

ABflare

**A Refined Air Quality Dispersion Model
for Evaluating Non-Routine Flaring for
Sour Gas Facilities**

User Guide, Version 1.01

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User Guide, Version 1.01

A Report Prepared for

Alberta Energy Regulator (AER)

Funded in Part by

Petroleum Technology Alliance of Canada (PTAC)
Alberta Upstream Petroleum Research Fund (AUPRF)
Alberta Energy Regulator (AER)

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Alberta Energy Regulator (AER) of Alberta, Canada

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Minimum System Requirements for *ABflare*

ABflare is a Windows® based software application requiring Microsoft® Excel as a user interface. The minimum system requirements are:

- FORTRAN compiler
- Windows®8; Windows®7
- Microsoft® Excel. (Office 2010, Office 2013)
- x64 or x86
- 1024x768 minimum resolution recommended
- 2 GHz processor minimum recommended
- 4 GB RAM minimum recommended
- Windows® - compatible mouse
- Optional: colour or b/w printer (300 dpi or better recommended)

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1. INTRODUCTION

ABflare, a Refined Model for Evaluating Non-Routine Flaring for Sour Gas Facilities

The Petroleum Technology Alliance of Canada (PTAC) and Alberta Energy Regulator (AER) with guidance from the Canadian Association of Petroleum Producers (CAPP) Non-Routine Flaring Task Team have developed *ABflare* for evaluating non-routine and routine flaring for sour gas facilities. This User Guide is for the *ABflare* modelling spreadsheet and associated modules. The User Guide outlines how to install the files, use the model and provides examples on the use of the model.

The *ABflare* model is an extension of the *AERflare* model. The user must have a good understanding of the *AERflare* and *CALPUFF* model user guides before proceeding with the *ABflare* model. The *ABflare* user guide only discusses *AERflare* inputs as necessary or relevant to the *ABflare* model, otherwise the user is directed to the *AERflare* user guide (AER 2014).

AERflare : is an AER spreadsheet tool for the assessment of non-routine flaring using screening to refined methods using the *AERMOD* air quality dispersion model

ABflare : is an AER spreadsheet tool for the assessment of non-routine flaring using refined methods using the *CALPUFF* air quality dispersion model.

The *ABflare* model documentation is comprised of several components that are described in the following table.

Module	Description
<i>ABflareUI.xlsm</i>	a Microsoft®-Excel (Office 2010) application software for Windows® containing macros and a user interface to external calculation modules.
<i>ABflare.exe</i>	a stand-alone FORTRAN coded program that creates a time varying flare source input file for CALPUFF based upon user inputs from <i>ABflare.xlsm</i> .
<i>CALPUFF.exe</i>	a stand-alone FORTRAN coded program that has been modified to accept a new time varying flare source.
<i>METSERIES.exe</i>	a stand-alone FORTRAN coded program that has been modified to output variables required by <i>ABflare.xlsm</i> .

<i>CALAVE.exe</i>	a stand-alone FORTRAN coded program that is used to post-process CALPUFF binary output files and write a time averaged binary file.
<i>CALMAX.exe</i>	a stand-alone FORTRAN coded program that is used to post-process CALPUFF binary output files combining several files into a single binary file that is the maximum of input files at each time step.
<i>CALRANK.exe</i>	a stand-alone FORTRAN coded program that is used to post-process CALPUFF binary output files calculating statistics at each receptor point such the n th highest concentration or a percentile value.
Examples	Ex1 - A test case that demonstrates some of the features of the <i>ABflare</i> model and comparison to monitoring results. Ex2 - A test case that demonstrates features of the <i>ABflare</i> model.
User Guide Version 1.01.pdf	this User Guide.
Source Code	source code is provided for each of the stand-alone programs.

All of these documents and programs are available as a single download from the AER website. For the latest updates visit the AER website (see Directive 060):

<http://www.aer.ca/rules-and-regulations/directives/>

Also required is the *CALPUFF* air dispersion model. The *CALPUFF* source code, documentation and executable files are available at the U.S. EPA Technology Transfer Network website:

[/http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#calpuff](http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#calpuff)

User Qualifications

ABflare is freely distributed to assist in D060 temporary flaring permitting, non-routine and routine flaring air dispersion modelling within Alberta. *ABflare* performs both screening level calculations (uses only a few user inputs to create a realistic and conservative estimate of flare emissions and concentrations) and also refined level calculations. Although relatively few inputs are required through the interface, it is a complex tool. *ABflare* requires inputs that may require sound engineering judgement or other technical expertise. It uses site-specific thermodynamics, fluid dynamics, and air dispersion modelling. Flare dispersion

assessment is a multidisciplinary and iterative task with many assumptions and judgments.

The *ABflare* and *AERflare* models were created so that a minimal amount of technical background is required to run the models. However, there remains some technical knowledge required to supply suitable inputs and the ability to understand whether the output is appropriate for the inputs and meets the needs of stakeholders. The user must recognise that the models are technical in nature and the correct interpretation of the result may require technical expertise that proceeds from consequences of the inputs. In any modelling assessment, high quality input data is very important.

The model has been created with a professional commitment to environmental protection and safeguarding the well-being of the public. It is the responsibility of the software user to accept and continue this commitment in their application of the software. The software is supplied as a tool to assist the user to comply with applicable statutes, regulations and bylaws. Neither the software nor application of the software is intended to replace statutes, regulations or bylaws.

Suitable Technical Background

Environmental issues are interdisciplinary in nature. The practice of environmental science requires the integration of diverse disciplines and philosophies; many projects will require a team of appropriate specialists to address complex environmental issues. Persons doing the assessment should undertake only that aspect of environmental work that they are competent to perform by virtue of training and experience. Thus they should seek out and use appropriate Environmental Specialists to provide expert advice on certain environmental issues.

The basis of the models is technical with expertise required in chemistry, thermodynamics, atmospheric physics, meteorological processes, industrial processes and regulatory affairs. While the full technical background is not a requirement to execute the models, the user of the software is required to have a general engineering and environmental science background; a general knowledge of the emission sources: wells, pipelines, and pipeline networks; and a working knowledge of the most current version of:

- *AER Directive 060* –
- Alberta ESRD Air Quality Model Guideline and Non-Routine Flaring Management: Model Guidance.
- *CALPUFF/CALMET* user guides



There are many technical inputs required by *ABflare* to perform the calculations. Some have been prescribed by as mandatory default entries. Others are input by the user for the specific flaring scenario. Use of *ABflare* and understanding whether the predictions are appropriate for the user inputs still, however, requires some specific technical understanding.

How this Document is Organized

This User Guide is organized as both an instructional guide and a tutorial. This guide is divided into the following chapters:

Chapter	Description
1 Introduction	Backgrounder for <i>ABflare</i>
2 Installation and Setup	How to install the <i>ABflare</i> program
3 Program Operation	Description of the program prompts and user entries, and description of the program output calculations and graphics
4 Example 1	Tutorial of a well test flare in complex terrain
5 Example 2	Tutorial of a user defined flare rate
6 Example 3	Tutorial of a vessel/pipeline blowdown

About this Guide

The following symbols and conventions are used in this guide

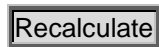
Bold Used for menu, command, and keyboard selections you make and screens you will see.

Italics Used for emphasis and to identify new terms.

text User typed responses or entries.

variable A named variable that is used in the spreadsheet to reference a cell location, equation variable or specific technical term.

PAGE A worksheet page name.



A spreadsheet button that is pressed to start a calculation or process.



Helpful information about a particular topic.



Important information to prevent problems and ensure that you are successful in using the software.

[link](#)

A hyperlink to a section within the User Guide, an internet web site or email address.

Where to Go for Help

AER welcomes your feedback. Comments on the current version, suggestions for features in future versions, or bug reports in the User Guide or *AERflare* software can be submitted to the email below. Please provide information on the version of Windows you are using, version of Excel, and enough information to duplicate the issue. Thank you.

Directive060Inbox@aer.ca

What is *ABflare* all about?

The *ABflare* spreadsheet tool was created to provide consistency in the calculation of flare-type source parameters for use with standard air quality dispersion models that are based upon chimney-type sources parameters. The basic premise of *ABflare* is to determine the momentum and energy released during a flaring event; this energy is released to the atmosphere giving buoyancy and momentum plume rise for the flare-type source. *ABflare* then uses the buoyancy and momentum energy and back-calculates chimney-type equivalent source parameters that can be used as inputs in typical air dispersion models. These parameters are the height, diameter, velocity and temperature of the source. The equivalent source parameters are frequently called pseudo-parameters. The parameters are called pseudo-parameters because they are not real-world dimensions, but only calculated inputs that represent the flare-type source so that the correct plume

height is used in the standard dispersion model. Standard dispersion models determine the plume rise based upon the calculation of buoyancy and momentum from the entered chimney source parameters (height, diameter, velocity and temperature).

Flaring can be loosely divided into three types: continuous, short-term steady and transient. Continuous flaring is flaring when the emissions occur hour after hour for long periods of time (weeks, months or years). The flared gas for continuous emissions can vary from zero flow rates, to low flow rates and to high flow rates over the course of the flare duration. Short-term steady flaring is similar to continuous flaring but flaring occurs only for prescribed period of time. Transient flaring is similar to short-term steady flaring where the flare is operated for a prescribed period of time, but the flow rate to the flare originates from a high pressure blow down resulting in a scientifically well-defined change in flow rates from very high to low over a specific period of time. In each of the flare types, it is important to examine the range of low flow rates to high flow rates and the pollutants released during these periods. Low flow rates are associated with low plume rise and high flow rates are associated with higher plume rise.

From a regulatory standpoint, flaring is divided into two broad categories: continuous (including short-term steady) flaring for routine operations; and, non-routine flaring (including short-term steady and transient flaring). Non-routine flaring has special regulations because it is associated with specific disposal of large amounts of gas and typically high pollutant emissions. Non-routine flaring is divided into two categories: planned flaring (including well test flaring, maintenance and turn-around operations); and, unplanned flaring (including upsets and emergency flaring). The distinction between routine, non-routine (planned) and non-routine (unplanned) is the frequency of the flaring events and the inherent risk to environmental harm (consequence). Planned non-routine flaring from temporary flares requires a permit from the AER.

ERCBflare version 1.x was originally created to specifically address the concerns related to the applications to AER for non-routine flaring associated with well test flaring. Because non-routine flaring events are often associated high energy and high levels of pollutant emissions, it was necessary to update the calculation tool to incorporate the more complex source conditions demanded by industry users, operations and high impact but low risk predictions. *AERflare* version 2.x was created to specifically address these complex questions and therefore *AERflare* is inherently more complex than its predecessors (*ERCBflare* version 1.x and ESRD flare tool). An important change also included in the *AERflare* 2.x is the updated air quality dispersion model used to predict environmental harm (*AERMOD*), and it too is more complex than its relatively simplistic predecessor (*SCREEN3*) used in *ERCBflare* version 1.x. *ABflare* was created for refined air dispersion modelling using the *CALPUFF* model.

The purpose of *ABflare* version 1.x is to provide a relatively easy-to-use user interface tool to assist the user in the complex analysis of routine and non-routine

flaring. The goal of *AERflare* is to predict a rapid (within minutes), conservative estimate of flaring impacts. It also provides next-step analyses methods to bridge the gap between rapid screening analysis and full-refined air quality dispersion modelling. The modelling associated with *ABflare* is not rapid since many of the steps associated with refined air dispersion modelling with the *CALPUFF-CALMET* system are complex or time-consuming to perform.

2. INSTALLATION AND SETUP

This chapter describes how to install the *ABflare* software. *ABflare* modelling package includes a user interface (a Microsoft[®]-*Excel* Office 2013 spreadsheet) that assists the user in creating input files to the various included stand-alone programs.



Microsoft Excel must be installed on your computer in order to use the *ABflare* tool.

Recommended version for *ABflare* are Office 2010 and Office 2013.

Overview of the Installation Process

If you have not already done so, download the installation software from the AER website (see below).

The single install ZIP file contains all of the software required for the *ABflare* program to run within the users existing Microsoft Office (including Excel) environment.

STEP 1: The *ABflare* tool is packaged as a downloadable ZIP file which the user can unpack to form a folder tree and access directly. Download the file *ABflare* package from:

<http://www.aer.ca/rules-and-regulations/directives/>

There are two download files provided

File	Intent	Recommended Download Destination Folder
ABlare_vxxxxxx.zip	Required	c:\myfiles\AERmodels\ABflare\
ABlare_UserGuide_vxxxxxx.pdf	Required	c:\myfiles\AERmodels\ABlare\docs\

The *ABflare_vxxxxxx.zip* file contains the necessary user-interface and example files. It is recommended that the users download and read this user guide for *ABflare*.



The files may be installed to the user's choice of alternate folder locations during the installation. The **iBIN** page within *ABflare* is used to locate the required file locations.

STEP 2: Using the Windows explorer (Windows Key + e) locate the *ABflare_vxxxxx.zip* file that you downloaded in **STEP 1**. Right click on the file and select 'unzip to here' (if you have the WINZIP utility) or 'unpack' (if you are using the embedded unzip functionality within Windows). The following folders and files will be created (where [mydir] is the folder used in **STEP 1**):

[mydir]ABflareUI_vxxxxx.xlsm	The <i>ABflare</i> user interface spreadsheet tool
[mydir]bin\	A convenient location to place the run-time files for <i>ABflare</i> operation
[mydir]bin\ABflare.exe	The <i>ABflare_vxxxxx.exe</i> accompaniment run-time file
[mydir]bin\calave.exe	The CALAVE run-time file
[mydir]bin\calmax.exe	The CALMAX run-time file
[mydir]bin\calrank.exe	The CALRANK run-time file
[mydir]utils\CALAVE_vxxxxx.zip	CALAVE utility source code and run-time file
[mydir]utils\CALMAX_vxxxxx.zip	CALMAX utility source code and run-time file
[mydir]utils\CALPUFF_Flare_Patch.zip	CALPUFF model source code changes and utility to modify the CALPUFF source code
[mydir]utils\CALRANK_vxxxxx.zip	CALRANK utility source code and run-time file
[mydir]utils\FLEMARB_example.zip	FLEMARB (FLare EMISSIONS ARbitrary) input file example
[mydir]utils\METSERIES_Flare_patch.zip	METSERIES model source code changes and utility to modify the METSERIES source code
[mydir]utils\TestCase.zip	Utility test case and example files
[mydir]examples\	<i>ABflare</i> spreadsheet tool example files
[mydir]metfiles\test_AERflare\ (aermod.sfc; aermod.pfl)	This folder contains an example site specific meteorological file. There is a *.SFC and *.PFL file representing an AERMOD ready surface and profile meteorology file, respectively



The program (*.exe) files may be installed to alternate folder locations



The *CALPUFF* and *METSERIES* developments are distributed in the form of a software patch the original code which changes the publicly-available official *CALPUFF* v6.42 and *METSERIES* v1.81, creating *CALPUFF* v6.42FL and *METSERIES* v1.81FL respectively.



The user must have a FORTRAN compiler to create an executable from the patched code.

Acquiring the default CALPUFF v6.42

The *CALPUFF* model is required for normal operation of *ABflare*. The *CALPUFF* modelling system is used in standard form as downloaded (see next steps) and as patched for *CALPUFF.exe* and *METSERIES.exe* (see following sections). The standard download provides *CALMET.exe*, *MAKEGEO.exe* and *TERREL.exe* which are included as part of the *CALPUFF* end-user agreement. The *CALPUFF.exe* and *METSERIES.exe*, however, have to be modified to work with the advanced capabilities of *ABflare*.

1. Using your internet browser, navigate to the web-site below to download the *CALPUFF* v.6.42 source code.

<http://www.src.com/calpuff/calpuff1.htm>

Click on the link for Download. You must agree to the (no cost) End-user License Agreement by pressing I Agree. You will be presented with an option to register, you can press Skip Registration to by-pass the registration and proceed to the download page.

You may optionally install all the *CALPUFF* modelling system using the *CALPRO* installation (**STEP 2**) or install only the components required by *ABflare* (**STEP 3**)

2. Find the link “CALPro_Setup_Version6_20110427.zip”, click the link. Then click on the link Download: CALPro GUI Install - Version 6 to download the file:

http://www.src.com/calpuff/download/Mod6_Files/CALPro_Setup_Version6_20110427.zip

After the file is download, unzip the file and run the included *CALProPlus_setup.exe*. This will create folder and files:
[mylocation]\CALPUFF\CALPRO\
[mylocation]\CALPUFF\CALPRO\

3. Alternatively, scroll down the page and find the link to *CALMET* (Version 6.334 Level 110421). Click on the link and download the file:

http://www.src.com/calpuff/download/Mod6_Files/CALMET_v6.334.zip

Using the Windows explorer (Windows Key + e) locate the *CALMET_v6.334.zip* file that you downloaded. Right click on the file and select ‘unzip to ...’ (if you have the *WINZIP* utility) or ‘unpack’ (if you are using the embedded unzip functionality within Windows). A good location is [mylocation]\CALPUFF\codes\
[mylocation]\CALPUFF\codes\
[mylocation]\CALPUFF\codes\

Repeat the process for *METSERIES* and *TERREL*.

http://www.src.com/calpuff/download/Mod6_Files/METSERIES_v1.81.zip

http://www.src.com/calpuff/download/Mod6_Files/TERREL_v3.69.zip

Creating CALPUFF v6.42FL from CALPUFF v6.42

The *CALPUFF* flare model is distributed in the form of a software patch that will modify the publicly-available code (v.6.42) to a version that includes a new flare source.

1. Using your internet browser, navigate to the web-site below to download the CALPUFF v.6.42 source code.

<http://www.src.com/calpuff/calpuff1.htm>

Click on the link for Download. You must agree to the (no cost) End-user License Agreement by pressing I Agree. You will be presented with an option to register, you can press Skip Registration to by-pass the registration and proceed to the download page.

Scroll down to the section marked “CALPUFF System; Version 6.42”. The patch provided with *ABflare* works with *CALPUFF* – Version 6.42-Level 110325.

Click on Codes & Related Processors to navigate to the specific page with the necessary source code.

Right click on CALPUFF (Version 6.42 (110325)) and Save target as..., to download the file

http://www.src.com/calpuff/download/Mod6_Files/CALPUFF_v6.42.zip

to

```
[mydir]utils\CALPUFF
```

Where [mydir] is the folder location you selected during the initial *ABflare* download.

2. Using the Windows explorer (Windows Key + e) locate the CALPUFF_v6.42.zip file that you downloaded in **STEP 1**. Right click on

the file and select 'unzip to here' (if you have the *WINZIP* utility) or 'unpack' (if you are using the embedded unzip functionality within Windows). The following folders and files will be created (where [mydir] is the folder used in the initial setup:

```
[mydir]\CALPUFF\{readme.txt and example files}
[mydir]\CALPUFF\EMARB_example\{standard CALPUFF
EMARB file examples}
[mydir]\CALPUFF\v6.42\{CALPUFF source code}
```

- Using the Windows explorer (Windows Key + e) locate the CALPUFF_Flare_Patch.zip file that you downloaded in the initial setup. Right click on the file and select 'unzip to here' (if you have the *WINZIP* utility) or 'unpack' (if you are using the embedded unzip functionality within Windows).

The following folder will be created

.\CALPUFF_FLARE_PATCH

which contains a set of 9 ".diff" files PLUS 2 new files

New Files: FLARE.FOR, FL2.PUF

diff Files:

- calpuff.for.diff
- api_chem.puf.diff
- isorropia.puf.diff
- comparm.puf.diff
- dataset.puf.diff
- filnam.puf.diff
- flags.puf.diff
- gridnest.puf.diff
- paramsx.puf.diff

- Copy all of the files to the location of the *CALPUFF* v.6.42 source code in **STEP 2**
- Double-click on the batch file "run_flare_patch.bat".



The "run_flare_patch.bat" may require administration privileges to run on some computer configurations, networks or anti-virus programs. A program "PATCHER.exe" is executed to perform the file changes.



On some computer configurations or network, *PATCHER.exe* may not function with complex folder names. Instead, copy the files to a simple folder (e.g., C:\FIX1\) and repeat the patch process. You may delete the files in C:\FIX1 after the patch process is complete and you have copied the created files as described below.

6. The program `patcher.exe` will update the 9 model code files associated with the ".diff" files identified above and will save the corresponding original files, adding the extension ".orig".

Updated Files: `calpuff.for`
`api_chem.puf`
`isorropia.puf`
`comparm.puf`
`dataset.puf`
`filnam.puf`
`flags.puf`
`gridnest.puf`
`paramsx.puf`

7. Compile *CALPUFF* using a LF95 (Lahey Fortran Version 95) or other FORTRAN compiler. For the LF95 compiler, the command line is:

```
lf95 calpuff.for -o0 -co -out calpuff.exe >cpl.out
```

8. Copy the new *CALPUFF.exe* file and *PARAMS.puf* to the folder below for convenient use in *ABflare*.

```
[mydir]\BIN\
```

Creating METSERIES v1.81FL from METSERIES v1.81

The *CALPUFF* flare model is distributed in the form of a software patch that will modify the publicly-available code (v.6.42) to a version that includes a new flare source.

1. Using your internet browser, navigate to the web-site below to download the METSERIES v.1.81 source code.

<http://www.src.com/calpuff/calpuff1.htm>

Click on the link for Download. You must agree to the (no cost) End-user License Agreement by pressing I Agree. You will be presented with an

option to register, you can press Skip Registration to by-pass the registration and proceed to the download page.

Scroll down to the section marked “CALPUFF System; Version 6.42”. The patch provided with *ABflare* works with *METSERIES* – Version 1.81-Level 110308.

Click on Codes & Related Processors to navigate to the specific page with the necessary source code.

Right click on METSERIES (Version 1.81 (110308)) and Save target as..., to download the file

http://www.src.com/calpuff/download/Mod6_Files/METSERIES_v1.81.zip

to

```
[mydir]utils\CALPUFF
```

Where [mydir] is the folder location you selected during the initial *ABflare* download.

- Using the Windows explorer (Windows Key + e) locate the *METSERIES_v1.81.zip* file that you downloaded in **STEP 1**. Right click on the file and select ‘unzip to *METSERIES*’ (if you have the *WINZIP* utility) or ‘unpack’ (if you are using the embedded unzip functionality within Windows). The following folders and files will be created (where [mydir] is the folder used in the initial setup:

```
[mydir]\METSERIES\{METSERIES source code}
```

- Using the Windows explorer (Windows Key + e) locate the *METSERIES_Flare_Patch.zip* file that you downloaded in the initial setup. Right click on the file and select ‘unzip to here’ (if you have the *WINZIP* utility) or ‘unpack’ (if you are using the embedded unzip functionality within Windows).

The following folder will be created

```
.\METSERIES_FLARE_PATCH  
which contains a set of 4 ".diff" files
```

```
diff Files:          metseries.for.diff  
                   metseries.ser.diff  
                   ctrl.ser.diff  
                   params.ser.diff
```

- Copy all of the files to the location of the *METSERIES* source code in **STEP 2**

5. Double-click on the batch file "run_metseries_patch.bat".



The "run_metseries_patch.bat" may require administration privileges to run on some computer configurations, networks or anti-virus programs. A program "PATCHER.exe" is executed to perform the file changes.



On some computer configurations or network, *PATCHER.exe* may not function with complex folder names. Instead, copy the files to a simple folder (e.g., C:\FIX2\) and repeat the patch process. You may delete the files in C:\FIX2 after the patch process is complete and you have copied the created files as described below.

6. The program patcher.exe will update the 4 model code files associated with the ".diff" files identified above and will save the corresponding original files, adding the extension ".orig".

Updated Files: metseries.for
 params.ser

7. Compile *METSERIES* using a LF95 (Lahey Fortran Version 95) or other FORTRAN compiler. For the LF95 compiler, the command line is:

```
lf95 metseries.for -o0 -trap dio -warn -out  
metseries.exe >cpl.out
```

8. Copy the new *METSERIES.exe* file and *PARAMS.ser* to the folder below for convenient use in *ABflare*.

```
[mydir]\BIN\
```

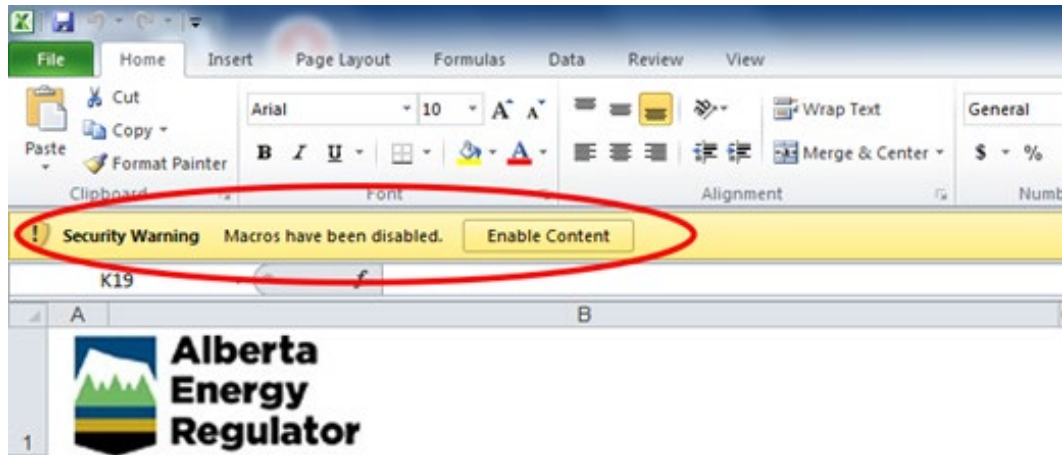
Initial Setup

Now that you are finished installing the *ABflare* spreadsheet tool, you can complete the installation by loading the *ABflare* spreadsheet and following the steps below.

1. From the select Windows *START->Microsoft Office XXXX->Microsoft Excel XXXX*; this will launch Excel. Then using the Excel menu option

File->Open or use the Windows Explorer to navigate to the installation folder for *ABflare* and [mydir] and double-click on the *ABflare_vxxxxx.xlsm* file. This will load the *ABflare* tool into Excel.

2. The *ABflare* spreadsheet is an XLSM file that contains typical spreadsheet-like calculations as well as program macros. This is the “M” part of the “.xlsm” filename extension. When the file is opened, your computer and office security settings may display a warning. Select ‘Trust this document’, ‘Enable Macros for this document’ or ‘Enable Content’ depending on your version of Windows if prompted when the file is opened. Failing to do so will prevent *ABflare* from operating.



3. Click on the **iSTART** page. Select “Show” for the *Hide iBIN Page* option.
4. Click on the **iBIN** page. For the entry for **ABFLARE**, type the full path and file name of the **ABFLARE.exe** file (previously installed). The **Browse...** button can be used to navigate your file folder tree using common Windows Explorer methods.

The files can be placed anywhere on your network. A typical location is:

[mydir]\bin\abflare.exe

5. Repeat the Step 4 process or each of the following run-time executable files required for operation of *ABflare*.

CALPUFF: default : [mydir]\bin\calpuff.exe

METSERIES: default : [mydir]\bin\metseries.exe

CALAVE: default : [mydir]\bin\calave.exe

CALMAX: default : [mydir]\bin\calmax.exe

CALRANK: default : [mydir]\bin\calrank.exe

MAKEGEO: OPTIONAL default :

[CALPUFF\CALPRO]\makegeo.exe

TERREL: OPTIONAL default : [CALPUFF\CALPRO]\terrel.exe

CALMET: OPTIONAL default : [CALPUFF\CALPRO]\calmet.exe

6. If the **BROWSE...** button was used to select the files or the **SAVE** button pressed, then *ABflare* stores the entry for your computer setup. If you load an uninitialized *ABflare* spreadsheet or a spreadsheet initialized to another users folder locations, *ABflare* synchronizes the settings to your computer setup. You have the option of saving the file when you have completed the calculations. You can force *ABflare* to synchronize by pressing the **SYNC** button.
7. Click on the **iSTART** page. Select “Hide” for the *Hide iBIN Page* option. Typically, you shouldn’t have to revisit the **iBIN** page. However, use the **iSTART** page to show the **iBIN** page to make any changes to your system as required.



Select ‘Trust this document’ or ‘Enable Macros for this document’ if prompted when the file is opened. Failing to do so will prevent *ABflare* from operating.



ABflare spreadsheets must be saved as an XLSM file type to preserve the macro (Visual Basic for Applications) functionality.

This completes the mandatory components initialization of the *ABflare*. The user may wish to also initialize several optional components of *ABflare*.

MAKEGEO: On the **iBIN** page, for the row entry for *MAKEGEO*, enter the full path for the location of the *MAKEGEO.exe* file or use the **BROWSE** button to navigate to the installation folder and click on the *MAKEGEO.exe*.

TERREL: On the **iBIN** page, for the row entry for *TERREL*, enter the full path for the location of the *TERREL.exe* file or use the **BROWSE** button to navigate to the installation folder and click on the *TERREL.exe*.

CALMET: On the **iBIN** page, for the row entry for *CALMET*, enter the full path for the location of the *CALMET.exe* file or use the **BROWSE** button to navigate to the installation folder and click on the *CALMET.exe*.

DEMLIB: On the **iBIN** page, for the row entry for **DEMLIB**, enter the full path for the location of where digital elevation files should be stored when downloaded from the internet. **DEMLIB** represents a library or cache to

save time on subsequent analyses to avoid download times. Also, the **DEMLIB** provides a library of files for repeatability of *ABflare* predictions.

