The Groundwater Game

MANUAL FOR GAME MANAGER

A serious same on improving groundwater management through cooperation and collective action

igrac
International Groundwater Resources Assessment Centre

The Groundwater Game was developed by the International Groundwater Resources Assessment Centre (IGRAC), the Institute of Development Studies (IDS) and the University College London UCL (University College London).

Projects: GroFutures

For information about the game or questions regarding the use of it, please contact the International Groundwater Resources Assessment Centre at info@un-igrac.org.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

1.1 ABOUT THE GAME

The Groundwater Game - A Serious Game[1] on Improving Groundwater Management through Cooperation and Collective Action (Groundwater Game) is a computer simulation, Excel based, which introduces players to different groundwater management scenarios in a rural community where the main economic activity is agriculture. The groundwater game embodies the dilemmas around groundwater use starting from the unmanaged use of groundwater to sustainable management by a group of farmers sharing the same water source.

1.1.1 Learning objectives

The main learning objective of this game is to improve the player's insight in the social dilemma of the tragedy of the commons through different groundwater management scenarios. The key dilemma in the groundwater game is how to sustainably abstract groundwater (the common pool) to serve the community needs. A conflict of interests exists between the individual user and the collective. The hidden nature of groundwater and incomprehension of its limits by end-users results in the unlimited abstraction by individuals to maximize production in a rural scenario where the economy mostly depends on agriculture. Over-abstraction of groundwater will have negative consequences for the whole community and farmers will have to cooperate in order to better manage the common resource. The game is divided into 3 scenarios in which different options are presented to players with the possibility of improving their performance and achieve the best results.

The overall objectives of the game are to:

1. improve participants' understanding of groundwater systems and its exploration;
2. foster a deeper appreciation of the impact of collective actions and the challenges in regulating groundwater use by establishing policies and management practices.
3. open up a discussion on the challenges of sustainable and equitable groundwater resource management.

By the end of the game players will have explored concepts such as groundwater development, common pool resources, development scenarios, regulation, transaction costs, groundwater management, and collective action.

1.1.2 Project references

The game was designed under the theory and article "The Tragedy of the Commons" published in 1968 by Garret Hardin. In 2008 at IGRAC, Frank van Weert adapted this idea and translated it into a game called "The Tragedy of the Groundwater Commons". This new version of the game continues Frank van Weerts' work adding new concepts and elements into the existing game.

IGRAC has further developed and adjusted the game since 2014 to be use as a tool for the Social Sciences component of the GroFutures project. The current version has been further optimized for the purposes of the GroFutures project and the reality of Sub-Saharan Africa and is now available to be played worldwide and in different contexts from classes to workshops and capacity building sessions around groundwater management and governance.

[1] *Serious Game: computer-based simulation platforms designed for a specific learning purpose.*

1.2 HOW TO USE THIS MANUAL

The manual contains the following structure:

1.0 Introduction:
This chapter introduces the game, the learning objectives and the main information about the game developments.

2.0 Game overview:
This section presents the game context and the main figures and roles.

3.0 Game rules:
This chapter describes all the rules of the game through the different scenarios.

4.0 Facilitating a game session:
All the instructions on how to play the game and use the Excel and PowerPoint files and the apps are listed step by step in this chapter.

5.0 References

6.0 Appendixes

2.0 GAME OVERVIEW

2.1 THE GROUNDWATER GAME COMPONENTS

The game is built within a MS-Excel calculation sheet which is managed by the game manager through the Groundwater Manager App (See section 4.4.1). Players decisions are entered in the Groundwater Player App (see section 4.4.2) and the game flow is supported by a PowerPoint presentation that assists the game manager in guiding the players through the game. Players' progress is presented first individually to the players in the Groundwater Player App and later to the group in the PowerPoint presentation.

2.2 CONTEXT OF THE GROUNDWATER GAME

The game's context is a rural community where players play the role of farmers. Each farmer owns a farm with 5 hectares of land and a well. Only one type of crop is grown and 1000 m3 of water is needed to irrigate 1 hectare of land each season (round).

There are nine wells in the game and so the game requires a minimum of 9 players (with more than 9 participants, group the participants into 9 teams). Each game round represents a growing season, producing a harvest and generating income.

Close by the farming community there is a lake where the farmers can fish to supplement their diets. The lake is also a tourist attraction which supports the local economy. The ecological balance of the lake, dependent on its water level, is influenced by the groundwater level in the aquifer which feeds the farmers' wells.

