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MINE-NEC - A Game for the Analysis of Regional Water Policies in Open-Pit Lignite Mining Areas: An Improved Implementation for the NEC PC-8201A

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PREFACE

Gaming was one of our approaches to analyse regional water policies in regions with intense socio-economic development. With the game MINE by Weigkricht and Kaden a game for the analysis of regional water policies in open-pit lignite mining areas was developed.

From experience in playing this game, we learnt that a high portability is most favourable. Therefore, it was decided to develop an improved version for the portable microcomputer NEC PC-8201A. This work was done partly by O. Varis in the framework of the Young Summer Scientists Program 1985 at IIASA. In the paper, the version MINE-NEC is documented.

S. Orlovski
Project Leader
Regional Water Policies

ABSTRACT

The game MINE was developed for the analysis of regional water policies in open-pit lignite mining areas. It is implemented for a GDR test area. The purpose of the game is above all to teach decision makers and their staff in mining regions in order to get a better understanding of the complex interrelated socio-economic processes with respect to water management in such regions. The game is designed to be played by five groups of players representing municipal and industrial water supply, agriculture, environmental protection and lignite mining.

In this paper an improved BASIC version for the portable NEC PC-8201A microcomputer is introduced.

CONTENTS

MINE-NEC – A GAME FOR THE ANALYSIS OF REGIONAL WATER POLICIES IN OPEN-PIT LIGNITE MINING AREAS; AN IMPROVED IMPLEMENTATION FOR THE NEC PC-8201A

S. Kaden and O. Varis

1. Introduction

The main concern of the IIASA project "Regional Water Policies" was to investigate areas with highly intensive use of both surface water and groundwater. Regions with open-pit lignite mining are one of the conspicuous examples of complex interactions in socio-economic and environmental systems with special regard to groundwater. These problems are particularly obvious in many Central and Eastern European countries.

The study "Water Policies: Regions with Open-pit Lignite Mining" was directed towards the development of methods and models to support the analysis of conflicts between different water users in the framework of the environmental capacity. This study is based on an implementation area in the German Democratic Republic, for a detailed description, see Kaden et al. 1985a. The research has been directed into two major directions:

- the development of a complex decision support model system based on recent methods of multicriteria analysis and its application on a main frame computer (VAX 11/780);

- the development of a game for the test region as an experimental and teaching tool.

The second direction resulted in the game MINE, see Weigkricht and Kaden 1985.

The first version of the game – MINE 1 – was implemented in BASIC on an APPLE IIe. This version also has been implemented on a portable computer NEC/PC 8201A. A playing board with appropriate pieces is associated to the game. During the game, the players are sitting around the board, filling out different forms with their decisions. The computer with the model is running in the background, the input of the decisions is made by the game operator. The communication between model and decision makers is realized by pieces moved on the board. All model outputs as allocation and quality of water, results, etc. are printed on an additional printer.

The second version – MINE 2 – was implemented in FORTRAN 77 on the VAX and the ALTOS. A graphic terminal can be associated to the VAX, that corresponds to the board in MINE 1. The input of the decisions is made by the players or by the game operator on the computer.

The gaming board for MINE 1 and the graphic schema for MINE 2 represent a schematical map of the test area (see Figure 1). They also show the stream, the two tributaries, the groundwater extraction possibility, the possibility of import and export. The lines between these items represent the pipelines for water allocation.

From the experience in running the game it was learnt that the simpler version of the game being implemented for small microcomputers is more favourable due to its communicative character. Above all the game should be portable as easy as possible. Therefore, it has been decided to improve the NEC version of the game. The portable NEC PC-8201A has 32k bytes Read Only Memory (ROM) capacity and 32k bytes Random Access Memory (RAM). The RAM capacity can be expanded to 96k bytes. It has a liquid crystal screen of 40 columns and 8 rows. Its weight is only 1.7 kg.

The following major improvements had to be done:

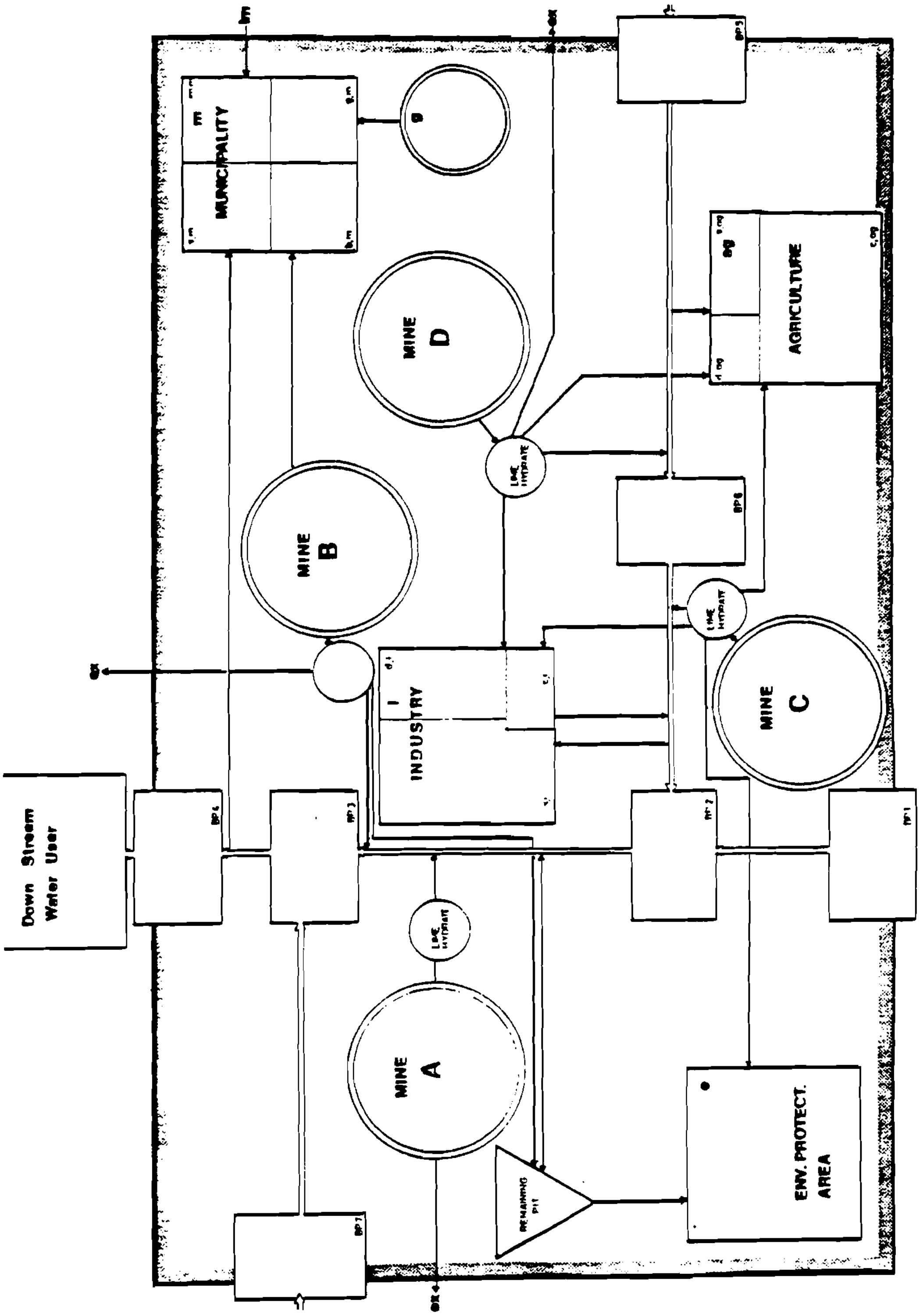

Figure 1: Game board

- adaptation of the programme to the special features of the NEC (storage and screen-size),
- actualization of the game according to the mathematical model documented in Kaden et al. 1985, above all realization of two water quality indicators (Fe^{2+}, pH-value),
- interactive programme handling for the game operator and enlarged output of model results.

In order to realize these improvements the game MINE 1 had to be largely reconstructed and programmed in a modular and storage saving form. In the following the game MINE-NEC is documented. It is generally applicable to low capacity microcomputers.

2. MINE – NEC

2.1. Description of the game

The given description is a slightly modified one of those given by Weigkricht and Kaden 1985.

We assume five players or playing groups (compare Figure 1), each group has at least one player:

[1] *Municipality*

[2] *Industry*

[3] *Agriculture* (irrigation; the water demand is increasing depending on mine drainage)

[4] *Environmental protection area and Down-stream water user*

[5] *Mining group representing the following mines*:

- Mine a (closes during the planning horizon and becomes a remaining pit to be used as a reservoir),
- Mine b,
- Mine c,

- Mine d is not working at the beginning of the game, water drainage has to be started before it opens.

There may be an additional group, representing a central planning authority, who decides in conflict situations. Another possibility is to make these decisions together by vote.

The submodels of the game are based on he same mathematical models as the Decision Support Model System developed for the GDR test area. In Kaden et al. 1985 all models are described in detail.

The game is designed for 10 planning periods (cycles). In Table 1 the time steps are given.

Table 1: Planning periods

Planning period	1	2	3	4	5	6	7	8	9	10
Years	1	2	4	6	8	10	17	25	35	50
Time steps (years)		1	2	2	2	2	7	8	10	15

Mine a closes in period 7. Mine drainage for mine d may start in period 2, mining of mine d starts in period 4.

The water quality is characterized by two indicators – the Fe^{2+}-concentration and the pH-value. In order to simplify the game a water quality index is defined according to Table 2. To display the water quality on the game board different colours are used.

2.1.1. Basic rules

There are certain water resources available in the region, that means mine drainage water, groundwater, surface water in the remaining pit, in the river and its tributaries, or water import. The water users have a certain demand that they should try to satisfy with the water being available.

