SOFTWARE RELEASE NOTICE

1. SRN Number: 323

2. Project Title: **FracMan**	Project No.
3. SRN Title: **FracMan V. 2.606** (includes DOS modules and FracWorks XP)	
4. Originator/Requestor: **Kevin Smart, Nathan Franklin**	Date: **4 August 2004**

5. Summary of Actions

- ■ Release of new software
- ☐ Change of access software
- ☐ Release of modified software:
- ☐ Software Retirement
  - ☐ Enhancements made
  - ☐ Corrections made

6. Validation Status

- ☐ Validated
- ☐ Limited Validation
- ■ Not Validated — Explain: Validation planned for 4th Quarter of FY04

7. Persons Authorized Access

Name	Read Only/Read-Write	Addition/Change/Delete
N/A		

8. Element Manager Approval: H. Lawrence McKague Date: **4-August-2004**

9. Remarks:

CNWRA Form TOP-6 (09/01)

SOFTWARE SUMMARY FORM

01. Summary Date: **4-August-2004**	02. Summary prepared by (Name and phone) **K. Smart (5859), N. Franklin (5207)**	03. Summary Action: **Place *FracMan* under TOP-018 control.**
04. Software Date: **2004**	05. Short Title: **FracMan**	
06. Software Title: **FracMan V. 2.606** (includes DOS modules and FracWorks XP)		07. Internal Software ID:

08. Software Type:	09. Processing Mode:	10. Application Area
☐ Automated Data System X Computer Program ☐ Subroutine/Module	X Interactive ☐ Batch ☐ Combination	a. General: X Scientific/Engineering ☐ Auxiliary Analyses ☐ Total System PA ☐ Subsystem PA ☐ Other b. Specific:

11. Submitting Organization and Address:	12. Technical Contact(s) and Phone:
CNWRA/SwRI 6220 Culebra Road San Antonio, TX 78228	**FracMan Technology Group** **Golder Associates Inc.** **18300 NE Union Hill Rd.** **Redmond, WA 98052 USA** **425-883-0777**

13. Software Application:
Analysis of fracture data and generation of synthetic fracture populations.

14. Computer Platform **Win 95/NT2000/XP**	15. Computer Operating System: **DOS, Win 95/NT2000/XP**	16. Programming Language(s): **N/A**	17. Number of Source Program Statements: **N/A**
18. Computer Memory Requirements: **N/A**	19. Tape Drives: **N/A**	20. Disk Units: **N/A**	21. Graphics: **N/A**

22. Other Operational Requirements
N/A

23. Software Availability:	24. Documentation Availability:
☐ Available X Limited ☐ In-House ONLY	X Available ☐ Preliminary ☐ In-House ONLY

25.

Software Developer: **Golder Associates, Inc.** Date: **4-August-2004**

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
QA VERIFICATION REPORT
FOR
→*ACQUIRED SOFTWARE NOT TO BE MODIFIED*←

Software Title/Name: FracMan

Version: V.2.606

Demonstration workstation: Petrel

Operating System: WIN 2000

User: N. Franklin / K. Smart

NOTE: Acquired software may or may not meet all requirements and will be evaluated on a case-by-case basis.

Installation Testing [TOP-018, Section 5.6]

Has *installation testing* been conducted for each intended computer platform and operating system?

Yes: ☒ No: ☐ N/A: ☐

Computer Platforms: PC Operating Systems: WIN 2000 NT, XP

Location of Acceptance Test Results: ___

Comments:. See attached memo from K. Smart 8/4/04

Software Output [TOP-018, Section 5.5.4]

Is software designed so that individual runs are uniquely identified by date, time, name of software and version?

Yes: ☐ No: ☐ N/A: ☒

Date and Time Displayed:___

Name/Version Displayed: ___

Comments: FracMan is interactive.

NOTE: Output identification content and format is typically taken as is.

Medium Documentation [TOP-018, Section 5.5.6]

The physical labeling of software medium (tapes, disks, etc.) contains: Program Name, Module/Name/Title, Module Revision, File type (ASCII, OBJ, EXE), Recording Date, and Operating System(s)?