The goal of the players is to reach prosperity and well-being. In the first rounds of the game players are expected to maximize their income by producing as much as possible. But as the game evolves groundwater table is expected to drawdown, which has environmental consequences, adversely affecting the community and the players, and represented in the game as penalties applied to the farmers.

2.3 GAME FLOW

The game consists of three different Groundwater Management Scenarios explored over 8 rounds of the game (Figure 1):

- Scenario 1 (Randomly pumping) - 2 rounds
- Scenario 2 (Reaching Cooperation) – 3 rounds
- Scenario 3 (Advanced Management) – 3 rounds

Within the different scenarios, players will be given the opportunity to take measures to better manage the common resource, groundwater, while maximizing profit from their crops. In every round, independent of

the scenario, players have to decide the area of their farm to crop, and therefore irrigate. Within the different scenarios rules change (see chapter 2). In each scenario players will have the opportunity to change their strategy by selecting new features, example buying water saving equipment or co-operating with other players in order to limit groundwater abstraction in the group. In the first scenario players are unaware how the game will develop and have limited access to information. In scenario 1, players only have information regarding their own decisions and don't have access to information on other players' decisions. In Scenario 2 players can communicate with one another and options for collective strategies are presented to players. In scenario 2 players also have access to information on the other players' decisions. Finally, in scenario 3, an advance management setting is established, and all players have an active role in the decisions that need to be made to manage groundwater.

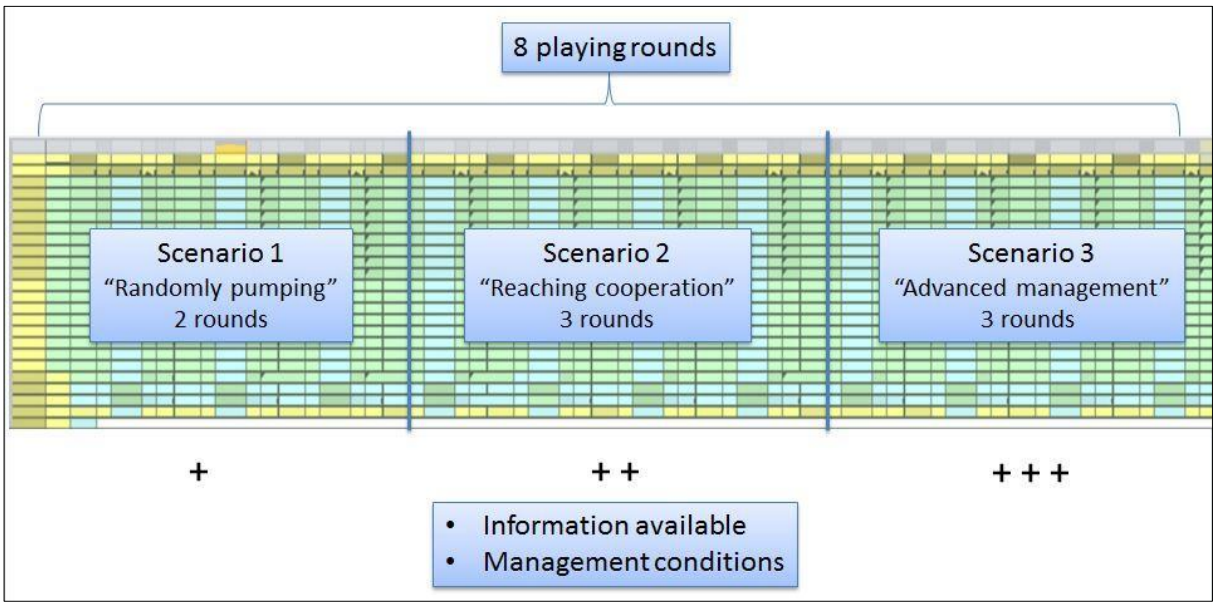

Figure 1 - Groundwater Game scenarios and rounds

In each round the players upload their decisions to the Groundwater Game Manager App which, under the control of the game manager, updates the Excel spreadsheet and sends data on the outcome of the decisions to each player's app. The players then assess the impact of their decisions and consider their strategy for the next round.

2.4 GAME ROLES AND FIGURES

2.4.1 Game manager

Game-sessions are facilitated by a game manager, the game manager, preferably assisted by a second person, especially when working with large groups. The game manager is responsible for running the game session. He/she manages the Groundwater Game Manager App, the Excel file and the PowerPoint presentation. The game manager directs the flow of the game by starting each simulation run and prompting the players in their decisions during the game. The game manager enforces the rules and provides motivation and guidance to the players throughout the game.