Table 2: Water quality index

Index	Colour	Fe^{2+} [mg/l]		pH-value	
1	blue		≤ 1	≥ 6.5	
2	green	> 1	≤ 5	≥ 6.0	< 6.5
3	yellow	> 5	≤ 10	≥ 5.5	< 6.0
4	white	> 10	≤ 20	≥ 5.0	< 5.5
5	red	> 20	≤ 50	≥ 4.5	< 5.0
6	black	> 50		< 4.5	

They have to decide on the water quality being required and they would like to have from where. The mining managers decide about the amount of lime they are adding to the water (which influences the possibilities of water allocation, because the users have to satisfy certain quality restrictions) and where they are releasing the mine drainage water not being used by water users. After this, if no constraint is violated, the results per year of the last playing period, and the accumulated results of the periods already being played are printed. If some constraints are violated (this happens usually, when no attention is paid to the decisions of the other players), the decisions have to be taken together (the majority decides) or another playing group, the central planning authority, can join the game and decides, what strategy would be the best and which are the priorities.

2.1.2. Goals and roles for players

The criteria for the quality of the decisions are economic criterias (cost, benefits), the satisfaction of the demands, and the quality of the water. It has to be considered that these criteria are long-term and global goals: for example, the decisions in a playing period where one has higher costs than necessary, but the total costs of the whole horizon are quite low, might be better than decisions, where all the interest groups try to minimize their own costs. It should be noticed that the players should not play against oach other, but that they should try to satisfy a common goal, the rational long-term development in the region.

[1] *Municipality*

The objective is to provide water for the municipal water supply and to minimize cost (with regard to the total cost and the satisfaction of all water users).

The water demand ca be satisfied by the following water allocations:

g - groundwater extraction
b - drainage water from mine b
s - stream
im - water import into the region.

Approximately the cost increase according to the order above. The following pipe capacity restrictions have to be considered:

Table 3: Capacity of pipelines for municipal water supply (m^3/sec).

	Period									
	1	2	3	4	5	6	7	8	9	10
s	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
g	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
im	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
b	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5

As the drinking water supply is very important, it gets the highest priority, i.e. the player 'municipality' decide first.

[2] *Industry*

The objective is to satisfy the industrial water demand and to minimize cost (with regard to the total cost and the satisfaction of all water users).

The water demand can be satisfied by the following water allocations:

s - stream

c - drainage water from mine c

d - drainage water from mine d.

The following pipe capacity restrictions are given:

Table 4: Capacity of pipelines for industrial water supply (m^3/sec).

	Period								
	1	2	3	4	5	6	7	8	9
s	3	3	3	3	3	3	3	3	3
c	2	2	2	2	2	2	2	2	2
d	0	0	1	1.1	2	2	2	2	2

Industrial water supply gets priority after drinking water supply. It has to be noticed that waste water of a bad quality is released into the tributary.

[3] *Agriculture*

The objective is to satisfy the agricultural water demand (depending on the the groundwater table, itself depending on the drainage activities of the mines) and to minimize cost (with regard to the total cost and the satisfaction of all water users).

The water demand can be satisfied by the following water allocations:

s - stream

c - drainage water from mine c

d - drainage water from mine d.

The following pipe capacity restrictions are valid:

Table 5: Capacity of pipelines for agricultural water supply (m^{3}/sec).

	Period									
	1	2	3	4	5	6	7	8	9	10
s	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
c	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
d	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Agricultural water supply has priority 3. There is not any demand at the beginning of the planning horizon, but because of the mining activities, the demand is increasing (especially when mine d is going into operation).

[4] *Environmental protection area and down-stream water user*

The objective is to satisfy the water demand (for artificial groundwater recharge) of the environmental protection area, depending on the groundwater table. The water quality should be worse than index 3. The downstream water user are getting the water left in the stream. The water quality mainly depends on the quality of the water released from mines and from the industry. Try also to minimize total costs.

The water demand for the environmental protection area can be satisfied by the following water allocations:

p - remaining pit (after closing of mine a)
c - drainage water from mine c

For the pipe capacity restrictions see Table 6.

Table 6: Capacity of pipelines for environmental protection (m^3/sec).

	Period									
	1	2	3	4	5	6	7	8	9	10
p	0	0	0	0	0	0	0	0.2	0.3	0.5
c	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.2	0.1	0.05

There is no priority at all. If more water is required than left, the constraints are not satisfied and the decisions have to be made a second time all together.

[5] *Mining group*

The mine drainage water has to be allocated with regard to the minimum of total costs for mine water drainage and allocation. Drainage water can be sold, if another user requires it, and if the quality is good enough. Lime hydrate can be added for water treatment in order to improve water quality for user. The water that could not be sold to the users has to be released into the river; if it is of bad quality, a fine for that has to be paid.

For the possibilities of water allocation see Table 7 below.

2.2. Computer Implementation

The programme is divided into a large number of modules (GOSUB subroutines). These modules are structured as far as possible similar to the submodels of the DSS MINE, Kaden et al. 1985, considering the specifics of BASIC.

In Figure 2 a rough flow chart of the programme MINE-NEC is given documenting the major modules. This figure is aimed to support further programme modifications as well as to serve as an operator's instructions flow chart. Each module is characterized as a box with the information of the function of each module, the required keyboard inputs during a run and line numbers of the module in the programme list.

Table 7: Capacity of pipelines for mine water allocation (m^3/sec).

	Period								
	1	2	3	4	5	6	7	8	9
a,s	4.1	3.9	3.3	2.8	2.2	1.8	1.5	0	0
a,ex	1.8	1.7	1.2	1.4	1.4	1.6	1.5	0	0
b,s	3	3.2	3.4	3.5	3.9	4.1	5	6.4	5.4
b,p	1.2	1.3	1.5	1.6	1.9	2	2	2	2
b,ex	1.2	1.3	1.5	1.6	1.9	2	2	2	2
c,s	2.1	2.3	2.7	2.3	2.5	2.6	2.8	2.9	3.2
d,s	0	0	1	1.1	3.8	3.9	4.3	4.3	3.1
d,ex	0	0	0	0.9	1.9	2	2	1.5	0
p,s	0	0	0	0	0	0	0	0.5	1
s,p	0	0	0	0	0	0	0	4	4

In Appendix A1 the complete listing of the programme is given; in A2 the notations used are explained. The programme listing includes as much as possible comments in order to support the "readability" of the programme. Due to storage restrictions these comments had to be minimized.

2.3. Operation of the game

Before starting the game the players should make aware of the idea, scope and restrictions of the game MINE-NEC. Each player should get acquainted with the role descriptions in Chapter 2.1. The information on capacity restrictions and the amount of water available help the operation by decreasing the number of constraint violations.

In addition to the MINE-NEC programme and required hardware, the board presented in Figure 1 with appropriate coins and pieces is necessary as well as the forms in Appendix B.

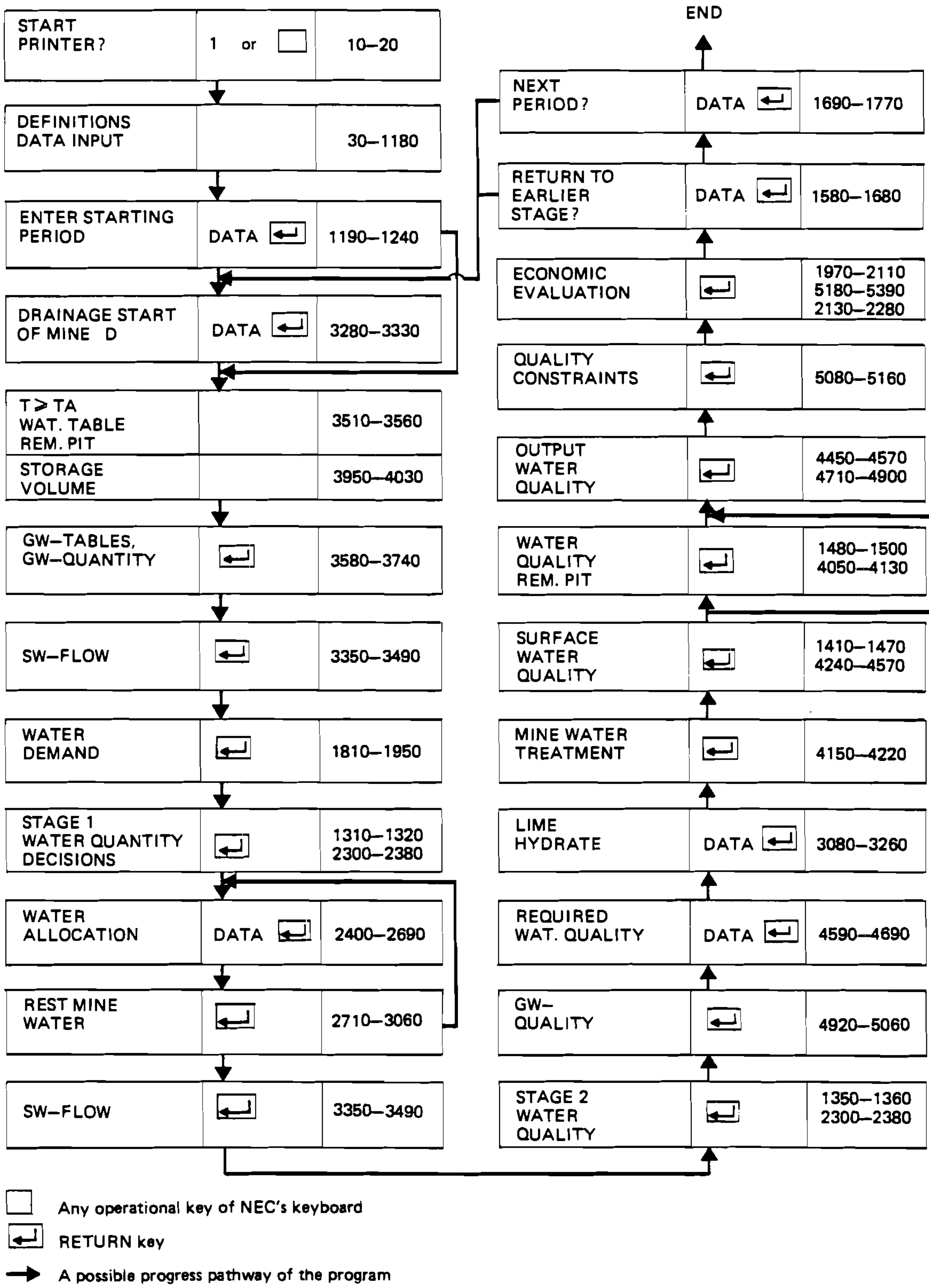

Figure 2: Flow chart of the programme MINE-NEC

To indicate the water quality coloured "pieces", e.g. small wooden blocks, are needed. For each colour in Table 2 about 15 pieces should be available. For the water quantity "coins" are required to represent the water quantity between 0.01 to 30 m^3/s for 16 locations. In our case play money (0.01, 0.05, 0.10, 0.50, 1.0, 5.0, 10.0) was used.

