SOFTWARE RELEASE NOTICE

1. SRN Number: **MGFE-SRN-218**	
2. Project Title: **TSPA & Technical Integration/Assistance**	Project No. **20-5708-761**
3. SRN Title: **UDEC Version 3.1**	
4. Originator/Requestor: **Bruce Mabrito**	Date: **04/17/2000**

5. Summary of Actions

- ☐ Release of new software
- ■ Release of modified software: **Software Upgrade for Acquired Code**
  - ☐ Enhancements made
  - ☐ Corrections made
- ☐ Change of access software
- ☐ Software Retirement

6. Persons Authorized Access

Name	Read Only/Read-Write	Addition/Change/Delete
Goodluck Ofoegbu	**RO**	
Simon Hsiung	**RO**	
Amit Ghosh	**RO**	
Rui Chen	**RW**	
Asad Chowdhury	**RO**	
Bis Dasgupta	**RO**	**Addition**

7. Element Manager Approval: [signature] Date: 4/19/2000

8. Remarks:

On January 7, 1997, Scientific & Engineering Software UDEC V3.0 was placed under version control at the CNWRA in the SCCS system.
On April 18, 1999, UDEC 3.0 was replaced by UDEC 3.1.

CNWRA Form TOP-6 (05/98)

SOFTWARE SUMMARY FORM

01. Summary Date: **04/17/2000**	02. Summary prepared by (Name and phone) **Rui Chen, (210) 522-5152**	03. Summary Action: **Required Code Upgrade**
04. Software Date: **03/2000**	05. Short Title: **UDEC, Version 3.1**	
06. Software Title: **Universal Distinct Element Code, Version 3.1**		07. Internal Software ID: **001-000**

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

11. Submitting Organization and Address: **ITASCA Consulting Group, Inc.** **Thresher Square East** **708 South Third Street, Suite 310** **Minneapolis, Minnesota 55414**	12. Technical Contact(s) and Phone: **Mark Christianson (612) 371-4711**

13. Software Application:
The distinct element method is a recognized discontinuum modeling approach for simulating the behavior of jointed media subjected to quasi-static or dynamic conditions. This program has three distinguishing features which make it well suited for discontinuum modeling. It covers a range of rock mass strengths and confining pressures which are encountered *in situ*.

14. Computer Platform **Windows NT**	15. Computer Operating System: **DOS**	16. Programming Language(s): **FORTRAN 77**	17. Number of Source Program Statements: **N/A**
18. Computer Memory Requirements: **Minimum 24 megabytes**	19. Tape Drives: **N/A**	20. Disk/Drum Units: **N/A**	21. Graphics: **VGA Monitor**

22. Other Operational Requirements: **N/A**

23. Software Availability: ■ Available ☐ Limited ☐ In-House ONLY	24. Documentation Availability: ■ Available ☐ Inadequate ☐ In-House ONLY

Software Developer: **Rui Chen** [signature] Date: **4/17/2000**

CNWRA Form TOP-4-1

Software Validation Test Plan

SOFTWARE VALIDATION TEST PLAN FOR THE UNIVERSAL DISTINCT ELEMENT CODE (UDEC) VERSION 3.1

May 2002

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

Author

Sui-Min Hsiung 6/10/2002
Date

Element Manager

Asadul H. Chowdhury 6/10/2002
Date

1.0 Scope of the Validation

The Universal Distinct Element Code (UDEC) Version 3.1 (Itasca Consulting Group Inc., 2000) is an acquired software that is not to be modified and is under configuration control at the Center for Nuclear Waste Regulatory Analyses. The UDEC Version 3.1 computer program performs stability analyses of jointed rock mass. Both static and dynamic analyses for underground openings can be performed. In conducting a regulatory review of a potential license application for high-level waste geologic disposal, the UDEC computer code is likely to be used to assess short-term stability (prior to permanent closure of the repository) and long-term performance of underground facilities (e.g., emplacement drifts, ventilation conduits, and shafts).

Because of the heat generated by the decay of high-level waste, the underground facilities will be in a heated condition for hundreds of years. On occasion, this high-temperature environment will be superimposed by seismic events (e.g., earthquakes). The stability of underground openings during the preclosure period and the potential rockfall from long-term degradation of rock mass and earthquake shaking after permanent closure are some of the key technical concerns for license application review.

The UDEC computer program may be used to assist with reviewing the areas discussed in the previous paragraph. Hence, the validation tests on UDEC Version 3.1 (Itasca Consulting Group, Inc., 2000) will be limited to examining the capabilities of UDEC in analyzing stability of underground openings under heated and dynamic conditions, more specifically,

- joint normal and shear displacement calculations
- wave propagation simulation
- ground support performance
- temperature prediction
- thermal-mechanical calculation.