LCCLIB: On the **iBIN** page, for the row entry for **LCCLIB**, enter the full path for the location of where land-use classification code (LCC) files should be stored when downloaded from the internet. **LCCLIB** represents a library or cache to save time on subsequent analyses to avoid download times. Also, the **LCCLIB** provides a library of files for repeatability of *ABflare* predictions.

DEMURL: on the **iBIN** page lists the internet URL where DEM files are downloaded from. This entry is not editable.

LCCURL: on the **iBIN** page lists the internet URL where LCC files are downloaded from. This entry is not editable.



It is recommended that you DO NOT continue to use your computer for other concurrent Windows applications because this can cause interference and instability within the calculations.

3. Program Operation

This chapter provides the following information about the general operation of the *ABflare* program:

- what the principal files are and how they work together
- what the buttons/menu items do
- overview of the calculation processes

Introduction

The *ABflare* program uses the familiar Microsoft Excel as host for the calculations. *ABflareUI.xlsm* contains the user-interface for the calculations, allowing the user to input information and view calculation results. The *ABflare* application consists of

- *ABflareUI.xlsm* spreadsheet and
- Related program stand-alone modules:
 - *ABflare.exe*
 - *METSERIES.exe*
 - *CALPUFF.exe*
 - *CALAVE.exe*
 - *CALMAX.exe*
 - *CALRANK.exe*
 - And optional:
 - *MAKEGEO.exe*
 - *TERREL.exe*
 - *CALMET.exe*



The *ABflareUI* spreadsheet is a stand-alone spreadsheet containing all of the necessary macros and programming to load and process input and output from the modules.



ABflareUI.xlsm is an Excel spreadsheet file (.xlsm) containing macros (programming) that acts as a user interface for input files and output from the processing modules.



All inputs and outputs are stored in folders as directed by the user.

User-Interface

Overview – The ABflareUI GUI in Excel

All user input and output are controlled using an *ABflareUI.xlsm* file for Microsoft Excel. The GUI (graphical user interface) file (*abflareui_v1xxxxx.xlsm*) contains several Excel worksheets (**pages**). Each *ABflareUI* module has a separate page. You can change to a page using the mouse by clicking on a tab or using the keyboard using `ctrl+pgup` or `ctrl+pgdn`. The pages are shown in Figure 1 and the figure shows the typical work flow linkages between the worksheets. In general, a user will progress through the pages in sequence, step 1, step 2, etc...

Although the spreadsheet workbook is designed to function like a work-desk to manage the processing flow, the spreadsheet can be copied and saved on a project by project basis, thus archiving the specific inputs used for each project.

The spreadsheet contains a synchronizing control so that all work will use the same **iBIN** folders by default. This feature can be turned on and off.

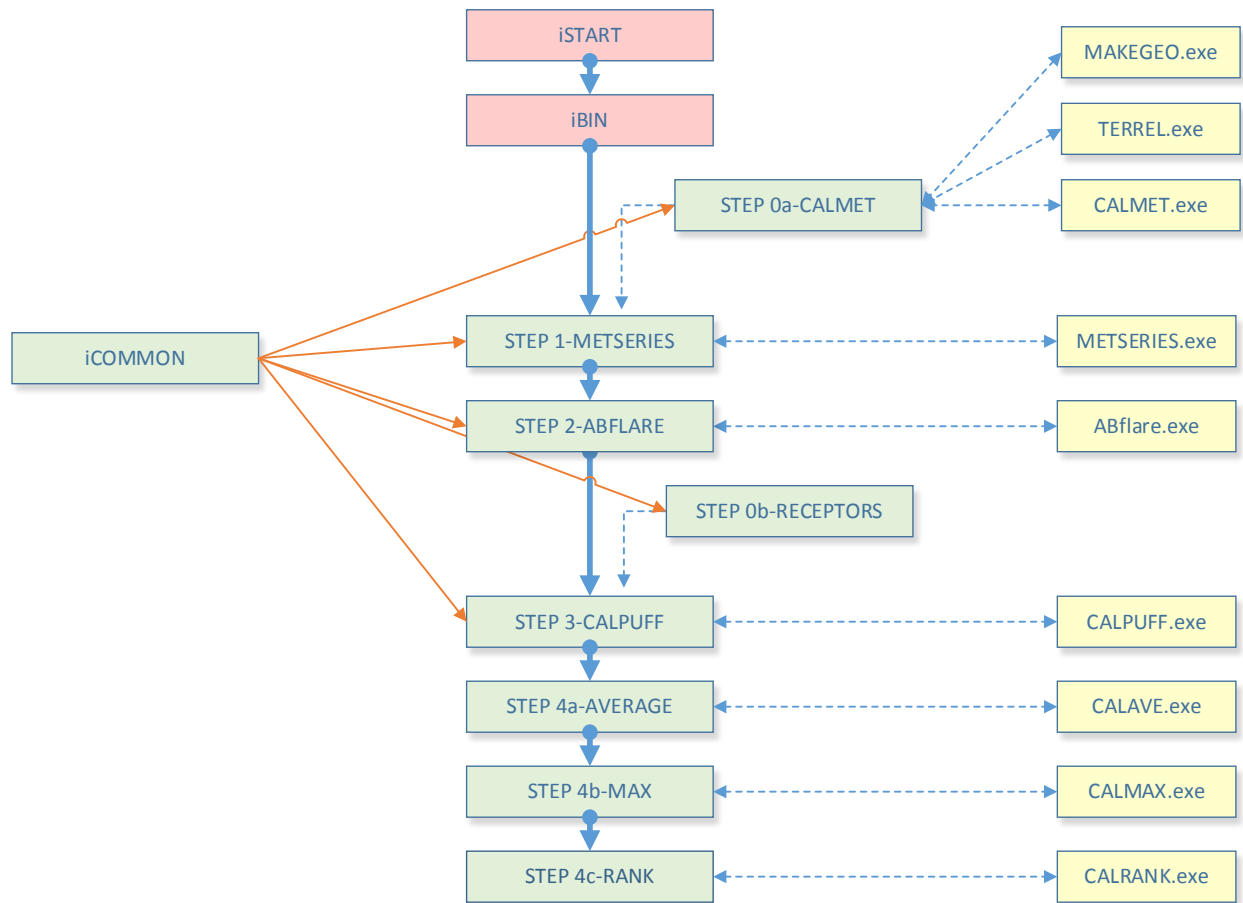


Figure 1: ABflareUI Page Name and Typical Linkage

The ABflareUI Excel Pages

ABflareUI has 11-principal GUI pages in the ABflareUI Excel user interface workbook. Pages for input and output are green while information pages are cyan (coloured tabs on pages are visible for Office 2002 and newer versions of Excel only).



Tabs for the page types are colour coded **for Office 2002 and newer** versions of Excel (earlier versions do not display the page colours).

Input pages are *green* and information pages are *cyan*.

A complete list of user-interface pages are described in the following table:

Page Name	Purpose	Description
ABOUT	User Information	General information and instructions for use of the spreadsheet. Use this sheet to link to the latest information regarding <i>ABflare</i> .
iSTART	User Interface Setup	This page allows the user to configure the <i>ABflare</i> control switches and select which pages to display.
iBIN	User Interface File Locations	The <i>ABflare.xls</i> GUI needs to know where the various post-processing programs have been installed.
iCOMMON	Input Location Setup	This page lists the common settings between the <i>CALPUFF</i> modules related to geographic location.
Step 0a-CALMET	Input Meteorological Processing	Create site specific meteorology.
Step 0b-RECEPTOR	Input Receptor Processing	Create site specific receptor grid.
Step 1-METSERIEIS	Input Meteorology Setup	Create an input file for the <i>METSERIES</i> program to extract meteorological data required by the <i>ABflare</i> program.
Step 2-ABflare	Input Source Setup	Create an input file for the <i>ABflare</i> program to create a time varying flare source input file for use with <i>CALPUFF</i> .
Step 3-CALPUFF	Input Dispersion Modelling	Create an input file for the <i>CALPUFF</i> program to create concentration predictions at each receptor point for a specific time period and meteorological data set.
Step 4a-AVERAGE	Input Post-Processing	Create an input file for the <i>CALAVE</i> program to create a time averaged concentration data file from <i>CALPUFF</i> program output.
Step 4b-MAX	Input Post-Processing	Create an input file for the <i>CALMAX</i> program to combine several <i>CALPUFF</i> output files into a single file representing the maximum concentration at each receptor location at each time increment in the file.
Step 4c-RANK	Input Post-Processing	Create an input file for the <i>CALRANK</i> program to determine n^{th} highest or percentile statistics from <i>CALPUFF</i> output files.
sABFLARE	Settings (Technical)	A list of the <i>ABflare</i> input file switches, settings and documentation of each that is also provided in the input files.
sCALMET	Settings (Technical)	A list of the <i>CALMET</i> input file switches, settings and documentation of each that is also provided in the input files.
sGEO	Settings (Technical)	A list of the <i>MAKEGEO</i> input file switches, settings and documentation of each that is also provided in the input files.
sTERREL	Settings (Technical)	A list of the <i>MAKETERREL</i> input file switches, settings and documentation of each that is also provided in the input files.
sCALPUFF	Settings (Technical)	A list of the <i>CALPUFF</i> input file switches, settings and documentation of each that is also provided in the input files.
sLCC	Settings (Technical)	A list of the Land Classification Characterization of the Bowen ratio, albedo and surface roughness used by <i>CALMET</i> for the land-use classification processing by <i>CALMET</i> to create the site specific meteorological data file.



The pages flagged having a Purpose of (Technical) may be hidden from view using the **iSTART** hide technical pages option. These pages are not required for routine modelling.

The *ABflare* Calculation Process

Calculations are directed by user entry and selections in the *ABflareUI.xlsm* spreadsheet file. The *ABflare.xlsm* spreadsheet does not perform any calculations; calculations are performed in the stand-alone modules. The modelling system is described in Figure 3. The green shaded area of Figure 3 represents the *ABflare* modelling system described in this user guide. The *AERflare* screening tool is the logical first step non-routine and routine flare modelling. The *ABflareUI.xlsm* can read the inputs already entered into *AERflare.xlsm* rather than the user having to re-enter the data. It is not necessary to run the *AERflare.xlsm* model before running *ABflare.xlsm* nor are any outputs from *AERflare.xlsm* used or required by *ABflareUI.xlsm*.

As will be described in more detail in the following pages, the *ABflareUI* workbook has been designed to work with an existing modelling assessment (i.e., some of the *CALPUFF* system modules have already been created) or to start a project from scratch. While the *ABflareUI* workbook provides for many detailed settings for the *CALPUFF* modelling system, *ABflare* is designed as a broad brush approach and specifically geared towards modelling of flares. More specific air quality model configuration tools may be found within the *CALPUFF* modelling system, such as the *CalPro* interface.

The simplified interaction of the *ABflare* calculation process with the common modelling tools is shown in Figure 2. The air quality dispersion assessment of non-routine or routine flaring can start with a screening assessment using *AERflare*. If the terrain is very complex surrounding the flare site or other more refined modelling is required, the *ABflareUI* tool can be used and the basic inputs can be copied from the *AERflare* tool. A second basic input required by *ABflare* is meteorology. The required meteorology can be a low-level 3D.dat file extracted from the AESRD MM5 data or a *CALMET* output file (met.dat). Optionally, a receptor grid (with x,y locations and terrain elevations), and pre-processed land-use data (LU.dat) can be used or created by *ABflare*. The output from the *ABflare* calculations can be further analyzed using Excel spreadsheets or graphics packages such as Golden Software's Surfer (not included in the *ABflare* system). The *ABflare* program will also allow a user to make use of *AERMOD* ready meteorological files. In this latter case, *ABflare* would be configured to read an *AERMET* surface file (*AERMET.sfc*) and control settings would be selected to create a source file for *AERMOD* rather than *CALPUFF*. *ABflare* does not run *AERMOD* nor post process *AERMOD* output.

The *ABflare* calculations are two-way, that is the user input directs calculations which are then post-processed and the module output list file is displayed to the user. The user should read the list files provided and check for error or warning messages. The final output from *ABflare* requires the user to post-process the results to view, map and interpret the results using third-party software or Excel basic functionality.

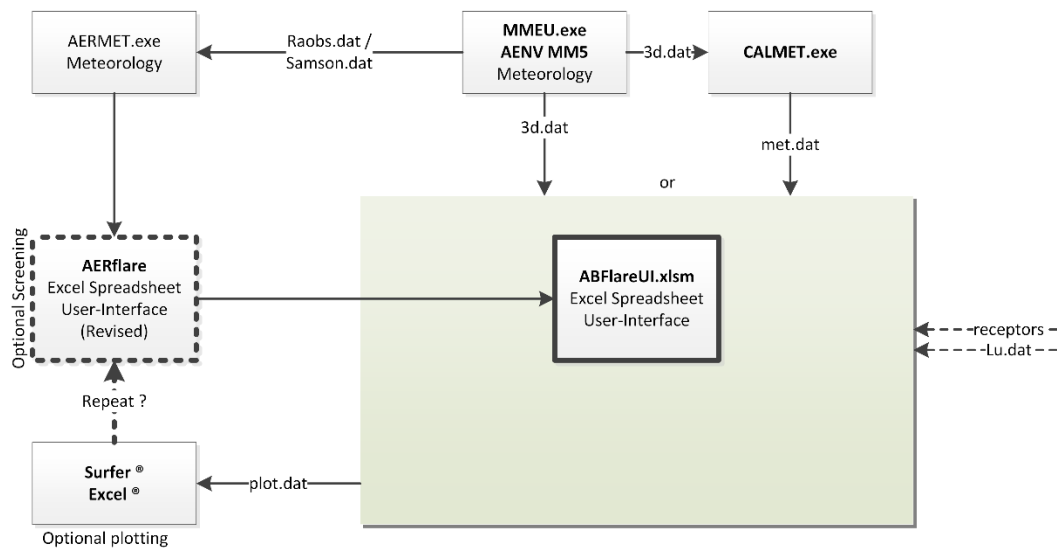


Figure 2: ABflare Simplified Calculation Process

The calculation process in more detail is shown in Figure 3 showing the individual modules. The *ABflare* Spreadsheet can be used to read and write the control input files for a wide variety of the *CALPUFF* modelling system modules. Starting from scratch, *ABflare* can be used to create and run *CALMET* meteorology by first creating land use characterization using *MAKEGEO.exe* and terrain processing using *TERREL.exe*. The *METSERIES.exe* module is required to create a time series meteorology file at flare stack height at the location of the flare. The meteorology input file (*met.dat*) can be either created internally to the *ABflare* system, or it can be an existing file created by the user external to the *ABflare* modelling system. Using the meteorological time series file (*met.tsf*) the *ABFLARE.exe* module is used to create a time varying source file (*flr.dat*) that describes the flare height, diameter, temperature, location and emissions as a function of time. The flare source file is used by *CALPUFF.exe* to define the source conditions and *CALPUFF.exe* creates binary output files that may require post processing to form a variety of time averages or to extract statistics of interest (for example, the 99th percentile value at each receptor location). Three post-processing modules can be used. *CALAVE.exe* is used to create time averaged concentration files similar to *CALPUFF* output files. *CALMAX.exe* is used to merge multiple run output files into a single output file. The maximum concentration for an averaging period from the listed input files is determined and a single *CALPUFF* like binary output file is created. *CALRANK.exe* is used to determine nth highest or percentile concentrations at each receptor location.

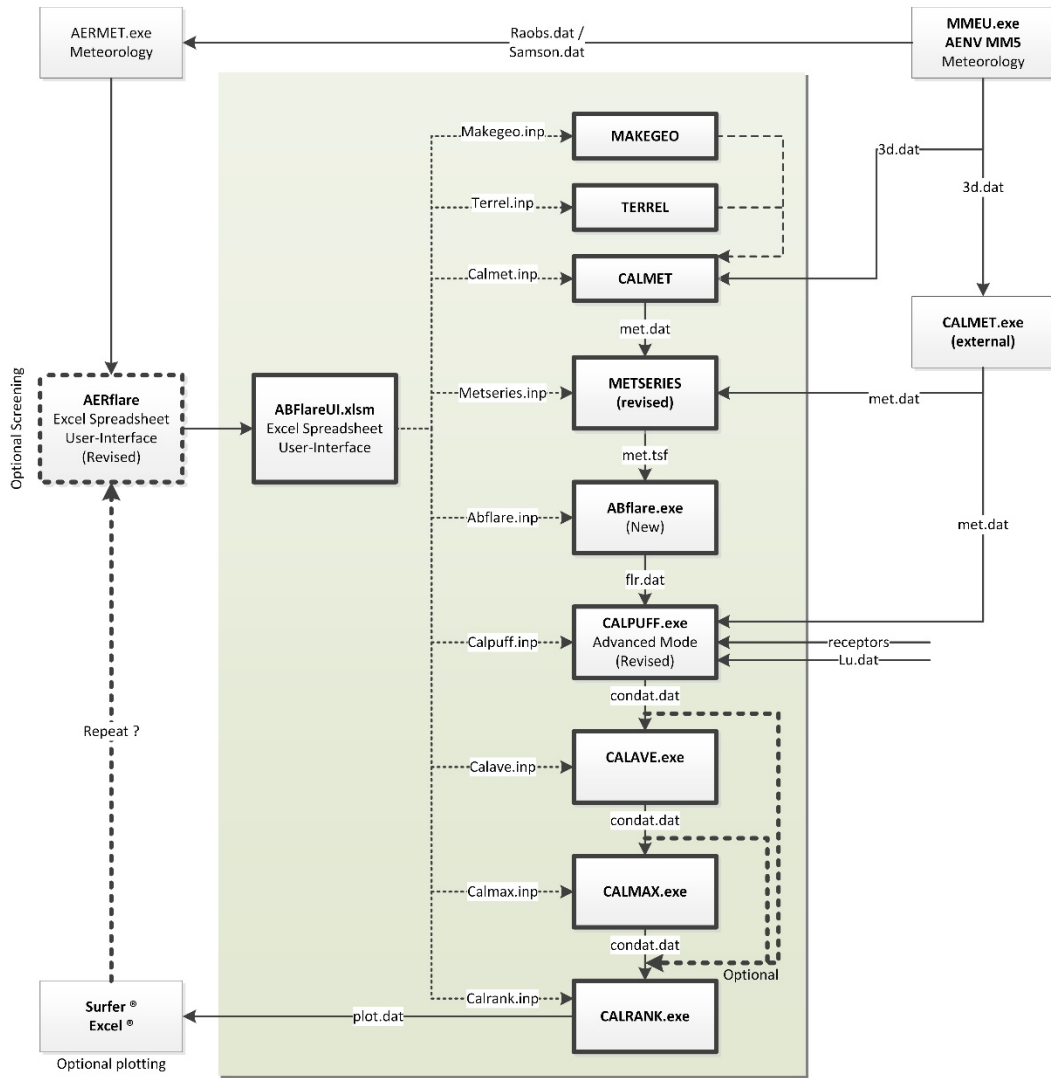


Figure 3: Schematic of ABflare Calculation Process

iSTART

The **iSTART** page fundamental entries are illustrated in the figure below. These options specify cosmetic or convenience modes (i.e., hide or don't hide technical information) but also control switches for how the calculations are to be performed.

Hide Technical Pages	<input checked="" type="radio"/> Hide	<input type="radio"/> Show
Hide iBIN Page	<input type="radio"/> Hide	<input checked="" type="radio"/> Show

Hide Technical Pages

The hide technical pages option is cosmetic for *ABflareUI* operations. Hide technical toggles the visibility of default settings pages for **sABFLARE**, **sCALMET**, **sGEO**, **sSTERREL**, **sCALPUFF** and **sLCC**.

Hide iBIN page

The hide **iBIN** page option is cosmetic for *ABflareUI* options. Hide **iBIN** is used to toggle the visibility of the **iBIN** page. Once the *ABflare* spreadsheet has been configured, typically operations will not require the **iBIN** page (see Chapter 2: Installation and Setup) and it can be hidden from view.

Advanced Switches

The advanced switches are useful for advanced users for debugging and for other automation links. The advanced switch block is shown in the figure below. The **Defaults** are shown and the user can over-ride the default by entering a value in the **Inputs** column. Entries different than the default are highlighted for convenience. In the example below, **mpause** switch is set to YES, and **mbatonly** is set to YES, whereas their default settings are both NO.

Advanced Technical Switches				
Description	Variable	Units	Inputs	Default
DEM always download files (1-Yes, 0-No)	mdemget	--	0	0
LCC always download files (1-Yes, 0-No)	mlccget	--	0	0
Minimize run window (1-Yes, 0-No)	mhide	--	1	1
Insert PAUSE at the end of a Batch file (1-Yes, 0-No)	mpause	--	1	0
Creates a batch file to be used at a later time (1-Yes, 0-No)	mbatonly	--	1	0
Synchronize settings between spreadsheets (1-Yes, 0-No)	msync	--	0	0

When an advanced setting has been selected the output pages are embossed with a warning message to notify the user. For example, the message below was created when two of the advanced settings were used.

ABFLARE Ver 1.01

RECEPTOR
USER TERRAIN DEVELOPMENT INPUT

2 ADVANCED SETTINGS

Step 1 Define Receptor Grid REFRESH

1.1	Press 'REFRESH' button on this page (see right)
1.2	Adjust the Receptor Grid Spacing. The Default entries represent the Air Quality Modelling Guideline recommended resolution

MDEMGET

The `mdemget` setting is used to force *ABflareUI* to download digital terrain data without first looking within the saved library. This switch can be used to ensure that the most up-to-date data is being used in the analysis at the expense of repeated down load time. It is recommended that this setting is set to “0” to not automatically download. For repeatability of the assessment it is recommended that a Library be created. Updates, when available from the download site, can be included by starting a new library periodically.

MLCCGET

Similar to the `mdemget` option, the `mlccget` setting is used to force *ABflareUI* to download land classification data without first looking within the saved library. This switch can be used to ensure that the most up-to-date data is being used in the analysis at the expense of repeated down load time. It is recommended that this setting is set to “0” to not automatically download. For repeatability of the assessment it is recommended that a Library be created. Updates, when available from the download site, can be included by starting a new library periodically.

MHIDE

The `mhide` setting is used to control the display of the run thread window to be minimized or not minimized. When `mhide=1`, the runtime window containing the execution of the respective model (e.g., *CALMET.exe*) will be minimized to the Windows task bar. When `mhide=0`, the window remains at its default size. During run time, the user can minimize or maximize the run time window and watch the progress of calculations.

MPAUSE

ABflareUI creates a synchronous secondary process using the command prompt. By default *ABflare* minimizes the command prompt to the task bar as a reference during the air dispersion modelling. The command prompt window is closed automatically after execution of a module (e.g., *CALAVE.exe*) and control is returned to *ABflareUI* calculation process. For debugging, a PAUSE statement can be added to the `RUN.bat` file to force the user to look at the command prompt window and enter an acknowledgment to proceed. Select `mpause=1` to include the PAUSE statement. The `mruntimebat=1` option should also be set to force the `RUN.BAT` file to be re-written.

MBATONLY

The **mbatonly** switch is used during the operation of **Step 0a-CALMET** and **Step 3-CALPUFF** calculations. When the user presses the **Run** button on these pages, a batch file will be created rather than actually running *CALMET.exe* or *CALPUFF.exe*. Because both these programs are numerically intensive and may require a significant time period to run, the batch file option can be used to defer the run to later more convenient time (i.e., overnight), run on an alternate machine, or can be edited and run on several different machines.

MSYNC

This switch is used to turn on or off the automatic synchronizing of the settings on the **iBIN** page. Setting **msync=0**, turns off synchronizing. With **msync=0**, when the *ABflareUI* spreadsheet opens it does not reset the spreadsheet values to the saved system values. Similarly, with **msync=0**, when files or folders are specified on the **iBIN** page, they are not saved to the system for later recall.

Non-Default Settings

The non-default settings are useful for advanced users for non-routine assessments and further analysis. The non-default settings block is shown in the figure below. The **Defaults** are shown and the user can over-ride the default by entering a value in the **Inputs** column. Entries different than the default are highlighted for convenience. The *ABflareUI* pages are highlighted with a warning flag specifying the number of non-default setting entries that have been used.

Description	Variable	Units	Inputs	Default
Modelling domain for receptor grid	rmaxdist	m	10000	10000
Modelling domain buffer beyond receptor grid	dombuf	m	5000	5000
Meteorological domain grid resolution	dgrid	m	250	250
LCC subsampling	lccsample	--	3	3
Receptor Resolution for Maximum Concentration	D _{min}	m	20	20

RMAXDIST

RMAXDIST is the size of the *CALPUFF* modelling domain measured from the flare source location. Therefore, **RMAXDIST** represents a radial distance. The default distance is **RMAXDIST=10 km**.

DOMBUF

The **DOMBUF** setting is the domain buffer added to **RMAXDIST** in which to model the meteorology. The **DOMBUF** should allow for terrain elevations that may impact the air patterns and hence the air dispersion modelling within the **RMAXDIST** modelling domain. The **DOMBUF** should also allow for the possibility of flow reversals. The default buffer size is **DOMBUF**=5 km. The default meteorological domain size is therefore,

$$\mathbf{RMAXDIST} + \mathbf{DOMBUF} = 15000 \text{ m (or 15 km)}$$

DGRID

The *CALPUFF/CALMET* modelling domain is divided into grid cells. Within each grid cell, the meteorological parameters will be calculated by *CALMET* and will vary in three dimensions from the adjacent cells. In *CALPUFF*, the meteorological conditions in each grid cell are used to determine the air dispersion for each incremental puff as it advects throughout the domain. The size of the grid cell should reflect the terrain elevation changes. The selection of **XORIGKM** and **YORIGKM** (see **iCOMMON**) should take into account the **DGRID** entry from **iSTART**. If **DGRID** is large compared to terrain features, terrain influences on the meteorology can be averaged or shifted and thus may strongly impact the air dispersion predictions.


LCCSUBSAMPLE

The **LCCSUBSAMPLE** setting is used to control the number of land-use LCC sub-samples used in the LCC processing of each grid cell. The default setting is **LCCSUBSAMPLE**=3 which divides each grid cell into 3 regions both vertically and horizontally. Therefore, the LCC shape file polygons are sampled 9-times for each grid cell to characterize the land-use. For a **DGRID**=250 m the **LCCSUBSAMPLE**=3 setting will sample land-use every 80 m. Reducing **LCCSUBSAMPLE**=1 (one sample per grid cell) causes the division of the grid cell coarser and the representation of the land-use for each grid cell will be less representative of the area while reducing the computational effort to characterize the grid cell. Similarly, increasing **LCCSUBSAMPLE**=5 (25 samples per grid cell) causes the grid cells to be divided into small sub-areas and may better characterize the grid cell land-use at the expense of computational effort.

DXMIN

The **DXMIN** setting is used to define the minimum receptor distance along the fenceline according to the AQMG. The default setting is **DXMIN**=20 m.

iBIN PAGE

The **iBIN** page is used to record the folder location and executable names of the binaries for each of the modules listed. The  browse buttons can be used to navigate the folder tree(s) to locate each of the files. Once the values have been set, they are copied to the computer system registry so that if the user uses multiple version of the *ABflareUI.xlsm* spreadsheet, all spreadsheets on the user's computer will synchronize to the same binaries when the spreadsheet opens.

Location of Executables		
BIN	FULL PATH	BROWSE
ABFLARE	O:\Fortran\ABflare\ABflare\Debug\ABflare.exe	file
CALPUFF	P:\ABflare\release130114\ABflare_v130114\BIN\calpuff.exe	file
METSERIES	P:\ABflare\release130114\ABflare_v130114\BIN\metseries.exe	file
CALAVE	P:\ABflare\release130114\ABflare_v130114\BIN\calave.exe	file
CALMAX	P:\ABflare\release130114\ABflare_v130114\BIN\calmax.exe	file
CALRANK	P:\ABflare\release130114\ABflare_v130114\BIN\calrank.exe	file
MAKEGEO	O:\CALPUFF\CALPro\MAKEGEO.EXE	file
TERREL	O:\CALPUFF\CALPro\TERREL.EXE	file
CALMET	O:\CALPUFF\calmetl.exe	file
DEMLIB	P:\2011\1100500-FlareModel\DEMLib\	folder
LCCLIB	P:\2011\1100500-FlareModel\LCCLib\	folder
DEMURL	ftp://ftp2.cits.mcan.gc.ca/pub/geobase/official/cded/50k_dem/	Do not edit
LCCURL	ftp://ftp2.cits.mcan.gc.ca/pub/geobase/official/lcc2000v_csc2000v/shp_en/	Do not edit

Most of the entries refer to a specific file, while **DEMLIB** and **LCCLIB** refer to the base of the folder tree to be used to collect and store DEM and LCC files.

During normal operation of *ABflareUI*, DEM or LCC files will be required to characterize land heights (DEM files) or land-use (LCC files). The data for these are down loaded from free websites for Canadian locations in a specific format(s). *ABflareUI* will download DEM or LCC files if not found within the **DEMLIB** or **LCCLIB** folder tree. The user can download all the files for a large region using an FTP client software and storing the 1:50,000 scale maps in the proper tree structure. Thus all the necessary files are available off-line at any time. Or the user, can incrementally build the library as required. Both have advantages and disadvantages. Forcing *ABflareUI* to download each time makes *ABflareUI* use the most recently available data, whereas using the off-library only makes modelling runs consistent between projects. See also the settings for **mdemget** and **mlccget** on the **iSTART** page.

iCOMMON Page

The **iCOMMON** page is used to specify the domain location information. This information is common to several modules of the *CALPUFF* modelling system.