The initial state for each period concerning water resources is illustrated by setting the coins and pieces a correspondingly locations on the board. The decisions made are demonstrated by moving the coins on the board: in the sequence of their priority the players have to make these decisions and to fill the data in the forms in Appendix B.

The programme can be loaded from a cassette tape by using for instance the NEC PC-828/A data recorder. The loading starts with the command CLOAD "MINE.BA". The LOAD key of the data recorder must be pressed down. The loading requires a few minutes. After loading the recorder stops automatically and the letters "OK" are displayed on the screen. The game can be started with the command RUN or pressing the key function f.5.

The programme MINE-NEC is self-explaining. All required data inputs are initiated by corresponding outputs on the screen, compare also Figure 2. In Appendix C a protocol of an example run is given, illustrating the user-friendly operation of the game.

REFERENCES

S. Kaden, J. Hummel, L. Luckner, D. Peukert and K. Tiemer. (1985) Water policies: regions with open-pit lignite mining (Introduction to the IIASA study), International Institute for Applied Systems Analysis (IIASA), WP-85-04, Laxenburg, Austria.

E. Weigkricht and S. Kaden. 1985 MINE – a game for the analysis of regional water policies in open-pit lignite mining areas. WP-85-46, IIASA, Laxenburg, Austria.

Appendix A1: BASIC-listing of the game MINE-NEC

```
10 SCREEN 0.0:DEFINT I-N,T:DEFSTR U:U8="          ":U9="           "
20 INPUT"OUTPUT ON PRINTER (YES=1)":IP
30 IF IP<>1 THEN IP=0
40 CLS
50 PRINT:PRINT:PRINT SPACE$(17)+"MINE"
60 U="GDR Minewater Study":PRINT SPACE$(10)+U:PRINT
70 U1="        IIASA  Laxenburg, Austria":PRINT U1:PRINT
80 PRINT SPACE$(14)+"DATA INPUT";
90 IF IP=0 GOTO 110
100 LPRINT SPACE$(17)+"MINE":LPRINT SPACE$(10)+U:LPRINT U1:LPRINT
110 '*** INPUT DATA
120 TA=8'PERIOD START REM.PIT
130 TD=100'PERIOD START MINE D
140 DIM UU(7),US(7) 'NAMES OF WAT.SUPPLIER AND USER
150 DIM LE(7,7)'PIPE EXISTS? (100 = NO, 1=YES. 0=LATER)
160 DIM II(7,7) 'ARBITR.ARRAY
170 DIM RE(3)'REST MINE WAT.
180 DIM IQ(7)'REQUIRED QUALITY INDEX
190 FOR I=0 TO 7
200 READ UU(I),US(I)
210 FOR J=0 TO 7:LE(I,J)=100:II(I,J)=8:NEXT
220 NEXT I
230 DATA " s"," m"," g"," i","im","ag"," a"," e"," b","os"," c","ex"," d"," p","
 p"," s"
240 LE(0,0)=1:LE(7,7)=0:LE(0,1)=1:LE(0,2)=1:LE(7,3)=0:LE(0,4)=1:LE(1,0)=0:LE(5,3
)=0:LE(2,0)=0:LE(6,5)=0:LE(3,5)=0:LE(3,7)=0:LE(5,1)=1:LE(5,2)=1:LE(6,7)=0:LE(6,1
)=0:LE(6,2)=1:LE(0,6)=0:LE(4,7)=0:LE(4,6)=0:LE(4,0)=0:LE(4,5)=0:LE(5,7)=0
250 II(7,7)=29:II(7,3)=30:II(0,6)=31:II(1,0)=32:II(0,0)=33:II(0,1)=34:II(0,2)=35
:II(2,0)=36:II(3,7)=37:II(3,5)=38:II(4,7)=39:II(4,6)=40:II(4,0)=41:II(4,5)=42
260 II(5,7)=43:II(5,1)=44:II(5,2)=45:II(5,3)=46:II(6,7)=47:II(6,1)=48:II(6,5)=49
:II(6,2)=50:II(0,4)=15
270 DIM TE(10)'YEARS PER PERIOD
280 TE(1)=1:TE(2)=1:TE(3)=2:TE(4)=2:TE(5)=2:TE(6)=2:TE(7)=6:TE(8)=8:TE(9)=10:TE(
10)=15
290 DIM SF(50,10)'COEFFIC./UPPER BOUNDS
300 FOR I=0 TO 50:FOR J=1 TO 10:READ SF(I,J):NEXT:NEXT
310 DATA 4.1,3.9,3.25,2.78,2.23,1.75,1.5,0,0,0:'0 - qga
320 DATA 0,0,0,.25,.5,.5,.5,.5,.5,.5:'1 - qgb1
330 DATA 2.95,3.15,3.4,3.5,3.98,4.1,4.98,6.23,5.11,2.61:'2 - qgb2,a1
340 DATA 0,0,0,0,0,0,0,.0012,.0027,.0028:'3 - qgb2,a2
350 DATA 3.05,2.25,2.7,2.28,2.45,2.6,2.82,2.78,2.86,3.18:'4 - qgc
360 DATA  0,0,0,1.13,3.8,3.85,4.25,4.25,3.09,.29:'5 - qgd,a1
370 DATA 0,0,-.183,-.7,-.412,-.175,-.225,-.063,-.128,-.023:'6 - qgd,a2
380 DATA 0,0,.092,.068,-.131,-.013,-.013,.019,.011,.003:'7 - qgd,a3
390 DATA 0,0,0,0,0,0,0,0,0,0:'NOT USED
400 DATA 141.5,141.5,141.5,141.5,141.3,140.7,137.8,135.1,137.5,139.5:'9 - hag.a1
410 DATA 0,0,0,0,.125,.325,.55,.3,0,0:'10 - hag,a2
420 DATA 0,0,0,0,-.038,-.038,-.05,-.075,0,0:'11 - hag.a3
430 DATA 118.9,118.9,117.9,115,111,106.3,93.1,0,0,0:'12 - hg,a1
440 DATA 0,0,0,.125,.35,.425,.1,0,0,0:'13 - hg,a2
450 DATA 0,0,0,-.038,.025,.213,.05,0,0,0:'14 - hg,a3
460 DATA 131.4,131.2,130.9,130.7,130.3,129.8,130.1,130.6,127,133:'15 - he.a1
470 DATA 0,0,0,0,0,0,0,0,.04,0:'16 - he,a2
480 DATA -.34,-.33,-.32,-.28,-.23,-.15,-.04,.27,.73,6.49:'17 - qi12,a1
490 DATA 0,0,0,0,0,0,0,-.0016,-.0065,-.057:'18 - qi12,a2
500 DATA .8,.8,.81,.84,.88,.9,.9,2.01,4.27,15: 19 - qi23,a1
510 DATA 0,0,0,0,0,0,0,-.013,-.035,-.129:'20 - qi23,a2
520 DATA -.09,-.08,-.07,-.06,-.05,-.05,-.04,-.04,-.06,.11:'21 - qi34
530 DATA .55,.55,.56,.61,.68,.69,.69,.69,.68,.33:'22 - qi62,a1
540 DATA 0,0,0,-.019,-.013,0,0,0,0,0:'23 - qi62,a2
550 DATA 0,0,0,-.004,-.004,0,0,0,0,0:'24 - qi62,a3
560 DATA -.47,-.47,-.46,-.46,-.43,-.36,-.26,-.19,-.09,.09:'25 - qi56.a1
570 DATA 0,0,0,-.015,-.025,-.025,-.01,0,0,0:'26 - qi56,a2
580 DATA 0,0,0,.005,.005,0,0,0,0,0:'27 0 qi56.a3
590 DATA 0,0,0,0,0,0,0,0,0,0:'28 - qi73
600 DATA 0,0,0,0,0,0,0,.5,1,1.5:'29 - ups
610 DATA 0,0,0,0,0,0,0,0.2,.3,.5:'30 - upe
620 DATA 0,0,0,0,0,0,0,4,4,4:'31 - usp
630 DATA .2,.2,.2,.5,.5,.5,.5,.5,.5,.5:'32 - ugm
640 DATA .5,.5,.5,.5,.5,.5,.5,.5,.5,.5:'33 - usm
650 DATA 3.,3.,3.,3.,3.,3.,3.,3.,3.,3.:'34 - usi
660 DATA .1,.1,.1,.1,.1,.1,.1,.1,.1,.1:'35 - usag
670 DATA 0.,0.,0.,.5,.5,.5,.5,.5,.5,.5:'36 - uimm
680 DATA 4.1,3.9,3.3,2.8,2.2,1.8,1.5,0,0,0:'37 - uas
690 DATA 1.8,1.7,1.2,1.4,1.4,1.6,1.5,0,0,0:'38 - uaex
```

```
700 DATA 3,3.2,3.4,3.5,3.9,4.1,5,6.4,5.4,3:'39 - ubs
710 DATA 1.2,1.3,1.5,1.6,1.9,1.9,2,2,2,2:'40 - ubo
720 DATA 0,0,0,.5,.5,.5,.5,.5,.5,.5:'41 - ubm
730 DATA  1.2,1.3,1.5,1.6,2,2,2,2,2,2:'42 - ubex
740 DATA 2.1,2.3,2.7,2.3,2.5,2.6,2.8,2.8,2.9,3.2:'43 - ucs
750 DATA 2.,2.,2.,2.,2.,2.,2.,2.,2.,2.:'44 - uci
760 DATA .1,.1,.1,.2,.2,.3,.3,.3,.1,.05:'45 - ucag
770 DATA .1,.1,.1,.2,.2,.3,.3,.2,.1,.1:'46 - uce
780 DATA 0,0,1.1,1.1,3.8,3.9,4.3,4.3,3.1,.3:'47 - uds
790 DATA 0,0,0,2.0,2,2,2,2,2,.3:'48 - udi
800 DATA 0,0,0,.5,1.9,1.9,2,2,1.5,0:'49 - udex
810 DATA .1,.1,.1,.1,.1,.1,.1,.1,.1,.1:'50 - udag
820 DIM CG(5,1,10),IM(7)'GW-QUALITY
830 DIM CQ(4),C(5,1)'LIME, MINE WAT. QUALITY
840 FOR I=0 TO 5
850 C(I,0)=0:C(I,1)=0:FOR J=1 TO 10:READ CG(I,0,J):NEXT
860 NEXT I'Fe
870 DATA 38.6,41.5,45.8,51.7,57.2,62.9,75.8,0,0,0:'cga
880 DATA 5,5,5,5,5,5,5,5,5,5:'cgb1
890 DATA 17,17.8,19,20.7,22.3,23.9,27.6,33.7,41.1,51.3:'cgb2
900 DATA 16.6,17.2,18,19.1,20.3,21.4,23.9,28.2,33.3,40.3:'cgc
910 DATA 0,0,11.6,12.5,13.5,14.5,16.20.3,24.6,30.7:'cgd
920 DATA 0,0,0,0,0,0,0.70,80,90:'cgp
930 FOR I=0 TO 5:FOR J=1 TO 10:READ CG(I,1,J):NEXT:NEXT'pH
940 DATA 6.03,6.01,5.97,5.92,5.87,5.82,5.71,0,0,0:'cga