At the end of the game, the game manager explains the outcomes and conclusions from the game and promotes a final discussion around the learning objectives of the game. The role of the game manager in directing the story and context of the game is essential to the success of the game. The learning objectives of the game rely heavily on how the game manager leads the game.

NOTE: The game manager must have a basic understanding of groundwater and thoroughly understand the game rules, the game setting and be familiar with the Groundwater Game apps, Excel file and PowerPoint presentation in advance of the game.

2.4.2 Farmers

Players (individual players or teams) will be participating in the game in the role of farmers. The main task of players is to decide how much land they want to farm in each round. The area to crop will be translated into the required volume of water pumped from the players' wells for irrigation. Players will have to manage their farms' production and regulate their individual and collective impact in the common source, groundwater. Through the three scenarios the game manager will present players with different strategies to explore.

2.4.3 The lake

The lake represents the environmental impacts of groundwater over-extraction and is therefore essential for the game storyline and learning objectives. The groundwater pumping activity by the farmers influences the water level in the lake, and if the lake runs dry it will result in negative environmental impacts and financial consequences for the players and the community.

2.4.4 The wells

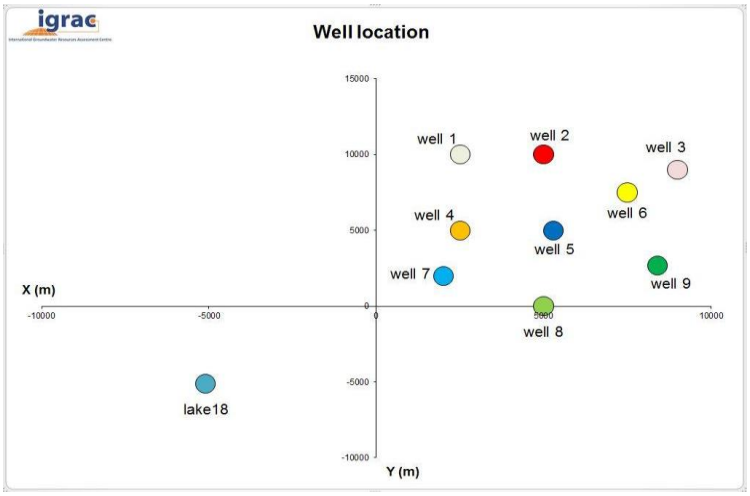

Figure 2 - Setting of the wells and the lake in the Groundwater Game.

The Groundwater Game develops around groundwater pumping activities. Pumping by farmers causes the drawdown of the groundwater table, which will vary according to the pumping rates of each player, i.e. the area each player decides to irrigate in each round (growing season). The drawdown is also affected by pumping in neighbouring wells, as illustrated in Figure 3.

Transient drawdown is calculated according to the Theis solution and the superposition principle. Over the years, over abstraction can result in depletion. Probably due to the assumptions behind the Theis solution, no significant depletion occurs during the game, only residual drawdown is visible.

