Publié dans Nagra/Cédra Technical Report 86-22, I-VI, 1-2, 1986,
source qui doit être utilisée pour toute référence à ce travail

TECHNICAL REPORT 86-22

CODE VERIFICATION OF THE GROUNDWATER FLOW MODEL FEM 301

HYDROCOIN – LEVEL 1 – CASE 2 and CASE 6

F. KIMMEIER
C. WACKER
P. PERROCHET
P. HUFSCHMIED
L. KIRALY

DECEMBER 1986

Nagra
Nationale
Genossenschaft
für die Lagerung
radioaktiver Abfälle

Cédra
Société coopérative
nationale
pour l'entreposage
de déchets radioactifs

Cisra
Società cooperativa
nazionale
per l'immagazzinamento
di scorie radioattive

Parkstrasse 23 5401 Baden / Schweiz Telephon 056 / 20 55 11

Der vorliegende Bericht wurde im Auftrag der Nagra erstellt. Die Autoren haben ihre eigenen Ansichten und Schlussfolgerungen dargestellt. Diese müssen nicht unbedingt mit denjenigen der Nagra übereinstimmen.

Le présent rapport a été préparé sur demande de la Cédra. Les opinions et conclusions présentées sont celles des auteurs et ne correspondent pas nécessairement à celles de la Cédra.

This report was prepared as an account of work sponsored by Nagra. The viewpoints presented and conclusions reached are those of the authors and do not necessarily represent those of Nagra.

ABSTRACT

The FEM301 code [10] allows modelling steady-state flow of groundwater circulation in saturated media in 1, 2 or 3 dimensions. FEM301 has been used in the project Gewähr [13] which summarises the safety analyses for final disposal of radioactive wastes in Switzerland. In order to check the accuracy of the results of FEM301, Nagra participates in the international HYDROCOIN project which comprises 24 teams from 10 different countries, the aim being to compare the results of different calculation codes. This report describes the work that has been done in this connection with the FEM301 code. Two cases are presented. The first is a two-dimensional model of a fractured rock mass. A quantitative comparison of FEM301 with 2 different models (GWHRT and STOKES) shows good agreement. The second case is a three-dimensional model of a sedimentary basin presenting marked contrasts in the hydraulic conductivities. A qualitative comparison has been carried out with the models SWENT, FE3DGW and CFEST. A detailed quantitative comparison must be published in the frame of the final report of HYDROCOIN - Level 1.

RESUME

Le programme de calcul FEM301 [10], permet de modéliser, en régime permanent, la circulation des eaux souterraines en milieu saturé en 1, 2 ou 3 dimensions. FEM301 a été utilisé dans le cadre du projet Gewähr [13] qui regroupe les analyses de sûreté pour le stockage final de déchets radioactifs en Suisse. Pour contrôler la fiabilité des résultats du programme FEM301, la Cédra fait partie du projet international HYDROCOIN regroupant 24 équipes de 10 pays différents, qui se propose de comparer les résultats obtenus par divers programmes de calcul. Ce rapport décrit les travaux qui ont été executés dans ce cadre. Deux cas sont présentés. Le premier est un modèle en deux dimensions d'un massif fissuré où une comparaison quantitative avec deux autres modèles (GWHRT et STOKES) montre une très bonne concordance entre les résultats calculés. Le deuxième cas est un modèle tridimensionnel d'un bassin sédimentaire présentant de hauts contrastes de perméabilités. Une comparaison qualitative a été effectuée avec les modèles SWENT, FE3DGW et CFEST. Une comparaison quantitative détaillée doit être publiée dans le cadre du rapport final d'HYDROCOIN - Level 1.