950 DATA 6,6,6,6,6,6,6,6,6,6:'cgb1
960 DATA 6.11,6.1,6.08,6.05,6.02,5.99,5.93,5.82,5.69,5.51:'cgb2
970 DATA 5.84,5.82,5.8,5.78,5.75,5.72,5.67,5.57,5.45,5.28:'cgc
980 DATA 6.03,6.02,6,5.97,5.94,5.91,5.85,5.74,5.61,5.43:'cgd
990 DATA 0,0,0,0,0,0,0,5.5,5.25,5:'cgp
1000 DIM DE(7,7,10)'DEMAND FOR ALLOCATION
1010 DIM CO(8,10)'COST
1020 DIM CI(1)'QUALITY WASTE WATER
1030 DIM D1(10),D2(10)'ECONOMIC FACTORS
1040 FOR I=1 TO 10:READ D1(I),D2(I):NEXT
1050 DATA .939,33.85,.882,34.75,.803,37.39,.708,41.20,.624,45.42,.55,50.09,.417,
62.65,.261,90.5,.149,149.87,.069,262.46
1060 BI=.16:BM=.7:BA=0:BE=.02:BS=.03:BW=.02:GT=6E-05:GM=.01:GI=.04'ECONOMIC COEF
.
1070 DIM HP(10)'WAT. TABLE REM.PIT
1080 DIM VP(10)'STORAGE VOL. REM.PIT
1090 VP(7)=0
1100 DIM QI(4,1)'BOUNDS FOR QUALITY INDEX (0/4:Fe,pH)
1110 QI(0,0)=1:QI(1,0)=5:QI(2,0)=10:QI(3,0)=20:QI(4,0)=50:QI(0,1)=6.5:QI(1.1)=6:
QI(2,1)=5.5:QI(3,1)=5:QI(4,1)=4.5
1120 DIM CS(7,1),CA(7,1),IS(7)'SURFACE WAT.QUALITY
1130 CS(1,0)=2:CS(5,0)=1:CS(7,0)=5:CS(1,1)=6.5:CS(5,1)=6.8:CS(7,1)=6.2
1140 FOR I=1 TO 7:CS(I,1)=10^(3-CS(I,1)):NEXT'AHU FROM INFLOW
1150 Q5=3.13:Q7=.98:Q1=4.71
1160 DIM RQ(4,10)'WATER REQUIREMENTS
1170 FOR I=1 TO 10:RQ(1,I)=4:READ RQ(0,I),RQ(4,I):NEXT:' 0 - m,4 - ds.1 - i
1180 DATA 0.2,25.,.21,25.,.22,25.,.23,25.,.24,25.,.26,26.,.29,27.,.35,28.,.42,30
.,.5,35.
1181 DIM UO(4)
1182 FOR I=0 TO 4:READ UO(I):NEXT
1183 DATA "MUNICIPALITY","INDUSTRY","AGRCULTURE","ENV.PROTECTION AREA","DOWN STR
EAM USER"
1190 '*** START OF GAME MINE
1200 U=" ENTER STARTING PERIOD (FROM 1 TO 9)"
1210 CLS:PRINT U;:INPUT T
1220 IF IP=1 THEN LPRINT U+" ?";T:LPRINT:LPRINT
1230 IF T<1 OR T>9 GOTO 1210
1240 IF T>2 AND TD=100 THEN GOSUB 3280'START MINE d?
1250 '*** ESTIMATION STATE PARAM.
1255 U="":U1=""
1260 IF T>=TA THEN GOSUB 3510'WAT. TABLE REM.PIT
1270 GOSUB 3580'GW-TABLES,-QUANTITY
1280 GOSUB 3350'SW-FLOW
1290 GOSUB 1810'WATER DEMAND
1300 N5=1:'(=1 -> 1.CALL ALLOC., =2 -> 2.CALL)
1310 '*** WATER QUANTITY DECISIONS
1320 N=1:GOSUB 2300'TITEL
1330 JF=0:GOSUB 2400'WATER ALLOCATION
1340 GOSUB 3350'SW-FLOW
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1350 '*** WATER QUALITY DECISIONS
1360 N=2:GOSUB 2300'TITEL
1370 GOSUB 4920'GW-QUALITY
1380 GOSUB 4590'REQUIRED WAT. QUALITY
1390 GOSUB 3080'ADDED LIME HYDRATE
1400 GOSUB 4150'MINE WAT. TREATMENT
1410 '*** SURFACE WATER QUALITY
1420 I=1:GOSUB 4240:I=5:GOSUB 4240:I=7:GOSUB 4240'SELF-PURIFICATION FE(II),bp1-2
,bp5-6,bp7-3
1430 N=0:GOSUB 4300:I=5:GOSUB 4270:N=1:GOSUB 4300'cs6
1440 N=0:GOSUB 4330:N=1:GOSUB 4330'c-i,s
1450 I=6:GOSUB 4240:N=0:GOSUB 4360:I=6:GOSUB 4270:I=1:GOSUB 4270:N=1:GOSUB 4360'
cs2
1460 I=2:GOSUB 4240:N=0:GOSUB 4390:I=2:GOSUB 4270:I=7:GOSUB 4270:N=1:GOSUB 4390'
cs3
1470 N=3:GOSUB 4240:N=0:GOSUB 4420:I=3:GOSUB 4270:N=1:GOSUB 4420'cs4
1480 IF T<TA GOTO 1510'NO REM.PIT
1490 C(0,T)=C(5,T-1)
1500 I=0:GOSUB 4090:GOSUB 4040:I=1:GOSUB 4090:GOSUB 4040'QUALITY REM.PIT
1510 GOSUB 4450'QUALITY INDEX
1520 GOSUP 4710'OUTPUT WAT.QUALITY
1530 GOSUB 5080'QUALITY CONSTRAINTS
1540 '*** ECONOMIC EVALUATION
1550 GOSUB 1990'COST PER PERIOD
1560 GOSUB 5180'OUTPUT OF COST
1570 IF T>1 THEN GOSUB 2130'TOTAL COST
1580 U="Do You want to  return to  some of  the  earlier stages or periods (1=YE
S,0=NO)"
1590 PRINT U;:INPUT N:IF N<0 OR N>1 GOTO 1590
1600 IF IP=1 THEN LPRINT U+" ?";N
1610 IF N<>1 OR T=1 GOTO 1690
1620 INPUT"Enter period";T1
1630 IF IP=1 THEN LPRINT"Enter period";T1
1640 IF T>T1 THEN T=T1:GOTO 1240
1650 U="Enter stage (1 = Water quantity; 2 = Water quality"
1660 PRINT U;:INPUT N
1670 IF IP=1 THEN LPRINT U+"?";N
1680 IF N=1 THEN GOTO 1270 ELSE GOTO 1350
1690 IF T=10 GOTO 1780
1700 U="PREVIOUS PERIOD WAS "
1710 U1="START NEXT PERIOD?(YES=1,NO=0)"
1720 CLS:PRINT U;T
1730 PRINT U1;:INPUT I
1740 IF IP=1 THEN LPRINT U;T:LPRINT U1;I
1750 IF I<0 OR I>1 GOTO 1720
1760 IF I=0 GOTO 1780
1770 T=T+1:GOTO 1240
1780 END
1790 '*** END OF GAME MINE ***
1800 '*** WATER DEMAND
1810 U="* WATER DEMAND *":PRINT U9;U
1820 IF IP=1 THEN LPRINT U9;U
1830 RQ(2,T)=0:IF HAG=<140.6 AND HAG>139.5 THEN RQ(2,T)=89.92-.64*HAG
1840 IF HAG<=139.5 THEN RQ(2,T)=.64
1850 RQ(3,T)=.075*(HENV-132)^2
1860 FOR I=0 TO 4:RQ(I,T)=INT(RQ(I,T)*100)/100:NEXT
1883 DATA "MUNICIPALITY","INDUSTRY","AGRICULTURE","ENV.PROTECTION AREA","DOWN ST
REAM USER"
1900 FOR I=0 TO 4
1910 PRINT UD(I);TAB(22);USING"##.##";RQ(I,T)
1920 IF IP=1 THEN LPRINT UD(I);TAB(22);USING"##.##";RQ(I,T)
1930 NEXT I
1940 GOSUB 5410
1950 RETURN
1960 '*** COST MINE DRAINAGE, WATER SUPPLY
1970 CO(0,T)=0:CO(3,T)=0
1980 IF T<TA THEN CO(0,T)=D1(T)*(.54+1.32+(.24*GA+(.05-BI)*DE(3,5,T)+(.015+(2E-0
5*C(1,0)-1E-03)*C(1,0)+GT*CQ(1))*DE(3,7,T))*D2(T))*TE(T)' COST-A
1990 CO(1,T)=D1(T)*(.99+2.38+(.35*SF(1,T)+(.05-BI)*DE(4,5,T)+(.28+.017+GT*CQ(2))
*GB-BM*DE(4,0,T)+(2E-05*C(2,0)-1E-03)*C(2,0)*DE(4,7,T))*D2(T))*TE(T)' COST-B
2000 CO(2,T)=D1(T)*(.54+.253+.316+((.03-BA)*DE(5,2,T)+(.03-BE)*DE(5,3,T)+(.28+.0
16+GT*CQ(3))*GC-BI*DE(5,1,T)+(2E-05*C(3,0)-1E-03)*C(3,0)*DE(5,7,T))*D2(T))*TE(T)
' COST-C
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2010 IF TD<=T THEN CO(3,T)=D1(T)*(.72+.19+3.803+((.02-BA)*DE(6,2,T)+(.07-BI)*DE(
6,5,T)+(.3+.017+GT*CO(4))*GD-BI*DE(6,1,T)+(2E-05*C(4,0)-1E-03)*C(4,0)*DE(6,7,T))
*D2(T))*TE(T)' COST-D
2020 CO(4,T)=D1(T)*(1.327+.2+1.327+((.1+.05)*DE(1,0,T)+(BM+.05)*DE(4,0,T)+(.05+.
05+GM*CS(3,0))*DE(0,0,T)+(BM+.05)*DE(2,0,T))*D2(T))*TE(T)' COST-M
2030 CO(5,T)=D1(T)*(.357+1.5+.197+.475+1.188+((.02+.05+BI+C(3,0)*GI)*DE(5,1,T)+(
.03+.05+BI+GI*C(4,0))*DE(6,1,T)+(.01+BS+.05+GI*CS(2,0))*DE(0,1,T)+(.01+BW+.2)*QW
)*D2(T))*TE(T)' COST-I
2040 CO(6,T)=D1(T)*(.063+((.01+BS)*DE(0,2,T)+BA*(DE(5,2,T)+DE(6,2,T)))*D2(T))*TE
(T)' COST-AG
2050 CO(7,T)=D1(T)*(.398+((.02+BE)*DE(7,3,T)+BE*DE(5,3,T))*D2(T))*TE(T)' COST-E
2060 CO(8,T)=D1(T)*(1.102+.395+.713+(.02*DE(0,6,T)+.01*DE(7,7,T)+.02*DE(4,6,T)-B
E*DE(7,3,T)+GT*CO(0))*D2(T))*TE(T)' COST-P
2070 CT=0
2080 FOR I=0 TO 8
2090 CO(I,0)=0:IF CO(I,T)<0 THEN CO(I,T)=0
2095 CT=CT+CO(I,T)
2100 NEXT I
2110 RETURN
2120 '*** TOTAL COST UP TO ACTUAL PERIOD
2130 FOR I=0 TO 8:FOR J=1 TO T:CO(I,0)=CO(I,0)+CO(I,J):NEXT:NEXT
2140 U="TOTAL RESULTS UP TO PERIOD":U1="             (in Mill.Mark)":PRINT U;T;U1
2150 IF IP=1 THEN LPRINT U;T;U1
2160 FOR I=0 TO 3
2170 PRINT"MINE     "+UU(I+3)+" :";TAB(30);USING"####.#";CO(I,0)
2180 IF IP=1 THEN LPRINT"MINE     "+UU(I+3)+" :";TAB(30);USING"####.#";CO(I,0)
2190 NEXT I
2200 GOSUB 5410
2210 FOR I=0 TO 3
2220 PRINT"USER     "+US(I)+" :";TAB(30);USING"####.#";CO(I+4,0)