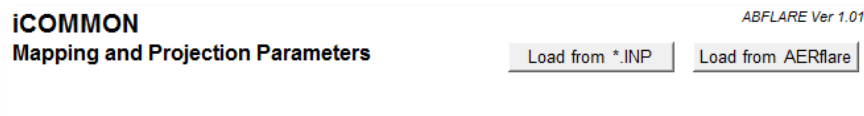
The mapping and projection inputs are listed in the table below. These inputs mirror the inputs required for the mapping and projection inputs for *CALMET* and *CALPUFF*. The most convenient and therefore the most common input projection is **PMAP=UTM** coordinates. If the UTM projection is selected, then **FEAST**, **FNORTH**, **RLAT0**, **RLON0**, are not required and may be left blank.

For consistency and ease of entry between different modelling input files, a browse button has been added to the right of **FEAST** and **FNORTH**. Use the browse button to load the inputs you may have already entered for the creation of a *CALMET* or *CALPUFF* file. The *CALMET* or *CALPUFF* file must exist. The mapping and projection group entries are read from the *CALMET* or *CALPUFF* file and loaded into the *ABflare* input group.

Dropdown list selection boxes are provided for **PMAP** and **DATUM** entries to prevent user entry errors. Select the projection and map data datum used from the list of recognized entries.

VARIABLE	INPUT	DESCRIPTION
PMAP	UTM	Map projection, see list to right UTM ▼
FEAST	0	False Easting and Northing (km) at the projection origin (Used only if PMAP= TTM, LCC, or LAZA)
FNORTH	0	False Easting and Northing (km) at the projection origin (Used only if PMAP= TTM, LCC, or LAZA)
IUTMZN	11	UTM zone (1 to 60) (Used only if PMAP=UTM)
UTMHEM	N	Hemisphere for UTM projection? (N or S) (Used only if PMAP=UTM)
RLAT0	0N	Latitude and Longitude (decimal degrees) of projection origin (Used only if PMAP= TTM, LCC, PS, EM, or LAZA) e.g., RLAT0=60N, RLON0=115W
RLON0	0E	Longitude and Latitude (decimal degrees) of projection origin (Used only if PMAP= TTM, LCC, PS, EM, or LAZA) e.g., RLAT0=60N, RLON0=115W
XLAT1	0N	Matching parallel(s) of latitude (decimal degrees) for projection (Used only if PMAP= LCC or PS)
XLAT2	0N	Matching parallel(s) of latitude (decimal degrees) for projection (Used only if PMAP= LCC or PS)
DATUM	NAR-B	Datum-region for output coordinates, see list to right NAR-B ▼
UNITS	KM	m or km
ABTZ	UTC-0700	UTC time zone for output PST = UTC-0800, MST = UTC-0700
NX	120	No. X grid cells
NY	120	No. Y grid cells
DGRIDKM	0.25	Grid spacing
XORIGKM	481	X Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)
YORIGKM	6176	Y Coordinate, Reference grid coordinate of SOUTHWEST corner of grid cell (1,1)

In the upper right of the **iCONTROL** page there is a **Load from AERflare** button and a **Load from *.INP** browse button. **Load from AERflare** is used to load an *AERflare* spreadsheet and extract location information from a screening assessment already completed. **Load from *.INP** is used to read location information from an existing *CALMET* input file. The *CALMET* input may be from an existing template file or a project already completed in the same area.





Use the **Load from *.INP** browse button adjacent the **FEAST** and **FNORTH** input area to load mapping and projection data from existing *CALMET.inp* or *CALPUFF.inp* files.

PMAP

PMAP is the projection mapping scheme to be used. *CALMET/CALPUFF* currently support Universal Transverse Mercator (UTM) grid, Lambert Conformal Projection (LCC) and Tangential Transverse Mercator (TTM). Lambert Conformal Projection should be used when the modeling domain is large, (> 300 km), because a Lambert Conformal grid accounts for the earth's curvature. If the LCC option is specified, the user-specified standard parallels (latitudes) and reference longitude to calculate a "cone constant" and the east-west distance from the reference longitude. The reference longitude is the longitude at which true north and map north are defined to be the same. It also defines where $x=0$ in the Lambert Conformal grid. The reference latitude defines where $y=0$ in the Lambert Conformal grid (see Scire et al 2000b).

FEAST, FNORTH

FEAST and **FNORTH** are the false easting and false northing values (see Scire et al 2000b).

iUTMZN

iUTMZN is the UTM zone number (1 to 60) (see Scire et al 2000b).

UTMHEM

UTMHEM is the hemisphere for UTM projection, entered as either 'N' or 'S' (see Scire et al 2000b).

RLATO, RLONO

Latitude and Longitude (decimal degrees) of the projection origin. These are not used when **PMAP**='UTM' (see Scire et al 2000b).

XLAT1, XLAT2

Standard reference latitudes (see Scire et al 2000b). These are not used when `PMAP='UTM'`.

DATUM

The Datum-Region for the output coordinates is identified by a character string. Many mapping products currently available use the model of the Earth known as the World Geodetic System 1984 (WGS-84). Other local models may be in use, and their selection in *TERREL* will make its output consistent with local mapping products. The list of Datum-Regions with official transformation parameters is provided by the National Imagery and Mapping Agency (NIMA) (see Scire et al 2000b).

UNITS

For the *CALMET/CALPUFF* modelling system all locations are referenced in units of kilometres, `UNITS='KM'`. When the `MDSPMOD=2` to create output for *AERMOD*, then the `UNITS='M'` should be used.

ABTZ

`ABTZ` defines the base time zone used for the entire simulation. This must match the base time zone of the meteorological data. The time zone is specified in hours relative to UTC (see Scire et al 2000b).

NX, NY

Together with `DGRIDKM`, the entries for `NX` and `NY` define the size of the meteorological modelling domain. These settings must match for both *CALMET* and *CALPUFF* configuration. `NX` is the number of grid cells in the east-west direction of size `DGRIDKM`. `NY` is the number of grid cells in the north-south direction of size `DGRIDKM`. The cells start at coordinates `XORIGKM` and `YORIGKM` at the lower left corner of a grid cell.

DGRIDKM

The size of a grid cell in the *CALMET* and *CALPUFF* configuration. A grid cell has equal dimensions in the east-west and north-south direction, with units of 'KM'.

XORIGKM, YORIGKM

Reference Coordinates of southwest corner of grid cell (1, 1) (see Scire et al 2000b). If the Lambert Conformal projection was selected, then the **XORIGKM** and **YORIGKM** and all the (x, y) coordinates must fit the chosen Lambert Conformal grid. Otherwise, for **PMAP=UTM**, the **XORIGKM** and **YORIGKM** are the UTM coordinates in KM units. The selection of **XORIGKM** and **YORIGKM** should take into account the **DGRID** entry from **iSTART**. If **DGRID** is large compared to terrain features, terrain influences on the meteorology can be averaged or shifted and thus may strongly impact the air dispersion predictions.

STEP 0a-CALMET Page

This page can be used to create and run *CALMET* meteorological file to create an output that is a prerequisite for running the *ABflare.exe* source model. The Step 0a-CALMET page is divided into six sub-steps.

The sub-steps walk the user through the development of *CALMET* meteorological file(s) required for *ABflareUI* and *CALPUFF* dispersion modelling.

Step	Title	Purpose
0a-1	Get MMEU Data	This step assists the user in specifying the coordinates and the domain size to be entered into the <i>MMEU</i> module for meteorological data extraction of the AESRD MM5 meteorological data for 2002-2006. The output from the MMEU is a 3D.dat file(s) for each year of the assessment.
0a-2	Get LCC Data	Land use classification characterization (LCC) data is downloaded from free web sources for Canadian locations and then used to calculate averages for the study domain.
0a-3	Extract DEM data	Digital elevation model (DEM) is downloaded from free web sources and is reformatted for input to the terrain processing module.
0a-4	Make TERREL.dat	The terrain processing module for <i>CALMET</i> is called TERREL. This module is used to create a processed terrain file, TERREL.dat for use in the <i>CALMET</i> program.
0a-5	Create GEO.dat Files for each season	The LCC data is combined with representative albedo, Bowen ratio, heat flux and surface roughness for each LCC. The processing module MAKEGEO is used to combine LCC data and these meteorological variables to create seasonal inputs for <i>CALMET</i> .
0a-6	Make CALMET file	The final step combines 3D.dat, TERREL.dat and seasonal GEO.dat files with processing by <i>CALMET</i> to create, typically, monthly meteorological files for each year of the assessment.

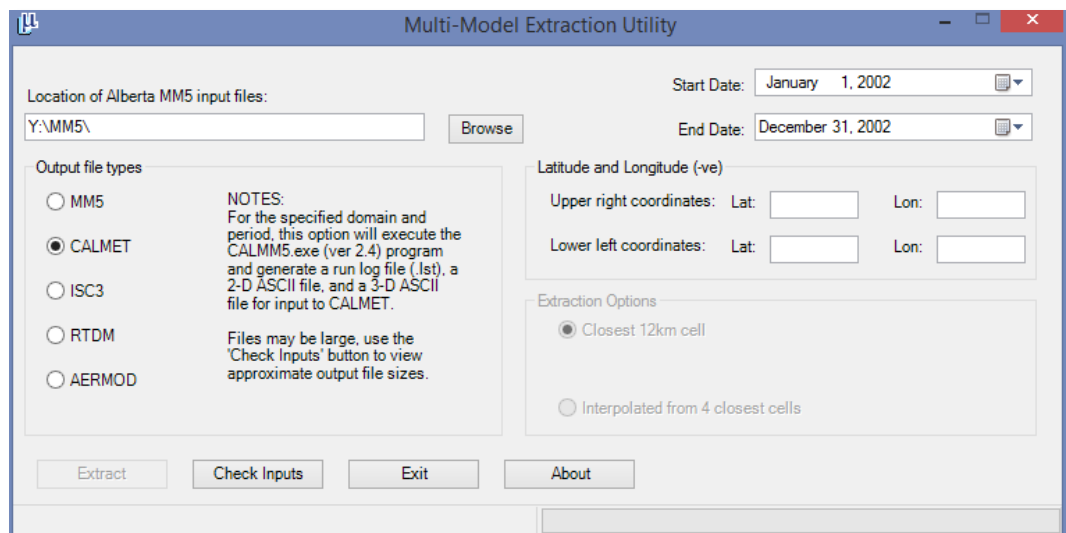
Step 0a-1 Get MMEU Data

This step assists the user in the extraction of the MM5 data from AESRD using the *MMEU* utility. The MM5 data and the *MMEU* utility may be downloaded from the web from:

<http://www.albertamm5data.com/>

The following sub-steps guide the user through the meteorological data extraction process:

1. Press **REFRESH** button on this page (see right). This will copy the mapping and projection information entered on the **iCOMMON** page and convert the information to coordinates that can be used to specify the modelling domain in *MMEU*. (Multi-Model Extraction Utility program).
2. Start the *MMEU* Multi-Model Extraction Utility. You will be asked to agree to an end-user agreement. Press **Agree** to continue. The main *MMEU* dialog window (version 2.2) will appear similar to the one below.



3. In the *MMEU* dialog window, select the 'CALMET' output file type.
4. In the *MMEU* dialog window, enter the lower-left (LL) coordinates of your modelling domain, as listed in the table (example is below).

	Lower Left Corner
Longitude	-117.3025
Latitude	55.7294
	Upper Right Corner
Longitude	-116.8236
Latitude	55.9992
	Dates Selected
Start Date	January 1, 2002
End Date	January 1, 2003

5. For computational speed and file size limits, it is better to limit the data extraction to yearly groups. Therefore, this process will have to be repeated for each year of the assessment. Enter start date is January 1, 2002 and end date is January 1, 2003 (allowing for carry over).
6. In the *MMEU* dialog window, press **Check Inputs** button to ensure inputs are valid.
7. In the *MMEU* dialog window, press **Extract** button to start extraction process using *MMEU*.
8. A dialog window will appear. Select the folder to where the meteorological data to will be extracted. Enter the location for the list, 2D.dat and 3D.dat files. Ensure that the lowest extraction level is 1 and the highest extraction level is 30. Record your entries for use in Step 3 below. Press **OK** to proceed with the extraction. The extraction process can take several hours depending upon the computer and network speed. It is therefore best to plan ahead to ensure that this Step 0a-1 is performed well in advance of the analysis.



It is best to plan ahead to ensure that this **Step 0a-1** is performed well in advance of the analysis.



Advanced users also can extract MM5 data into 3D.dat files using the *CALMM5.exe* processor. *CALMM5.exe* is well suited for batch file operations and is available from <http://www.src.com/calpuff/calpuff1.html>

Step 0a-2 Get LCC Data

In this sub-step, land use classification characterization (LCC) data is downloaded from free web sources for Canadian locations and then used to calculate averages for the study domain. The domain is defined on the **iCOMMON** page.

The following sub-steps guide the user through the process of acquiring LCC data and creating the LU.dat file.

1. In the entry below, specify the path and filename for the land use output file, LU.dat. The browse button can be used to assist the user in navigating to a folder to specify the file.

Step 0a-2 Get LCC Data		Get LCC Data	
2.1	Specify the path and filename for the land use output file, LU.dat		
2.2	Press 'Get LCC Data' to get LCC data from web and process it for the study area		
Output Files	FULL PATH	BROWSE	COMMENTS
LU.dat	Y:\ABflare\example\met\lu.dat	<input type="button" value="..."/>	

2. Press to get LCC data from web and process it for the study area. During the process, the **MAP SHEETS** field will be updated with the 1:250,000 scale map sheets used in the analysis.

Map Sheets	083n
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The processing involves extraction of geographic information systems (GIS) shape files that define polygons of land-use. Each grid cell is divided vertically and horizontally **LCCSUBSAMPLE** times (see **iSTART**). The Canadian LCC codes are converted to *CALPUFF* codes using the conversion chart on the **SLCC DOC** page.

The output from the processing is displayed in the table below this processing sub-group. An example of the output is shown below. The table shows the number of sub-sample counts and the fraction of the domain that that is represented by each LCC. In this case, the domain is 97.8% cropland. The user should verify that this interpretation of the land-use for the domain is valid.

CALPUFF Landuse Classification Code Summary				
ID	LCC	Description	Count	Percent
0	0	Unknown/Missing/Cloud/Shadow	0	0.0%
1	11	Residential	0	0.0%
2	12	Commerical and Services	0	0.0%
3	13	Industrial	0	0.0%
4	14	Transport/Comm/Utils	0	0.0%
5	15	Industry/Commercial Complexes	0	0.0%
6	16	Mixed Urban or Built-up Land	1476	1.1%
7	17	Other Urban or Built-up Land	0	0.0%
8	21	Cropland and Pasture	126801	97.8%
9	22	Orchards, etc.	0	0.0%
10	23	Confined Feeding Operations	0	0.0%
11	24	Other Agricultural Land	0	0.0%
12	31	Herbaceous Rangeland	0	0.0%
13	32	Shrub and brush Rangeland	0	0.0%
14	33	Mixed Rangeland	0	0.0%
15	41	Deciduaous Forest Land	522	0.4%
16	42	Evergreen Forest Land	0	0.0%
17	43	Mixed Forest Land	0	0.0%
18	51	Streams and Canals	0	0.0%
19	52	Lakes	72	0.1%
20	53	Reservoirs	0	0.0%
21	54	Bays and estuaries	0	0.0%
22	55	Oceans and Seas	0	0.0%
23	61	Forested wetland	153	0.1%
24	62	Nonforested wetland	0	0.0%
25	71	Dry salt flats	0	0.0%
26	72	Beaches	0	0.0%
27	73	Sandy areas other than beaches	9	0.0%
28	74	Bare Exposed Rock	0	0.0%
29	75	Strip Mines, Quarries and Gravel pits	0	0.0%
30	76	Transitional areas	0	0.0%
31	77	Mixed barren land	0	0.0%
32	81	Shrub and brush tundra	0	0.0%
33	82	Herbaceous tundra	567	0.4%
34	83	bare ground	0	0.0%
35	84	Wet tundra	0	0.0%
36	85	Mixed tundra	0	0.0%
37	91	Perennial snow or ice	0	0.0%
38	92	Glaciers	0	0.0%
Total			129600	100.0%
Minimum count in cell			9	
Maximum count in cell			9	

Step 0a-3 Extract DEM data

The digital elevation model (DEM) data is downloaded from free web sources and is reformatted for input to the terrain processing module.

The following sub-steps guide the user through the process of acquiring DEM data and creating the TERR.xyz file.

1. In the entry below, specify the path and filename for the terrain xyz, comma separated output file, TERR.xyz. The browse button can be used to assist the user in navigating to a folder to specify the file.

Step 0a-3 Extract DEM data		Create XYZ	
3.1	Specify the path and filename for the terrain output file, terr.xyz		
3.2	Press 'Create XYZ' to get DEM data from web and process it for the study area		
	PATH FOR OUTPUT FILES	BROWSE	COMMENTS
terr.xyz	Y:\ABflare\example\terr.xyz	...	

2. Press **Create XYZ** button to get DEM data from web and process it for the study area. During the process, the **MAP SHEETS** field will be updated with the 1:50,000 scale map sheets used in the analysis.

Map Sheets	083n11;083n14;083n15;083n10
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The output file is a comma separated file. The first row contains the UTM zone in the third column, as shown in the example below. The first two columns are X,Y in UTM coordinates units of metres, followed by the terrain elevation in metres.

```

1,1,11
484299.4,6176011.9,581.0
484299.5,6176035.1,581.0
484299.5,6176058.3,581.0
484299.6,6176081.5,581.0
484299.7,6176104.7,581.0

```

Step 0a-4 Make TERREL.dat

The terrain processing module for *CALMET* is called *TERREL*. This module is used to create a processed terrain file, *TERREL.dat*, for use in the *CALMET* program.

The following sub-steps guide the user through the process of creating the *TERREL.dat* file.

1. There are two sets of entries, one of **INPUT** files and the other for **OUTPUT** files. The *TERR.xyz* is a comma separated file listing the utm zone and raw DEM data for the modelling domain. This file could be created in the Step 0a-3 or a file created by the user. The second file is the name of a control settings file that will be created by *ABflareUI* and is used as the input file for *TERREL*. The **...** browse buttons can be used to assist the user in navigating to a folder to specify the files.

Step 0a-4 Make TERREL.dat		Make Terrel	
Specify the path and filename for inputs:			
4.1 a) the terrain file, terr.xyz b) Terrel.inp file to be created and OUTPUT files to be created by the TERREL.exe			
a) TERREL.dat containing processed terrain data b) TERREL.lst containing runtime documentation from TERREL.exe c) QATERREL.grd a QA/QC file from TERREL.exe useful for plotting using Surfer			
4.2 Press 'Make Terrel' to get to run TERREL.exe			
PATH FOR INPUT FILES		BROWSE	COMMENTS
terr.xyz	Y:\ABflare\example\met\terr.xyz	...	
terrel.inp	Y:\ABflare\example\met\terrel.inp	...	
PATH FOR OUTPUT FILES		BROWSE	COMMENTS
terrel.dat	Y:\ABflare\example\met\terrel.dat	...	
terrel.lst	Y:\ABflare\example\met\terrel.lst	...	
qaterrel.grd	Y:\ABflare\example\met\terrel.grd	...	

There are two sets of entries, one of **INPUT** files and the other for **OUTPUT** files. The `TERR.xyz` is a comma separated file listing the UTM zone and raw DEM data for the modelling domain. This file could be created in the Step 0a-3 or a file created by the user. The second file is the name of a control settings file that will be created by *ABflareUI* and is used as the input file for *TERREL.exe*. The browse buttons can be used to assist the user in navigating to a folder to specify the files.

The `TERREL.dat` file will be created by the *TERREL.exe* processing. It will contain processed terrain elevations for each grid cell based upon the `TERR.xyz` input file. The `TERREL.lst` file will contain a listing of the inputs as interpreted by *TERREL.exe* and will list any warnings or errors. The output file `QATERREL.grd` is a Surfer format grid file. It is useful for verification that the terrain elevations have been entered correctly and represent that intended region.

2. Press button to process the terrain using *TERREL.exe*. When the processing is completed the `TERREL.lst` file will be displayed. The user should scroll to the bottom and confirm that the program was run successfully and that there are no errors or warnings.

Step 0a-5 Create GEO.dat Files for each season

The terrain and LCC data is combined with representative albedo, Bowen ratio, heat flux and surface roughness for each LCC. The processing module

MAKEGEO is used to combine LCC data and these meteorological variables to create seasonal inputs for *CALMET*.

Step 0a-5 Create GEO.dat Files for each season				Make GEO	
5.1	Specify the season property and filenames for output				
5.2	Enter the input pathnames and files and the output path for the MAKEGEO.exe output files				
5.3	Press 'Make GEO' to create the GEO.dat files based upon the LU.dat and TERREL.dat files				
5.4					
5.5					
Season	Property Index	File Name (no path)	Default (if blank)	COMMENTS	
Spring	1	geospr	geospr	See "CALMET PROPERTIES" 1=Spring 2=Summer 3=Fall 4=Winter 5=Winter 2 0=do not use	
Summer	2	geosum	geosum		
Fall	3	geofall	geofall		
Winter	4	geowin	geowin		
Winter2	0		geosno		
PATH FOR INPUT FILES				BROWSE	COMMENTS
geo.inp path	Y:\ABflare\example\met\puf\			...	
lu.dat	Y:\ABflare\example\met\puf\lu.dat			...	
terr.dat	Y:\ABflare\example\met\puf\terrel.dat			...	
PATH FOR OUTPUT FILES				BROWSE	COMMENTS
geo.dat path	Y:\ABflare\example\met\puf\			...	

The following sub-steps guide the user through the creation of the GEO.dat files for each season.

1. The default configuration for a flaring assessment divides the year into four seasons: spring, summer, fall and winter. The winter season assumes snow cover. In the [Property Index](#) column, specify the season index corresponding to the desired season. The parameters for each [Property Index](#) season are defined on the [sLCC](#) page.

Property Index	Season	Description
0	Do not use	Use this setting to exclude this season from the assessment.
1	Spring	No snow cover, vegetation in transition.
2	Summer	No snow cover, vegetation in full leaf growth.
3	Fall	No snow cover, vegetation in transition to dormant state.
4	Winter	Snow cover, vegetation may be in partial snow cover.
5	Winter 2	No snow cover, vegetation dormant.

2. Specify the complete path for the input files already created in the steps above for, LU.dat and TERREL.dat. Also, specify the folder where the *MAKEGEO.exe* input control files will be created for each of the seasons.

3. Specify the output folder for where the *MAKEGEO.exe* output *GEO.dat* files will be created. These files will be required in the next step of the meteorological file creation process.
4. Press the **Make GEO** button to create each of the four or five *GEO.dat* files specified in sub-step 1. When the processing is completed the *GEO.lst* file will be displayed for the last season. The user should scroll to the bottom and confirm that the program was run successfully and that there are no errors or warnings. The user should also read the *.lst* files for the other seasons to confirm there are no errors or warnings in those files.



Interesting but not explicitly accounted for in the modelling. The Calgary extreme daily snowfall for June, July and August is 24.9 cm, 0.3 cm, 0.6 cm (Canada Climate Normals). The month with the highest extreme daily snow fall is June. The Edmonton extreme daily snowfall for June, July and August is 0 cm, 0 cm, 2 cm (Canada Climate Normals).

Step 0a-6 Make CALMET file

The final step combines *3D.dat*, *TERREL.dat* and seasonal *GEO.dat* files with processing by *CALMET* to create, typically, monthly meteorological files for each year of the assessment.

The following sub-steps guide the user through the creation of the *CALMET.dat* files for each season.

1. Because only prognostic data are being used in the creation of the *CALMET* data files, the only *CALMET* setting required is for **TERRAD**. Refer to the *CALMET* documentation for a complete description of the **TERRAD** setting. This setting adjust the weighting terrain influences on the meteorological outputs such as slope flows and terrain influenced wind directions. Typical range for **TERRAD** is 10 km to 15 km, with 12 km being a good estimate. The **TERRAD** selection can be confirmed by reviewing the detailed meteorological output from *CALMET.exe* on an hourly basis to determine whether the wind directions are appropriate with respect to seasonal or time of day compared to expected wind field patterns through complex terrain.

TERRAD

12



The interpretation of *CALMET* output may require specific technical background in meteorology. Meteorology is one the principal inputs in air dispersion modelling.

- The second set of inputs required for *CALMET.exe* is the specification of the boundary layer face heights. The Alberta Air Quality Model Guideline (ESRD 2013) specifies a default 12 layer boundary to be used for *CALPUFF* modelling as listed below. Higher resolution in the heights near the stack and plume heights can be used in alternative modeling scenarios to better characterize the effects of shear and dispersion in that region.

NZFACE	12	The number of layers of meteorology	
ZFACE	Elevation (m)	Default (m)	Depth (m)
0	0	0	0
1	20	20	20
2	40	40	20
3	80	80	40
4	120	120	40
5	280	280	160
6	520	520	240
7	880	880	360
8	1320	1320	440
9	1820	1820	500
10	2380	2380	560
11	3000	3000	620
12	4000	4000	1000
13			
14			
15			

- The third step is to specify dates and corresponding *GEO.dat* files. For typical modelling domains, the meteorological files can be quite large and depending upon the computer platform (Windows operation system, Linux, and/or hard drive configuration) large files (greater than about two gigabytes) may not be supported or may be difficult to manage (for example, backups). It is recommended that yearly meteorology be divided into monthly divisions. For a typical assessment of five years, this will create 60-monthly meteorological input files, each about 2 gigabytes in size. *ABflareUI* requires the inputs below for each year of the assessment. The start and end date and time for each month is specified and the *GEO.dat* file to be used for each month period is specified. The *GEO.dat* files were created in **0a-5 Create GEO.dat** step (see above).

Date Options Group

NSECDT	3600	Time interval					
Date	yr	imo	iday	ih	isec	GEO DAT	
Met 1-Start	2002	1	1	0	0	geosum	
End	2002	1	31	23	3600		
Met 2-Start	2002	2	1	0	0	geowin	
End	2002	2	28	23	3600		
Met 3-Start	2002	3	1	0	0	geospr	
End	2002	3	31	23	3600		
Met 4-Start	2002	4	1	0	0	geospr	
End	2002	4	30	23	3600		
Met 5-Start	2002	5	1	0	0	geospr	
End	2002	5	31	23	3600		
Met 6-Start	2002	6	1	0	0	geosum	
End	2002	6	30	23	3600		
Met 7-Start	2002	7	1	0	0	geosum	
End	2002	7	31	23	3600		
Met 8-Start	2002	8	1	0	0	geosum	
End	2002	8	31	23	3600		
Met 9-Start	2002	9	1	0	0	geofall	
End	2002	9	30	23	3600		
Met 10-Start	2002	10	1	0	0	geofall	
End	2002	10	31	23	3600		
Met 11-Start	2002	11	1	0	0	geofall	
End	2002	11	30	23	3600		
Met 12-Start	2002	12	1	0	0	geowin	
End	2002	12	31	23	3600		

The default division of the year is listed below:

Month Range	GEO.dat File	Description
Mar-May	GEOspring.dat	No snow, transition to full vegetation.
Jun-Aug	GEOsummer.dat	No snow, full vegetation.
Sep-Nov	GEOfall.dat	No snow, transition to dormant vegetation.
Dec-Feb	GEOwinter.dat	Snow cover, dormant vegetation.

The inputs for the **Date Options Group**, shown previously, are displayed for the 2002 year. The process must be completed for each year of the meteorological assessment 2002, 2003, 2004, 2005 and 2006 according to the Alberta Air Quality Model Guideline (ESRD 2013).

The **NSECDT** variable is used to control the time step used in the meteorological processing. By default the time step is 3600 sec. This time step corresponds to the same time step in the meteorological 3D.dat file being processed. The same time step must be used in the *CALPUFF* modelling configuration. Non-default flaring assessments can process the meteorology using an **NSECDT** setting that is different than the 3D.dat file time step, for instance **NSECDT**=600 sec. Processing in this way will allow *CALMET* to create time steps of 600 sec (10 minutes) based upon 1 h time steps of meteorology. Although the meteorology inherently changes only on 1 h increments, the *CALPUFF* modelling based upon the **NSECDT**=600 sec will produce 10 min time averages directly, producing short-term peak concentrations and accounting for along-wind diffusion. This may be suitable for air toxics assessments or **NSECDT**=180 to 600 sec may be appropriate for odour assessments. The *CALPUFF* results would require post-processing using *CALAVE* to create 1 h averages from the **NSECDT**=600 sec output created by *CALPUFF*.

- Complete the input and output files and path name input group table. The table lists user inputs for: the path for creation of `CALMET.inp` file by *ABflareUI*; the full path of the `3D.dat` corresponding to the meteorological period being assessed (see also **Step 0a-1 Get MMEU Data**); and, the path where the `GEO.dat` files can be found.

Input Files	FULL PATH	BROWSE	COMMENTS
CALMET.inp path	Y:\ABflare\example\met\puf\	...	
3D.dat	Y:\ABflare\example\met\puf\mm5_02\3d2002.dat	...	
GEODAT.dat path	Y:\ABflare\example\met\puf\	...	
Output Files	FULL PATH	BROWSE	COMMENTS
CALMET.dat path	Y:\ABflare\example\met\puf\	...	