2.0 Environment

2.1 Software

UDEC Version 3.1 (Itasca Consulting Group, Inc., 2000), available to the Center for Nuclear Waste Regulatory Analyses, is designed for a desktop personal computer environment. The UDEC executable file is *udec.exe*. The validation tests for UDEC Version 3.1 will be performed using the Microsoft Windows NT operating system Version 4.0 (Build 1381: Service Pack 6). The data input files will be developed for each test case discussed in Section 6 of this validation plan as appropriate.

To validate UDEC Version 3.1, analytical solutions, field measurements, and results from another numerical method will be used to compare with the UDEC model results. The numerical method used in this validation activities will be the Fast Lagrangian Analysis of Continua (FLAC) code (Itasca Consulting Group, Inc., 1996). FLAC is a two-dimensional explicit finite difference code for engineering mechanics computation and is commercially available. Validation of FLAC will be subject of separate activities.

2.2 Hardware

The hardware required is an IBM-compatible personal computer. An identification key from Itasca Consulting Group, Inc. is needed to execute the program. The test results will be presented as text outputs or graphics. A QMS 3825 printer will be used to process text outputs, and graphics will be printed using an HP Color LaserJet printer. No other hardware peripherals are needed for conducting the validation tests.

3.0 Prerequisites

No specific prerequisites are necessary to perform testing activities.

4.0 Assumptions and Constraints

No assumptions and constraints are identified for performing the validation tests.

5.0 Test Cases

In this validation plan, seven test cases are proposed. Specifically, Test Case 1 is related to cyclic loading of a specimen with a slipping joint. Test Case 2 studies joint slip intersected by a circular excavation. Test Case 3 examines shear wave propagation through a jointed continuum. Test Case 4 concerns the dynamic behavior of a single discontinuity under explosive loading. Test Case 5 relates to heat conduction through a composite wall. Test Case 6 validate cable bolt performance. Test Case 7 examines the mechanical response of a joint subject to a heat load.

Test Cases 1 and 2 are intended to validate the joint behavior modeled in UDEC. Test Cases 3 and 4 are designed to validate wave propagation through jointed media. Test Case 5 examines the acceptability of thermal conduction algorithm implemented in UDEC. Test Case 6 verifies the validity of the cable bolt support function, and Test Case 7 validates the thermal-mechanical algorithm implemented in UDEC.

The first four test cases were used to validate an earlier version of UDEC as part of a 1988–1994 research program supported by the Office of Nuclear Research, U.S. Nuclear Regulatory Commission. The results of these test cases were published in the Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock in 1990 (Brady et al., 1990). The paper authored by Brady et al. (1990) is attached for reference.

Three of the four test case results are also included in the UDEC Online Manual and associated documents for Version 3.1 (Itasca Consulting Group, Inc., 2000). Test Case 1 is discussed in the Verification Problems and Example Applications portion of the UDEC Online Manual for Version 3.1, whereas Test Cases 3 and 4 are discussed in Section 4, Dynamic Analysis–Theory and Background, of the UDEC Online Manual for Version 3.1.

The results presented in the UDEC Online Manual for Version 3.1 for the three test cases are comparable to those in the paper prepared by Brady at al. (1990). It is, therefore, determined that the results of the test cases presented in the paper published by Brady et al. (1990) are adequate to support this validation effort. No repeat calculations for these three test cases are necessary. The validation results and conclusions for these three test cases can be found in the attachment.

Because Test Case 2 is not included in the UDEC Online Manual, it will be analyzed in this study (For case description, please refer to the attachment).

Sections 5.1 through 5.3 provide problem descriptions for Test Cases 5, 6, and 7.

5.1 Heat Conduction Through a Composite Wall Test

This test involves heat conduction calculation through a composite wall and comparison of the UDEC results with known analytical solutions, provided by the code developer. This test simulates an infinite wall, consisting of two distinct layers, exposed to a condition with high temperature on one side and low temperature on the other. The wall eventually reaches an equilibrium at a constant heat flux and temperature distribution. The heat flux is activated in UDEC through thermal convection coefficients associated with the composite wall and the temperature difference between the two opposite sides of the wall. The test objective is to validate the thermal analysis component of UDEC. Analytical solutions to this test case are discussed in the UDEC Online Manual for Version 3.1 (Itasca Consulting Group, Inc., 2000). These results will be compared with the UDEC results.

5.1.1 Test Input

The input file required for the test is provided by the code developer. This input file includes calculation of both UDEC modeling results and analytical solution. Consequently, both results can be presented in one graph with a simple UDEC command.