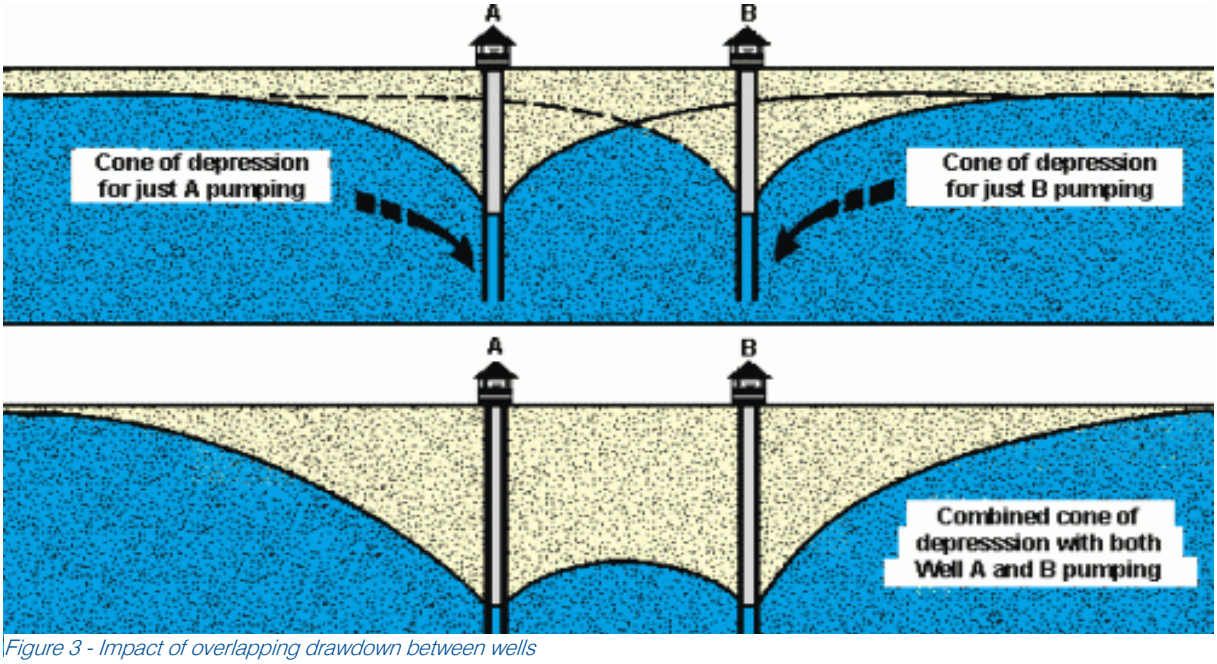

Figure 3 - Impact of overlapping drawdown between wells

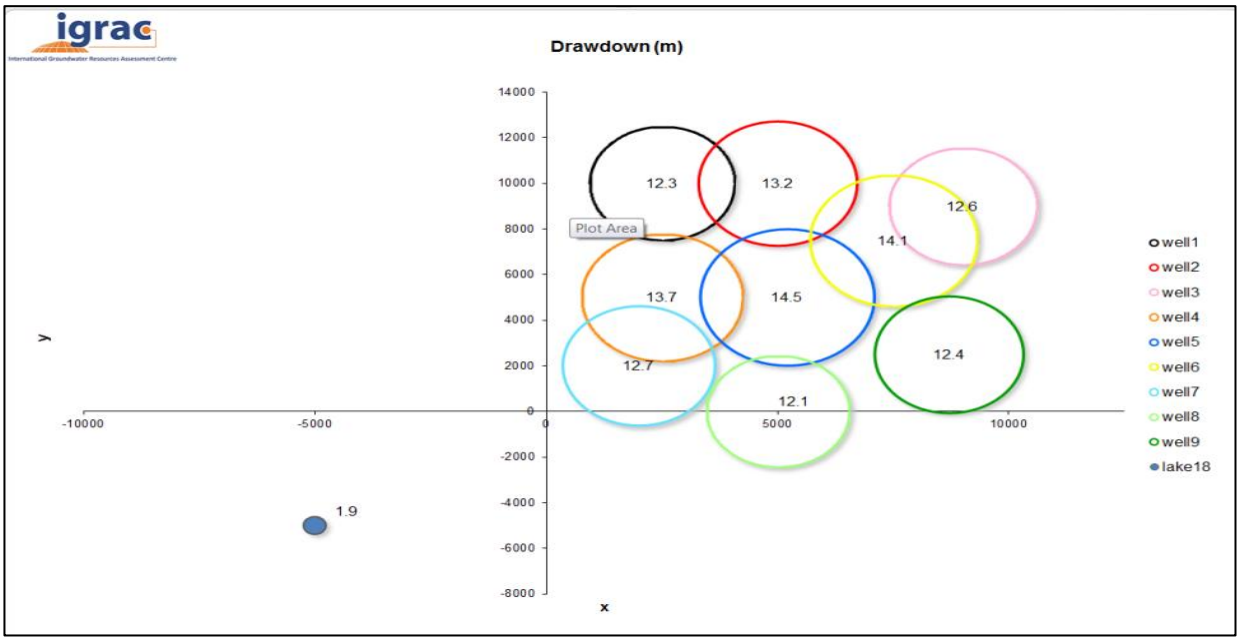

Figure 4 - Drawdown illustration on a map, view from above

Drawdown

Drawdowns are horizontally represented by circles around the wells, which are proportionally represented, according to the influence radius in meters (Figure 4). Depletion is the long-term declination of groundwater levels caused by unsustainable groundwater pumping which can result in the drying up of wells, reduction of water in streams and lakes and the increase of pumping costs.

3.0 GAME RULES

And the winner is (are)…

… the farmer (or team) that has accumulated the most profit at the end of the game!