Also required, is the output path for the where the `CALMET.dat` output files for each month will be created. The `CALMET.dat` output files will be created using the following template filename:

m[YYYY]_[mm].dat

where YYYY is the four digit year, and mm is the two digit month number.

- Press the **Make CALMET** button to create each of the twelve `CALMET.dat` files specified. When the processing is completed the user should review the `CALMET.lst` files to confirm that the program was run successfully and that there are no errors or warnings.



The process must be completed for each year of the meteorological assessment 2002, 2003, 2004, 2005 and 2006 according to the Alberta Air Quality Model Guideline.

- Repeat the **0a-6 Make CALMET** file steps for each of the 2002, 2003, 2004, 2005 and 2006 years for the meteorological assessment.



The creation of the `CALMET.dat` files is numerical intensive and may take extended periods of time. The **MBATONLY** option can be used to create Windows `CMD.exe` batch files so that the `CALMET` creation process can be executed at a later time or divided between several computers.

STEP 0b-RECEPTOR Page

This page can be used to create a receptor grid that forms part of the *CALPUFF* model input file and is a prerequisite for a modelling assessment.

Step 0b-1 Define Receptor Grid

Press the **REFRESH** button to read the flare location coordinates from the **STEP 2-ABFLARE** page. The refresh button also displays the longitude and latitude of the UTM coordinates for reference. The user may alternatively enter the X UTM, Y UTM coordinates manually (without regard to the longitude or latitude values below the entry) to create a receptor grid centred on the location entered.

Centre of Domain	
X UTM	496000
Y UTM	6191000
UTM Zone	11
Conversion to Geographic Coordinates	
Longitude	-117.3025
Latitude	55.7294

In the Receptor Grid Spacing table, adjust the receptor grid spacing as desired. The default settings listed in the table define the default receptor grid as specified in the Alberta Air Quality Model Guideline. The user may wish to use a different grid spacing for screening purposes or more refined grid near the location of the point of maximum impingement.

ID	Resolution (m)	Default (m)	Distance	Default	Receptors
1	20	20	100	100	40
2	50	50	500	500	416
3	100	100	500	500	0
4	250	250	2000	2000	264
5	500	500	5000	5000	360
6	1000	1000	10000	10000	320
7	5000	5000	10000	10000	0
Total					1400

The table has seven layers or Cartesian coordinates grid spacing. By setting a distance equal to an adjacent layer, that layer of receptor is excluded (because it will have zero width relative to the next layer). In the example below, a fence line is defined at 100 m with 20 m receptor spacing. Beyond the fence line, to a distance of 2000 m, a receptor spacing of 250 m is used.

ID	Resolution (m)	Default (m)	Distance	Default	Receptors
1	20	20	100	100	40
2	50	50	100	500	0
3	100	100	100	500	0
4	250	250	2000	2000	288
5	500	500	2000	5000	0
6	1000	1000	2000	10000	0
7	5000	5000	2000	10000	0
Total					328

Entries that differ from the default settings are highlighted in orange colour.

A user defined receptor grid can be inserted into the processing in the next step. The user defined receptor by-passes the **Receptor Grid Spacing** table selections.

Step 0b-2 Create Receptors for AERMOD

The second step is specify the source of the digital terrain to be used to determine the receptor heights. By default, *ABflareUI* reads DEM data from the [DEMlib](#) or downloads the data according to the BIN page. The data is expected to be in Canadian DEM format.

The receptor grid to be processed is specified in the **Step 0b-1** described above. Alternatively, the user may input a comma separated XY data file containing a user defined receptor grid in the same coordinates used in the assessment. This user receptor grid is input into *ABflareUI*, then the DEM processing is applied to each location.

The user may specify flag pole heights for each receptor location as specified by the [Flag Pole Receptor Height](#) entry. The flag pole height is applied to each receptor location.

The full path for the output complex file `terrain.ctr` must be specified. This file will be created by *ABflareUI* when the **Create Receptors** button is pressed. The `terrain.ctr` file will be used as an insert file specifying the receptor locations for the *CALPUFF.exe* input files.

During the processing of the terrain, the [Map Sheets](#) field is updated to show the DEM mapsheets used to create the receptor file.

A graphic is displayed at the bottom of the page showing the receptor grid created by *ABflareUI* for references purposes. Below the graphic, is a list of the receptor points and elevations determined from the DEM file. Elevations are determined by the closest DEM data points to the receptor location.

STEP 1-METSERIES Page

The **METSERIES** page is composed of five input groups as listed in the table below. The *METSERIES* module is a powerful data extraction tool but entries included in the *ABflareUI* are restricted for the purposes of extracting meteorological time series data. For the other features of *METSERIES*, the user is directed to the *CALPRO* (<http://www.src.com/calpuff/calpuff1.htm>) GUI.

Field	Description
INPUT and OUTPUT FOLDERS	User selects: the folder to contain the output files; root name of the file for output; location of the list file for output.
Mapping and Projection	These settings mirror the settings used for the user's configuration of <i>CALMET</i> .
Output Options	These settings direct <i>METSERIES</i> to extract meteorological data at the specified location and height.
Date Options	These settings direct <i>METSERIES</i> to extract meteorological data for the specified date range.
Met Files for Extraction	A list of meteorological data files to be processed.

Input and Output Folders Group

The output path is the drive and folder path where the output file(s) will be written. The user can make use of the browse button to assist in the navigating folder trees and selecting final location.

The time series output file name (**TSFOUT**) is the root name to be used for the *METSERIES* output. The output file will have a .tsf extension.

The output list file (**LSTDAT**) is the full path and file name of the list file output which will include an echo of the data read by *METSERIES* and any error or warning messages. The user can make use of the browse button to assist in navigating the folder trees and selecting a file name. The list file does not need to be in **OUTPATH** output path.

VARIABLE	INPUT	DESCRIPTION	BROWSE
Output Path		Y:\ABflare\PeaceRiver\met\	<input type="button" value="..."/>
TSFOUT	f1rsite	Timeseries data are written to the following NTSFOUT files .TSF file extension WILL BE ADDED to the names provided	
output: LSTDAT List-file name Default: METSERIES.LST		Y:\ABflare\PeaceRiver\met\METSERIES.lst	<input type="button" value="..."/>

Output Options Group

A dropdown list selection box is provided for the **MDATA** entry to assist in preventing user entry errors. Alternatively, the user can type a selection into the input box.

VARIABLE	INPUT	DESCRIPTION
MDATA	CALMET	Input Data Type CALMET
XESTN	496	X-Easting Coordinate (km, deg, or cell)
YNSTN	6191	Y-Northing Coordinate (km, deg, or cell)
METSIM	1	1=interpolate; 2=nearest grid cell
ZWIND	30.5	Measurement height (m AGL) for wind (-1. to exclude)
ZTEMP	30.5	Measurement height (m AGL) for temperature (-1. to exclude)
ZRHUM	30.5	Measurement height (m AGL) for humidity (-1. to exclude)

Date Options Group

The start and end periods of the meteorological data to process are entered in the Data Options Group. The start and end times must be inclusive of the data in the meteorological data being processed.

	yr	imo	iday	ihr	isec
Start met	2002	7	1	0	0
End met	2002	7	5	23	3600
NSECDT	3600	Time interval			

Meteorology Files for Extraction Group

For the meteorology files group the number of meteorological files to process is set using **NMETINP** entry. The full path and file name of the list of meteorological data files to process can be entered in to the list. The first file can be selected using the **BROWSE** button, and then using the cut and paste functionality of Excel, the user can readily fill in the remaining meteorological file names.

NMETINP	Number of met files to extract	BROWSE
1		...
MetDat1	Y:\ABflare\PeaceRiver\met\2002_07.dat	
MetDat2		
MetDat3		
MetDat4		
MetDat5		
MetDat6		

STEP 2-ABFLARE Page

ABflare is designed to accommodate a range of source descriptions as described in the table below:

MINPUT	MBLOWDOWN	NPUFFS
1: User inputs source exit conditions; <i>ABflare</i> calculates source parameters that vary with meteorology.	1: User provides QMAX and QTOTAL (which represent the exponential blowdown curve).	1: QMAX is used to represent a static hourly emission rate; <i>ABflare</i> calculates source parameters that vary with meteorology.
	2: <i>ABflare</i> calculates QMAX and QTOTAL based upon user-entry of vessel initial conditions.	>1: QMAX and QTOTAL are used by <i>ABflare</i> to calculate a blowdown sequence; <i>ABflare</i> calculates source parameters that vary with meteorology. <i>ABflare</i> calculates a blowdown sequence; <i>ABflare</i> calculates source parameters that vary with meteorology.
	2: User inputs a repeatable sequence of rates; <i>ABflare</i> calculates source parameters that vary with meteorology. See NSEQ .	--
3: User inputs pre-determined pseudo-stack parameters; <i>ABflare</i> uses the user-inputs which DO NOT vary with meteorology. See PSHS , PSTS , PSDS , PSUS and QEMIT .	--	NPUFFS=1

It is recommended that a minimum of three equal mass steps be used to represent a blowdown curve. Figure 4 shows an exponential blowdown curve for a vessel of $23.3 \times 10^3 \text{ m}^3$ with an initial flow rate of $1110 \times 10^3 \text{ m}^3/\text{d}$. The equal mass sequence will better represent the original curve than the equal duration sequence. The dispersion modelling pseudo-parameters for plume rise closely match the original curve ensuring a realistic representation of the sequence.

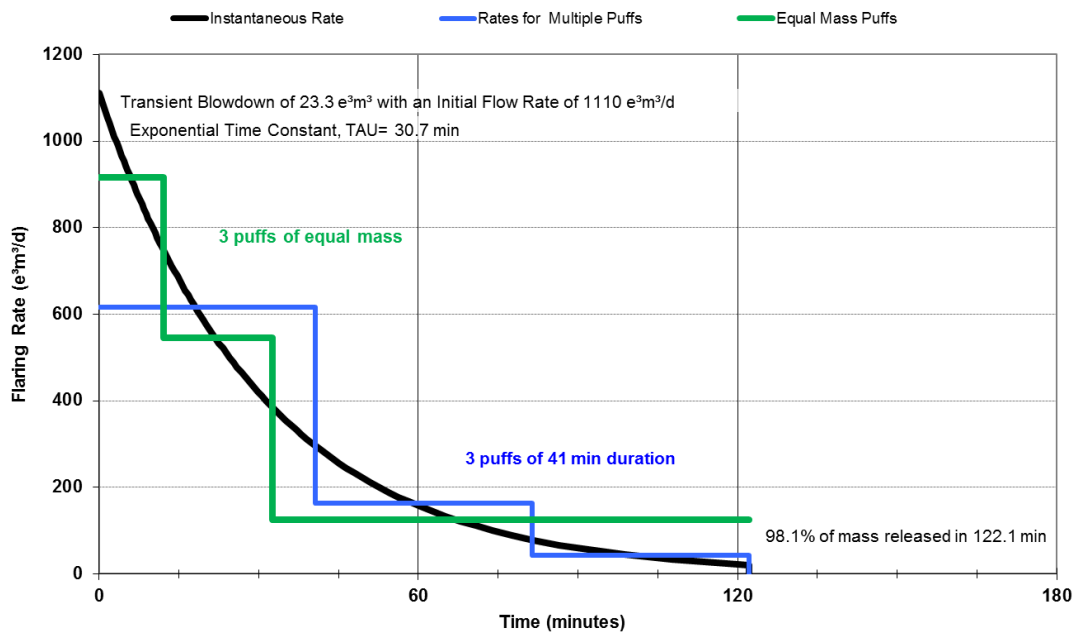


Figure 4: Exponential Blowdown Represented by a Sequence of Puffs

The inputs for *ABflare* are divided into 10 **Input Groups** and are listed in the table below. The **Control Group** is used to direct how the calculations are to be performed and the type of output required. The other **Input Groups** are principally user inputs.

Input Group	Description
INPUT and OUTPUT FOLDERS	User selects: the folder to contain the output files; root name of the file for output; location of the list file for output.
Control	Entries to direct <i>ABflare</i> calculations and output.
Mapping and Projection	User entries that describe the coordinate mapping and projections used.
Chemistry	<i>ABflare</i> emits only a single species at a time and is designed to emit either SO ₂ or H ₂ S, as the oxidized or un-combusted raw gas stream emission.
Date Options	User entries that describe the time frame for the modelling.
Source Description	User entries that provide information on the source as per CONTROL GROUP settings.
Flare Assist	Entries that specify the flare assist (fuel gas, steam assist and/or air assist).
Gas Composition	Gas composition of the raw gas and fuel gas (if used).

Input Group	Description
Meteorology	If directed by the CONTROL GROUP, the meteorology can be made static for the purposes of the source calculations rather than varying hour-by-hour as per the input meteorological file.
User Defined Blowdown	If directed by the CONTROL GROUP, the user can provide a sequence of emission rates that describe the blowdown rather than letting <i>ABflare</i> calculate the emissions. Source parameters will vary with meteorology.

Input and Output Folders Group

The input and output folders group specifies where files are read from and are to be written to.

SNAME is the source name to be used for the flare. The *ABflare* output file will create an arbitrary time varying input file for use with *CALPUFF*. The source name should not conflict with other sources that may be used in the *CALPUFF* file.

STITLE1 is a one line description that *ABflare* will write to the arbitrary time varying input file for use with *CALPUFF*. **STITLE1** only used for the user's future reference to describe the source file.

OUTPATH is the full drive and folder path for where the *ABflare* output will be written to. The output will be a single file if *ABflare* is directed to create a single arbitrary time varying source characterization (**MINPUT=1**, **MBLOWDOWN=1**) or may be a set of 24-files representing a blowdown starting at one hour increments (**MINPUT=1**, **MBLOWDOWN=2**).

METDAT is the full drive and folder path for the meteorological time series file created by *METSERIES*. *ABflare* uses the meteorological time series to create the source parameters that vary with meteorology. The **METDAT** file should represent the meteorology at the flare stack tip height.

LSTDAT is the full drive and folder path for the output listing from *ABflare*. *ABflare* will echo the input source file and will write other run-time information to this file.

LOGDAT is the full drive and folder path for the debug log file. *ABflare* will write debug information to this file. If this output is not required, then this setting should be left blank.

LCFILES is used to force the output file names to be lower case or upper case. This setting is commonly used to prevent errors in LINUX environments where path names are case sensitive.

Input and Output Folders Group			
VARIABLE	INPUT	DESCRIPTION	BROWSE
SNAME	FLR1	Source Name (12 chars) A short one word identifier for the source, example: FLARE1	
STITLE1	Example 1-Same as ERCBflarev1.05 Released		
OUTPATH path for ABflare output files		Y:\ABflare\PeaceRiver\puf\blowdown\	...
input: TSF Metseries output file from METDAT or AERMOD.SFC Default: METDAT.TSF		Y:\ABflare\PeaceRiver\met\FLRSITE.tsf	...
input: METDAT2 AERMET Metseries PFL file Default: METDAT.PFL			...
output: LSTDAT List-file name Default: ABFLARE.LST		Y:\ABflare\PeaceRiver\puf\blowdown\abflare.lst	...
output: LOGDAT debug listing log-file name Default: ABFLARE.LOG		Y:\ABflare\PeaceRiver\puf\blowdown\abflare.log	...
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F	

Control Group

The control group settings are used to direct the program flow in *ABflare*. Some controls settings make input entries optional or required entries in the various *ABflare* input groups.

MINPUT is used to specify the type of flare source to be input into *ABflare*. The types of sources that can be input into *ABflare* are: (**MINPUT**=1) a blowdown where *ABflare* calculates the blowdown from the input source description; (**MINPUT**=2) a blowdown where the user has calculated the blowdown sequence; (**MINPUT**=3) a static source. **MINPUT** is described in more detail in the **SOURCE GROUP** description.

MBLOWDOWN is used to specify whether *ABflare* is to calculate the blowdown from user entry of QMAX and QTOTAL or if *ABflare* is to calculate the blowdown from user entry of the vessel or pipeline description. **MBLOWDOWN** is described in more detail in the **SOURCE GROUP** description.

MDIST directs *ABflare* to divide the blowdown into segments of equal duration or of equal mass. The recommended setting is to calculate segments of equal mass. The blowdown emission curve is well represented by an exponential decrease in emissions with time. The mass emissions are therefore exponentially distributed in time. The *ABflare* calculated source parameters to represent the plume rise are therefore naturally changing as a function of mass emissions. Equal duration steps may be more convenient when trying to match results from other dispersion models or for simplifying the calculation of time averages. If the equal duration steps are used for an exponential blowdown, the source parameters calculated by *ABflare* are based upon the step volume, and therefore at small

release times, more mass is released at lower effective plume heights (see also later, Figure 4).

MSTRIP directs *ABflare* to calculate emissions for SO₂ assuming 100% conversion efficiency (the recommended and conservative setting for regulatory modelling in Alberta) or to calculate emissions assuming conversion efficiency varies with meteorology. If **MSTRIP**=1, then *ABflare* will calculate the emissions of H₂S and source parameters for gases stripped off of the flared gas resulting from cross-wind effects at the combustion zone. The effective source when **MSTRIP**=1 is set at half of the calculated effective flame height with very little buoyancy rise. These settings are an approximation allowing for momentum of the stripped gases and some radiant heating of the flared gas. If **MSTRIP**=2, then *ABflare* will calculate the emissions of SO₂ using the calculated efficiency for the meteorology. The efficiency can drop below 98% for high wind speeds, but is not allowed to drop below 25% as a limit of the calculations.

MMET is used to direct *ABflare* to read meteorological data from a file or to use a static user input meteorological conditions for use in calculating emissions and efficiency. **MMET** is useful for creating input files for comparison to other dispersion models. *ABflare* can process either *CALPUF* (*METSERIES* style) meteorological data or *AERMOD* (*AERMET* style) meteorological data surface files.

MFUELGAS is used to specify whether fuel gas will be used to assist flare combustion and dispersion.

MFGR is used to specify how fuel will be added to the raw gas. **MFGR**=1 specifies that the fuel gas ratio is proportional to time varying flaring rate. **MFGR**=2 specifies that the fuel gas ratio is proportional to the initial QMAX rate of the blowdown.

MFASSIST is used to specify if steam and/or air assist is added to the flare combustion zone to aid in mixing and vertical momentum.

NSEP is the number of hours separating blowdown sequences for a given source file. Each blowdown sequence starts every hour on the hour. Typically, **NSEP**=24, resulting in *ABflare* creating 24-arbitrary varying flare input files. Each input file is an independent run of *CALPUFF*. When **NSEP**=24, the blowdown duration must be less than 24 hours and also allow time for the plume to leave the modelling domain. **NSEP** specifies the frequency of when the starting hour can be used again. **NSEP** must be a multiple of 24. A blowdown duration greater than 24 should use **NSEP**=48. A blowdown duration greater than 48 should use **NSEP**=72. If **NSEP**=48, *ABflare* will create 48 input files for *CALPUFF*, and if **NSEP**=72, *ABflare* will create 72 input files for *CALPUFF*.

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	1	MINPUT = 1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN	1	MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST	2	MDIST=1 : blowdown sequence is created based upon puffs of equal duration 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	0	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT= 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUELGAS	1	Is fuel gas added? MFUELGAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR	2	MFGR =1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFTGAS	0	Is lift gas used ? MLIFTGAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	1	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

Chemistry Group

The chemistry group is used to specify the chemical species emitted by the flare. *ABflare* allows only a single species to be emitted at a time, being either SO₂ or H₂S. SO₂ and H₂S cannot be emitted at the same time since the source parameters for these are different because of the how these species are created in the flare combustion zone.

For **MSTRIP=0** or **MSTRIP=2**, **CHEMLST= SO2**. For **MSTRIP=1**, **CHEMLST= H2S**.

Chemistry Group				
VARIABLE	INPUT	DESCRIPTION		
NSPEC	1	Number of species to be modelled NSPEC=1		
	CHEMLST	Mole Weight kg/kmol	Emission Rate g/s	
FLARE: SPEC 1	SO2	64.065	1	This is the Flare source, the emissions are either STATIC or are overwritten by ABflare
STATIC: SPEC 2	H2S	34.082	2	List of chemical species to be modelled Example: SO2, H2S Default =SO2
STATIC: SPEC 3	NOX	46	5234.567	
STATIC: SPEC 4	CO	28.01	0.0123	
STATIC: SPEC 5				List of molecular weights of chemical species to be modelled. Example:SO2=64.065,H2S=34.082 Default =64.065
STATIC: SPEC 6				
STATIC: SPEC 7				
STATIC: SPEC 8				List of static emission rate for all species
STATIC: SPEC 9				
STATIC: SPEC 10				

Date Options Group

The date options group is used to specify the start and end of the source calculations. It must start at *ihr*=0 and *isec*=0. The **TIMEINC** should match the interval of the meteorology used in the *CALMET* modelling.

Date Options Group					
VARIABLE	yr	imo	iday	ihr	isec
START	2002	7	1	0	0
END	2002	7	5	23	3600
TIMEINC	3600	Time step, s Default=3600			

Source Description Group

The source description group is divided into four logical sub-groups. Sub-group 1 are mandatory entries. Sub-group 2 and Sub-group 3 are required only for specific source characterization. Sub-group 4 has entries that are optional depending upon the specific source characterization.

Sub-group 1, specifies the real location, height above grade and inside diameter at flare stack top.

Sub-group 2 is used only if **MINPUT**=1 and **MBLOWDOWN**=2 and is used to describe the initial conditions of the vessel or pipeline for the blowdown calculations. The initial pressure (kPa) and temperature (°C) describe the vessel or pipeline before the blowdown. If the vessel pressure is variable, then the maximum pressure should be entered. If the vessel temperature is variable, then the minimum temperature should be used. To specify the vessel temperature as ambient temperature, enter -9999 and *ABflare* will use the ambient temperature from the **METDAT** file at the start of the blowdown sequence as the vessel or pipeline initial temperature. *ABflare* uses the ambient temperature from

METDAT and not the ambient temperature from **MMET**=3, if specified. If the vessel or pipeline initial temperature needs to match **TAMB** when **MMET**=3, then set the minimum initial vessel temperature to **TAMB**.

The vessel or pipeline inside diameter and length are relatively straight forward. If the blowdown includes more than just a single vessel, then the equivalent enclosed volume can be calculated and a representative diameter and length can be entered. For a pipeline, the segment length between emergency shut-down values (ESD) should be used.

The minimum orifice diameter will control the rate of gas through and out of the system because of choked flow. The discharge coefficient is not readily determined, since it may be impacted by back pressure through piping to the flare. A limiting case for flow through an orifice (Figure 5, Mannan 2005) provides a default value of 0.6 which allows for pipe friction from the orifice to the flare.

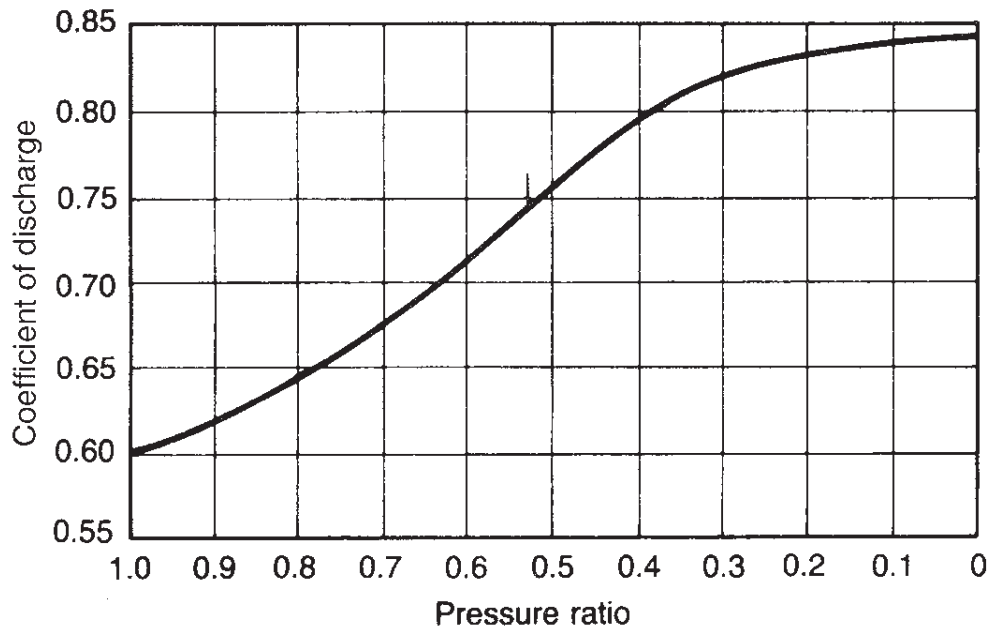


Figure 5: Coefficient of Discharge for Gas Flow Through an Orifice (Mannan 2005)

Sub-group 3 is used only if **MINPUT**=3. This option allows the user to specify the parameters to be output using *ABflare*. The parameters, since specified by the user, do not change with meteorology. The user should enter the flare pseudo-height, diameter, temperature and velocity as well as the mass emission rate.

Sub-group 4 contains optional and required entries. **RH2S** is a required entry that is used to specify the H₂S content of the raw gas. **RH2S** may be different than the gas composition to allow for regulatory limits or the maximum expected

value. The gas composition is re-normalized to account for the change in RH2S. If MINPUT=1 and MBLowDOWN=1, the user may enter QMAX, QTOTAL, DURATION and FREL directly and by-passing the vessel blowdown calculations. This option can be used to specify a flaring rate that is constant in time at QMAX but the flaring parameters will change with meteorology. In this case the user should enter DURATION=3600, FREL=1 and NPUFFS=1. In this case QTOTAL is not used. This option is also useful for debugging purposes or if a vessel blowdown is not a good model for the scenario modelled.

PUFFDUR and NPUFFS can be selected to change how the blowdown curve is divided for modelling. For MDIST=2 (constant mass puffs) the PUFFDUR is ignored and the NPUFFS determines the number of discrete intervals used to divide the exponential blowdown curve. For MDIST=1 (constant duration puffs) either PUFFDUR or NPUFFS can be selected.

Source Description Group		
VARIABLE	INPUT	DESCRIPTION
XCOORD	496	Easting location of the flare, see DATUM coordinates
YCOORD	6187	Northing location of the flare, see DATUM coordinates
ZCOORD	649	Terrain elevation at source, m
HS	30.5	Actual height of the flare, m
DS	0.305	Actual inside diameter of flare at top, m
RH2S	0.301	Mole fraction of H2S in raw gas
TGINIT	262.1109925	Initial fuel gas and raw gas temperature, K, or negative to set to ambient
Expected Maximum Initial Pressure		kPa (gauge) If MBLowDOWN=2, enter the maximum initial pressure of the vessel or pipeline
Expected Minimum Initial Gas Temperature		K If MINPUT=1, enter the minimum initial temperature of the vessel or pipeline
Expected Minimum Final Pressure		kPa (gauge) If MBLowDOWN=2, enter the minimum final pressure of the vessel or pipeline when flaring is stopped and the gas release is shut-in
Pipeline/Vessel Inside Diameter		m If MBLowDOWN=2, enter the vessel or pipeline inside diameter
Pipeline/Vessel Length		m If MBLowDOWN=2, enter the vessel or pipeline length
Minimum Orifice Diameter		mm If MBLowDOWN=2, enter the minimum orifice diameter where the gas escapes from the vessel or pipeline
Discharge Coefficient		-- If MBLowDOWN=2, enter the orifice discharge coefficient DEFAULT=0.6
psHS		Pseudo-Height of flare source, m Used if MINPUT=3
psDS		Pseudo-diameter of flare source, m Used if MINPUT=3
psTS		Pseudo-temperature of flare source, K Used if MINPUT=3
psUS		Pseudo-velocity of flare source, m/s Used if MINPUT=3
QMAX	695.6400596	Peak flow rate of flared gas, e ³ m ³ /d Used if MINPUT=1
QTOTAL	151.2945757	Total volume of gas contained within pipeline or vessel to be flared, e ³ m ³ /d Used if MINPUT=1
DURATION	3600	Duration of blowdown, s Used if MINPUT=1
FREL	0.978645133	Fraction of gas remaining in pipeline or vessel at the end of DURATION. Default= 0.99 Used if MBLowDOWN=2
PUFFDUR		Using MDIST=1, the user can specify either the puff duration (s) or the number of puffs, NPUFFS below.
NPUFFS	3	npuffs = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1 npuffs = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLowDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that that vary with meteorology npuffs > 1 : Number of puffs in blowdown Default = 3

Flare Assist Group

The flare assist group includes entries for fuel gas, steam assist and air assist flares.

If **MFUELGAS**=1, then **FGR** should be set to the fuel gas ratio for the flaring event. **FGR** is $(\text{e}^3\text{m}^3/\text{d fuel gas})/(\text{e}^3\text{m}^3/\text{d raw gas})$. The fuel gas ratio could be a constant flow prorated to **QMAX** or a flow proportional to exponential blowdown curve. This option is set using **MFGR**=1 (constant) or **MFGR**=2 (proportional).

If **MFASSIST**=1 to 3, then the flare is steam and/or air assisted. Steam assist parameters are entered in the **STM_** sub-group entries, and the air assist parameters are entered in the **AIR_** sub-group entries. Steam assist requires the number and diameter of the injection ports. If the steam quality (pressure and/or temperature) is known, then these values can be entered. If these values are not known, then saturated steam is assumed. Steam may be specified in either mass or volume units (**STM_IMASSVOL**=1 for mass flow or **STM_IMASSVOL**=2 for volume flow). The flow amount is entered as **STM_FLOW**.