2230 IF IP=1 THEN LPRINT"USER     "+US(I)+" :";TAB(30);USING"####.#";CO(I+4,0)
2240 NEXT I
2250 PRINT"REM.PIT:";TAB(30);USING"####.";CO(8,0)
2260 IF IP=1 THEN LPRINT"REM.PIT:";TAB(30);USING"####.#;CO(8,0)
2270 GOSUB 5410
2280 RETURN
2290 '*** INFORMATION
2300 PRINT:PRINT SPACE$(15);"Stage  ";N
2310 PRINT SPACE$(15);"Period ";T:PRINT
2320 IF N=1 THEN U=" Water Quantity Decisions " ELSE U="Water Quality Requiremen
ts"
2330 PRINT"       "+U:PRINT:PRINT
2340 IF IP=0 GOTO 2370
2350 LPRINT:LPRINT SPACE$(15);"Stage  ";N
2360 LPRINT SPACE$(15);"Period ";T:LPRINT:LPRINT"       "+U:LPRINT:LPRINT
2370 GOSUB 5410
2380 RETURN
2390 '*** DECISIONS ON WATER ALLOCATION
2400 FOR J=0 TO 7:FOR I=0 TO 7
2410 IF N5=2 AND I<3 GOTO 2670
2420 IF LE(I,J)>1 GOTO 2670'NO PIPELINE
2430 IF T>7 AND I=3 GOTO 2670'NO MINE A
2440 IF T>7 GOTO 2460
2450 IF I=7 OR J=6 GOTO 2670'NO REM.PIT
2460 IF T < TD AND I=6 GOTO 2670'NO MINE D
2470 K=0:IF I=3 AND J=5 THEN K=1:GOSUB 2710'REST MINE WAT.
2480 IF J<5 THEN U="DEMAND THROUGH THE FOLLOWING PIPE:" ELSE U="ALLOCATION THROU
GH THE FOLLOWING PIPE:"
2490 CLS:PRINT U
2500 IF IP=1 THEN LPRINT:LPRINT U
2510 U="WATER QUANTITY":PRINT UU(I);"  ->  ";US(J):IF N5<2 THEN PRINT U;
2520 IF IP=1 THEN LPRINT UU(I);"  ->  ";US(J):IF N5<2 THEN LPRINT U;
2530 IF N5<2 GOTO 2600
2540 U="YOUR PREVIOUS DECISION WAS":U1="DO YOU WANT TO CHANGE IT (1=YES) ?"
2550 PRINT U;DE(I,J,T):PRINT U1
2560 IF IP=1 THEN LPRINT U;DE(I,J,T):LPRINT U1
2570 U=INPUT$(1):IF U<>CHR$(49) GOTO 2670
2580 PRINT"NEW VALUE";
2590 IF IP=1 THEN LPRINT"NEW VALUE"
2600 INPUT DE(I,J,T):IF DE(I,J,T)<0 GOTO 2600
2610 IF IP=1 THEN LPRINT" ?";DE(I,J,T)
2620 IF DE(I,J,T)<=SF(II(I,J),T) THEN GOTO 2670
2630 U="TOO HIGH DEMAND. MAXIMUM CAPACITY IS":U1="GIVE NEW VALUE"
2640 PRINT U;SF(II(I,J),T):PRINT U1;:INPUT DE(I,J,T)
2650 IF IP=1 THEN LPRINT U;SF(II(I,J),T):LPRINT U1+" ?";DE(I,J,T)
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2660 GOTO 2620
2670 NEXT I:NEXT J
2680 JF=0:GOSUB 2710'REST MINE WAT.
2690 RETURN
2700 '*** BALANCING MINE WATER
2710 RE(0)=GA-DE(3,7,T)-DE(3,5,T)' MINE A
2720 IF T>TA THEN RE(0)=0
2730 RE(1)=SF(1,T)+GB-DE(4,7,T)-DE(4,6,T)-DE(4,0,T)-DE(4,5,T)' MINE B
2740 RE(2)=GC-DE(5,7,T)-DE(5,3,T)-DE(5,1,T)-DE(5,2,T)' MINE C
2750 IF T>=TD THEN RE(3)=GD-DE(6,7,T)-DE(6,1,T)-DE(6,5,T)-DE(6,2,T)' MINE D
2760 FOR L=0 TO 3:IF ABS(RE(L))<.01 THEN RE(L)=0:NEXT
2770 IF DE(1,0,T)<=PGM GOTO 2820
2780 U="TOO HIGH GROUNDWATER DEMAND":PRINT:PRINT U
2790 IF IP=0 GOTO 2810
2800 LPRINT:LPRINT U
2810 GOSUB 5410
2820 IF T>TA OR 118>=HP(T) GOTO 2850
2830 JF=1:U="TOO HIGH WATER TABLE IN THE REMAINING PIT":PRINT:PRINT U
2840 IF IP=1 THEN LPRINT:LPRINT U
2850 GOSUB 5410
2860 CLS:IF K=1 GOTO 2980
2870 FOR L=0 TO 3
2880 IF L=3 AND T<TD GOTO 2920
2890 IF RE(L)=0 GOTO 2920
2900 JF=2:U=" IS UNBALANCED BY":PRINT"MINE"+UU(3+L)+U:RE(L)
2910 IF IP=1 THEN LPRINT"MINE"+UU(3+L)+U;RE(L)
2920 NEXT L
2930 IF JF=2 THEN GOSUB 5410
2940 N3=1:IF JF<>0 THEN N5=2:GOTO 1320'REPETITION WATER QUANTITY
2950 U="QUANTITY CONSTRAINTS ARE OK":PRINT U:
2960 IF IP=1 THEN LPRINT U
2970 GOSUB 5410
2980 U="  * REST MINE WATER *":CLS:PRINT U8;U:PRINT
2990 IF IP=1 THEN LPRINT U8;U:LPRINT
3000 FOR L=0 TO 3
3010 IF L=3 AND T<TD GOTO 3040
3020 PRINT"MINE"+UU(L+3);TAB(22);RE(L)
3030 IF IP=1 THEN LPRINT"MINE"+UU(L+3);TAB(22);RE(L)
3040 NEXT L
3050 GOSUB 5410
3060 RETURN
3070 '*** DECISIONS ON WATER TREATMENT
3080 CLS
3090 FOR I=0 TO 4
3100 CQ(I)=0
3110 U="MINE WATER TREATMENT: LIME TO ADD IN"
3140 IF (T<TA AND I=0) OR (TD=100 AND I=4) OR (T>=TA AND I=1) GOTO 3250
3145 CLS:PRINT U::PRINT
3146 IF IP=1 THEN LPRINT U::LPRINT
3150 IF I=0 THEN 3160 ELSE 3190
3160 INPUT"REMAINING PIT";CQ(0)
3170 IF IP=1 THEN LPRINT"REMAINING PIT ?";CQ(0)
3180 GOTO 3250
3190 PRINT"MINE "+UU(2+I);:INPUT CQ(I)
3200 IF IP=1 THEN LPRINT"MINE "+UU(2+I)+" ?";CQ(I)
3210 IF CQ(I)<=300 GOTO 3250
3220 U="TOO MUCH LIME IN MINE ":PRINT U+UU(2+I)
3230 IF IP=1 THEN LPRINT U+UU(2+I)
3240 GOTO 3190
3250 NEXT I
3260 RETURN
3270 '*** TIMING DRAINAGE MINE D
3280 U="HOW MANY YEARS SHOULD THE DRAINAGE OF MINE d BE STARTED BEFORE MINING (1
 - 5)"
3290 PRINT:PRINT U;
3300 INPUT DT:TD=5-CINT(DT/2):DT=3-DT
3310 IF IP=1 THEN LPRINT:LPRINT U;DT
3320 GOSUB 5410
3330 RETURN
3340 '*** SURFACE WATER FLOW
3350 U1="* SURFACE WATER FLOWS *":PRINT U8;U1
3360 PRINT:PRINT"QS1";TAB(22);:Q1:PRINT"QS5";TAB(22);Q5:PRINT"QS7":TAB(22);Q7
3370 IF IP=1 THEN LPRINT U8:U1:LPRINT:LPRINT"QS1";TAB(22);Q1:LPRINT"QS5":TAB(22)
:Q5:LPRINT"QS7";TAB(22);Q7
3380 GOSUB 5410
3390 F1=SF(17,T)+SF(18,T)*HP(T):F2=SF(19,T)+SF(20,T)*HP(T)' q112,q127
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3400 F3=SF(21,T):F7=SF(28,T)' qi34,qi73
3410 F5=SF(25,T)+SF(26,T)*TM+SF(27,T)*TM*TM:F6=SF(22,T)+SF(23,T)*TM+SF(24,T)*TM*
TM' qi56,qi62
3420 Q6=-F5+.5+Q5+DE(6,7,T)-DE(0,2,T)
3430 QW=.3*(DE(0,1,T)+DE(5,1,T)+DE(6,1,T)):Q2=-F1-F6+4.9+Q6+Q1+QW+DE(5,7,T)-DE(0
,1,T)' QW=q-1,s
3440 Q3=-F2-F7+Q2+Q7+DE(7,7,T)+DE(4,7,T)+DE(3,7,T)-DE(0,6,T)
3450 Q4=-F3+2'+Q3-DE(0,0,T)
3460 PRINT U9;U1:PRINT:PRINT"QS6":TAB(22);Q6:PRINT"QS2";TAB(22);Q2:PRINT"QS3";TA
B(22):Q3:PRINT"QS4";TAB(22):Q4
3470 IF IP=1 THEN LPRINT U8;U1:LPRINT:LPRINT"QS6";TAB(22):Q6:LPRINT"QS2":TAB(22)
:Q2:LPRINT"QS3";TAB(22);Q3:LPRINT"QS4";TAB(22);Q4
3480 GOSUB 5410
3490 RETURN
3500 '*** WATER TABLE REM.PIT
3510 DQ=DE(4,6,T)+DE(0,6,T)-DE(7,7,T)-DE(7,3,T)
3520 IF T=8 THEN HP(8)=100.08+(6.43+1.2*DQ)*DQ
3530 IF T=9 THEN HP(9)=78.399+.252*HP(8)+(10.241+.1481*DQ)*DQ
3540 IF T=10 THEN HP(10)=-63.767+(2.857-.0192*HP(9))*HP(9)+(13.273-.8089*DQ)*DQ
3550 GOSUB 3960'STORAGE VOLUME
3560 RETURN
3570 '*** WATER TABLES, GW.QUANTITY
3580 CLS:U="* WATER TABLES *":PRINT U9:U
3590 IF IP=1 THEN LPRINT U9;U
3600 IF T<8 GOTO 3630
3610 PRINT:PRINT"HP=";HP(T)
3620 IF IP=1 THEN LPRINT:LPRINT"HP=";HP(T)
3630 HG=SF(12,T)+SF(13,T)*DT+SF(14,T)*DT^2
3640 HAG=SF(9,T)+SF(10,T)*DT+SF(11,T)*TDT2
3650 HENV=SF(15,T)+SF(16,T)*HP(T)
3660 U="AGRICULTURAL AREA      "
3670 U1="ENV. PROTECTION AREA "
3680 U2="GROUNDWATER EXTRACT. "
3690 PRINT:PRINT U;HAG:PRINT U1;HENV:PRINT U2;HG
3700 IF IP=1 THEN LPRINT:LPRINT U;HAG:LPRINT U1;HENV:LPRINT U2:HG
3710 GOSUB 5410
3720 U="* GROUNDWATER QUANTITY *":PRINT U8;U
3730 IF IP=1 THEN LPRINT U8;U
3740 PGM=.034*HG-3.54
3750 IF PGM<0 THEN PGM=0
3760 U="MUNIC.GROUNDWATER"
3770 PRINT:PRINT U;TAB(22);PGM
3780 IF IP=0 GOTO 3800
3790 LPRINT:LPRINT U:TAB(22);PGM
3800 GA=SF(0,T)
3810 PRINT"MINE a":TAB(22);GA
3820 IF IP=1 THEN LPRINT"MINE a";TAB(22);GA
3830 GB=SF(2,T)+SF(3,T)*HP(T)
3840 PRINT"MINE b";TAB(22);SF(1,T)+GB