Yes: ☒ No: ☐ N/A: ☐

Comments:

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
QA VERIFICATION REPORT
FOR
→*ACQUIRED SOFTWARE <u>NOT</u> TO BE MODIFIED*←

User Documentation [TOP-018, Section 5.5.7]

Is there a Users' Manual for the software and is it up-to-date?

Yes: ☒ No: ☐ N/A: ☐

User's Manual Version and Date: 2.6 1/1/98
Comments:

Are there basic instructions for the *installation* and *use* of the software?

Yes: ☒ No: ☐ N/A: ☐

Location of Instructions: User Manual
Comments:

Configuration Control [TOP-018, Section 5.7, 5.9.3]

Is the Software Summary Form (Form TOP-4-1) completed and signed?

Yes: ☑ No: ☐ N/A: ☐

Date of Approval: 4/10/04

Is the list of files attached to the Software Summary Form complete and accurate?

Yes: ☐ No: ☐ N/A: ☑

Comments:
Commercial Software

Is the source code available or, is the executable code available in the case of (acquired/commercial codes)?

Executable Only
Yes: ☑ No: ☐ N/A: ☐

Location of Source Code: IMS, & Attached
Comments:

.

Have all the script/make files and executable files been submitted to the Software Custodian?

Only the executable files are being submitted.

Yes: ☑ No: ☐ N/A: ☐

Location of executable files: Attached
Comments:

Software Release [TOP-018, Section 5.9]

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES
QA VERIFICATION REPORT
FOR
→*ACQUIRED SOFTWARE <u>NOT</u> TO BE MODIFIED*←

Upon acceptance of the software as verified above, has a Software Release Notice (SRN), Form TOP-6 been issued and does the version number of the software match the documentation?

Yes: ☑ No: ☐ N/A: ☐

SRN Number: 323

Comments:

Software Validation [TOP-018, Section 5.10]

Has a Software Validation Test Plan (SVTP) been prepared for the ***range of application*** of the software?

Yes: ☐ No: ☒ N/A: ☐

Version and Date of SVTP: TBD

Date Reviewed and Approved via QAP-002: ___

Comments:

Has a Software Validation Test Report (SVTR) been prepared that documents the results of the validation cases, interpretation of the results, and determination if the software has been validated?

Yes: ☐ No: ☐ N/A: ☐

Version and Date of SVTR: ____

Date Reviewed and Approved via QAP-002: _____

Comments.:

Additional Comments:

Kevin J. Smart 8/4/04
Software Evaluator/User/Date

R. D. Manager 8/4/04
Software Custodian/Date

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

MEMORANDUM

August 4, 2004

TO: Robert Brient, Director
Quality Assurance

FROM: Kevin J. Smart, Research Scientist
Geology & Geophysics

SUBJECT: Acceptance/Installation Test for *FracMan* (version 2.606)

FracMan (version 2.606) is developed and marketed by Golder Associates Inc., Redmond, Washington and according to TOP-018 is classified as "Acquired Software -- Not To Be Modified." *FracMan* consists of several modules (i.e., *FracSys, FracWorks*, *MeshMaker*, *FracView*, *FracSimile*) that operate within a DOS window on the Windows operating system. The *FracWorks* module is also available for the Windows NT/2000/XP platforms (i.e., *FracWorksXP*).

FracMan is designed to operate on any IBM-compatible computer running the Microsoft® Windows 98/ME/NT/2000/XP operating system. All DOS modules of *FracMan* (version 2.606) are installed on "Petrel" in the GIS lab (A251), while the *FracWorksXP* module is currently installed on Darrell Sims' workstation in A224. All installations were conducted by members of the IMS staff.

The standard *FracMan* installation provides numerous sample files that illustrate the capabilities of the various modules (and functions within the modules). At this time, we expect to make use of only the *FracSys* and *FracWorks/FracWorksXP* modules. All of the sample files that work with these modules were successfully opened into *FracMan*..