Air assist requires the number and diameter of the air assist injection ports . Air flow is entered as volumetric using **AIR_FLOW**.

Both steam and air assist assume vertical momentum and complete mixing within the combustion zone. Caution should be used when setting flare assist, since too much steam or air can extinguish the flare.

Lift and Flare Assist Group

VARIABLE	INPUT	DESCRIPTION
FGR	0	Fuel gas ratio. Ratio of flow rate of fuel $10^3\text{m}^3/\text{d}$ to the flow rate of raw flared gas $10^3\text{m}^3/\text{d}$
QLIFTGAS		Lift gas flow rate $10^3\text{m}^3/\text{d}$
STM_NPORTS	300	Number of steam injection ports
STM_DIA	0.009	Diameter of an individual steam injection port,m
STM_PRESS		Steam injection pressure, kPa, if known else leave blank
STM_TEMP	320	Steam injection temperature, K, if known else leave blank
STM_IMASSVOL	1	=1 if steam flow is to be entered as mass flow, kg/s =2 if steam flow is entered as volume flow, $10^3\text{m}^3/\text{d}$
STM_FLOW	5	Steam flow, in kg/s or $\text{e}^3\text{m}^3/\text{d}$ as specified by STM_IMASSVOL
AIR_NPORTS	300	Number of air injection ports
AIR_DIA	0.009	Diameter of an individual air injection port, m
AIR_FLOW	2	Air flow, $10^3\text{m}^3/\text{d}$



CAUTION should be used when setting steam and flare assist since the addition of too much steam and/or air will create an over-assisted flare and extinguish the flame.

Gas Composition Group

The gas composition group provides entries for the raw gas and fuel gas streams. The flare assist streams of steam and air have known gas composition and don't require entry. The user should provide a documented raw gas stream composition that may or may not have the same H₂S concentration as the flare modelled amount. The reason for this is to allow for regulatory H₂S limit or fluctuating range of H₂S. The *ABflare* model will re-normalize the raw gas composition using **RH2S** in place of the H₂S content specified in the Raw Gas composition.

The fuel gas composition is similarly entered. Typically, fuel gas will be 100% propane if the flaring is performed at remote locations. Otherwise, fuel gas may be supplied by pipeline spec natural gas which contains typically >90% methane. Representative pipeline quality natural gas composition is listed in Hubbard (2009) and TransCanada (2012) are listed in Table 1.

Table 1: Representative Pipeline Quality Natural Gas (Hubbard 2009)

Major & Minor Components (Mole%)	Minimum	Maximum	Alberta Maximums
Methane	75	--	Not specified
Ethane	--	10	Not specified
Propane	--	5	Not specified
Butanes	--	2	Not specified
Pentanes plus	--	0.5	Not specified
Nitrogen & other inerts	--	3-4	Not specified
Carbon dioxide	--	3-4	2% by Volume
Trace Components			
Hydrogen Sulphide	--	0.25-1.0 gr/100scf	23 mg/m ³
Mercaptan Sulphur	--	0.25-1.0 gr/100scf	
Total Sulphur	--	5-20 gr/100scf	115 mg/m ³
Water Vapour	--	7.0 lb/mm scf	65 mg/m ³
Oxygen	--	0.2-1.0 ppmv	0.4% by volume

The gas composition must sum to exactly 1. If the entries do not sum to 1, a warning is displayed as shown below. This feature assists in preventing typographical errors.

Gas Composition					
Gas Compositions (mole fraction)	Fuel Gas	Lift Gas	Raw Gas	WARNINGS	COMMENTS
H ₂ O					Dry gas composition may have to be adjusted to pre-flare-tip conditions of temperature and pressure
H ₂					
He					
N ₂		1			
CO ₂					
H ₂ S					Model will adjust reference analysis to maximum requested H ₂ S, see RH2S
CH ₄			1		
C ₂ H ₆					
C ₃ H ₈	1				Set C ₃ H ₈ to 1 for propane fuel gas
i-C ₄ H ₁₀					
n-C ₄ H ₁₀					
i-C ₅ H ₁₂					
n-C ₅ H ₁₂					
n-C ₆ H ₁₄					
C _n +1					
CO					
NH ₃					
Ar					
Total	1	1	1		

Meteorology Group

The meteorology group entries must be provided if **MMET**=3. The meteorology group allows a specific meteorology to be used for the purposes calculating the flare emission parameters.

Meteorology Group		
VARIABLE	INPUT	DESCRIPTION
WINDSP	3.5	Wind speed, m/s
WINDDR	90	Wind direction, degrees wind blowing from set to -1, to use real wind
TAMB	278.15	Ambient temperature, K
PGCLASS	4	Pasquill-Gifford atmospheric stability, (1=A,2=B,3=C,4=D,5=E,6=F)
ZREF	10	Windspeed anemometer height

User Defined Blowdown Group

The user defined blowdown group allows entry of a repeatable time series of flow rate defining the blowdown, using **MINPUT**=2. This option can be used if the *ABflare* single vessel or pipeline exponential blowdown is not appropriate and the user can provide the time series independently. The user defined blowdown is processed by *ABflare* in the same way as the default single vessel or pipeline blowdown curve, that is, each time increment of the flaring curve is processed by *ABflare* to determine the flare source parameters and the effects of the meteorology on the parameters.

The user defined blowdown allows entry for rate (e³m³/d) of raw gas flared, duration of time (seconds) at that rate, the H₂S mole fraction at that increment and the fuel gas ratio for that increment.

The user defined blowdown can be used to define an arbitrary time varying flare rate by continuing the number of points in the sequence indefinitely. The last

entry of the time sequence should have a duration long enough to extend beyond the end time period, to prevent repeating of the sequence. *ABflare* creates **NSEP** number of files to start the sequence at each start hour of the day. If the user defined curve is arbitrary then the user should run all **NSEP** cases, however, if the user defined curve matches the start hour of the modelling, then the only the first *ABflare* output file can be used.

User Defined Blowdown Group				
NSEQ	3	Number of points in the user defined blowdown curve. Used when MINPUT=2		
SEQ #	Rate (10 ³ m ³ /d)	Duration (s)	H ₂ S Mole Fraction	FGR
1	574.728486	7419.563618	0.301	0
2	342.8203142	12438.68694	0.301	0
3	81.34544142	52421.30955	0.301	0
4				
5				
6				
7				

Step 3-CALPUFF Page

The *CALPUFF* module is used to check *CALPUFF* model input files for settings compatible with recommended settings. The module reads an existing *CALPUFF* input file and parameters are changed in the two groups below: file locations; and parameter settings. The existing *CALPUFF* input file should contain proper reference to meteorology, mapping and projection, and receptor locations.

The *CALPUFF* module can be used to change three file path and file names: **PUFLST**, **CONDAT** and **FLRDAT**. The **PUFLST** is the output list for the *CALPUFF* model run. **CONDAT** is the concentration output file for the *CALPUFF* model run. **FLRDAT** is the *ABflare* module output, and the *CALPUFF* arbitrary flare source input file. These three settings should be changed for each modelling run. *CALPUFF* warnings and errors are listed in the **PUFLST** file.

PARAMETER	ENTRY FOR ABFLARE	DESCRIPTION	BROWSE
PUFLST	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002.lst	Output list file Default: CALPUFF.LST	...
CONDAT	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002.con	Output bin file with concentration prediction output Default: CALPUFF.con	...
FLDAT	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002.dat	Input ABflare source file Default: abflare.dat	...

Typically, a flaring assessment will be for a 5-year meteorological period. In this case, each meteorological year is typically run as a separate *CALPUFF* run, then the results from each year are analyzed and the worse year is compared to endpoints. In the **Date Options Group**, enter the start and end date and time

for this assessment. Shorter-term assessments are performed in a similar fashion, but the start and end dates would be for a portion of a year.

The entry for **NSECDT** for the *CALPUFF* input file must match the **NSECDT** setting used in the creation of the *CALMET .dat* files used in the assessment.


Date Options Group					
	YEAR	MONTH	DAY	HOUR	SEC
Start met	2002	7	1		0
End met	2002	7	5	23	0
NSECDT	3600	time step (seconds) must match the METDAT file setup			



The entry for **NSECDT** for the *CALPUFF* input file must match the **NSECDT** setting used in the creation of the *CALMET .dat* files used in the assessment. See **Step 0a-CALMET**.

In the **Meteorological Data Group** entry area, the list of *CALMET .dat* files that match the **Date Options Group** entries are input. For a flaring assessment covering an annual period, typically twelve *CALMET .dat* files are specified. In the example below, a short-term assessment only uses month #7 *CALMET .dat* file, so only a single file is entered.

Meteorological Data Group			
NMETDAT			
1			
METDAT	Y:\ABflare\PeaceRiver\met\2002_07.dat	1	...
METDAT		2	...
METDAT		3	...
METDAT		4	...
METDAT		5	...
METDAT		6	...
METDAT		7	...
METDAT		8	...
METDAT		9	...
METDAT		10	...
METDAT		11	...
METDAT		12	...

The **Discrete Receptor Input Group** entry area is used to specify the complex terrain receptor insert file that was created using **Step 0b-Receptor**. Use the  browse button to navigate using Windows explorer or enter the *RECFIL .ctr* file by typing the complete path in the field. If the browse button is used, the *RECFIL .ctr* is scanned for the number of receptor found in the file and is listed in the **NREC** field for reference.

Discrete Receptor Input Group			
RECFIL.ctr			
Y:\ABflare\PeaceRiver\puf\user\er.ctr		CALPUFF ready discrete receptor insert file. See the MakeReceptors pre-processor page. Blank if the file was input and is being revised.	...
NREC	2920	Number of receptor points found in file	

CALPUFF model switches and settings are listed in the table below. The table provides: the *ABflare* default setting and the user setting. If a user setting has been selected that is different than the recommended *ABflare* setting, it is flagged as a warning (orange background). The *CALPUFF* default settings are listed on the **sCALPUFF** page.

SWITCH CHECKER GROUP			
PARAMETER	ABFlare DEFAULT	USER ENTRY	DESCRIPTION
NSPEC	1	1	Number of Chemical Species modelled is run specific
NSE	1	1	Number of chemical species emitted is run specific
AVET	60	60	Averaging time assumed for Pasquill Gifford plume spreads
PGTIME	60	60	Reference averaging time for Pasquill Gifford plume spreads
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Complex terrain not modelled
MSLUG	0	0	Near-field puffs; not modelled as slugs
MTRANS	1	1	Transitional plume rise not modelled
MTIP	1	1	Stack tip downwash used (except for upset flaring where stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE	1	1	1=Brigg's rise; 2=Numerical Rise
MBDW	2	2	Method to simulate building downwash 1=isc, 2=prime\nPrime is the preferred method
MSHEAR	1	1	Vertical wind shear not modelled
MSPLIT	0	0	Puffs are not split
MCHEM	0	0	Transformation rates: 0=turned off 3=computed internally using RVAD/ARM3 scheme
MAQCHEM	0	0	Aqueous phase transformation flag (used only if MCEM=6 or 7)
MLWC	1	1	Liquid Water Content flag (Used only if MAQCHEM=1)
MWET	0	0	Wet removal modelled
MDRY	0	0	Dry removal modelled
MTLT	0	0	Gravitational settling (plume title) modelled
MDISP	2	2	dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L)
MTURBVW	3	3	Use both ?v and ?z not adjusted for roughness
MDISP2	3	3	Backup method for dispersion, PG dispersion coefficients for rural areas (using ISCST3 approximation) areas when measured turbulence data missing
MTAULY	0	0	Method used for Lagrangian timescale for Sigma-y\n(used only if MDISP=1,2 or MDISP2=1,2)\n0 = Draxler default 617.284 (s)
MTAADV	0	0	Method used for Advective-Decay timescale for Turbulence\n(used only if MDISP=2 or MDISP2=2)\n0 = No turbulence advection
MCTURB	1	1	Method used to compute turbulence sigma-v & sigma-w using micrometeorological variables\n(Used only if MDISP = 2 or MDISP2 = 2)\n1 = Standard CALPUFF subroutines
MROUGH	0	0	PG Sigma_y and sigma_z adjusted for roughness
MPARTL	1	1	No partial plume penetration of elevated inversion
MPARTLBA	0	0	Partial plume penetration of elevated inversion modelled for buoyant area sources
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPOF	1	1	PDF used for dispersion under convective conditions
MSGTBL	0	0	Sub-grid TBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MSOURCE	0	0	Individual source contributions saved
MFOG	0	0	Do not configure for FOG model output
MREG	0	0	Do not test options specified to see if they conform to USEPA regulatory values
CSPEC	SO2	SO2	Species modelled SO2, H2S \n(0-No, 1-Yes, 2-Computed)
SO2	1,1,0,0	1,1,0,0	Modelled, emitted, deposited, group number
NPT1	0	0	Number of point sources with constant stack parameters or variable emission rate scale factors
NSPT1	0	0	Number of source-species combinations with variable emissions scaling factors
NPT2	0	0	Number of point sources with variable emission parameters provided in external file
NAR1	0	0	Number of polygon area sources
NSAR1	0	0	Number of source-species combinations with variable emissions scaling factors
NAR2	0	0	Number of point sources with variable emission parameters provided in external file
NLH2	0	0	Number of buoyant line sources with variable location and emission parameters
NLHES	0	0	Number of buoyant line sources with variable location and emission parameters
NSLN1	0	0	Number of source-species combinations with variable emissions scaling factors
NVL1	0	0	Number of volume sources
NSVL1	0	0	Number of source-species combinations with variable emissions scaling factors
NVL2	0	0	Number of point sources with variable emission parameters provided in external file
NFL2	1	1	Number of flare sources defined in FLEMARB.DAT
MTP_FL	0	0	For Flare Sources: Stack tip downwash is NOT used (because stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE_FL	1	1	For flare source(s): 1=Brigg's rise; 2=Numerical Rise (Default: 1)
NFLDAT	1	1	Number of flare source files

Step 4a-CALAVE Page

The *CALAVE* module is used to post-process the **CONDAT** file output from *CALPUFF*. *CALAVE* creates block averages or running averages from a binary **CONDAT** file and outputs a binary averaged concentration file. *CALAVE* was created principally for the determination of 24 hour running averages but can be used for other time averages, such as 3 h or 8 h averages. Running averages (**MODE=1**) and block averages (**MODE =2**) can be created as described below. The averaging period is set by either **AVGPD_HH** (hours) or **AVGPD_MM** (minutes). The total averaging period is:

$$\mathbf{AVGPD_HH*3600 + AVGPD_MM*60 = seconds.}$$

CALAVE processes one or more *CALPUFF* binary output files (dataset v2.1 (*CALPUFF* output file created by *CALPUFF* prior to v6.41) or v2.2 (current output format with *CALPUFF* v6.42 and v6.42FL) and computes running or block averages of concentrations, dry fluxes or wet fluxes. A binary output file with a format similar to that of a binary *CALPUFF* output file is generated for each *CALPUFF* binary file that is being processed. When blocked averages are produced, the output file is a ‘standard’ *CALPUFF* file that can be processed by any of the postprocessors in the *CALPUFF* system. Running averages use the same format, but because begin and end-times for each average span a time longer than the interval between the reported values, most of the postprocessors will not accept the running averages.

The output from *CALAVE* has the same file name but is appended with **OUT_EXT** in the same path location. Filenames can be forced to upper or lower case using the **LCFILES** switch.

Mode 1: Running Averages

In Mode 1, *CALAVE* reads a *CALPUFF* output file (CONC, WET, DRY) and creates a running average of its contents. These averages are reported from a specified start-time (**START_HHMM**) and are written for each data period thereafter.

For example, if 24-hour averages starting at 10 AM (start time, **START_HHMM = 1000**) are requested and the original *CALPUFF* output file contains half-hour values beginning at 0930 on March 13, the following averages will be computed:

- 1) First 24-hour average: 1000 (March 13) to 1000 (March 14)
- 2) Second 24-hour average: 1030 (March 13) to 1030 (March 14)
- 3) Third 24-hour average: 1100 (March 13) to 1100 (March 14)
- 4) The last 24-hour period will end at the end of the last 30-minute period in the file

A file containing 1 h average values for a single year, will have 8760 values at each receptor. After running *CALAVE* for a 24 h running average, the output will have 8760 values at each receptor representing a 24 h average.

Mode 2: Block Averages

In Mode 2, *CALAVE* reads a *CALPUFF* output file (CONC, WET, DRY) and creates a blocked average of its contents. These averages are reported from a specified start-time (**START_HHMM**) and are written end-to-end thereafter.

For example, if calendar-day 24-hour averages are requested (start time, **START_HHMM** = 0000) and the original *CALPUFF* output file contains half-hour values beginning at 0930 on March 13, the following averages will be computed:

- 1) First 24-hour average: 0000 (March 14) to 0000 (March 15)
- 2) Second 24-hour average: 0000 (March 15) to 0000 (March 16)
- 3) Third 24-hour average: 0000 (March 16) to 0000 (March 17)
- 4) The last 24-hour period will end at the end of the last full day in the file

A file containing 1 h average values for a single year, will have 8760 values at each receptor. After running *CALAVE* for a 24 h block average, the output will have 365 values at each receptor representing a 24 h average.

VARIABLE	INPUT	DESCRIPTION	BROWSE
AVGPD_HH	24	Averaging Period (hours)	
AVGPD_MM	0	Averaging Period (minutes)	
MODE	1	1 = Running averages 2 = Block averages	
START_HHMM	0	Starting time (HHMM)	
OUT_EXT	.24r	The output associated with the file(s) listed below for 'source1.dat' would be named 'source1.dat.ave' Output data file extension DEFAULT: .ave	
output: LSTFILE List-file name Default: CALAVE.LST		P:\2011\1100500-FlareModel\ex3\calave.2002.lst	...
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F	
INPFILE 1	P:\cd\ABflare_v130114\Example3\Output\ABFLARE.2002_01.CON		...
INPFILE 2	P:\cd\ABflare_v130114\Example3\Output\ABFLARE.2002_02.CON		
INPFILE 3	P:\cd\ABflare_v130114\Example3\Output\ABFLARE.2002_03.CON		
INPFILE 4	P:\cd\ABflare_v130114\Example3\Output\ABFLARE.2002_04.CON		
INPFILE 5	P:\cd\ABflare_v130114\Example3\Output\ABFLARE.2002_05.CON		
INPFILE 6	P:\cd\ABflare_v130114\Example3\Output\ABFLARE.2002_06.CON		

Step 4b-CALMAX Page

The *CALMAX* module is used to post-process *CONDAT* files output from *CALPUFF*. *CALMAX* determines the maximum concentration for each of the same time period in the files and outputs a single file with the maximum concentrations.

CALMAX reads a set of *CALPUFF*-type binary output files (*CONC*, *WET*, or *DRY*) and selects the maximum value at each receptor for each time period, for each species. Many such files can be included without limit and *CALMAX* will cycle through all. Since the main output file from *CALMAX* is also a *CALPUFF*-type binary file, *CALMAX* can be applied sequentially, using a mix of 'regular' *CALPUFF* files, *CALAVE* output files, and *CALMAX* files. The receptors and species must be the same in all files, and the period of data in each file must include the processing period requested. Because *CALAVE* generates *CALPUFF*-like binary output files, the output from *CALAVE* can be processed by *CALMAX* (and vice versa).

A *CALMAX* application creates two output data files:

1. An ASCII file of Calendar Day maximum values (*DAILYMAX.OUT*) for each species (one value per species per calendar day).
2. A binary *CALPUFF*-format file of all maximum values (one maximum value at each receptor for each 'timestep' (z timestep being either an actual *CALPUFF* timestep or an averaging time set in *CALAVE*).

A file containing 1 h average values for a single year, will have 8760 values at each receptor. After running *CALAVE* for a 24 h running average, the output will have 8760 values at each receptor representing a 24 h average. Running *CALMAX* on a set these files, will produce a single file with 8760 values representing 24-h running averages.

CALMAX cannot be run on set of block-averaged files, if the start times were incremented on each file.

VARIABLE	Year	Month	Day	Time (00:00:00)
START	2002	7	1	0:00:00
END	2002	7	5	23:00:00
VARIABLE	INPUT	DESCRIPTION	BROWSE	
output: PERFILE ASCII file of Period-Maximum values		Y:\ABflare\PeaceRiver\puf\blowdown\calmax_per.1h.dat	...	
output: BINFILE Binary CALPUFF-format file of all maximum values		Y:\ABflare\PeaceRiver\puf\blowdown\calmax.1h.con	...	
output: LSTFILE List-file name Default: CALMAX.LST		Y:\ABflare\PeaceRiver\puf\blowdown\calave.1h.lst	...	
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F		
INPFILE 1	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_01.con		...	
INPFILE 2	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_02.con			
INPFILE 3	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_03.con			
INPFILE 4	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_04.con			
INPFILE 5	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_05.con			
INPFILE 6	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_06.con			
INPFILE 7	Y:\ABflare\PeaceRiver\puf\blowdown\abflare.2002_07.con			

Step 4c-CALRANK Page

The *CALRANK* module is used to post-process *CONDAT* files output from *CALPUFF*. *CALRANK* determines the n^{th} highest or percentile concentration at each receptor location for the input file and outputs a plot file for each of the selected n^{th} highest or percentiles.

CALRANK reads a *CALPUFF*-type concentration/flux output file (dataset v2.1 or v2.2), ranks the timeseries for each species at each receptor for the entire application period, and identifies the n^{th} -highest values and the percentile values requested in the *CALRANK.inp* input file. More than one rank or percentile can be requested in a single run, and because of the overhead of ranking all of the values at each receptor, a single application with all desired ranks is normally prepared.

Individual plot-files are created for each requested rank/percentile, and include the location of each receptor, the value of the requested rank/percentile at that receptor, and the date and time at which that value occurred. If more than one species is in the file, this information is provided for each species. Additionally the largest among all receptors is tabulated for each requested rank/percentile and species in the *CALRANK.lst* file.

CALRANK can be used to process running average statistics for 24 h averages using the *ICDAY* flag setting. If *ICDAY*=0, each time period result in the file is processed as is; this is suitable for processing 1 h time averages. If *ICDAY*=1, each time period result in the file is first grouped into calendar day and the maximum value is included in the ranking; this is suitable for ranking 24 h running averages (8760 values from 1 h time averages) to produce statistics for a calendar year (365 days).

VARIABLE	INPUT	DESCRIPTION	BROWSE	
input: DATFILE File of modeled data (include path if desired) output: LSTFILE List-file name Default: CALRANK.LST		Y:\ABflare\PeaceRiver\pub\blowdown\calmax_per.1h.dat	...	
		Y:\ABflare\PeaceRiver\pub\blowdown\calrank.1h.lst	...	
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F		
ICDAY	0	Peak values that are ranked may be restricted to no more than 1 per calendar day (e.g., the calendar-day maximum). The day in which a value is placed is determined by its start-time. Report as Calendar-Day maximums? 0 = No : all values at each receptor are ranked (more than 1 rank may be in same day) 1 = Yes : peak value in calendar day at each receptor is ranked		
MASS_UNIT	3	Reported mass units 1: g/m ³ or g/m ² /s grams 2: mg/m ³ or mg/m ² /s milligrams (1.0e-03 g) 3: ug/m ³ or ug/m ² /s micrograms (1.0e-06 g) 4: ng/m ³ or ng/m ² /s nanograms (1.0e-09 g) 5: pg/m ³ or pg/m ² /s picograms (1.0e-12 g) Default : 1		
VARIABLE	INPUT	VARIABLE	INPUT %	COMMENT
NTH_HIGHEST 1	1	PERCENTILE 1	50	
NTH_HIGHEST 2	2	PERCENTILE 2	60	
NTH_HIGHEST 3	9	PERCENTILE 3	70	
NTH_HIGHEST 4		PERCENTILE 4	80	
NTH_HIGHEST 5		PERCENTILE 5	90	
NTH_HIGHEST 6		PERCENTILE 6	95	
NTH_HIGHEST 7		PERCENTILE 7	96	
NTH_HIGHEST 8		PERCENTILE 8	97	
NTH_HIGHEST 9		PERCENTILE 9	98	
NTH_HIGHEST 10		PERCENTILE 10	98.5	
NTH_HIGHEST 11		PERCENTILE 11	99	
NTH_HIGHEST 12		PERCENTILE 12	99.5	
NTH_HIGHEST 13		PERCENTILE 13	99.80000305	
NTH_HIGHEST 14		PERCENTILE 14	99.90000153	
NTH_HIGHEST 15		PERCENTILE 15		
NTH_HIGHEST 16		PERCENTILE 16		
NTH_HIGHEST 17		PERCENTILE 17		
NTH_HIGHEST 18		PERCENTILE 18		
NTH_HIGHEST 19		PERCENTILE 19		
NTH_HIGHEST 20		PERCENTILE 20		
NTH_HIGHEST 21		PERCENTILE 21		
NTH_HIGHEST 22		PERCENTILE 22		
NTH_HIGHEST 23		PERCENTILE 23		
NTH_HIGHEST 24		PERCENTILE 24		
NTH_HIGHEST 25		PERCENTILE 25		

4. EXAMPLE 1: Well Test Flare in Complex Terrain

This example was selected to demonstrate the ability of *ABflare* to model real-world flares and produce realistic predictions. The focus of the modelling was on matching observed conditions rather than modelling for regulatory approval. For regulatory approval the AESRD (2002-2006) meteorological data set would be used and maximum flow rates would be modelled.

Location

The well test flare is located in south west Alberta at the coordinates below:

Northing (m)	5513080
Easting (m)	688183
Site Elevation (m ASL)	1878

UTM-Z11-NAD83

The domain coordinates are UTM-Z11-NAD83:

Model	X	Y	Corner
CALPUFF	678184	5503080	BL
	698184	5523080	TR
CALMET	673184	5498080	BL
	703184	5528080	TR

UTM-Z11-NAD83

The topography in the region surrounding the well site is shown in Figure 6. The Terrain rises from 1878 m at the well test flare location to 2245 m within 2.2 km. The well test was operated with 12 real-time air quality monitoring stations surrounding the flare location. The locations of the monitoring stations are listed in Table 2.

Table 2: Locations of Well Test Air Quality Monitoring Stations

Label	X	Y	Elev	Distance (m)	Direction To	Wind From
#1:	688628	5514341	2052	1337	19	199
#2:	689424	5514228	2027	1690	47	227
#3:	689837	5513678	2127	1758	70	250
#4:	689888	5512886	2140	1716	96	276
#5:	689216	5512564	2123	1154	117	297
#6:	689018	5512180	2120	1227	137	317
#7:	688899	5511785	2103	1480	151	331
#8:	686141	5509059	2028	4510	207	27
#9:	685848	5510684	1893	3346	224	44
#10:	681292	5509794	1861	7635	245	65
#11:	683804	5512380	2026	4435	261	81
#12:	687461	5513001	1935	727	264	84

UTM-Z11-NAD83

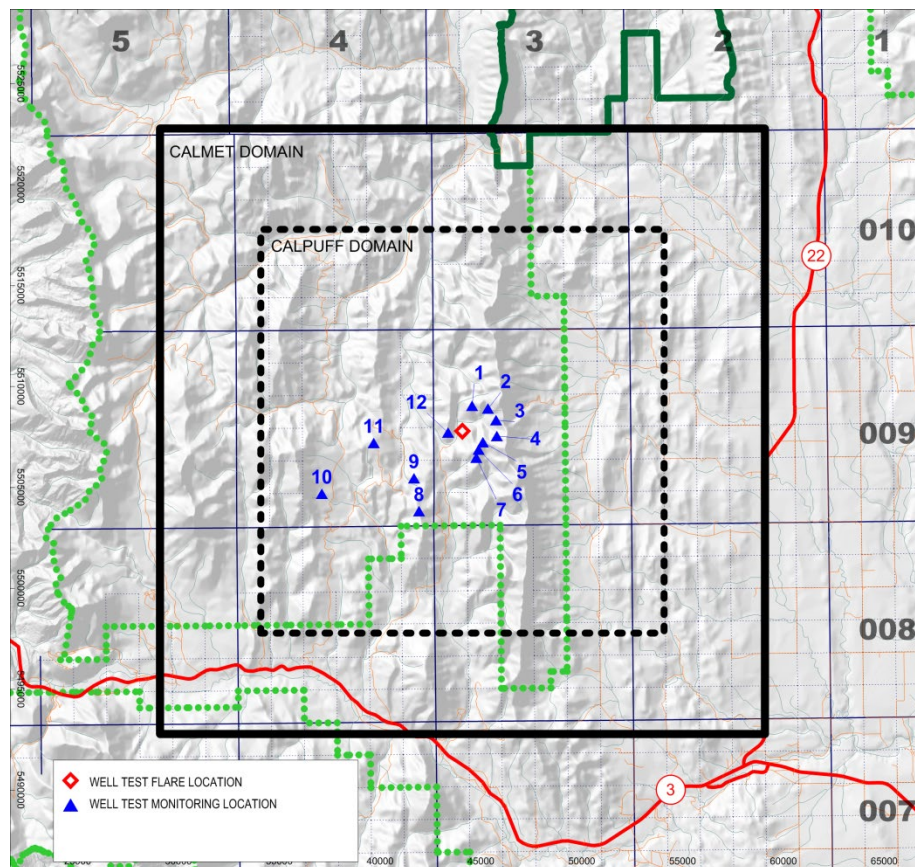


Figure 6: Topography in the Region of the Well Test Flare Showing Terrain Elevations and Locations of Monitoring stations

More detail of the elevations near the well test flare location is shown in Figure 7. Receptor locations for air quality modelling were selected in two patterns: a grid over the entire domain similar to what would be used for regulatory approval air quality modelling; and, localized arc arrays over an 11.25° arc centred at the monitoring station. It is shown in the next section that the observed winds were predominantly from 200° (or blow to 20°, station #1). However, the modelled meteorology predicted winds at some times during the same interval towards 20°, 50° and 73°. Therefore, the modelling receptor grid used arc arrays to capture likely concentrations that would be comparable to the observed record.