3850 IF IP=1 THEN LPRINT"MINE b";TAB(22):SF(1,T)+GB
3860 GC=SF(4,T)
3870 PRINT"MINE c";TAB(22):GC
3880 IF IP=1 THEN LPRINT"MINE c";TAB(22):GC
3890 IF T<TD GOTO 3930
3900 GD=SF(5,T)+SF(6,T)*DT+SF(7,T)*DT^2
3910 PRINT"MINE d";TAB(22):GD
3920 IF IP=1 THEN LPRINT"MINE d";TAB(22):GD
3930 GOSUB 5410
3940 RETURN
3950 '*** STORAGE VOLUME REM.PIT
3960 IF HP(T)<=68 THEN VP(T)=0:GOTO 4020
3970 IF HP(T)>62 AND HP(T)<=70 THEN VP(T)=(1-(70-HP(T))/2)*1.4:GOTO 4030
3980 IF HP(T)>70 AND HP(T)<=80 THEN VP(T)=(1-(80-HP(T))/10)*2.3+1.4:GOTO 4030
3990 IF HP(T)>80 AND HP(T)<=90 THEN VP(T)=(1-(90-HP(T))/10)*6.3+3.7:GOTO 4030
4000 IF HP(T)>90 AND HP(T)<=100 THEN VP(T)=(1-(100-HP(T))/10)*18+10:GOTO 4030
4010 IF HP(T)>100 AND HP(T)<=110 THEN VP(T)=(1-(100-HP(T))/10)*42+26:GOTO 4030
4020 IF HP(T)>110 THEN VP(T)=(1-(118-HP(T))/8)*59+70
4030 RETURN
4040 '*** QUALITY REM.PIT
4050 GP=(VP(T)-VP(T-1))*.0317-(DE(4,6,T)+DE(0,6,T)-DE(7,7,T)-DE(7,3,T)
4060 C(5,I)=A1+(C(0,I)-A1)*EXP(-2'*A2*TE(T)/(VP(T-1+VP(T))
4070 RETURN
4080 '*** COEFF.QUALITY REM.PIT
4090 A2=(VP(T)-VP(T-1))/ZE(T)*(1+(1-I)*4.1E-18/C(0,1)^2)+DE(7,3,T)+DE(7,7,T)
4100 A1=DE(0,6,T)*CS(3,I)+DE(4,6,T)*C(2,I)+GP*CB(5,I,T)
4110 IF I=0 THEN A1=A1+.022*CQ(0) ELSE A1=A1+3.58E-05*(C(0,0)*VP(T-1)-C(5,0)*VP(
T))/TE(T)
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4120 A1=A1/A2
4130 RETURN
4140 '*** MINE WATER TREATMENT
4150 FOR I=1 TO 4
4160 IF I>1 THEN J=0 ELSE J=1
4170 A1=10^(3-CG(I-J,1,T)):C0=CG(I-J,0,T)-.698*CQ(I)
4180 IF C0<0 THEN C(I,0)=0 ELSE C(I,0)=C0
4190 IF C0>0 THEN C(I,1)=A1-.025*CQ(I)+.0358*(CG(I-J,0,T)-C0) ELSE C(I,1)=A1
4200 IF C(I,1)<10^(-8.5) THEN C(I,1)=10^(-8.5)
4210 NEXT I
4220 RETURN
4230 '*** SELF-PURIFICATION STREAM FE(II), STILL NEGLECTED
4240 CA(I,0)=CS(I,0)
4250 RETURN
4260 '*** SELF-PURIFICATION STREAM H(+), STILL NEGLECTED
4270 CA(I,1)=CS(I,1)
4280 RETURN
4290 '*** WAT.QUALITY BP6
4300 CS(6,N)=(CA(5,N)*(Q5+.5-DE(0,2,T))+C(4,N)*DE(6,7,T))/(Q6+1E-03)
4310 RETURN
4320 '*** WAT.QUALITY INDUSTRY
4330 CI(N)=(CS(6,N)*DE(0,1,T)+C(4,N)*DE(6,1,T)+C(3,N)*DE(5,1,T))/(QW+1E-03)
4340 RETURN
4350 '*** WAT.QUALITY BP2
4360 CS(2,N)=(CA(1,N)*(Q1+4.9)+CA(6,N)*Q6-CS(6,N)*DE(0,1,T)+C(3,N)*DE(5,7,T)+CI(
N)*QW)/(Q2+1E-03)
4370 RETURN
4380 '*** WAT.QUALITY BP3
4390 CS(3,N)=(CA(2,N)*Q2+CA(7,N)*Q7+C(0,N)*DE(3,7,T)+C(1,N)*DE(4,7,T)+C(5,N)*DE(
7,7,T)-CS(2,N)*DE(0,6,T))/(Q3+1E-03)
4400 RETURN
4410 '*** WAT.QUALITY BP4
4420 CS(4,N)=(CA(3,N)*(Q3+2!)-CS(3,N)*DE(0,0,T))/(Q4+1E-03)
4430 RETURN
4440 '*** WAT.QUALITY INDEX
4450 FOR I=1 TO 7
4460 IF CS(I,1)>0 THEN CS(I,1)=3-LOG(CS(I,1))/LOG(10)
4470 FOR J=0 TO 4
4480 IF CS(I,0)<=QI(J,0) AND CS(I,1)>=QI(J,1) THEN IS(I)=J+1:GOTO 4500
4490 IS(I)=0:NEXT J
4500 NEXT I:IM(0)=IS(4):IM(1)=1:IM(2)=1
4510 FOR I=0 TO 5
4520 IF C(I,1)>0 THEN C(I,1)=3-LOG(C(I,1))/LOG(10)
4530 FOR J=0 TO 4
4540 IF C(I,0)<=QI(J,0) AND C(I,1)>=QI(J,1) THEN IM(I+2)=J+1:GOTO 4560
4550 IM(I+2)=0:NEXT J
4560 NEXT I
4570 RETURN
4580 '*** REQUIRED WATER QUALITY
4590 FOR I=0 TO 7
4600 IF I=6 AND T<TA GOTO 4680
4610 U="REQUIRED WATER QUALITY INDEX (1-6)"
4620 IF I=0 OR I=4 THEN CLS:PRINT U:PRINT
4630 PRINT"FOR USER - ";US(I);" -";
4640 INPUT IQ(I)
4650 IF IP=1 AND (I=0 OR I=4) THEN LPRINT U:LPRINT
4670 IF IP=1 THEN LPRINT"FOR USER - ";US(I);" -";IQ(I)
4680 NEXT I
4690 RETURN
4700 '*** OUTPUT WAT.QUALITY
4710 CLS:U="* WATER QUALITY *"
4720 U1="            Fe(mg/l)      pH      Index"
4730 PRINT U9;U:PRINT U1
4740 IF IP=1 THEN LPRINT U9;U:LPRINT U1
4750 FOR L=1 TO 4
4760 IF (L=1 AND T>=TA) OR (L=4 AND T<TD) GOTO 4790
4770 PRINT"MINE "+UU(L+2)+"    "USING"  ##.##      ##.#        #";C(L,0);C(L,1);IM(L
+2)
4780 IF IP=1 THEN LPRINT"MINE "+UU(L+2)+"    "USING"  ##.##      ##.#        #";C(L,
0);C(L,1);IM(L+2)
4790 NEXT L
4800 IF T<TA THEN GOTO 4830
4810 PRINT"REM. PIT "USING"  ##.##       #.#       #";C(0,0);C(0,1);IM(0)
4820 IF IP=1 THEN LPRINT"REM. PIT "USING"  ##.##       #.#       #";C(0,0);C(0,1);
IM(0)
4830 GOSUB 5410
```

```
4840 FOR L=1 TO 7
4845 IF CS(L,0)<0 THEN CS(L,0)=0
4850 PRINT"CS"USING"#";L;
4860 PRINT"        "USING"  ##.##       #.#       #";CS(L,0);CS(L,1);IS(L)
4870 IF IP=1 THEN LPRINT"CS"USING"#";L;
4880 IF IP=1 THEN LPRINT"        "USING"  ##.##       #.#       #";CS(L,0):CS(L,1);I
S(L)
4890 NEXT L:GOSUB 5410
4900 RETURN
4910 '*** OUTPUT GW.QUALITY
4920 FOR I=0 TO 5:FOR J=0 TO 4
4930 IF CG(I,0,T)<=QI(J,0) AND CG(I,1,T)=>QI(J,1) THEN IM(I)=J+1:GOTO 4950
4940 IM(I)=0:NEXT J
4950 NEXT I
4960 U="* GROUND WATER QUALITY *":U1="          Fe(mg/l)       pH    Index"
4970 PRINT U8;U:PRINT U1
4980 IF IP=1 THEN LPRINT U8;U:LPRINT U1
4990 FOR I=0 TO 5
5000 IF (I=0 AND T>=TA) OR (I=4 AND T<TD) OR (I=5 AND T<TA) GOTO 5040
5005 U=" ":J=I:IF I>1 THEN J=I-1
5010 IF I=1 THEN U="1":IF I=2 THEN U="2"
5020 PRINT"cg"+UU(J+3)+U+"     "USING"  ##.##       #.#       #";CG(I,0,T):CG(I,1,
T):IM(I)
5030 IF IP=1 THEN LPRINT"cg"+UU(J+3)+U+"     "USING"  ##.##       #.#       #";CG(
I,0,T):CG(I,1,T):IM(I)
5040 NEXT I
5050 GOSUB 5410
5060 RETURN
5070 '*** CONSTRAINTS WATER QUALITY
5080 FOR I=0 TO 7:FOR J=0 TO 7
5090 IF LE(I,J)<>1 THEN GOTO 5150
5100 IF DE(I,J,T)>0 AND IM(J)>IQ(J) THEN 5110 ELSE 5150
5110 U="WATER QUALITY IN ":U1=" IS NOT SATISFACTORY FOR USER "
5120 PRINT U;UU(I);U1;US(J)
5130 IF IP=1 THEN LPRINT U;UU(I);U1;US(J)
5140 GOSUB 5410
5150 NEXT J:NEXT I
5160 RETURN
5170 '*** OUTPUT COSTS
5180 U="RESULTS OF THE PERIOD ":PRINT U:T:" (Mill.M/year)"
5190 IF IP=1 THEN LPRINT U;T;" (Mill.M/year)"
5200 FOR I=0 TO 3
5210 IF (I=0 AND T>=TA) OR (I=3 AND TD>T) GOTO 5240
5220 U="COSTS FOR MINE ":PRINT U+UU(I+3)+" :";TAB(32);USING"####.#";CO(I,T)
5230 IF IP=1 THEN LPRINT U+UU(I+3)+" :";TAB(32);USING"####.#";CO(I,T)
5240 NEXT I:A1=CO(0,T)+CO(1,T)+CO(2,T)+CO(3,T)
5250 U="SUM                   :":PRINT U;TAB(32);USING"####.#";A1
5260 IF IP=1 THEN LPRINT U;TAB(32);USING"####.#";A1
5270 GOSUB 5410
5280 FOR I=0 TO 3
5290 U="COSTS FOR USER ":PRINT U+US(I)+" :";TAB(32):USING"####.#";CO(I+4,T)
5300 IF IP=1 THEN LPRINT U+US(I)+" :";TAB(32):USING"####.#";CO(I+4,T)
5310 NEXT I
5320 IF T<TA GOTO 5350
5330 U="COSTS FOR REMAINING PIT:"PRINT U;TAB(32);USING"####.#";CO(8,T)
5340 IF IP=1 THEN LPRINT U;TAB(32);USING"####.#";CO(8,T)
5350 GOSUB 5410
5360 U="TOTAL ANNUAL COSTS:":PRINT U;TAB(30):CT
5370 IF IP=1 THEN LPRINT U:TAB(30);CT
5380 GOSUB 5410
5390 RETURN
5400 '*** WAIT
5410 U="*****   Hit any key to continue   *****"
5420 LOCATE 0,8:PRINT U;
5430 IF IP=1 THEN LPRINT:LPRINT U:LPRINT:LPRINT
5440 A$=INKEY$:IF A$="" THEN 5440
5450 CLS:RETURN
```