At this time, I therefore recommend that *FracMan* (version 2.606) be considered to have successfully passed the acceptance/installation test requirements. If you have any questions, please do not hesitate to contact me.

SOFTWARE VALIDATION TEST PLAN FOR FRACMAN, VERSION 2.606

KJS
11/18/2004

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC-02-02-012

Prepared by

Danielle Wyrick
Kevin J. Smart

Center for Nuclear Waste Regulatory Analyses
San Antonio, TX

October 2004

Approved by:

H. Lawrence McKague
Manager, Geology & Geophysics

11/12/04
Date

CONTENTS

1 SCOPE OF THE VALIDATION

This document establishes the Software Validation Test Plan for validating the functionality of the commercial code FracMan, Version 2.6. FracMan Version 2.6 is a software package developed by Golder Associates Inc. to model the geometry of discrete features, such as fractures in fractured rock masses for rock mechanics and hydrologic applications. FracMan's data analysis capabilities include techniques for analyzing fracture orientation, size, and intensity. FracMan consists of several program modules that operate within a MSDOS shell (i.e., HeterFrac, FracSys, FracWorks) and one module (FracWorksXP) that has been ported to the Windows 95/NT/2000/XP environment. Software validation will be restricted to those modules that are expected to be used for Center for Nuclear Waste Regulatory Analyses (CNWRA) activities. Specifically, this software validation test plan contains test cases for the modules HeterFrac and FracWorksXP.

2 REFERENCES

Dershowitz, W.S. and H. H. Herda. "Interpretation of Fracture Spacing and Intensity." *Rock Mechanics.* Edited by Tillerson and Wawersik. Balkema, Rotterdam. pp. 757–766. 1992.

Golder Associates Inc. "FracMan Interactive Discrete Feature Data Analysis, Geometric Modeling, and Exploration Simulation User Documentation, Version 2.6." Seattle, Washington. 1998.

Golder Associates Inc. "FracWorksXP Module User Documentation." Seattle, Washington. 2002.

3 ENVIRONMENT

3.1 Software

FracMan, Version 2.6, is commercial software developed by Golder Associates Inc. Version 2.6 runs in MS-DOS™ Versions 3.0, 3.1, 3.3, 4.01, 5.0, 6.0, and 6.2. The FracWorksXP module requires a Microsoft Windows® operating environment (95, 98, 2000, NT, or XP). The following software items are required to perform the testing activity described in Section 6.1:

(i) FracMan, Version 2.6 software, including HeterFrac module
(ii) MS-DOS™ 3.0, 3.1, 3.3, 4.01, 5.0, 6.0, or 6.2 operating system

The following software items are required to perform testing activities described in Sections 6.2 and 6.3:

(i) FracWorksXP module software package
(ii) Windows® 95, 98, 2000, NT, or XP operating system
(iii) Microsoft Excel
(iv) Rockware StereoStat Version 1.3

3.2 Hardware Requirements

FracMan Version 2.6 runs on any MS-DOS™ compatible computer with an Intel CPU and math coprocessor – including 80286/80287 (IBM-AT), 80386/80387, i486, and Pentium™ class computers. FracMan will not run without a math coprocessor, except with i486 DX and Pentium™ computers, which include built in math coprocessor support. FracMan requires at least 1 Mb of installed memory and a graphics card that can operate in at least one of the following modes: (i) Video Graphics Array (VGA), 640 x 480 resolution, black and white or (ii) VGA, 640 x 480 resolution, 16-color. Although FracMan can run with just 1 Mb of RAM, an additional 2 to 4 Mb configure as a random access memory disk is recommended to improve performance on larger problems. A high-speed hard drive with a least 1 Mb free is also recommended. For the FracWorksXP module, any PC compatible computer that operates Windows may be used. A minimum of 128 Mb of RAM is required with a recommendation of 256 Mb. The computer must be equipped with an openGL compatible graphics card. No peripherals (e.g., tape drives, printers, plotters) are necessary to perform testing activities (Golder Associates Inc., 1998, 2002).