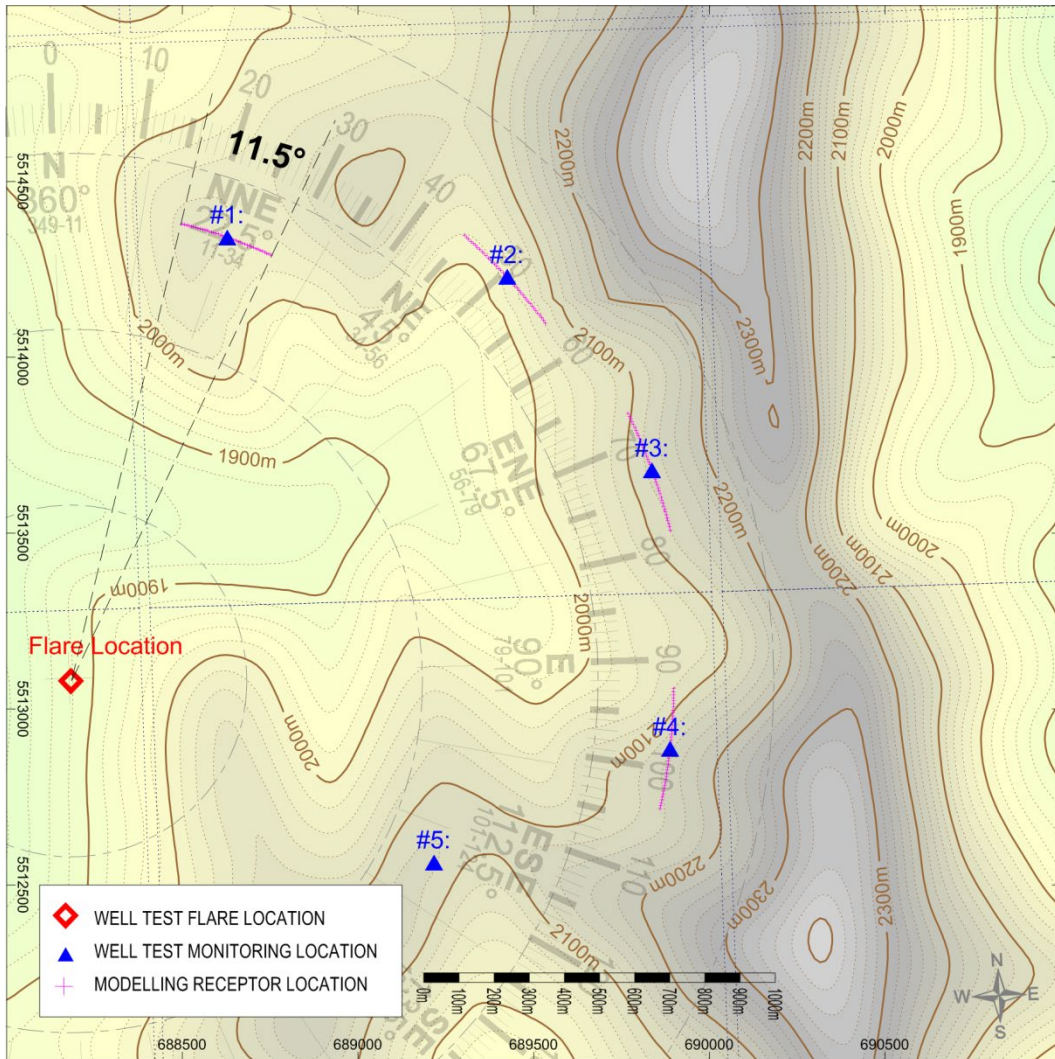


Figure 7: Air Quality Modelling Receptor Locations Near Monitoring Locations with Measurements

Meteorology

The meteorology used in this example was created from historical WRF data for the time of the well test. RWDI Calgary (www.rwdiair.com) provided a CALMET ready 3D .dat file for the time period (15-Oct-2010 to 18 Nov-2010) of the well test flare at 1 km resolution. This data was input into CALMET using land-use (Geobase 2009) and terrain elevations (Geobase 2000).

A comparison of the wind rose observed at the site to the modelled CALMET wind rose is shown in Figure 8. The observed windrose (Figure 8-left) shows an almost exclusive wind direction from S-SSW. Whereas, the CALMET derived windrose (Figure 8-right) shows influences of Western-Canada typical westerly winds as well as other directions.

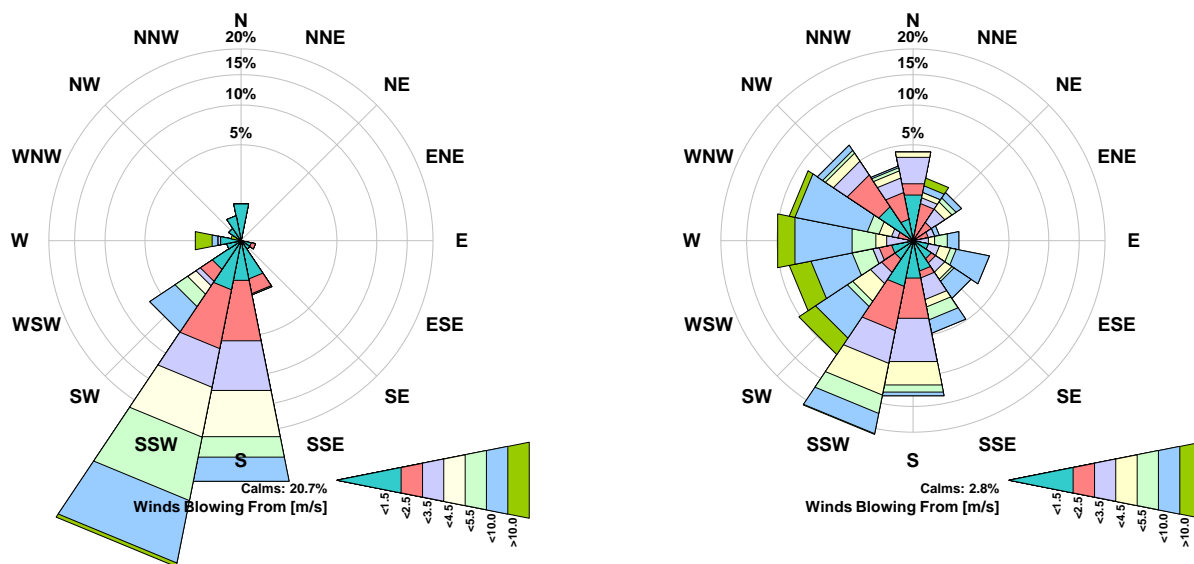


Figure 8: Comparison of Wind Rose observed at the Well Test Site Location (left) and Extracted from CALMET Derived Meteorology (right)

A comparison of the wind direction time series observed at the site (1 h running average of 15 min samples, measured at 32.2 m) to the modelled CALMET wind directions (1 h averages, extracted at flare tip height 36.6 m) are shown in Figure 9. The concentration data collected at monitoring stations showed observations between 29-Oct to 1-Nov and nominally over the period 27-Oct to 8-Nov. There is general agreement between the observed and the modelled for parts of the period. The observed wind direction blows steadily toward monitoring station #1 (from 200°) whereas the resolved CALMET meteorology predicts

winds blowing alternating between station #1, station #2 and station #3 (from 200°, 227° to 250°).

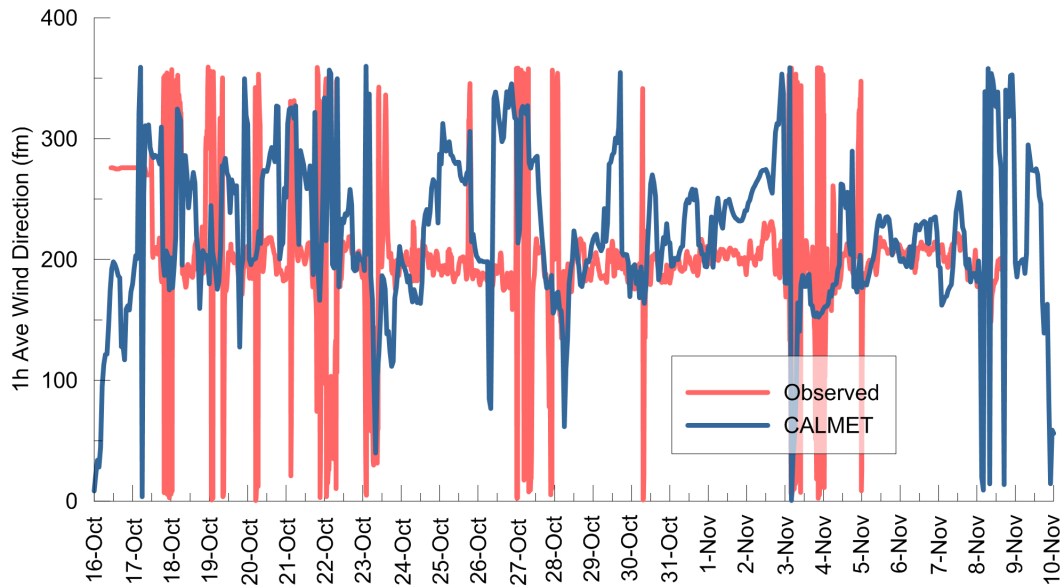


Figure 9: Comparison of Observed to Modelled Meteorology: Wind Direction (27-Oct to 8-Nov)

The predicted wind speeds closely resemble the observed (1 h average) wind speeds (Figure 10). Wind speed can have important impacts on the efficiency of the flare combustion and the predicted concentrations are inversely proportional to wind speed. However, because the dispersion is in complex terrain, the velocity along the flight path between source and receptor is not measured, and therefore the wind speed at the source is just an indication of dispersion differences.

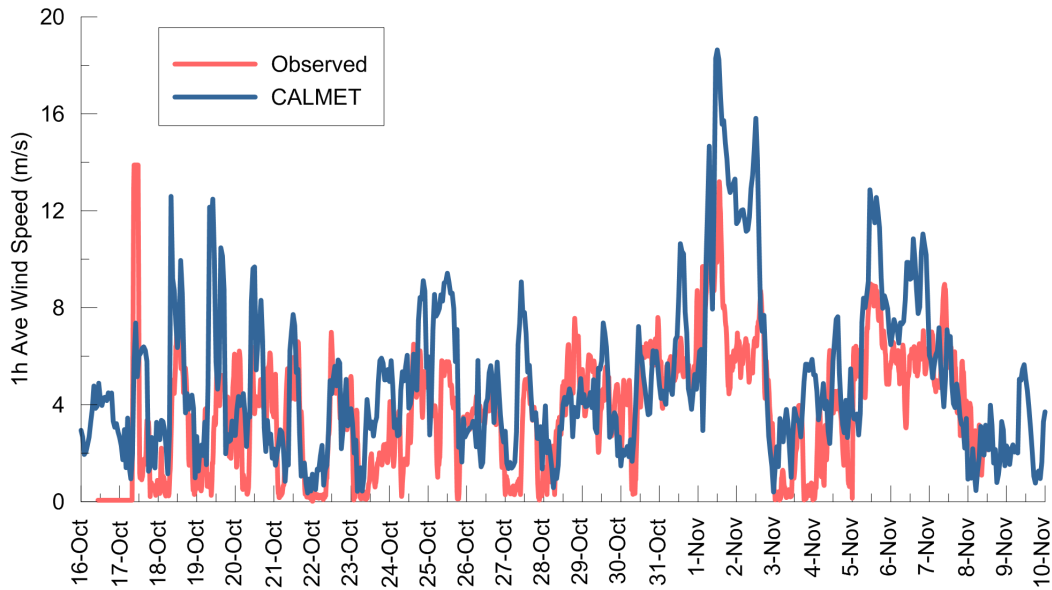


Figure 10: Comparison of Observed to Modelled Meteorology: Wind Speed (27-Oct to 8-Nov)

Predicted versus observed atmospheric turbulence, at the flare location, are shown in Figure 11. The Pasquill-Gifford (PG) stability class is a useful simplification for comparison of turbulence. Again, there are periods of time that show good relative agreement between the observed PG and modelled PG. During this period the differences are predominantly ± 1 PG class and never more than 2 PG classes.

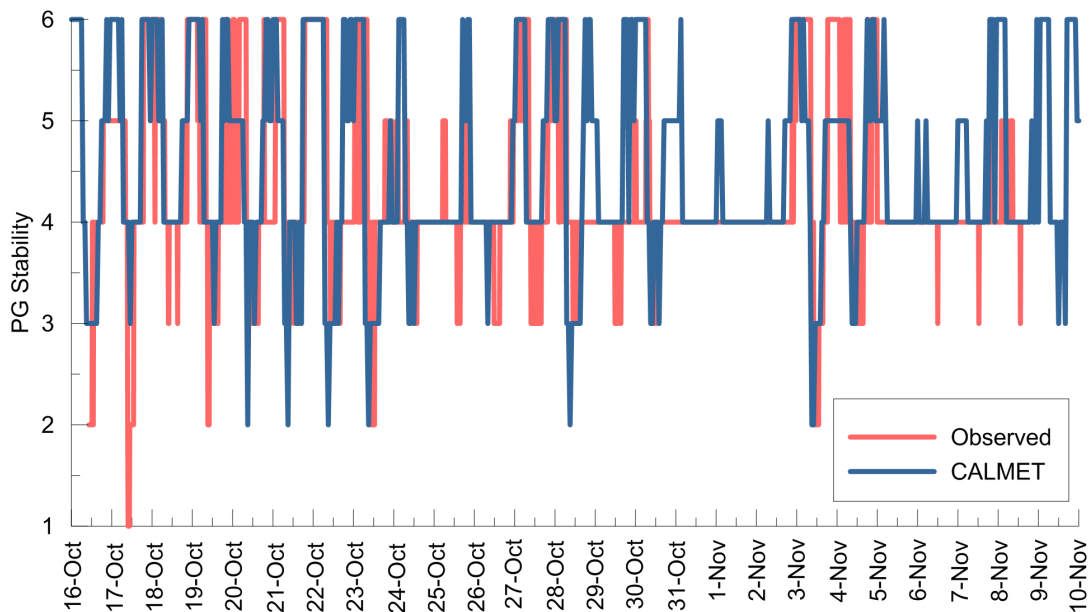


Figure 11: Comparison of Observed to Modelled Meteorology: Turbulence PG Stability Class (27-Oct to 8-Nov)

Source

The well clean up and associated gas rates being flared vary in time as shown in Figure 12. The flare rates were stopped, as marked, based upon real-time air quality dispersion modelling to prevent potential ground level exceedances. The gas rates observed during the well test are listed in the table below. The average gas rate was used in this modelling example to best represent observed conditions. For regulatory modelling for approval of a well test flare, the maximum rate gas should be used.

Flare Stack Tip Exit Height	m	36.6
Flare Stack Tip Exit Diameter	mm	154
Requested Maximum Raw Gas H ₂ S Concentration for Subject Zone	% (for approvals round up to 0.5% increment)	27.500%
Total Volume of Raw Gas to be Flared during Clean-up and Testing of ALL Zones	10 ³ m ³ (15°C and 101.325 kPa)	1.9
Maximum Raw Gas Flow Rate for Subject Zone	10 ³ m ³ /d (15°C and 101.325 kPa)	45.000

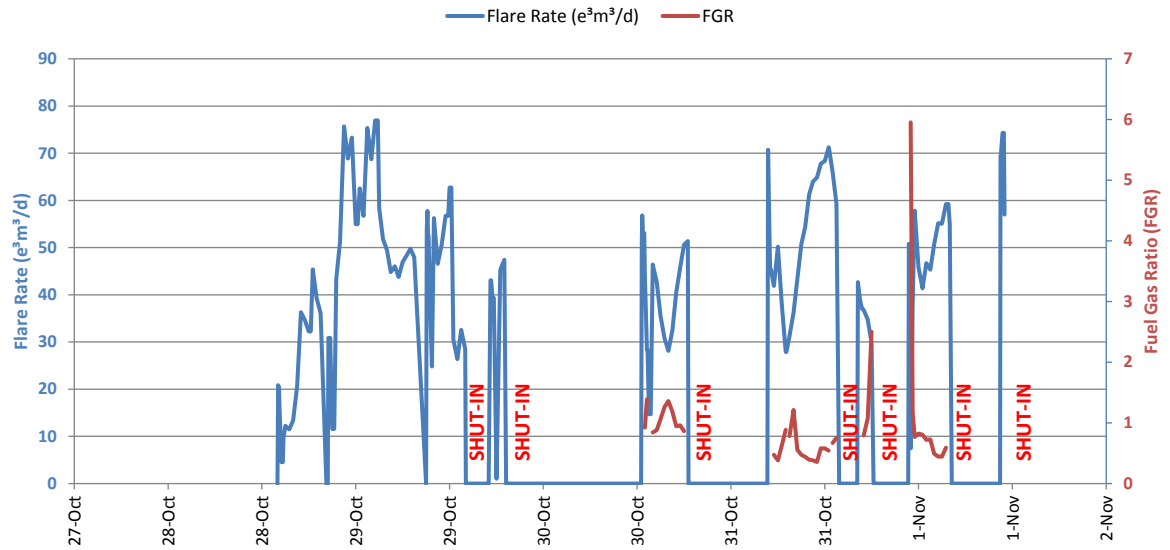


Figure 12: Flare Gas Rate and Fuel Gas Ratio During Well Test Flaring

Fuel gas (propane) was added to the raw gas flared but the rates were sparsely recorded. The average fuel gas ratio (FGR) was 0.95.

The gas analysis used for the well test flare was taken during clean-up operations. It represents the best estimate of the gas being flared.

Gas Compositions (mole fraction)	Fuel Gas	Raw Gas
H ₂ O		0
H ₂		0.0002
He		0.0001
N ₂		0.0197
CO ₂		0.07
H ₂ S		0.275
CH ₄		0.6328
C ₂ H ₆		0.0014
C ₃ H ₈	1	0.0002
i-C ₄ H ₁₀		0.0001
n-C ₄ H ₁₀		0.0001
i-C ₅ H ₁₂		0.0001
n-C ₅ H ₁₂		0.0001
n-C ₆ H ₁₄		0.0001
C ₇ ⁺		0.0001
CO		0
NH ₃		0
Total	1	1.0000

ABflare Modelling

This section of the example shows how to enter information in the *ABflare* modelling framework to model the example well test flare.

Step 0b-RECEPTOR

In this case a standard receptor grid is not of interest, but instead, a series of receptors were created centred at the monitoring sites during the well test flare. The receptor locations were determined external to *ABflare*. The receptor locations were saved as a comma separated XY file of the locations.

Selecting the [Read User Receptor Grid](#) option (see below) when the **Create Receptors** button is pressed, the user is prompted for the name of the CSV file. In this case, navigate to the Example 1 folder and selected the file.

Step 2 Create Receptors for AERMOD		Create Receptors
2.1	Enter the path name for the output receptor list	
2.2	Press 'Create Receptors' to create a receptor grid as specified in Step 1, and output to the path name. Or, select the check box to read receptors from a CSV file. Map sheets for DEM are automatically download as required or loaded from DEMLIB. <input checked="" type="checkbox"/> Read User Receptor Grid	
2.3	The DEM map sheets used in the creation of the receptor files are listed below. The receptor locations (X,Y), elevation and hill scale heights are listed at the bottom	
Entry	Resolution (m)	Default (m)
Flag Pole Receptor Height	0	0

Step 1–METSERIES

The first step in preparation for modelling the well test flare is to extract a time series of meteorological data at the flare location at the flare tip height. The meteorological data is extracted from an existing *CALMET* data set as previously described above.

The mapping and projection input group were configured with the following settings that match the location and data.

VARIABLE	INPUT	DESCRIPTION	
PMAP	UTM	Map projection, see list to right	UTM ▼
FEAST	0	False Easting and Northing (km) at the projection origin (Used only if PMAP= TTM, LCC, or LAZA)	
FNORTH	0		
IUTMZN	11	UTM zone (1 to 60) (Used only if PMAP=UTM)	
UTMHEM	N	Hemisphere for UTM projection? (N or S) (Used only if PMAP=UTM)	
RLAT0	0N	Latitude and Longitude (decimal degrees) of projection origin (Used only if PMAP= TTM, LCC, PS, EM, or LAZA) e.g., RLAT0=60N, ROLON0=115W	
ROLON0	0E		
XLAT1	0N	Matching parallel(s) of latitude (decimal degrees) for projection (Used only if PMAP= LCC or PS)	
XLAT2	0N		
DATUM	NAR-B	Datum-region for output coordinates, see list to right	NAR-B ▼
UNITS	KM	m or km	

The output group settings are selected to match the stack tip height. *CALMET* is a gridded data set, and *METSERIES* is directed ([METSIM=1](#)) to interpolate the meteorological time series at the well flare location.

VARIABLE	INPUT	DESCRIPTION
MDATA	CALMET	Input Data Type CALMET
XESTN	688.183	X-Easting Coordinate (km, deg, or cell)
YNSTN	5513.08	Y-Northing Coordinate (km, deg, or cell)
METSIM	1	1=interpolate; 2=nearest grid cell
ZWIND	36.6	Measurement height (m AGL) for wind (-1. to exclude)
ZTEMP	36.6	Measurement height (m AGL) for temperature (-1. to exclude)
ZRHUM	36.6	Measurement height (m AGL) for humidity (-1. to exclude)

The well test flare monitoring period was Oct 15 through Nov 18, 2010.

	iyr	imo	iday	ihr	isec
Start met	2010	10	15	0	0
End met	2010	11	18	0	0
NSECDT	3600	Time interval			

There is only a single meteorological data file to be processed since the time period is relatively short. The full path of the data file is entered.

NMETINP	Number of met files to extract	BROWSE
1		
MetDat1	Y:\2011\11005\met\m1_01.dat	...
MetDat2		

The input and output folders group are selected to match the users' computer configuration. The root name for the output is used by *METSERIES* in the naming of its output files.

VARIABLE	INPUT	DESCRIPTION
Output Path	P:\2011\1100500\ex1\	
TSFOUT	m2010	Timeseries data are written to the following NTSFOUT files .TSF file extension WILL BE ADDED to the names provided
output: LSTDAT List-file name Default: METSERIES.LST	P:\2011\1100500\ex1\metseries.lst	

The user should then save the *ABflare.xlsx* spreadsheet and the user should then save the *METSERIES* page inputs by pressing the **SAVE AS...** button at the top of the page. The **SAVE AS...** button creates a *METSERIES* input file and displays the selected file name at the top of the page for reference.

Step 2 – ABflare Variable Source

The default source model for *ABflare* creates an hour-by-hour variable emissions source. The control variables for *ABflare* are listed below. *ABflare* is configured with **MINPUT**=1 and **MBLOWDOWN**=1. In this case, the source is not a blowdown, but a steady rate at **QMAX**. **MSTRIP**=0, indicating that a conservative modelling approach is used with 100% H₂S being converted to SO₂.

Otherwise *ABflare* uses the calculated combustion efficiency for all other calculations.

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	1	MINPUT=1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN	1	MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST	2	MDIST=1 : blowdown sequence is created based upon puffs of equal volume 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	0	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT = 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUEL GAS	1	Is fuel gas added? MFUEL GAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR	2	MFGR =1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFT GAS	0	Is lift gas used ? MLIFT GAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

The mapping and projection group is configured the same as for the *METSERIES* module.

The chemistry group inputs are listed below. These settings reflect the selection of **MSTRIP=1**, and therefore SO₂ is modelled.

VARIABLE	INPUT	DESCRIPTION		
NSPEC	1	Number of species to be modelled NSPEC=1		
	CHEMLST	Mole Weight kg/kmol	Emission Rate g/s	
FLARE: SPEC 1	SO2	64.065	1	This is the Flare source, the emissions are either STATIC or are overwritten by ABflare

The full time period of the meteorological data set is run.

VARIABLE	yr	imo	iday	ihr	isec
START	2010	10	15	0	0
END	2010	11	18	0	0
TIMEINC	3600	Time step, s Default=3600			

The source description group inputs are listed below. The flare location is entered as the X,Y origin. The actual stack height and flare tip inside diameter are entered. **RH2S** list the maximum H₂S content in the raw gas and will be used to re-normalize the raw gas composition, as previously listed.

VARIABLE	INPUT	DESCRIPTION
XCOORD	688.183	Easting location of the flare, see DATUM coordinates
YCOORD	5513.08	Northing location of the flare, see DATUM coordinates
ZCOORD	1878.4	Terrain elevation at source, m
HS	36.6	Actual height of the flare, m
DS	0.154	Actual inside diameter of flare at top, m
RH2S	0.275	Mole fraction of H ₂ S in raw gas

And

QMAX	45	Peak flow rate of flared gas, e ² m ² /d Used if MINPUT=1
QTOTAL	45	Total volume of gas contained within pipeline or vessel to be flared, e ² m ² /d Used if MINPUT=1
DURATION	3600	Duration of blowdown, s Used if MINPUT=1
FREL	0.95	Fraction of gas remaining in pipeline or vessel at the end of DURATION. Default= 0.99 Used if MBLOWDOWN=2
PUFFDUR		Using MDIST=1, the user can specify either the puff duration (s) or the number of puffs, NPUFFS below.
NPUFFS	1	npuffs = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1 npuffs = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLOWDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that vary with meteorology npuffs > 1 : Number of puffs in blowdown Default = 3

After saving the inputs to an `ABflare.inp` file, the **RUN** button is pressed to execute the *ABflare* program. The run-time list file is presented when the program completes. The list file contains a print-out of the parameters read. Error or warning messages will be displayed at the bottom of the listing should any occur.