	Type	Cost	Benefit	Explanation
All scenarios	Starting capital	₳ = 0		Each farmer starts with zero capital.
	Farming profit		₳ 40 /ha	Crop value per hectare.
	Living costs	₳ 25		Payed at each round per well, applied during the entire game!
	Bankrupted			Out of the game when reaches a debt of ₳ 150.
	Abstraction costs	Variable		Costs vary and are a function of (i) volume of groundwater needed (Q), (ii) groundwater level in the well and (iii) price per unit volume: ₳ 0.0015 /m3 Abs_cost = Q * drawdown * unit price
	Environment costs	₳ 35 / variable		₳ 35 during scenarios 1 & 2. Proportional to Q during scenario 3.
Scenario 1 (2 rounds)	Basic irrigation		1000 m3/ha	Crops need 1000 m3/ha of groundwater for irrigation.
Scenario 2 (3 rounds)	Water saving equipment costs	₳ 100	20% water saving	The investment only needs to be done once. Costs payed per well.
	Advanced irrigation		800 m3/ha	Crops need 800 m3/ha of groundwater if investment in equipment is made.
	Cap rule transaction cost	₳ 100 / well joining the cape rule		At least 5 wells need to join the rule. Players joining it will decide the limit.
	Cap rule penalty	Variable		Penalty = amount of wells joining the rule * ₳ 10.
Scenario 3 (3 rounds)	Social benefit		10% of average cumulative net benefit	Assigned per well to all farmers and fisherman in the subsequent round.
	Cap rule transaction costs	Paid by GW authority		Cap rule will be applied by default. All players will decide the limit.
	Cap rule penalty	Variable		Farmers decide on penalty amount.

Table 1: Summary of the rules provided to the players at the beginning of the game-session

3.1 GENERAL RULES – ALL SCENARIOS

Each player can bring a maximum of 5 hectares of land into production in each round. It is possible to choose a value between 0.1 and 5 (interval of a tenth). Only one type of crop is grown.

The currency of the game has been chosen to be a fictive one, called Aqua (₳).

3.1.1 Starting capital

All households start with a capital of ₳ 0.

3.1.2 Farming profit

The farming profit is equal to ₳ 40 per hectare. This is a fixed value throughout the game. The benefit accumulated in each round is proportional to the hectares brought into production.

3.1.3 Living costs

The living cost for each player is ₳ 25 per round. It is a fixed value throughout the game and is payable whether or not the player farms any land.

The living costs represent the cost of the farmer and his household. It includes food, water, clothing, farming tools, house maintenance, etc.

3.1.4 Bankrupted

If a household reaches a debt of ₳ 150 the household is out of business for the rest of the game.

3.1.5 Abstraction costs

Groundwater abstraction has maintenance and operational costs, e.g. electricity bills to pump water. The abstraction cost is a function of the volume of pumped groundwater (Q), groundwater level (drawdown) and a unit price per unit volume (₳ 0.0015 /m3). The abstraction cost is calculated automatically according to the following equation:

Abstraction cost = Q * drawdown * unit price per unit volume

These are the pumping costs to farmers, calculated in each round. These costs will increase if the farmer abstracts more water. The abstraction costs also depend on well's drawdown which not only depends on well's abstraction volumes but also the pumping rates of the neighbouring wells interfering with each farmer well (see Figure 3).

3.1.6 Environmental costs

If the lake runs dry due to over abstraction of the aquifer by the farmers, each player will have extra living costs, ₳ 35 per player. The lake is a tourist attraction, and if it runs dry the normal influx of tourists to the village will decrease which will adversely impact the local economy which depends on local trades (e.g. handicrafts). Furthermore, the farmers fish in the lake and if the lake runs dry farmers will have to buy fish, increasing the household living costs. The environmental costs apply only to scenarios 1 & 2. During scenario 3, an environmental fee is set and calculated proportionally to water abstraction (see section 3.4).

This cost is due to the fact that players, together as a group, pumped so much water that the drawdown reached the lake and therefore the lake dried up. The cost is automatically activated in the calculation sheet when the drawdown at the lake reaches a value greater than 3.0 meters.

3.2 SCENARIO 1 – "RANDOMLY PUMPING"

Scenario 1, which starts the game, is based on the Tragedy of the Commons (See Section 1.1.2). Farmers can pump as much water as they want independently of other farms' abstraction rates. Players don't communicate with one another and results are not shared with the group. In the first 2 rounds the players don't know the other players outcomes, only their own. Environmental costs might be applied depending on the impact of farmers' abstraction.