4 PREREQUISITES

Running FracMan Version 2.6 requires installation of the commercially available software, per the developers' User Documentation (Golder Associates Inc., 1998, 2002).

5 ASSUMPTIONS AND CONSTRAINTS

The user of FracMan Version 2.6 is assumed to be familiar with discrete fracture modeling and should familiarize themselves with the working definitions specific to the study of fracture systems as defined in the User Documentation (Golder Associates Inc., 1998, 2002) and the scientific literature (Dershowitz and Herda, 1992).

6 TEST CASES

The test cases described in this section are used to validate the specific modules of FracMan to be used within the CNWRA. The HeterFrac module of FracMan is designed to analyze actual fracture population data for statistical analysis of fracture size and intensity. The FracWorksXP module is designed to generate synthetic fracture populations based on user inputs that describe the orientation, intensity, and size characteristics of a natural fracture population.

6.1 Test Case 1 – FracSys: HeterFrac Fracture Data Analysis

HeterFrac geologic structure analysis allows the evaluation of trace plane maps containing linear fracture traces. The results provide statistical analysis of fracture size and intensity. The test case described in this section uses a synthetic test case (an analog of actual fracture data) created to compare results from an analytical solution to the results obtained from FracMan Version 2.6.

6.1.1 Test Input

Geologic structure analysis requires specification of two input files before execution. The first file (*.F2D) contains the specification of the fracture trace maps to be analyzed. This file contains the individual traces expressed as pairs of beginning and end coordinates of line segments in the coordinate system of the fracture trace data. The following information is required input for a HeterFrac (*.F2D) file:

*.SAB: The name of the sampling file associated with the .F2D file
np: Number of sampling structure. This is the traceplane identification number contained in the .SAB file
x1, y1, x2, y2: The coordinates of the two endpoints of the fracture trace
tr: Fracture trend in degrees
pl: Fracture plunge in degrees

Refer to the example test1_stvp.F2D for specific ASCII file format requirements. For the purpose of testing, a simplified fracture network was created. The test file test1_stvp.F2D consists of six fractures. Four fractures are oriented with a trend of 45 degrees and plunge of 0; two fractures are oriented with a trend of 135 degrees and plunge of 0. This creates an overall fracture set with two fractures terminating at an intersection with other fractures.

The geometry of the trace plane is defined in a standard FracMan survey file (*.SAB). The following information is required input for a FracMan (*.SAB) survey file:

name: The name of .SAB file
origin: Beginning x, y, z coordinates of traceplane as defined from the center of the right hand edge of the traceplane.
scan_trend: The scan vector trend from the center of the right hand edge of the traceplane to the center of the left hand edge of the traceplane.
scan_plunge: The scan vector plunge from the center of the right hand edge of the traceplane to the center of the left hand edge of the traceplane.
scan_length: The length of the traceplane.
tran_trend: The transverse vector trend from the center of the right hand edge of the traceplane to the top of the right hand edge of the traceplane.
tran_plunge: The transverse vector plunge from the center of the right hand edge of the traceplane to the top of the right hand edge of the traceplane.
tran_width: The width of the traceplane. This value is twice the length of the transverse vector from the center of the right hand edge of the traceplane to the top of the right hand edge of the traceplane.

Refer to the example STVP.SAB for specific ASCII file format requirements. For the purpose of testing, a traceplane survey file with one traceplane was created. The traceplane is defined as a plane 12 meters in length and 2 meters in width, with a scan trend of 90 degrees, plunge of 0 and transverse trend of 0, plunge of 0. This traceplane was used in order to capture all sample fracture data.

6.1.2 Analytical Solution

HeterFrac provides the following fracture analysis functions. The statistics below are solved for the test1_stvp.F2D fracture network, using the SVTP.SAB survey file.