A listing of the *ABflare* output file is provided for the first 12 hours in Figure 13. Notice how the effective X,Y location

change hour by hour as a result of the wind speed and direction at flare tip pushes the flame over. Also changing hour by hour are the effective height, diameter, temperature and vertical speed. The mass emission rate does not change since the modelling is being performed assuming 100% conversion of H₂S to SO₂. Because of the relatively high flare rate compared to the ambient wind speed, the flare efficiency is relatively high. In

Figure 14, the mass emission including flare combustion efficiency is shown and is greater than 99% efficient.

```

PLEMARB.DAT      1.0          Initial configuration
7
Time-invariant (8 variables) var1=stack input type  var2-var8=not used
  var1=1:  T(K), U, V, W (m/s)
  var1=2:  Fb, Fmx, Fmy, Fmz (i.e., buoyancy and momentum fluxes)
Time-variant (if var1=1)
  X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),T(K),U,V,W,Sigy(m),Sigz(m),Q(g/s)...
Time-variant (if var1=2)
  X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),Fb,Fmx,Fmy,Fmz,Sigy(m),Sigz(m),Q(g/s)...
JTM
11N
NAR-B
KM
JTC-0700
2010 288  0  0  2010 322  0  0
1  1
SO2'
64.065
FLR1'  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
2010 288  0  0  2010 288  1  0
FLR1'  688.19737 5513.08602 39.623 1878.400 8.252 1133.7 0.000 0.000 2.054 0.000 0.000 388.07364
2010 288  1  0  2010 288  2  0
FLR1'  688.19729 5513.08569 39.843 1878.400 8.251 1133.2 0.000 0.000 2.054 0.000 0.000 388.07364
2010 288  2  0  2010 288  3  0
FLR1'  688.19709 5513.08615 39.842 1878.400 8.249 1132.7 0.000 0.000 2.054 0.000 0.000 388.07364
2010 288  3  0  2010 288  4  0
FLR1'  688.19711 5513.08631 39.718 1878.400 8.246 1132.2 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288  4  0  2010 288  5  0
FLR1'  688.19731 5513.08642 39.437 1878.400 8.243 1131.7 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288  5  0  2010 288  6  0
FLR1'  688.19774 5513.08589 39.194 1878.400 8.238 1131.0 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288  6  0  2010 288  7  0
FLR1'  688.19794 5513.08500 39.265 1878.400 8.235 1130.1 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288  7  0  2010 288  8  0
FLR1'  688.19793 5513.08389 39.450 1878.400 8.234 1129.6 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288  8  0  2010 288  9  0
FLR1'  688.19806 5513.08309 39.296 1878.400 8.233 1129.6 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288  9  0  2010 288 10  0
FLR1'  688.19810 5513.08283 39.219 1878.400 8.233 1129.6 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288 10  0  2010 288 11  0
FLR1'  688.19816 5513.08262 39.121 1878.400 8.233 1129.8 0.000 0.000 2.055 0.000 0.000 388.07364
2010 288 11  0  2010 288 12  0
FLR1'  688.19794 5513.08197 39.251 1878.400 8.236 1130.3 0.000 0.000 2.055 0.000 0.000 388.07364

```

Figure 13: Listing of the *ABflare* Time Varying Source Output File

```

FLEMARB.DAT 1.0 Initial configuration
7
Time-invariant (8 variables) var1=stack input type var2-var8=not used
var1=1: T(K), U, V, W (m/s)
var1=2: Fb, Fmx, Fmy, Fmz (i.e., buoyancy and momentum fluxes)
Time-variant (if var1=1)
X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),T(K),U,V,W,Sigy(m),Sigz(m),Q(g/s)...
Time-variant (if var1=2)
X(km),Y(km),Z(mAGL),Elev(mMSL),D(m),Fb,Fmx,Fmy,Fmz,Sigy(m),Sigz(m),Q(g/s)...
UTM
11N
NAR-B
KM
UTC-0700
2010 288 0 0 2010 322 0 0
1 1
'SO2'
64.065
'FLR1' 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
2010 288 0 0 2010 288 1 0
'FLR1' 688.19737 5513.08602 39.623 1878.400 8.252 1133.7 0.000 0.000 2.054 0.000 0.000 386.00725
2010 288 1 0 2010 288 2 0
'FLR1' 688.19729 5513.08569 39.843 1878.400 8.251 1133.2 0.000 0.000 2.054 0.000 0.000 386.15200
2010 288 2 0 2010 288 3 0
'FLR1' 688.19709 5513.08615 39.842 1878.400 8.249 1132.7 0.000 0.000 2.054 0.000 0.000 386.15358
2010 288 3 0 2010 288 4 0
'FLR1' 688.19711 5513.08631 39.718 1878.400 8.246 1132.2 0.000 0.000 2.055 0.000 0.000 386.08053
2010 288 4 0 2010 288 5 0
'FLR1' 688.19731 5513.08642 39.437 1878.400 8.243 1131.7 0.000 0.000 2.055 0.000 0.000 385.86708
2010 288 5 0 2010 288 6 0
'FLR1' 688.19774 5513.08589 39.194 1878.400 8.238 1131.0 0.000 0.000 2.055 0.000 0.000 385.61414
2010 288 6 0 2010 288 7 0
'FLR1' 688.19794 5513.08500 39.265 1878.400 8.235 1130.1 0.000 0.000 2.055 0.000 0.000 385.70509
2010 288 7 0 2010 288 8 0
'FLR1' 688.19793 5513.08389 39.450 1878.400 8.234 1129.6 0.000 0.000 2.055 0.000 0.000 385.89158
2010 288 8 0 2010 288 9 0
'FLR1' 688.19806 5513.08309 39.296 1878.400 8.233 1129.6 0.000 0.000 2.055 0.000 0.000 385.74180
2010 288 9 0 2010 288 10 0
'FLR1' 688.19810 5513.08283 39.219 1878.400 8.233 1129.6 0.000 0.000 2.055 0.000 0.000 385.65475
2010 288 10 0 2010 288 11 0
'FLR1' 688.19816 5513.08262 39.121 1878.400 8.233 1129.8 0.000 0.000 2.055 0.000 0.000 385.52720
2010 288 11 0 2010 288 12 0
'FLR1' 688.19794 5513.08197 39.251 1878.400 8.236 1130.3 0.000 0.000 2.055 0.000 0.000 385.68668
2010 288 12 0 2010 288 13 0
'FLR1' 688.19754 5513.08113 39.428 1878.400 8.238 1130.7 0.000 0.000 2.055 0.000 0.000 385.86511

```

Figure 14: Listing of the ABflare Time Varying Source Output File with Emissions calculated from Combustion Efficiency

Step 3 – CALPUFF

Only ABflare-default settings were used for the modelling using Figure 13 emissions. An important setting to remember is, **MTIP_FL=0**. This setting turns OFF stack tip downwash for flare sources, since stack tip down wash is accounted for in the source parameters.

NFL2	1	1	Number of flare sources defined in FLEMARB.DAT
MTIP_FL	0	0	For Flare Sources: Stack tip downwash is NOT used (because stack tip down wash is accounted for in the source term using the AER spreadsheet)
MRISE_FL	1	1	For flare source(s): 1=Brigg's rise; 2=Numerical Rise (Default: 1)
NFLDAT	1	1	Number of flare source files

Step 4a – CALAVE

In this short-term example, the only time period of interest is the 1 h average, therefore the *CALAVE* module is not required.

Step 4b – CALMAX

In this short-term example, the only time period of interest is the 1 h average, therefore the *CALMAX* module is not required.

Step 4c – CALRANK

The *CALRANK* module is configured to read the *CALPUFF* output file `calpuff.con`. A typical ranking file request is listed below. The n^{th} highest values are useful for direct comparison to regulatory modelling required criteria. The percentile values are useful for plotting the probability distribution of predictions. For a dataset with 8760 hourly predictions, the 99.9th prediction will be the same as the 9th highest.

VARIABLE	INPUT		VARIABLE	INPUT %
NTH_HIGHEST 1	1		PERCENTILE 1	50
NTH_HIGHEST 2	2		PERCENTILE 2	60
NTH_HIGHEST 3	9		PERCENTILE 3	70
NTH_HIGHEST 4			PERCENTILE 4	80
NTH_HIGHEST 5			PERCENTILE 5	90
NTH_HIGHEST 6			PERCENTILE 6	95
NTH_HIGHEST 7			PERCENTILE 7	96
NTH_HIGHEST 8			PERCENTILE 8	97
NTH_HIGHEST 9			PERCENTILE 9	98
NTH_HIGHEST 10			PERCENTILE 10	98.5
NTH_HIGHEST 11			PERCENTILE 11	99
NTH_HIGHEST 12			PERCENTILE 12	99.5
NTH_HIGHEST 13			PERCENTILE 13	99.8
NTH_HIGHEST 14			PERCENTILE 14	99.9

The *ICDAY* option is not required in this case, since only hourly maximum averages are of interest.

The input file is saved to a `calrank.inp` file and then the *CALRANK* program is executed. A run-time file listing is displayed after the program terminates. The list file displays the type. The list file is shown below in Figure 15. The location and time of the maximum n^{th} highest and percentile values are listed in the list file.

CALRANK also creates plottable file output for each of the n^{th} highest and percentile values. The file names for these outputs are listed in the list file and the files are located in the folder containing the list file.

CALRANK RESULTS SUMMARY
VERSION:1.1 LEVEL:120915

File Processed: p:\abflare\examples\example1\calpuff.con

Selected Header Information From File:

Produced by CALPUFF Version: 6.42_x1. Level: 121203
Internal Coordinate Transformations --- COORDLIB Version: 1.99 Level: 070921
CALPUFF.INP 2.1 Group 18 added
ABflare test case r1
48-hour simulation using CALMET met data
Arc Receptors 41 on 30x30km met grid

Information about data in file

Averages (DAY,HH,MM,SS) = 0 1 0 0
Type of Averaging = BLOCK
Number of averages/day = 24
Number of days = 11
Number of receptors = 4120
Number of species = 1
First day (YYYYJJJ) = 2010301 UTC-0700
Last day (YYYYJJJ) = 2010311 UTC-0700

Model data for each receptor are ranked over all times based on magnitude and the requested Nth-Highest and/or Percentile values are reported for each receptor in the output files:

p:\abflare\examples\example1\calrank.lst_PLOT_RANK-0001.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_RANK-0002.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_RANK-0009.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-50.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-60.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-70.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-80.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-90.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-95.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-96.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-97.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-98.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-98.500.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.000.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.500.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.800.DAT
p:\abflare\examples\example1\calrank.lst_PLOT_PCTL-99.900.DAT

Figure 15: CALRANK program output list file

The largest of these for each rank are tabulated below with the location and time

 Tabulation for Requested Nth-Highest Values
 Results for the Maximum Receptor
 All Values in Each Day are Included

N	Percentile	Species - Level	Modeled	Units	Location		Starting UTC-0700	
					X (KM)	Y (KM)	Date (YYYY_JJJ)	Time (HH:MM:SS)
1	99.811	SO2	1 6.9553643E+03	ug/m3	688.450	5513.000	2010_306	18:00:00
2	99.432	SO2	1 3.8266162E+03	ug/m3	688.450	5513.000	2010_308	18:00:00
9	96.780	SO2	1 3.0401165E+03	ug/m3	688.375	5513.075	2010_306	12:00:00

 Note: number of times in period = 264

 Tabulation for Requested Percentile Values
 Results for the Maximum Receptor
 All Values in Each Day are Included

N	Percentile	Species - Level	Modeled	Units	Location		Starting UTC-0700	
					X (KM)	Y (KM)	Date (YYYY_JJJ)	Time (HH:MM:SS)
133	50.000	SO2	1 1.4546561E+02	ug/m3	688.400	5513.200	2010_308	23:00:00
107	60.000	SO2	1 3.5565048E+02	ug/m3	688.425	5513.175	2010_310	08:00:00
80	70.000	SO2	1 7.9965356E+02	ug/m3	688.375	5513.175	2010_309	19:00:00
54	80.000	SO2	1 1.2728715E+03	ug/m3	688.400	5513.200	2010_310	11:00:00
27	90.000	SO2	1 2.1104839E+03	ug/m3	688.375	5513.175	2010_305	21:00:00
14	95.000	SO2	1 2.6285774E+03	ug/m3	688.375	5513.125	2010_306	08:00:00
12	96.000	SO2	1 2.8103999E+03	ug/m3	688.350	5513.100	2010_306	12:00:00
9	97.000	SO2	1 3.0401165E+03	ug/m3	688.375	5513.075	2010_306	12:00:00
6	98.000	SO2	1 3.3129653E+03	ug/m3	688.375	5513.075	2010_306	10:00:00
5	98.500	SO2	1 3.4995078E+03	ug/m3	688.325	5513.075	2010_306	09:00:00
4	99.000	SO2	1 3.6119949E+03	ug/m3	688.325	5513.075	2010_306	10:00:00
2	99.500	SO2	1 3.8266162E+03	ug/m3	688.450	5513.000	2010_308	18:00:00
2	99.800	SO2	1 3.8266162E+03	ug/m3	688.450	5513.000	2010_308	18:00:00
1	99.900	SO2	1 6.9553643E+03	ug/m3	688.450	5513.000	2010_306	18:00:00

 Note: number of times in period = 264

Figure 15: CALRANK program output list file (continued)

A map of the 99.9th percentile concentrations for the region shown in Figure 7 is presented in Figure 16 for the full meteorological time period modelled at the average flare rate and $FGR=0.95$. The map shows that there is potential for high concentrations (greater than the regulatory limit of $450 \mu\text{g}/\text{m}^3$) throughout the mapped area which is within 2.5 km of the flare source.

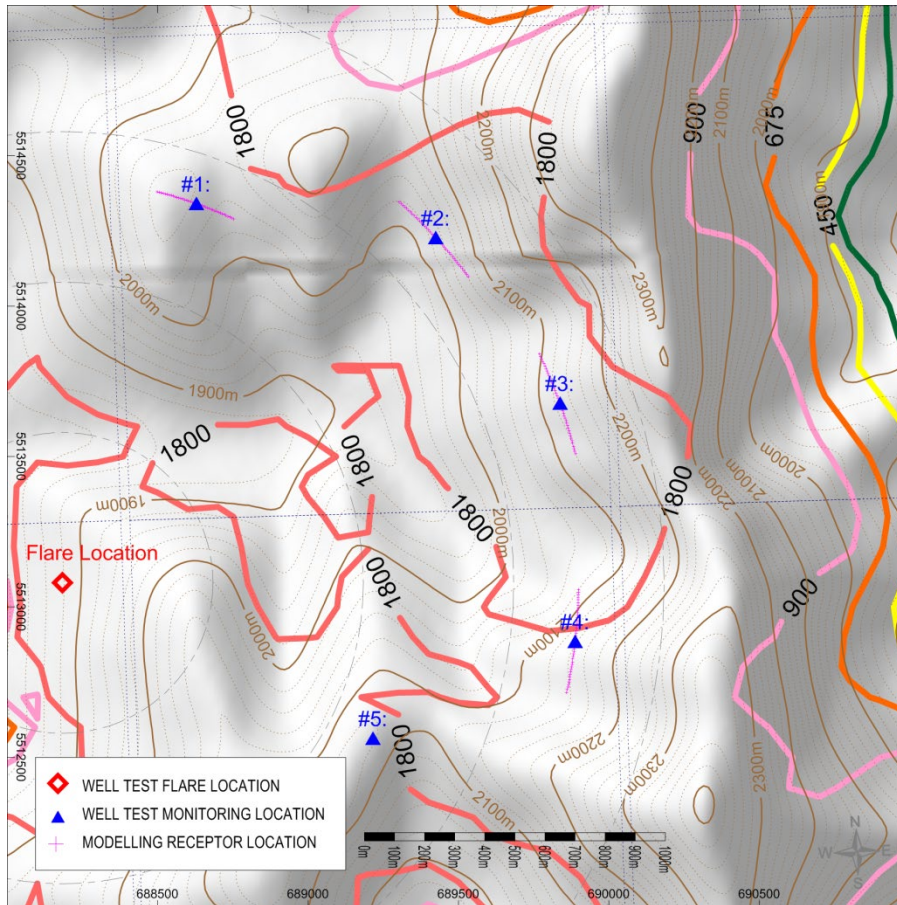


Figure 16: 99.9th Percentile Predicted Concentrations for the Complete Meteorological Time Period at Average Emission and FGR=0.95

Comparison to Monitoring Data

CALPUFF was reconfigured for only the period where active flaring was occurring (28th Oct -2st Nov) and only for receptor array locations as shown in Figure 7 that would resemble the distances and locations for the monitoring data collected.

In Figure 17 the monitoring data for 1h concentrations is compared to the flaring rates. The on-off cycle of the flaring rate was used to prevent ground level exceedences based upon real-time air quality modeling. In Figure 18, the monitoring data at Station #1 is compared to modelled predictions at Arc 1. Because of the differences between the observed wind rose and the modelled meteorology windrose, an exact replication of the flare test results is not expected. Figure 18, shows the wind directions are missing the Arc 1 receptor locations.

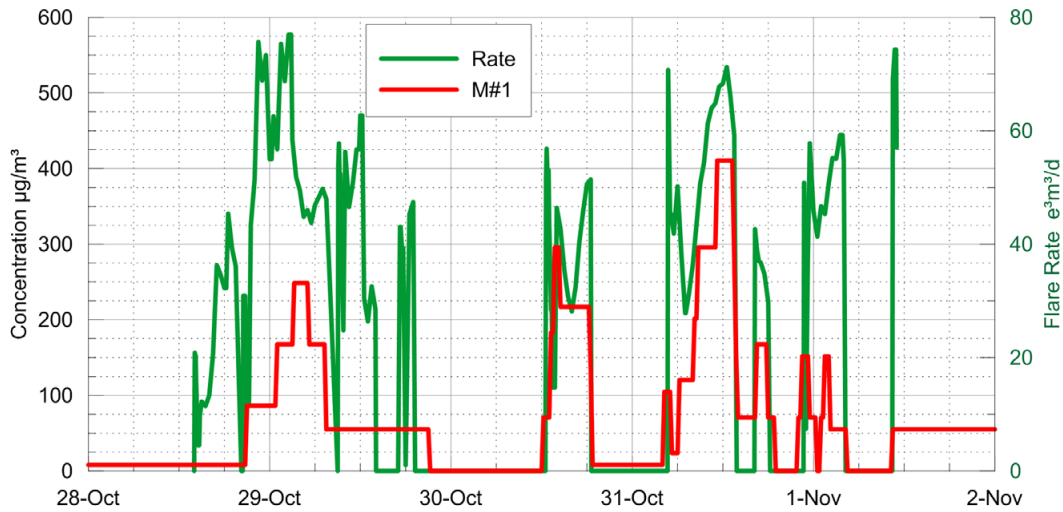


Figure 17: Concentration Monitoring 1h Data at Station #1 Compared to Flaring Rates

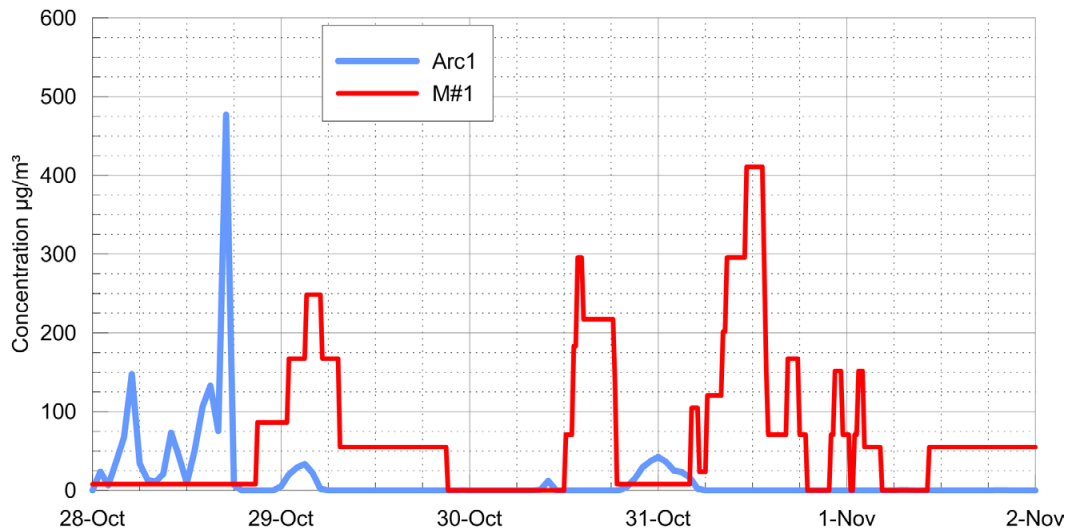


Figure 18: Concentration Monitoring 1h Data at Station #1 Compared to Modelled 1h Predictions at Arc 1

The receptor arcs used in the modelling are at similar distances from the flare source (see Table 2). Therefore, ignoring the influence of terrain elevation, the concentrations should be similar at one monitoring location compared to another. Figure 19 shows a comparison of the maximum of Arc 1, 2, 3 and 4 predictions compared to the maximum of Monitoring Station #1, #2, #3 and #4 data. In this comparison some of the discrepancy of wind direction is removed, however,

influence of terrain, among other things, may contribute to differences. In general, there is good agreement between the modelling and the observations. The probability distribution shown in Figure 20 indicates that based upon these modelling results for a constant flare rate at the average rate and average fuel gas ratio, the modelling over predicts the concentrations by a factor of two.

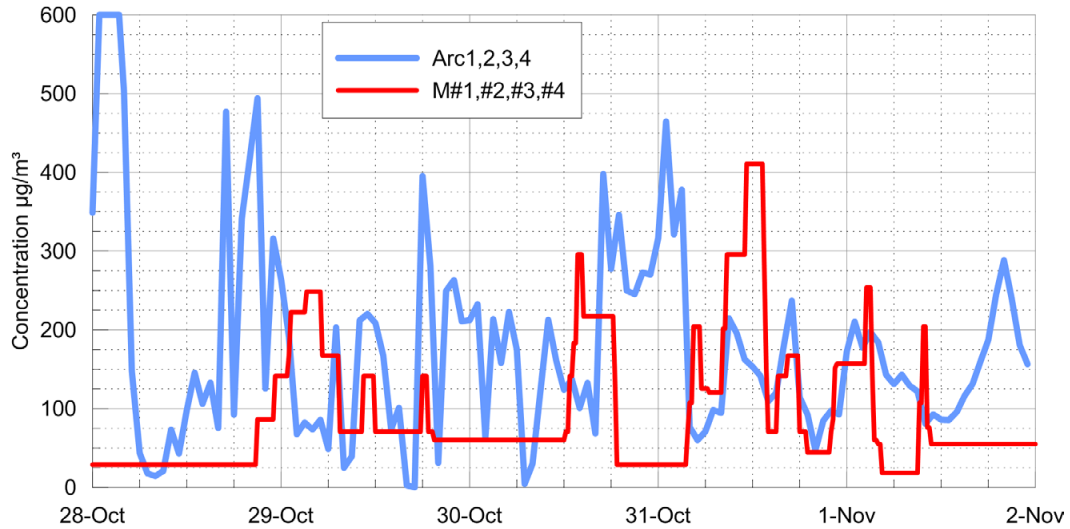


Figure 19: Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

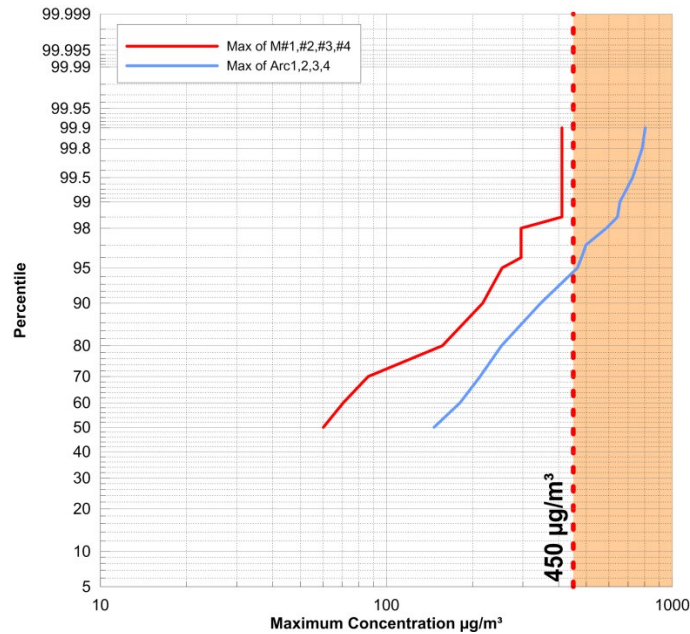


Figure 20: Probability Distribution Comparison of Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

5. EXAMPLE 2: User Defined Flare Rate

An extension to the example shown in Example 1, is the application of *ABflare* to the actual flare rate and fuel gas flare assist as shown in Figure 12. The *ABflare* was configured using the following settings in the control group. The change from Example 1 to Example 2, is **MINPUT=2**, which directs *ABflare* to read a user defined blow down curve and **MSTRIP=2**, which directs *ABflare* to use actual SO₂ emissions including the effects of combustion efficiency.

The user defined blowdown, in this case, is not a blowdown but the time series of flare rates of variable duration as recorded during the flare event. The rates are listed in Table 3. The H₂S mole fractions are set to -1 and the **RH2S** variable is used to define the assumed constant gas analysis. The **FGR** is alternately set between -1 and the actual rate. When the table FGR is -1, the fuel gas ratio uses the default setting in the variable **FGR=0.95**. In this example, the **FGR** varies and is assumed to be proportional to an initial flow of 47×10^3 m³/d, therefore, set **MFGR=2** and set **QMAX=47**.

When *ABflare* is run, it creates 24-source files according to the **NSEP =24** setting. This setting is used for blowdown curves and presumes a blowdown starts at each hour of the day. In this case, we are using *ABflare* to create the source file and are using only the first output file. The first output file matches the date/time of the flare rates Oct 28 through Nov 2. The remaining 23-*ABflare* output files are discarded.

The results of this modelling are shown in Figure 21 for the maximum of receptor arc 1, 2, 3 and 4 compared to the maximum of monitoring locations #1, #2, #3, and #4. There is relatively good agreement between the modelling and the observations. In Figure 22 a comparison of the probability distributions shows that the distribution of concentrations also agrees well with observations.

The combustion efficiency of this flare is high because of the relatively high rate as shown in Figure 23. In this case the option to use **MSTRIP=2** (SO₂ emissions include the conversion efficiency) versus the conservative **MSTRIP=0** (SO₂ emissions assume 100% conversion) does not impact the predicted SO₂ concentrations in a significant amount.

VARIABLE	INPUT	DESCRIPTION
MDSPMOD	1	MDSPMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	2	MINPUT =1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that that don't vary with meteorology DEFAULT = 1
MBLOWDOWN		MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST		MDIST=1 : blowdown sequence is created based upon puffs of equal volume 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	2	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT= 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUEL GAS	1	Is fuel gas added? MFUEL GAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR	2	MFGR =1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFT GAS	0	Is lift gas used ? MLIFT GAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

Table 3: Actual Flare Rates and Fuel Gas

#	Rate (e ³ m ³ /d)	Durati on (s)	FGR	#	Rate (e ³ m ³ /d)	Durati on (s)	FGR	#	Rate (e ³ m ³ /d)	Durati on (s)	FGR	#	Rate (e ³ m ³ /d)	Durati on (s)	FGR	#	Rate (e ³ m ³ /d)	Durati on (s)	FGR	#	Rate (e ³ m ³ /d)	Durati on (s)	FGR
1	0.0	3600	-1.00	51	68.7	1800	-1.00	101	0.0	300	-1.00	151	32.5	1800	1.18	201	71.2	60	0.54	251	0.0	300	-1.00
2	0.0	3600	-1.00	52	77.0	1200	-1.00	102	0.0	900	-1.00	152	40.5	1800	0.95	202	71.2	1740	-1.00	252	0.0	300	-1.00
3	0.0	3600	-1.00	53	77.0	600	-1.00	103	0.0	900	-1.00	153	45.9	1800	0.96	203	65.9	1800	0.67	253	0.0	300	-1.00
4	0.0	3600	-1.00	54	58.4	1800	-1.00	104	0.0	1800	-1.00	154	50.6	60	0.86	204	59.2	1200	0.75	254	0.0	900	-1.00
5	0.0	3600	-1.00	55	51.8	1800	-1.00	105	0.0	1800	-1.00	155	50.6	1740	-1.00	205	0.0	300	-1.00	255	0.0	900	-1.00
6	0.0	3600	-1.00	56	49.5	1800	-1.00	106	0.0	1800	-1.00	156	51.4	300	0.85	206	0.0	300	-1.00	256	0.0	900	-1.00
7	0.0	3600	-1.00	57	44.8	1800	-1.00	107	0.0	1800	-1.00	157	0.0	300	-1.00	207	0.0	900	-1.00	257	0.0	900	-1.00
8	0.0	3600	-1.00	58	46.0	1800	-1.00	108	0.0	1800	-1.00	158	0.0	300	-1.00	208	0.0	900	-1.00	258	0.0	1800	-1.00
9	0.0	3600	-1.00	59	43.8	1800	-1.00	109	0.0	1800	-1.00	159	0.0	900	-1.00	209	0.0	1800	-1.00	259	0.0	1800	-1.00
10	0.0	3600	-1.00	60	46.9	1800	-1.00	110	0.0	1800	-1.00	160	0.0	900	-1.00	210	0.0	1800	-1.00	260	0.0	1800	-1.00
11	0.0	3600	-1.00	61	48.3	1800	-1.00	111	0.0	1800	-1.00	161	0.0	900	-1.00	211	0.0	1800	-1.00	261	0.0	1800	-1.00
12	0.0	4500	-1.00	62	49.8	1800	-1.00	112	0.0	1800	-1.00	162	0.0	1800	-1.00	212	0.0	300	-1.00	262	0.0	1800	-1.00
13	0.0	5400	-1.00	63	47.9	5400	-1.00	113	0.0	1800	-1.00	163	0.0	1800	-1.00	213	0.0	300	-1.00	263	0.0	1800	-1.00
14	0.0	900	-1.00	64	0.0	300	-1.00	114	0.0	1800	-1.00	164	0.0	1800	-1.00	214	0.0	300	-1.00	264	0.0	1800	-1.00
15	0.0	300	-1.00	65	54.1	300	-1.00	115	0.0	1800	-1.00	165	0.0	1800	-1.00	215	42.6	900	-1.00	265	0.0	1800	-1.00
16	20.8	300	-1.00	66	57.8	300	-1.00	116	0.0	1800	-1.00	166	0.0	1800	-1.00	216	39.1	900	0.76	266	0.0	1800	-1.00
17	20.3	120	-1.00	67	52.4	300	-1.00	117	0.0	1800	-1.00	167	0.0	1800	-1.00	217	37.1	900	-1.00	267	0.0	1200	-1.00
18	20.3	180	-1.00	68	52.4	600	-1.00	118	0.0	1800	-1.00	168	0.0	1800	-1.00	218	36.7	1800	0.79	268	0.0	300	-1.00
19	16.3	900	-1.00	69	40.2	900	-1.00	119	0.0	1800	-1.00	169	0.0	1800	-1.00	219	34.7	1800	1.08	269	0.0	300	-1.00
20	4.5	600	-1.00	70	24.8	900	-1.00	120	0.0	1800	-1.00	170	0.0	1800	-1.00	220	29.8	900	2.50	270	69.3	60	1.00
21	4.5	300	-1.00	71	56.3	1800	-1.00	121	0.0	1800	-1.00	171	0.0	1800	-1.00	221	0.0	300	-1.00	271	69.3	840	-1.00
22	9.7	900	-1.00	72	46.5	1800	-1.00	122	0.0	1800	-1.00	172	0.0	1800	-1.00	222	0.0	300	-1.00	272	74.3	300	-1.00
23	12.2	1800	-1.00	73	50.7	1800	-1.00	123	0.0	1800	-1.00	173	0.0	1800	-1.00	223	0.0	300	-1.00	273	74.3	300	-1.00
24	11.5	1800	-1.00	74	56.7	1200	-1.00	124	0.0	1800	-1.00	174	0.0	1800	-1.00	224	0.0	900	-1.00	274	74.3	300	-1.00
25	13.3	1800	-1.00	75	56.7	600	-1.00	125	0.0	1800	-1.00	175	0.0	1800	-1.00	225	0.0	900	-1.00	275	57.0	60	1.21
26	20.6	1800	-1.00	76	62.7	900	-1.00	126	0.0	600	-1.00	176	0.0	1800	-1.00	226	0.0	900	-1.00	276	0.0	540	-1.00
27	36.3	1800	-1.00	77	62.7	900	-1.00	127	0.0	5400	-1.00	177	0.0	1800	-1.00	227	0.0	900	-1.00	277	0.0	46200	-1.00
28	34.6	1800	-1.00	78	30.5	1800	-1.00	128	0.0	1200	-1.00	178	0.0	1800	-1.00	228	0.0	1800	-1.00				
29	32.3	900	-1.00	79	26.4	1800	-1.00	129	0.0	3600	-1.00	179	0.0	1800	-1.00	229	0.0	1800	-1.00				
30	32.3	900	-1.00	80	32.6	1800	-1.00	130	0.0	1200	-1.00	180	0.0	300	-1.00	230	0.0	1800	-1.00				
31	45.4	1800	-1.00	81	28.5	300	-1.00	131	0.0	2280	-1.00	181	0.0	300	-1.00	231	0.0	1800	-1.00				
32	39.3	1800	-1.00	82	0.0	300	-1.00	132	0.0	120	-1.00	182	0.0	300	-1.00	232	0.0	1800	-1.00				
33	36.1	2700	-1.00	83	0.0	300	-1.00	133	0.0	1200	-1.00	183	70.7	900	-1.00	233	0.0	1800	-1.00				
34	0.0	300	-1.00	84	0.0	900	-1.00	134	0.0	2400	-1.00	184	45.5	300	0.53	234	0.0	300	-1.00				
35	0.0	300	-1.00	85	0.0	900	-1.00	135	0.0	1800	-1.00	185	45.5	1500	-1.00	235	0.0	300	-1.00				
36	0.0	300	-1.00	86	0.0	900	-1.00	136	0.0	300	-1.00	186	41.9	1800	0.47	236	0.0	300	-1.00				
37	30.9	900	-1.00	87	0.0	1800	-1.00	137	51.3	300	-1.00	187	50.2	1800	0.38	237	50.8	900	-1.00				
38	30.9	900	-1.00	88	0.0	1800	-1.00	138	56.8	300	-1.00	188	38.2	1800	0.62	238	7.4	900	5.95				
39	11.6	900	-1.00	89	0.0	1800	-1.00	139	53.1	600	0.73	189	27.9	300	0.88	239	38.0	900	1.17				
40	11.6	900	-1.00	90	0.0	1800	-1.00	140	53.1	300	-1.00	190	27.9	1500	-1.00	240	57.8	1740	0.77				
41	43.4	1800	-1.00	91	0.0	900	-1.00	141	43.9	900	0.92	191	31.3	1800	0.78	241	45.9	1860	0.82				
42	51.3	1800	-1.00	92	43.1	300	-1.00	142	28.4	300	1.39	192	36.2	1800	1.21	242	41.3	1800	0.81				
43	75.7	1800	-1.00	93	43.1	600	-1.00	143	28.4	600	-1.00	193	43.4	1800	0.55	243	46.7	1800	0.72				
44	68.9	1800	-1.00	94	39.3	600	-1.00	144	14.7	900	2.78	194	50.7	1800	0.47	244	45.3	1800	0.73				
45	73.3	1800	-1.00	95	39.3	1200	-1.00	145	14.7	900	-1.00	195	54.4	1800	0.44	245	50.7	1800	0.49				
46	55.0	900	-1.00	96	1.0	1800	-1.00	146	46.4	1800	0.84	196	61.3	1800	0.39	246	55.2	1800	0.44				
47	55.0	900	-1.00	97	45.3	1800	-1.00	147	42.7	1800	0.88	197	64.0	1800	0.38	247	55.1	1800	0.45				
48	62.6	1800	-1.00	98	47.4	900	-1.00	148	35.5	1800	1.06	198	64.8	1800	0.36	248	59.2	1200	0.59				
49	56.7	1800	-1.00	99	0.0	300	-1.00	149	30.7	1800	1.26	199	67.8	1800	0.58	249	59.2	600	-1.00				
50	75.3	1800	-1.00	100	0.0	300	-1.00	150	28.1	1800	1.36	200	68.3	1800	0.58	250	54.8	900	0.79				