3.2.1 Basic irrigation

During scenario 1 farmers only have access to basic irrigation. They can cultivate as much area as they want to a maximum of 5 ha. To grow their crops, they need 1000 m3 of groundwater to irrigate 1 hectare of land per round.

3.3 SCENARIO 2 – "REACHING COOPERATION"

During scenario 2 players are able to add 2 new features to their strategy: water saving equipment and the option of setting up a water authority to stipulate a cap rule to limit water abstraction among farmers.

This latter feature promotes communication between farmers.

3.3.1 Water saving equipment

This rule offers the players the chance to invest in 'improved irrigation schemes', an opportunity which is available only in Scenario 2. The investment is made only once, and players can invest in the water saving equipment in any of the three rounds during this Scenario 2. The investment results in 20% water saving in the total discharge Q (groundwater need per ha = 800 m3/ha) which reduces abstraction costs. Investment in the water saving equipment costs ₳ 100.

Even though this is a high cost for a farmer, the investment in water saving equipment will bring long term benefits. Players will clearly see the savings and will start profiting from the investment as soon as they make it.

3.3.2 Cap rule transaction cost

The cap rule is used to set a limit for groundwater abstraction among players. The South African Groundwater Case Study Report (Pietersen et al. 2011) indicates that a direct management measure to control groundwater abstraction was made by limiting the cropping area among the users. Applying this measure in the game through the cap rule sets a limit to the number of hectares that a player can farm, and therefore limits or "caps" the volume abstracted. This can help avoid the lake drying up with its associated environmental costs.

To implement the cap rule, players have to organize together in a Water Association and decide on a limit to the volume of water to be abstract per farmer per season. A minimum of 50% of the players (i.e. 5 players) have to join this rule in order for it to be applied. The transaction cost of this rule is ₳ 100, the cost divided among the players joining the rule and payed to the Water Association. If players wanting to form the Water Association can convince other players to join, it will make their transaction costs smaller. The rule is only valid for one round. For each round in Scenario 2 the players must decide again if they want to join the Water Association and also pay again the transaction costs.

3.3.3 Penalty cost for no compliance with cap rule

Players who don't follow the rule and abstract more water than the amount permitted by the Water Association will receive this penalty cost. The penalty cost is a function of the number of players that join the rule times a pre-establish value of ₳ 10. E.g. If 6 players join the rule; penalty costs for those who don't comply is 6*10 = ₳ 60. Note that the penalty is applied to all players who exceed the cap limit, whether or not they joined the Water Association.

3.4 SCENARIO 3 – "ADVANCED MANAGEMENT"

In this scenario a new figure is added to the Game, the Groundwater Authority. This scenario represents an advanced management scenario where water abstraction, environmental costs and transitional costs associated with the cap rule are regulated by the Groundwater Authority in cooperation with the farmers.

3.4.1 Social benefit

In each Scenario 3 round, an average cumulative net benefit coming from all the players is calculated. If the figure is positive, 10% of that amount is apportioned to each player in the subsequent round.

The story behind the benefit includes: (i) money coming from the overall benefits of players resulting in more money circulating in the village and a general "social benefit" distributed among all, (ii) social welfare coming from the inclusion of the new Groundwater Authority to the village.

This benefit is used to show players the advantages of having a sustainable management of groundwater resources. As long as players profit in their individual households, that benefit will be beneficial for the whole community.

3.4.2 Environmental costs

During this last scenario, if the lake runs dry environmental costs are assigned to each player according to the proportion of water each player pumps (Q) during the ongoing simulation run.

Environmental costs = (Q wellx/Qtotal) * 350 ₳

This new allocation of environmental cost comes due to the inclusion of the new Groundwater Authority. Environmental costs are paid to the Groundwater Authority and it is a more "equitable" way to assign the costs in order to protect the environment and penalize those who abstract more.

3.4.3 Penalty cost for no compliance with cap rule

During this scenario the cap rule is applied to all players by default. Costs for non-compliance with the cap rule are paid to the Groundwater Authority. The new Groundwater Authority gives the players the right to choose both the cap limit and the size of penalty levied on players who exceed the limit.

4.0 PLAYING THE GAME

4.1 SET UP

The game session is led by the game manager and in the case of big groups an assistant, both who must prepare in advance for the task. Experience shows that the game-sessions can be very different from each other and surprisingly dynamic. The game manager needs to be prepared for a very intense and energetic experience.