5.1.2 Test Procedure

The test procedure involves the following steps.

Step 1: Execute UDEC

Step 2: Run the input file at the prompt

Step 3: Set up output device for processing postscript graphic files

Step 4: Produce output plots

5.1.3 Test Results

Because the infinite wall is made of two distinct layers, it is expected that the pattern of temperature distributions in the two layers should be different depending on the relative contrast of thermal properties of the two layers. The UDEC results are expected to have a good agreement with those obtained from the analytical solutions. A difference smaller than 1% is considered to be acceptable because the analytical problem is a simple one-dimensional one.

5.2 Grouted Cable Anchor Pullout Test

This test involves applying an axial force on a cable fully grouted in an elastic rock block. This test models a typical pullout test performed in the field on a small segment of grouted cables. It should be noted that a pullout test is the common method for determining cable deformation and strength properties. This simple test case is intended to validate the cable model in UDEC by comparing its force-displacement curve with that measured in the field. The field measurements are provided in Volume IV: Verification Problems and Example Applications of the User Manual of the Fast Lagrangian Analysis of Continua (FLAC) code (Itasca Consulting Group, Inc., 1996).

5.2.1 Test Input

The input file required for the test is to be developed.

5.2.2 Test Procedure

The test procedure involves the following steps.

Step 1: Execute UDEC

Step 2: Run the input file at the prompt

Step 3: Set up output device for processing postscript graphic files

Step 4: Produce output plots

Step 5: Compare the results with field measurements

5.2.3 Test Results

The cable element in UDEC is expected to exhibit similar force-displacement behavior as that obtained from the field test. The general trending between the UDEC results and those measured in the field is expected to be the same. However, the nonlinear force-displacement behavior observed in the field is not going to be modeled using UDEC although modeling such behavior is possible using the FISH function provided by the UDEC. The UDEC results are acceptable if the predicted displacement at which the peak force is reached is within 15% of the field measurements. This allowance is reasonable because the inherent uncertainties and variability associated with the rock properties in the field and the uncertainties related to the grout properties are not going to be considered in the UDEC runs.

5.3 Joint Displacement Induced by Temperature Increase Test

This test involves a heat source in an infinite elastic medium with an inclined transgressing joint. This heat source will be placed near the joint. A Mohr-Coulomb failure criterion will be used to model the joint shear behavior. As temperature increases, the joint is expected to experience joint displacements or, in some case, joint slip. This test case is intended to validate the thermal-mechanical model implemented in UDEC. The UDEC results will be compared with those produced using the FLAC code (Itasca Consulting Group, Inc., 1996). The FLAC code has an interface model that allows explicit joint modeling, thus, making the direct comparison possible.

Before the performance of the joint shear behavior in heated condition is examined, capability of UDEC to model thermal-mechanical behavior of a continuous medium will be validated by treating the joint as a glued joint. The UDEC results will be compared with the FLAC code results for the same model.

5.3.1 Test Input

The input files for both UDEC and FLAC required for the test are to be developed.

5.3.2 Test Procedure

The test procedure involves the following steps.

Step 1: Execute UDEC

Step 2: Run the input file at the prompt

Step 3: Set up output device for processing postscript graphic files

Step 4: Produce output plots

Step 5: Execute FLAC

Step 6: Run the input file at the FLAC prompt

Step 7: Set up output device for processing postscript graphic files for FLAC run

Step 8: Produce FLAC output plots

Step 9: Compare the UDEC results with those from the FLAC run

5.3.3 Test Results

The results for this test case remain to be developed. It is, in general, expected that the portion of the joint near the heat source will experience more joint slip than other portions of the joint as the temperature increases. Because that portion of the joint is closer to the source of heat, it will thus experience higher temperature also. A difference of smaller than 10% between the predicted results of UDEC and FLAC should be considered acceptable due to the inherent differences in the numerical techniques used.

6.0 Notes

None

7.0 References

Brady, B.H., S.H. Hsiung, A.H. Chowdhury, and J. Philip. 1990. Verification studies on the UDEC computational model of jointed rock. *Proceedings of the International Conference on Mechanics of Jointed and Faulted Rock. Mechanics of Jointed and Faulted Rock.* H.P. Rossmanith, ed. Rotterdam, Netherlands: A.A. Balkema.

Itasca Consulting Group, Inc. 1996. *FLAC—Fast Lagrangian Analysis of Continua User's Manual.* Version 3.3. Minneapolis, Minnesota: Itasca Consulting Group, Inc.

Itasca Consulting Group, Inc. 2000. *UDEC—Universal Distinct Element Code Online Manual.* Version 3.1. Minneapolis, Minnesota: Itasca Consulting Group, Inc.