Statistical Definition	Analytical Solution	FracMan Solution
Total number of trace segments	6	
Total length of all traces	14.14 m	
Mean trace length	2.357 m	
Trace length standard deviation	0.7303 m	
Traceplane dimension	12 m x 2 m	
Selected region area	24 m^2	
Number of non-terminating intersection (X_S) *X_S is defined as the number of intersections that do not terminate against another fracture.*	0	
Number of terminating intersections (T_S) *T_S is defined as the number of intersections that produce a termination*	3	
Fracture intensity (P_{20}) *Fracture intensity P_{20} is defined as the number of fractures in a set per unit area of the traceplane*	0.25 #/m^2	
Fracture intensity (P_{21}) *Fracture intensity P_{21} is defined as the total fracture length per unit area of the traceplane*	0.5893 m^{-1}	
Intersection intensity (C_{20}) *Intersection intensity is defined as the number of intersections per unit area of the traceplane*	0.125 m^{-2}	
Termination probability (P[T/I]) *Termination probability is defined as the total number of intersections divided by the number of terminating intersections*	100%	
Termination percentage (T%) *Termination percentage is defined as the percentage of fracture terminations on the traceplane which are terminations at intersections with other fractures*	100%	

6.1.3 Test Procedure

The HeterFrac Traceplane Analysis is run from within the FracMan graphical user interface. To execute, select the FracSys data analysis module from the main FracMan screen, then choose HeterFrac from the main FracSys screen. Then select Trace Plane Analysis. Load the test file test1_stvp.F2D. Select Statistics, but do not re-set subregion. The screen will display a number of fracture statistics, which can be saved to a text file.

6.1.4 Test Results

The calculations should be rounded to the number of decimal places that is generated by the software. The statistics calculated can be directly compared to analytical solutions outlined above. Calculated results should be within +/− 5% of the analytical solutions.

6.2 Test Case 2 – FracWorks XP: Analysis of Statistical Data

Within FracWorksXP, a wide variety of discrete features can be generated from stochastic descriptions and user inputs. Fracture realizations can be saved in a variety of formats for use in simulation and modeling. All stochastic generation begins with a random seed number. For the purposes of validation, all fracture generation will be performed using a seed number of 1234. Given user inputs, a statistical analysis of fracture orientation, intensity, and size can be performed. These results will be compared to analytical solutions.

6.2.1 Test Input

Fracture generation must begin by defining the region. For this test case, the defining region shall be a box with dimensions of 20m x 20m x 20m (region name: STVP1_box). The parameters for the geometric fracture generation set are as follows:

Generation region = standard, STVP1_box
Clipping region = standard, STVP1_box
Generation model = Enhanced Baecher
Fracture intensity = measure by number of fractures
Parameters = 100 fractures
Fracture orientation: Constant, trend = 90, plunge = 0
Orientation specified by = Pole
Fracture size = Constant, parameter = 2
Fracture shape = 6 sides
Transmissivity = Normal distribution
Storativity = Exponential distribution
Aperture = Uniform distribution
Termination percentage = 0

6.2.2 Analytical Solution

Using the above user input values, the following statistics can be calculated:

Statistical Definition	Analytical Solution	FracMan Solution
Number of fractures	100	
Total fracture area	1256.64 m^2	
Volume of model bounding box	8000 m^3	
Fracture intensity P_{32} *Fracture intensity P_{32} is defined as the total fracture area per unit volume of the model bounding box*	0.157080 m^{-1}	
Mean orientation	90 trend, 0 plunge	
Mean equivalent radius	2	
Mean fracture area	12.5664 m^2	

6.2.3 Test Procedure

Upon opening FracWorks XP module, select Insert -> Region Box. Set Box dimensions to test input values. Select Fracture -> Add Set -> Geometric. The Windows™ interface will guide the user through the parameters needed to run the test. Use the values as described in Section 6.2.1. Select Analysis -> Statistics and fill in Fracman statistics given in Section 6.2.2.

6.2.4 Test Results

The analytical calculations as described above are calculated for an ideal fracture generation in which all fractures fall entirely within the region box. Because of the stochastic nature of the program, fractures generated may partially fall outside of the region box defined. The test case described clips all fractures at the border of the region box. Therefore the mean equivalent radius, mean fracture area, and total fracture area generated by the test will always be less than or equal to the ideal. An acceptable range of values will fall within −10 percent of the ideal fracture calculations.