Appendix A2: Notations of the game MINE-NEC in alphabetical order

Notation in game MINE-NEC		Notation in DSS-MINE (Kaden et al. 1985)	Description
BA		β_{ag}	specific benefit for water allocation to agriculture
BE		β_e	specific benefit for water allocation to environmental protection
BI		β_i	specific benefit for water allocation to industry
BM		β_m	specific benefit for water allocation to municipality
C(I,L)	I = 0 1 2 3 4 5	$c_p(j-1,l)$ $c_a(j,l)$ $c_b(j,l)$ $c_c(j,l)$ $c_d(j,l)$ $c_p(j,l)$	Water quality after treatment $L=0 \rightarrow [Fe^{++}]$ $L=1 \rightarrow [H^+]$
CA(I,L)			auxiliary parameter for surface water quality, see CS(I,L)
CG(I,L,T)	I = 0 1 2 3 4 5	$cg_a(j,l)$ $cg_{b1}(j,l)$ $cg_{b2}(j,l)$ $cg_c(j,l)$ $cg_d(j,l)$ $cg_p(j,l)$	groundwater quality for period T L: see above
CI(L)		$c_i(l)$	water quality industrial waste water L: see above
CS(I,L)		$cs_i(l)$	surface water quality for balance profile i (bp1,2 ... 7) L: see above
CO(I,T)	I = 0 1 2 3 4 5 6	$cost_a(j)$ $cost_b(j)$ $cost_c(j)$ $cost_d(j)$ $cost_m(j)$ $cost_i(j)$ $cost_{ag}(j)$	cost for mine drainage, water supply period T; $T=0 \rightarrow$ total cost