Preparing a game session:

1. **Number of participants:** minimum 9, maximum 30;
   In the case of more than 9 players, organize into teams to a maximum of 4 players per team.
2. **Game duration:** 120 - 160 min (depending on the players and the setting where the game is being played).
3. **Prepare in advance:**
   A computer with access to MS Excel and PowerPoint;
   The Groundwater-Game PowerPoint Presentation;
   The Groundwater Manager App installed on the game manager computer;
   A Wi-Fi router (See 4.1.1);
   A Beamer;
   Blank sheets/Note books and pens;
   Ask all participants with an Android phone or Windows laptop to download the player app. To install the app on an Android phone search for 'Groundwater Game Player' in the Google Play Store. To install on a Windows computer, download the installation file from the Groundwater Game webpage (https://www.un-igrac.org/special-project/groundwater-game).

Print in advance if necessary:

Input and output tables for players (Appendix 1);

Note: If it happens that one or more players don't have a computer or smartphone or if the Wi-Fi connection fails, then paper-based tables can be distributed for the players to enter their decisions and strategies. This takes longer and demands patience from the players to wait for the game manager to input the players'

strategy in the Groundwater Manager App. In this situation is helpful to have a second person interacting with the players. These tables are used only in the case that one or more players do not have a smartphone or laptop, or if they have problems with their devices.

4.1.1 Wi-Fi router setup

Router interfaces vary between manufactures and models and so the notes here can only give general guidance. If necessary, you should consult your router Users' Manual for more detailed instructions.

1. Power on your router – when it powers up it will create its Wi-Fi network. The network name (SSID) and wireless password are usually written on the back of the router.
2. On your computer, go to Internet & Network Settings. The wireless network should be listed.
3. If the router has a 'WPS' button press this and then click 'Connect' in the Internet & Network Settings on your computer. You should be connected to the wireless network.
4. If the router does not support 'WPS', click 'Connect' in the Internet & Network Settings on your computer and when prompted enter the wireless password.
5. Update Slide 2 of the PowerPoint presentation with the network name and wireless password.

4.2 USING THE EXCEL FILE

The Excel file contains several worksheets that will perform the calculations and outcomes of the game. Some Excel worksheets (defined by default) are linked to the PowerPoint presentation to facilitate the game flow. When data is updated in the Excel file and calculations are completed, the links must be manually updated to synchronize the Excel data to the PowerPoint presentation (see section 4.3). The Excel file opens automatically once a new game is started in the Manager App. Players use the Player App to enter their decisions which are sent to the Manager App which then updates the Excel file. Calculations made in the Excel file are read by the Manager App which sends the results to the Player Apps.

An overview of the Excel worksheets is given below:

Worksheet	Type	Content
basic_inp	Input	Input of well locations and hydraulic properties
Wells_map	Map/chart	Map showing the location of the wells and the lake
sim_inp	Input	Input of players decisions/moves (e.g. hectares to irrigate, cap rule & investments), costs & benefits
costben_outp	Calculation sheet	Calculation of players' balance (₳) in each round
Scn1_outp	Main output	Summarizes players' balance (₳) in scenario 1
Scn2_outp	Main output	Summarizes players' balance (₳) in scenario 2
Scn3_outp	Main output	Summarizes players' balance (₳) in scenario 3
Cum₳_sum_outp	Main output	Summarizes players' balance (₳) in all rounds
Q_SUMm3 per well	Map/chart	Chart showing the contribution [absolute] of each well in the total discharge per round
Q_%total	Map/chart	Chart showing the contribution [percentage] of each well in the total discharge per round
Down_graph	Map/chart	Chart showing the cumulative drawdown in each well and in the lake
Down_map	Map/chart	Map showing the drawdown in the wells in the ongoing round
Down_%well	Map/chart	Chart showing the contribution of all wells to each well and lake drawdown
Costben_chart	Map/chart	Chart showing players' benefits and costs in the ongoing round

CUM_graph	Map/chart	Chart showing players cumulative balance (₳)
Down_Well1	Calculation sheet	Calculates the drawdown induced by Well 1 in all wells and in the lake
Down_WellX	Calculation sheet	Calculates the drawdown induced by WellX in all wells and in the lake
Breakdown_drawdown	Calculation sheet	Calculates the total drawdown in the wells and in the lake

NOTE: Do not change the names of the worksheets or the order of the worksheets.

