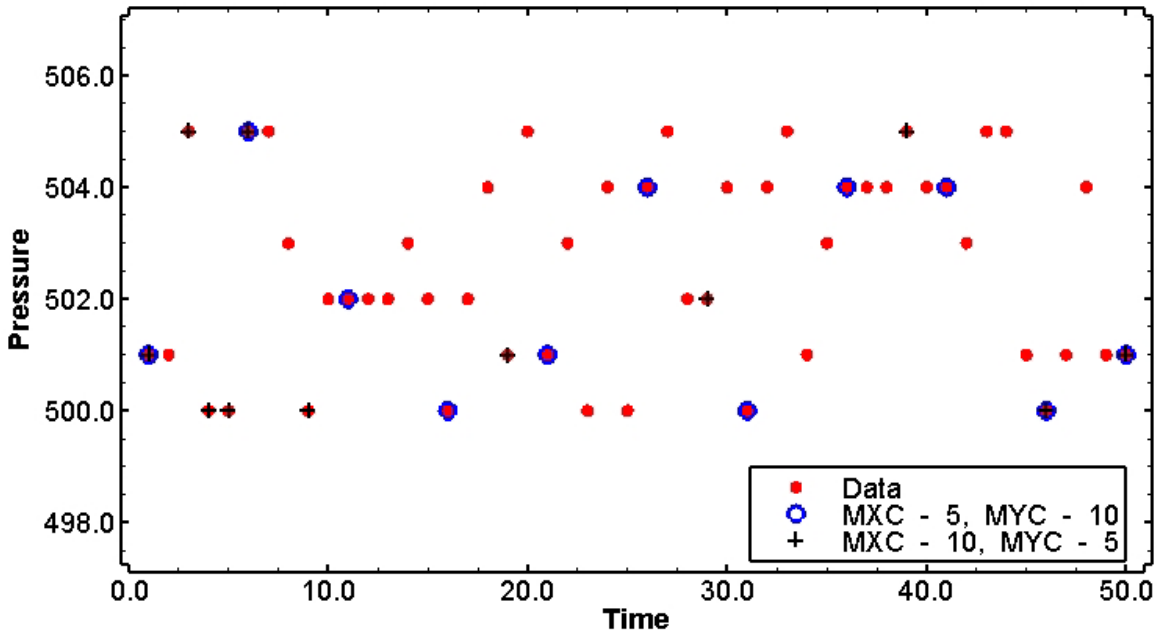

Figure 4: The *Data Reduction Operation* applied to pressure data (red) using a *Maximum X Change* of 5 with a *Maximum Y Change* of 10 (blue) and a *Maximum X Change* of 10 with a *Maximum Y Change* of 5 (black).

The third option is using *Both* in the *Data Reduction Operation* dropdown menu, which uses a combination of *Point Skip Interval* and MXC/MYC. This data thinning option holds the MXC/MYC as the priority over the supplied Point Skip Interval. The only difference is that instead of the MXC/MYC selecting the two points that exhibit the largest difference, a point inside the skip interval will not be selected if it does not exceed the MXC/MYC interval with the original point. An illustration of the *Both* option can be seen in Figure 5.

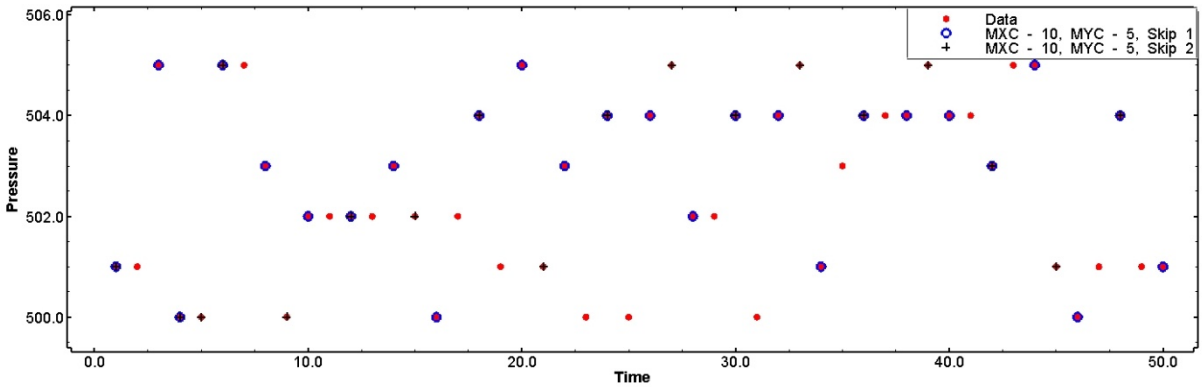

Figure 5: The *Data Reduction Operation* applied to pressure data (red) using a *Both* with *Maximum X Change* of 10 and *Maximum Y Change* of 5 with a *Skip* of 1 (blue) and *Skip* of 2 (black).

In relation to WIPP wells, the *Maximum Change* option will be most commonly used in the data reduction of well pressure data. The MXC will be the primary criterion to remove data points for data in which there is little or no activity at the well. Pressure data is typically recorded at a regular time interval so the MXC value is then dependant on the data frequency desired. The MYC value is to be

larger than pressure fluctuations seen when there is no activity at the well, but smaller than the pressure changes when hydraulic tests are being conducted at the well.

2.6 Safety

The activities described in this SP shall conform to SNL Environmental Safety and Health programs (ES&H). All activities described in this SP will be conducted in the SNL office facility.

2.7 References

Barnhart, K. S. 2011. “nSIGHTS Version 2.41a Design Document.” ERMS# 555650. Albuquerque, NM: Sandia National Laboratories.

Toll, N.J. 2005. “Addennum to the WIPP User’s Manual for TSoft Version 2.1.0.” ERMS# 541705 Albuquerque, NM: Sandia National Laboratories.

Toll, N.J. and T. C. Rasmussen 2007. Removal of Barometric Pressure Effects and Earth Tides from Observed Water Levels. *Ground Water*, Vol.45, No. 1, pgs 101-105.

3.0 Records

The following QA records generated through implementation of this procedure shall be prepared and submitted to the WIPP Records Center in accordance with NP 17-1, “Records”.

QA Record

- Data sections located in Hydrologic Data Reports produced by AP-160

4.0 Appendices

There are no appendices associated with this document.

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