ZUSAMMENFASSUNG

Das Computerprogramm FEM301 [10] erlaubt die stationäre Berechnung von Grundwasserströmungen in gesättigten, porösen Medien in 1, 2 oder 3 Dimensionen. FEM301 wurde im Projekt Gewähr [13] im Rahmen der Sicherheitsanalysen für die Endlagerung radioaktiver Abfälle in der Schweiz eingesetzt. Um die numerische Genauigkeit und Zuverlässigkeit der Resultate von FEM301 zu verifizieren, beteiligte sich die Nagra am internationalen Projekt HYDROCOIN. Das Projekt HYDROCOIN vereinigt 24 Projekt-Teams aus 10 verschiedenen Ländern, mit dem Ziel, die Berechnungsergebnisse von Grundwassermodellen anhand genau definierter Testfälle zu vergleichen. Der vorliegende Bericht beschreibt die Arbeiten, welche in diesem Zusammenhang mit FEM301 ausgeführt worden sind. Zwei Testfälle werden präsentiert. Der erste ist ein zweidimensionales Modell eines geklüfteten Festgesteins. Ein detaillierter quantitativer Vergleich der Resultate von FEM301 mit zwei anderen am Projekt beteiligten Modellen (GWHRT und STOKES) zeigt eine gute Uebereinstimmung. Der zweite Testfall ist ein dreidimensionales Modell eines Sedimentbeckens mit stark unterschiedlichen Durchlässigkeiten der einzelnen Gesteinsformationen. Für diesen Testfall werden qualitative Vergleiche durchgeführt mit den Modellen SWENT, FE3DGW und CFEST. Zusätzliche, detaillierte, quantitative Vergleiche sollen im Rahmen des Schlussberichtes zu HYDROCOIN - Level 1 publiziert werden.

TABLE OF CONTENTS

LIST OF APPENDICES

1 INTRODUCTION

Projekt Gewähr 1985 [13] describes the safety analyses to investigate the feasibility of the final disposal of radioactive wastes in Switzerland. An important component of the safety analysis consists of using numerical models to quantify (1) the groundwater flow regime (in particular the likely paths of radionuclide migration from possible repository sites to the biosphere and the groundwater velocities along these paths), (2) the near-field thermal environment, (3) near-field and far-field radionuclide transport, and (4) radionuclide migration in the biosphere. Each of these numerical models must be verified to assure that the results generated during their application are free of numerical inaccuracies. Of course, in addition to verifying the numerical models, the conceptual models of the hydrogeology of the area of interest should be validated to the extent feasible. This entails assuring that the modeled conditions reproduce the observed field conditions.

In the present document we focus on the verification of FEM301 [10], the steady-state, three-dimensional finite-element groundwater flow code used to evaluate the groundwater flow regime of northern Switzerland [12]. While some verification tests are described in the FEM301 code document and user's manual [10], additional verification tests have been performed under the international HYDROCOIN project. The results of these verification problems are described in this document.

The international HYDROCOIN project (see Appendix AIII, List of participants) is organised at the initiative of the Swedish Nuclear Power Inspectorate (SKI) in order to verify and validate hydrological models used for nuclear waste repository performance assessment. The HYDROCOIN project comprises three levels :

Level 1 is designed to verify the impact of different solution algorithms on the groundwater flow calculations. Level 2 is a validation exercise aimed at testing the ability of groundwater flow models to describe experimental data. Level 3 is a sensitivity and uncertainty study.

This report describes the results of the Level 1 calculations on Case 2 and Case 6 obtained with the three-dimensional finite element code FEM301 and comparisons with some routines of other participants in HYDROCOIN.

In order to achieve a more specific verification of the FEM301 solution algorithm as well as some of its post-processing routines, some calculations and intercomparisons have been executed beyond the requirements of HYDROCOIN. In particular, the nodal values of head have been compared. This complementary work was necessary because the comparison procedure adopted by HYDROCOIN did not allow for direct comparison between the outputs of the main programs which calculate nodal values of head and flux. In fact the comparison was based on results obtained with different meshes, post-processing routines and main codes. Therefore, it is difficult to explain some of the differences between the various codes because they can arise from three sources :

1. Discretization of model domain,
2. Calculation of nodal values,
3. Post-processing interpolation schemes.

It is impossible to separate the influence of each of these three points if the intermediate results are not available. In order to check their respective importance, Case 2 was detailed and for each operation the results of GWHRT code [3, 15] and the FEM301 code [10] were compared.

Unfortunately this procedure could not be applied to Case 6 because grid and nodal values were not available in time. Moreover, some problems with the initial input data defined by Gupta et al. [5] did not allow for a serious intercomparison between their results and those obtained by FEM301. However, a qualitative comparison with the results of the other participants has been realized. Furthermore some interesting additional runs have been performed to attempt to obtain more realistic results and these are also described in this report.