	7	$cost_e(j)$	
	8	$cost_p(j)$	
Q(I)	I = 0	cq_p	supply with lime hydrate for water treatment
	1	cq_a	
	2	cq_b	
	3	cq_c	
	4	cq_d	
$D_E(M,N,T)$		$M=0 \rightarrow S$ $N=0 \rightarrow m$ $1 \rightarrow g$ $1 \rightarrow i$ $2 \rightarrow im$ $2 \rightarrow ag$ $3 \rightarrow a$ $3 \rightarrow e$ $4 \rightarrow b$ $4 \rightarrow ds$ $5 \rightarrow c$ $5 \rightarrow ex$ $6 \rightarrow d$ $6 \rightarrow p$ $7 \rightarrow p$ $7 \rightarrow s$	water requirement of user N from supplier N
DQ		dq_p	inflow/outflow remaining pit
F1		$qi_{1,2}$	infiltration balance segment
F2		$qi_{2,3}$	
F3		$qi_{3,4}$	
F7		$qi_{7,3}$	
F5		$qi_{5,6}$	
F6		$qi_{6,2}$	
GA		qg_a	groundwater flow to mines
GB		qg_b	
GC		qg_c	
GD		qg_d	
GP		qg_p	groundwater flow to remaining pit
GI		γ_i	economic parameter
GM		γ_m	economic parameter
GT		γ_t	economic parameter
HAG		h_{ag}	groundwater table agricultural area
HENV		h_e	groundwater table environmental protection area
HG		h_g	groundwater table groundwater wells
HP(T)		$h_p(j)$	water table remaining pit
II(M,N)		M,N see DE	arbitrary array/ coordination of M,N with array SF
IM(7)			water quality index

IQ(N)	N see DE	required water quality index user N
IS(7)		water quality index streams
LE(M,N)	M,N see DE	pipeline between M–N; =0 → planned =1 → existent =100 → not
PGM	$p_{g,m}$	possible groundwater extraction
Q1,Q2, ... Q7	$qs_1, \ldots, qs_7$	flow balance profile
QG	$scost$	total ost
QI(4,1)		bounds for quality index
QW	$q_{i,s}$	waste water industry → stream
RE(I)	$I=0 \rightarrow a$ $1 \rightarrow b$ $2 \rightarrow c$ $3 \rightarrow d$	rest mine water after allocation to users
RQ(I,T)	$I=0 \rightarrow m$ $1 \rightarrow i$ $2 \rightarrow ag$ $3 \rightarrow e$ $4 \rightarrow ds$	water demand of users
SF(50,10)		coefficients for submodels, explanation see Appendix A1, programme listing
T	j	planning period
TA	j_a	starting period remaining pit mine a closed
TD	j_d	starting period mine d
TE(T)	ΔT_j	number of years per period
UU(N)	N see DE	names of water users
US(M)	M see DE	names of water suppliers
VP(T)	$v_p(j)$	storage volume remaining pit

Appendix B: Forms for the game MINE–NEC

PERIOD:

Water allocation	User: m	i	ag	e	ds
s					
g					
im					
a					
b					
c					
d					
p					

s	Stream
g	Groundwater reservoir
im	Import
a,b,c,d	Mines
p	Remaining pit
m	Municipality
i	Industry
ag	Agriculture
e	Env. protect. area
ds	Down-stream water user

DEMAND:

m :

i : 3.0

ag :

e :

ds :

PERIOD:

Quantity of lime:

a :

b :

c :

d :

p :

Distribution of water left in mines:

	ex	p	s
a			
b			
c			
d			

Appendix C: Protocol of an example run for one planning period

```
                MINE
        GDR Minewater Study
     IIASA  Laxenburg, Austria

 ENTER STARTING PERIOD (FROM 1 TO 9) ? 1


        * WATER TABLES *

AGRICULTURAL AREA       141.5
ENV. PROTECTION AREA    131.4
GROUNDWATER EXTRACT.    118.9

*****    Hit any key to continue    *****


        * GROUNDWATER QUANTITY *

MUNIC.GROUNDWATER         .5026
MINE a                    4.1
MINE b                    2.95
MINE c                    2.05

*****    Hit any key to continue    *****


        * SURFACE WATER FLOWS *

OS1                       4.71
OS5                       3.13
OS7                       .98

*****    Hit any key to continue    *****


        * SURFACE WATER FLOWS *

OS6                       4.1
OS2                       13.5
OS3                       13.68
OS4                       15.77

*****    Hit any key to continue    *****


        * WATER DEMAND *
MUNICIPALITY              0.20
INDUSTRY                  4.00
AGRCULTURE                0.00
ENV.PROTECTION AREA       0.02
DOWN STREAM USER         25.00

*****    Hit any key to continue    *****


            Stage    1
            Period   1

      Water Quantity Decisions


*****    Hit any key to continue    *****

DEMAND THROUGH THE FOLLOWING PIPE:
 s  ->   m
WATER QUANTITY ? .2

DEMAND THROUGH THE FOLLOWING PIPE:
 g  ->   m
WATER QUANTITY ? 0

DEMAND THROUGH THE FOLLOWING PIPE:
1m  ->   m
WATER QUANTITY ? 0

DEMAND THROUGH THE FOLLOWING PIPE:
 b  ->   m
WATER QUANTITY ? 0

DEMAND THROUGH THE FOLLOWING PIPE:
 s  ->   i
WATER QUANTITY ? 2

DEMAND THROUGH THE FOLLOWING PIPE:
 c  ->   i
WATER QUANTITY ? 2

DEMAND THROUGH THE FOLLOWING PIPE:
 s  ->  ag
WATER QUANTITY ? 0

DEMAND THROUGH THE FOLLOWING PIPE:
 c  ->  ag
WATER QUANTITY ? 0

DEMAND THROUGH THE FOLLOWING PIPE:
 c  ->   e
WATER QUANTITY ? .03

DEMAND THROUGH THE FOLLOWING PIPE:
 s  ->  ds
WATER QUANTITY ? 25

*****    Hit any key to continue    *****

            * REST MINE WATER *

MINE a                    4.1
MINE b                    2.95
MINE c                    .02

*****    Hit any key to continue    *****


ALLOCATION THROUGH THE FOLLOWING PIPE:
 a  ->  ex
WATER QUANTITY ? 1.8

ALLOCATION THROUGH THE FOLLOWING PIPE:
 b  ->  ex
WATER QUANTITY ? 1.5
TOO HIGH DEMAND, MAXIMUM CAPACITY IS 1.2
GIVE NEW VALUE ? 1.2

ALLOCATION THROUGH THE FOLLOWING PIPE:
 a  ->   s
WATER QUANTITY ? 2.3

ALLOCATION THROUGH THE FOLLOWING PIPE:
 b  ->   s
WATER QUANTITY ? 1.75

ALLOCATION THROUGH THE FOLLOWING PIPE:
 c  ->   s
WATER QUANTITY ? .02

*****    Hit any key to continue    *****
QUANTITY CONSTRAINTS ARE OK

*****    Hit any key to continue    *****


            * REST MINE WATER *

MINE a                    0
MINE b                    0
MINE c                    0

*****    Hit any key to continue    *****
```

```
        * SURFACE WATER FLOWS *

QS1                    4.71
QS5                    3.13
QS7                    .98

*****    Hit any key to continue    *****

        * SURFACE WATER FLOWS *

QS6                    4.1
QS2                    12.72
QS3                    16.95
QS4                    18.84

*****    Hit any key to continue    *****


               Stage   2
               Period  1

      Water Quality Requirements


*****    Hit any key to continue    *****

       * GROUND WATER QUALITY *
        Fe(mg/l)      pH     Index
cg a     38.60        6.0      5
cg bi     5.00        6.0      2
cg b     17.00        6.1      4
cg c     16.60        5.8      4

*****    Hit any key to continue    *****

REQUIRED WATER QUALITY INDEX (1-6)

FOR USER -  m - 1
FOR USER -  i - 4
FOR USER - ag - 4
FOR USER -  e - 4
REQUIRED WATER QUALITY INDEX (1-6)

FOR USER - ds - 2
FOR USER - ex - 3
FOR USER -  s - 3
MINE WATER TREATMENT: LIME TO ADD IN
MINE  a ? 0
MINE WATER TREATMENT: LIME TO ADD IN
MINE  b ? 50
MINE WATER TREATMENT: LIME TO ADD IN
MINE  c ? 10
          * WATER QUALITY *
          Fe(mg/l)     pH     Index
MINE  a    38.60       6.0      5
MINE  b     0.00       6.7      1
MINE  c     9.62       5.8      3

*****    Hit any key to continue    *****


CS1         2.00       6.5      2
CS2         3.32       6.3      2
CS3         6.77       6.3      3
CS4         0.00       6.3      2
CS5         1.00       6.8      1
CS6         0.89       6.9      1
CS7         5.00       6.2      2

*****    Hit any key to continue    *****
```

```
WATER QUALITY IN  s IS NOT SATISFACTORY
FOR USER  m

*****    Hit any key to continue    *****

WATER QUALITY IN  c IS NOT SATISFACTORY
FOR USER  e

*****    Hit any key to continue    *****

RESULTS OF THE PERIOD  1  (Mill.M/year)
COSTS FOR MINE   a :                27.2
COSTS FOR MINE   b :                27.1
COSTS FOR MINE   c :                10.2
SUM                :                64.5

*****    Hit any key to continue    *****

COSTS FOR USER   m :                 3.7
COSTS FOR USER   i :                65.5
COSTS FOR USER  ag :                 0.1
COSTS FOR USER   e :                 0.4

*****    Hit any key to continue    *****

TOTAL ANNUAL COSTS:              136.271

*****    Hit any key to continue    *****

Do You want to  return to  some of  the
earlier stages or perioos (1=YES,0=NO)

? 0
PREVIOUS PERIOD WAS  1
START NEXT PERIOD?(YES=1,NO=0) 1
         * WATER TABLES *

AGRICULTURAL AREA        141.5
ENV. PROTECTION AREA     131.2
GROUNDWATER EXTRACT.     118.9

*****    Hit any key to continue    *****
```