6.3 Test Case 2 – Verify Orientation and Distribution

Within FracWorksXP, generated fracture sets can be plotted on an equal-area stereonet to visualize fracture orientation. Histograms of fracture size distribution can also be produced. All stochastic generation begins with a random seed number. For the purposes of validation, all fracture generation will be performed using a seed number of 1234. This test is designed to confirm stereonet plots and histograms produced by FracWorksXP using similar software programs.

6.3.1 Test Input

Fracture generation must begin by defining the region. For this test case, the defining region shall be a box with dimensions of 20m x 20m x 20m (region name: STVP1_box). The parameters for the geometric fracture generation set are as follows:

Generation region = standard, STVP1_box
Clipping region = standard, STVP1_box
Generation model = Enhanced Baecher
Fracture intensity = measure by number of fractures
Parameters = 100 fractures
Fracture orientation: Fisher distribution, trend = 10, plunge = 45, dispersion = 100
Orientation specified by = Pole
Fracture size = Log normal, parameter = 2, deviation = 0.5
Fracture shape = 6 sides
Transmissivity = Normal distribution
Storativity = Exponential distribution
Aperture = Uniform distribution
Termination percentage = 0

6.3.2 Test Procedure

Upon opening FracWorksXP module, select Insert -> Region Box. Set Box dimensions to test input values. Select Fracture -> Add Set -> Geometric. The Windows™ interface will guide the user through the parameters needed to run the test. Use the values as described in Section 6.3.1. To plot a stereonet, select Analysis -> Stereonet. To verify histogram, select right click on the fracture definition set (located on the left hand side of screen). Select histogram -> radius.

6.3.3 Result Verification Stereonet

To verify FracWorksXP is plotting fracture data correctly, the fracture data must be exported and then imported into Rockware StereoStat Version 1.3. Select File –> Export –> Fracture file in FracWorksXP. This exports the data as a *.fab file (an ASCII text file). This ASCII text file will need to be reformatted so that it can then be imported into Rockware StereoStat. In StereoStat, plot a lower hemisphere, equal area stereonet. Also, select Data Analysis -> Analyze Data and click Fisher axis. StereoStat will provide the mean fracture orientation (trend and plunge) and the Fisher dispersion coefficient (K value), which can then be compared to the original input values.

A visual comparison of stereonets should be done. Although the two programs display the lower hemisphere, equal area plots slightly different, the data points should plot identically. Because of the stochastic nature of FracWorksXP, there will be an expected variation in the fracture data from the input values. For fracture orientation (trend and plunge), an acceptable range of values would be ±5 degrees from input values. The calculated K value has an acceptable value range of ±10 percent from the input dispersion value.

6.3.4 Result Verification Histogram

The same fracture data file can be imported into Excel. In Excel, create a log normal histogram to compare to the plot generated in FracWorksXP. The histograms should plot the same.

```
#########################################################
# Sample STVP.SAB file
# For use with Software Validation of FracMan 2.6
#########################################################

BEGIN traceplane
    name   = "dyw1"
    origin = 0.000      0.000 0.000
    scan_trend  =      90.000
    scan_plunge =      0.000
    scan_length =      12.000

    tran_trend  =        0.000
    tran_plunge =        0.000
    tran_width  =      2.000
END
```

```
#######################################################
# Sample test1_stvp.F2D file
# for use with Software Validation for FracMan 2.6
#######################################################

STVP.SAB                    [Sampling file name]
   0  [frac. orientation, 0:pole, 1:dip]
 ******* (np, x1, y1, x2, y2, tr, pl) *******
1      2      1      0      -1     45     0
1      4      1      2      -1     45     0
1      6      1      4      -1     45     0
1      8      1      6      -1     45     0
1      5      0      6      -1     135    0
1      7      0      8      -1     135    0
```