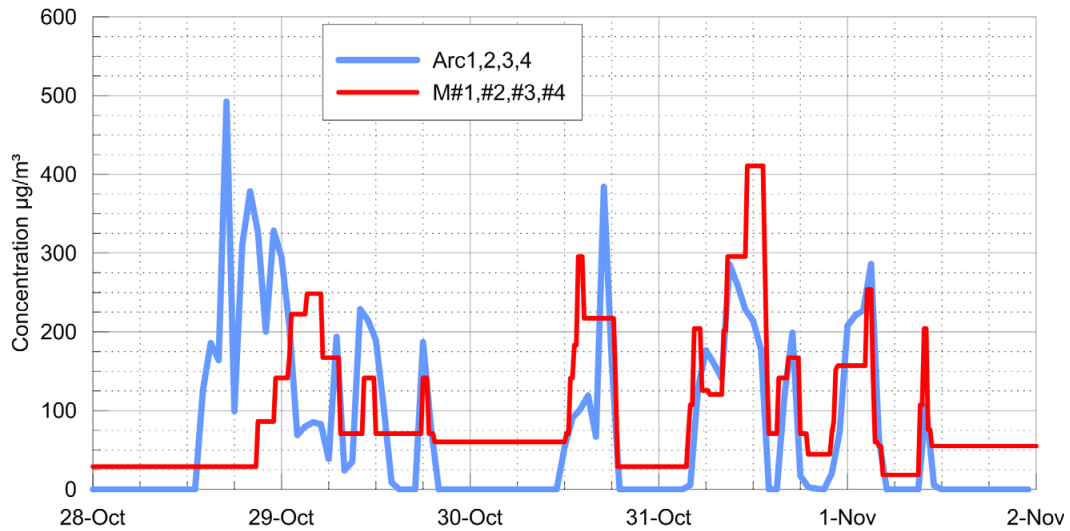


Figure 21: Example 2 Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

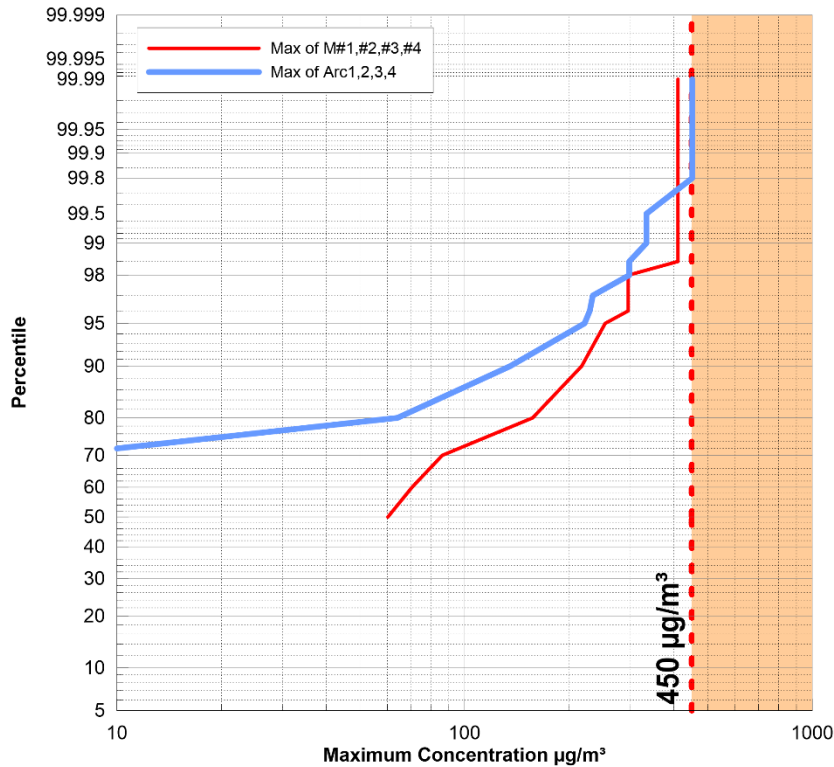


Figure 22: Example 2 Probability Distribution Comparison of Concentration Monitoring 1h Data at Station #1, #2, #3 and #4 Compared to Modelled 1h Predictions at Arc 1, 2, 3 and 4

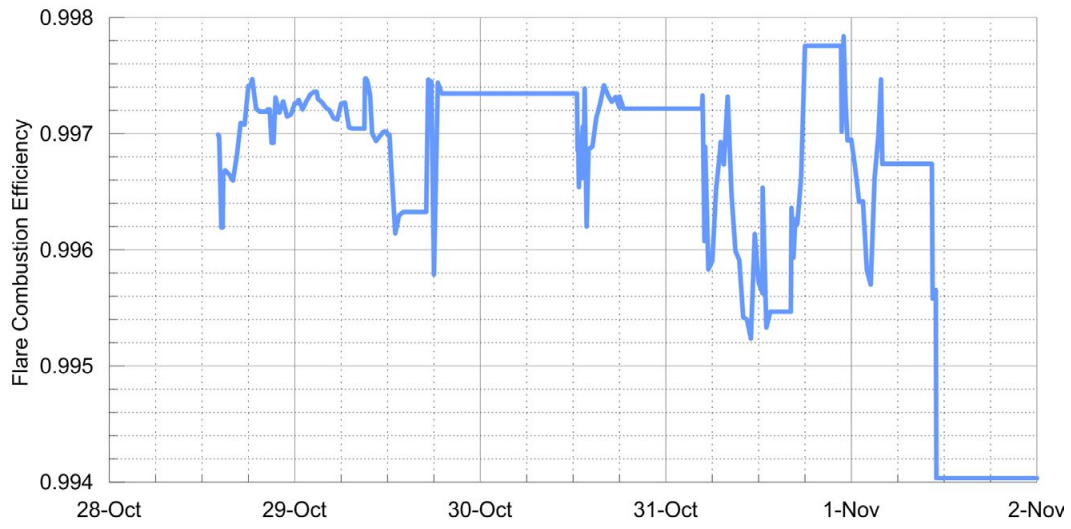


Figure 23: Predicted Combustion Efficiency as a Function of Time

6. EXAMPLE 3: Vessel/Pipeline Blowdown

This example is derived from a composite of emergency flaring cases for the purposes of demonstrating features of *ABflare*.

Source

The source in this example is a 25.1 km pipeline that goes through a blowdown sequence in order to service the pipeline for hydrate blockage. The pipeline carries gas with a maximum licenced H₂S content of 28%. The pipeline inside diameter is 436.4 mm. The pipeline is connected to a flare and the minimum orifice diameter in the system between the pipeline and the flare is 43 mm. The distance between the orifice and the flare exit is unknown, the default discharge coefficient of 0.6 is appropriate. However, in this example a conservative assumption adopted a discharge coefficient of 1.0. The maximum expected initial pressure of the pipeline is 4200 kPa with a zero final pressure. The pipeline is heated to 30 °C. The flare height is 30.5 m and has a flare tip inside diameter of 203 mm.

The gas composition of the raw gas to be flared is listed below. The facility does not have the option to add fuel gas.

Gas Compositions (mole fraction)	Fuel Gas	Lift Gas	Raw Gas
H ₂ O			
H ₂			0
He			0.0001
N ₂		1	0.0021
CO ₂			0.053
H ₂ S			0.0619
CH ₄			0.8557
C ₂ H ₆			0.0204
C ₃ H ₈	1		0.004
i-C ₄ H ₁₀			0.0009
n-C ₄ H ₁₀			0.0008
i-C ₅ H ₁₂			0.0003
n-C ₅ H ₁₂			0.0002
n-C ₆ H ₁₄			0.0002
C ₇₊			0.0004
CO			
NH ₃			
Ar			
Total	1	1	1

ABflare Modelling

Step 1 – METSERIES

METSERIES was run for the time period of the example.

Step 2 – ABFLARE Variable Source

The ABflare module settings for the source have been listed above. The control group settings required for this vessel/pipeline blowdown are listed below. The MINPUT=1 to have ABflare calculate source parameters based upon input source characteristics. MBLOWDOWN=2 to have ABflare calculate a blowdown curve based upon the vessel/pipeline specifications.

VARIABLE	INPUT	DESCRIPTION
MDSMOD	1	MDSMOD = 1 : create files for CALPUFF 2 : create files for AERMOD DEFAULT = 1
MINPUT	1	MINPUT = 1 : source conditions are input and blowdown is calculated (see MBLOWDOWN) 2 : blowdown curve sequence is input (see NSEQ) 3 : static source is input (see SOURCE DESCRIPTION GROUP). Use setting 3 for a steady flare source with parameters that don't vary with meteorology DEFAULT = 1
MBLOWDOWN	2	MBLOWDOWN=1 : user input QMAX and QTOTAL 2 : blowdown exponential model parameters are calculated from pipeline/vessel initial conditions DEFAULT = 2
MDIST	2	MDIST=1 : blowdown sequence is created based upon puffs of equal volume 2 : blowdown sequence is created based upon puffs of equal mass DEFAULT = 2
MSTRIP	0	MSTRIP=0 : source is described by input (100% conversion to SO2) =1 : source is a stripped flow source (H2S) =2 : source is actual SO2 (accounting for efficiency) DEFAULT = 0
MMET	1	MMET=1: meteorology is read from METPATH (CALPUFF) =2: meteorology is read from METPATH (AERMOD) =3: force met to be WINDSP, WINDDR, TAMB DEFAULT = 1
MFUELGAS	0	Is fuel gas added? MFUELGAS=0 : no fuel gas is added 1 : fuel gas is added Default = NONE
MFGR		MFGR = 1 : fuel gas is proportional to qmax rate =2 : fuel gas is constant amount based upon initial qmax DEFAULT = 2
MLIFTGAS	0	Is lift gas used ? MLIFTGAS = 0 : no lift gas = 1 : lift gas is used DEFAULT = 0
MFASSIST	0	Is flare assist used ? MFASSIST = 0 : no flare assist 1 : steam assist 2 : air assist 3 : both steam and air assist is used DEFAULT = 0
MDEBUG	0	Print debug and verbose information MDEBUG = 0 : no debug = 1 : print debug/verbose DEFAULT = 0
NSEP	24	Number of hours separating blowdown sequences. Must be a multiple of 24. Each blowdown sequence starts every hour on the hour. NSEP specifies the frequency of when the starting hour can be used again. A blowdown duration greater than 24 should use NSEP=48. A blowdown duration greater than 48 should use NSEP=72. DEFAULT=24
NSOURCES		Number of co-located AERMOD sources to represent range of meteorological sensitive source conditions DEFAULT=9

The source description group settings include both the flare description and the vessel/pipeline description. For simplicity, the minimum number of blowdown divisions was selected ($NPUFFS=3$).

VARIABLE	INPUT	DESCRIPTION
XCOORD	649.532	Easting location of the flare, see DATUM coordinates
YCOORD	5648.184	Northing location of the flare, see DATUM coordinates
ZCOORD	1946	Terrain elevation at source, m
HS	30.5	Actual height of the flare, m
DS	0.203	Actual inside diameter of flare at top, m
RH2S	0.28	Mole fraction of H2S in raw gas
TGINIT	278.15	Initial fuel gas and raw gas temperature, K, or negative to set to ambient

Expected Maximum Initial Pressure	4200	kPa (gauge) If MBLOWDOWN=2, enter the maximum initial pressure of the vessel or pipeline
Expected Minimum Initial Gas Temperature	303.15	K If MINPUT=1, enter the minimum initial temperature of the vessel or pipeline
Expected Minimum Final Pressure	0	kPa (gauge) If MBLOWDOWN=2, enter the minimum final pressure of the vessel or pipeline when flaring is stopped and the gas release is shut-in
Pipeline/Vessel Inside Diameter	0.4364	m If MBLOWDOWN=2, enter the vessel or pipeline inside diameter
Pipeline/Vessel Length	25100	m If MBLOWDOWN=2, enter the vessel or pipeline length
Minimum Orifice Diameter	43	mm If MBLOWDOWN=2, enter the minimum orifice diameter where the gas escapes from the vessel or pipeline
Discharge Coefficient	1	-- If MBLOWDOWN=2, enter the orifice discharge coefficient DEFAULT=0.6

NPUFFS	3	<p>npufts = 0 : Program calculates number of puffs, when PUFFDUR is specified and MDIST=1</p> <p>npufts = 1 : Force blowdown to a single puff of duration PUFFDUR, if MINPUT=1 and MBLOWDOWN=1 then NPUFF=1 for a hourly varying flare or if MINPUT=3, then use input source rather than calculated blowdown. Use this setting for a steady flare source with parameters that vary with meteorology</p> <p>npufts > 1 : Number of puffs in blowdown Default = 3</p>
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In this case, the discharge coefficient is adjusted from the default value of 0.6 to 1.0. The flow rate is determined by an orifice well upstream of the discharge location and the minimum orifice is smaller than the discharge location.

When *ABflare* is run for this configuration, it creates 24-output flare source files for *CALPUFF*. Each file contains a blowdown sequence of equal mass puffs starting on the hour for each hour of the day. The first file contains blowdown curves starting on hour 1, the second file contains blowdown curves starting on hour 2, etc. The blowdown sequence is shown in Figure 24.

The source parameters for this blowdown curve are determined as a function of the hour by hour meteorology. The effective height and pseudo-source parameters (diameter and velocity) are shown as a function of blowdown step in Figure 25. The effective height shows a wide variation which results from the effects of stack top wind speed on the bent over flame.

The effective location of the source is also a function of the bent-over flame tip location. The effective locations for this blowdown flare are shown in Figure 26.

The distribution of the locations will be a function of the windrose and flare rate. The figure displays concentric *rings* which are a function of the discrete regimes of the model.

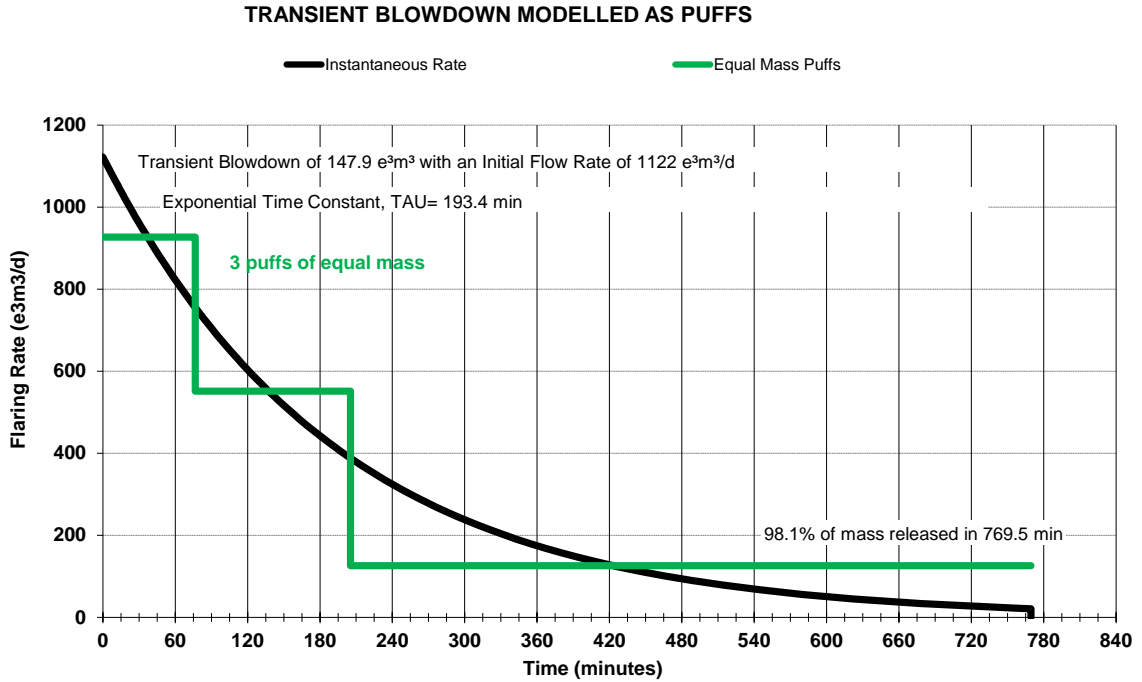


Figure 24: Example 3 Blowdown Curve

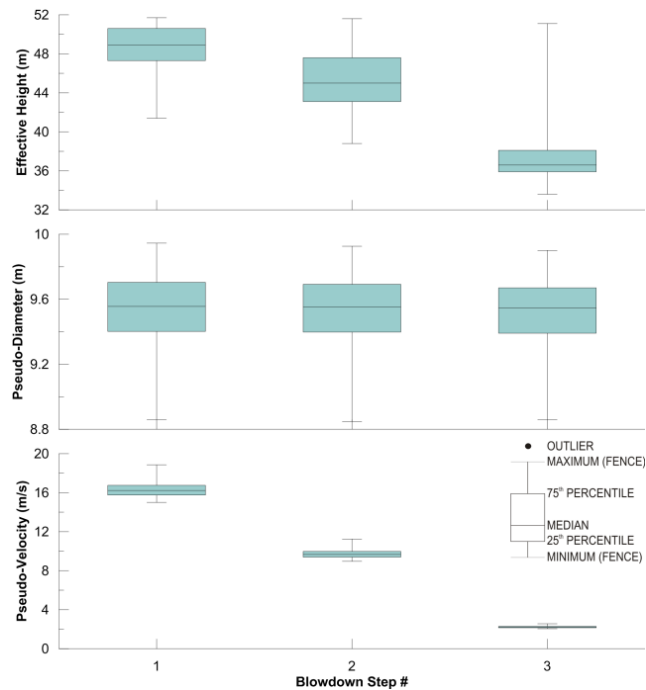


Figure 25: The Pseudo-Parameters for the Blowdown Curve for Complete Year 2002 showing Variation for Each Step of the Blowdown (NPUFFS=3)

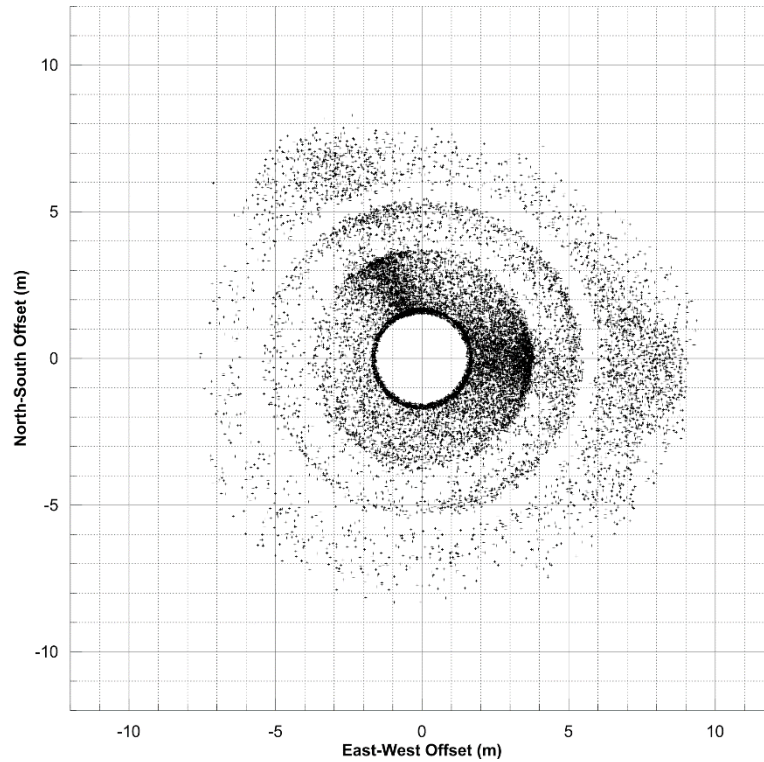


Figure 26: Effective Flare Location for Complete Year 2002

Step 3 – CALPUFF

The blowdown source and *ABflare* creates 24-flare source files. Each file must be independently run using *CALPUFF*. Therefore, *CALPUFF* must be run 24-times in order to determine the possible start hour-blowdown combinations.

Step 4a – CALAVE

In this case, because the flare for the blowdown will extend more than 10-hours, the maximum allowable daily average concentration is an important regulatory restriction for environmental protection. The daily average is calculated using a combination of the *CALAVE*, *CALMAX* and *CALRANK*.

The first step is to determine the running 24-h average for each of the individual 24- *CALPUFF* output files. *CALAVE* is configured with the inputs shown below. The time average required is 24 hours, therefore `AVGPD_HH=24`. The two averaging periods `AVGPD_HH` and `AVGPD_MM` are additive, so in this case `AVGPD_MM=0`. The running sum is required, `MODE=1`. The start hour for all

of the output files is `START_HHMM=0`. A valid file extension is selected “.24r” to represent “24h running average”.

VARIABLE	INPUT	DESCRIPTION
AVGPD_HH	24	Averaging Period (hours)
AVGPD_MM	0	Averaging Period (minutes)
MODE	1	1 = Running averages 2 = Block averages
START_HHMM	0	Starting time (HHMM)
OUT_EXT	.24r	The output associated with the file(s) listed below for 'source1.dat' would be named 'source1.dat.ave' Output data file extension DEFAULT: .ave

After *CALAVE* is run, it will create a time-averaged version of the *CALPUFF* output file. *CALAVE* is run once for each of the *CALPUFF* output files.

Step 4b – CALMAX

The 24-files create by the *CALAVE* processing can be combined using the *CALMAX* module. *CALMAX* will determine the maximum concentration from each of the input files, at each period in the record. Therefore, 24-files are input into *CALMAX* and a single file containing the maximum running averages for each hour of the day is output.

CALMAX creates a binary *CALPUFF*-like output file containing the running averages for each hour at each hour of the day. Also output is a [dayfile](#) that contains a listing of the maximum calendar day outputs. This output is only useful for the 24h average running sums.

An example configuration is shown below.

VARIABLE	INPUT	DESCRIPTION
output: PERFILE ASCII file of Period-Maximum values		calmax.24h.dat
output: BINFILE Binary CALPUFF-format file of all maximum values		calmax.24h.con
output: LSTFILE List-file name Default: CALMAX.LST		calmax.24h.lst
LCFILES	T	All file names will be converted to either lower or upper case T = lower case F = UPPER CASE DEFAULT: F
INFILE 1	P:\2011\1100500\ex3\abflare_00.2002.con.24r	
INFILE 2	P:\2011\1100500\ex3\abflare_01.2002.con.24r	
INFILE 3	P:\2011\1100500\ex3\abflare_02.2002.con.24r	
INFILE 4	P:\2011\1100500\ex3\abflare_03.2002.con.24r	
INFILE 5	P:\2011\1100500\ex3\abflare_04.2002.con.24r	
INFILE 6	P:\2011\1100500\ex3\abflare_05.2002.con.24r	
INFILE 7	P:\2011\1100500\ex3\abflare_06.2002.con.24r	
INFILE 8	P:\2011\1100500\ex3\abflare_07.2002.con.24r	
INFILE 9	P:\2011\1100500\ex3\abflare_08.2002.con.24r	
INFILE 10	P:\2011\1100500\ex3\abflare_09.2002.con.24r	
INFILE 11	P:\2011\1100500\ex3\abflare_10.2002.con.24r	
INFILE 12	P:\2011\1100500\ex3\abflare_11.2002.con.24r	
INFILE 13	P:\2011\1100500\ex3\abflare_12.2002.con.24r	
INFILE 14	P:\2011\1100500\ex3\abflare_13.2002.con.24r	
INFILE 15	P:\2011\1100500\ex3\abflare_14.2002.con.24r	
INFILE 16	P:\2011\1100500\ex3\abflare_15.2002.con.24r	
INFILE 17	P:\2011\1100500\ex3\abflare_16.2002.con.24r	
INFILE 18	P:\2011\1100500\ex3\abflare_17.2002.con.24r	
INFILE 19	P:\2011\1100500\ex3\abflare_18.2002.con.24r	
INFILE 20	P:\2011\1100500\ex3\abflare_19.2002.con.24r	
INFILE 21	P:\2011\1100500\ex3\abflare_20.2002.con.24r	
INFILE 22	P:\2011\1100500\ex3\abflare_21.2002.con.24r	
INFILE 23	P:\2011\1100500\ex3\abflare_22.2002.con.24r	
INFILE 24	P:\2011\1100500\ex3\abflare_23.2002.con.24r	

Step 4c – CALRANK

The third step in the post-processing sequence is to determine the data set statistics. For the 24 h averages statistics can be determined from the running averages using *CALRANK* using the *ICDAY* switch. When *ICDAY*=1, the peak concentration in each calendar day is selected from the input file and included in the data set for the statistics. For running averages, each hour of the day contains the average of the following 24 hours. Thus for each calendar in the data set, there are 24 data points representing 24 h running averages. *CALMAX* with *ICDAY*=1 selects the maximum of the 24 data points for each calendar day.

When *CALRANK* is run, it will create a plottable output file for each of the n^{th} highest statistics or percentile values selected. Each file will contain the n^{th} highest (or percentile) statistic at each receptor point. The output listing file for *CALRANK* will list the maximum statistical for all receptor locations.

For 1 h averages, *CALAVE* and *CALMAX* are not required, and *CALRANK* can be run on the *CALPUFF* output files directly. Select different list file names for *CALRANK.lst* to distinguish the output files such as:

CALRANK-1h.lst	for 1h averages
CALRANK-24r.lst	for 24h averages

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