4.3 USING THE POWERPOINT PRESENTATION

The PowerPoint presentation was set up to help the game manager guiding the players through the game-session. It can be downloaded from the Groundwater Game web page together with this manual (https://www.un-igrac.org/special-project/groundwater-game). For each new game-session, the only necessary modifications to the PowerPoint presentation are in the first (date, location, project name, etc.) and second (Wi-Fi network information and server details) slides

At the end of Scenario 1 and at the end of each round in Scenarios 2 and 3 results are shown directly in the PowerPoint. In the end of the eight rounds all tables and charts generated during the game will be presented for discussion with the players.

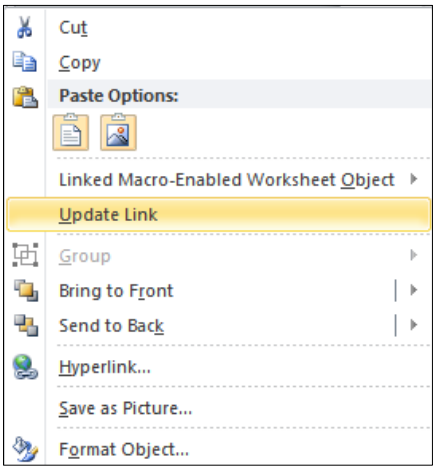

Figure 5 - Update links menu item

The results tables and charts in the PowerPoint presentation are linked to the Excel file as OLE objects. However, the links must be updated manually during the game to ensure the correct data is displayed in the presentation. The Game Manager app will instruct you when this needs to be done.

There are two ways in which links can be updated. The first method is to right-click on the table or chart in the PowerPoint slide and select 'Update link' from the menu as shown in figure 5.

The other method is to select the 'File' from the PowerPoint top menu and then click 'Edit Links to Files' from the bottom of the right-hand panel to display the Links window as shown below:

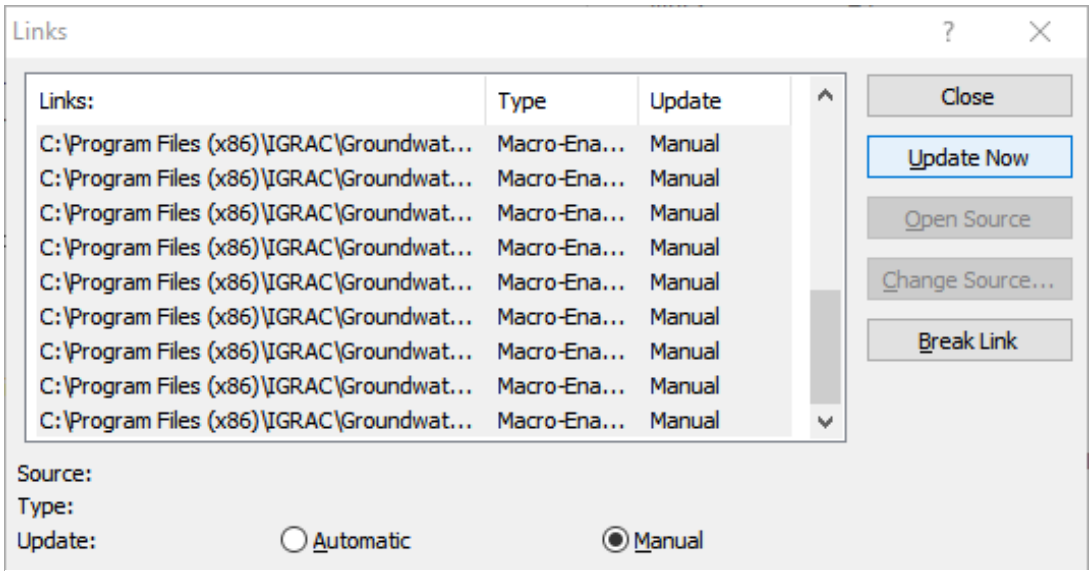

Figure 6 - Powerpoint links window

Click on the first link and then scroll to the end of the list. While holding down the SHIFT key, click on the final link to select all links in the list. Click 'Update Now' to update all OLE objects in the presentation. This method can be used throughout the game but is strongly recommended when there are multiple tables or charts to update (e.g. at the end of round 8).

It might happen that the game manager needs to show a specific graphic before the end of all rounds. If that is the case then the game manager will have to switch from the PowerPoint presentation to the Excel file. The game manager is free to show more or less information as seems appropriate for the audience and circumstances (time available, motivation of participants, level of understanding).

NOTE: Be aware that in the end of the game the game manager might need some time to analyse the final results before leading the final group discussion. It is recommended to have a short interval when the game is finished and before the final discussion so that the game manager can get acquainted with the final results.

4.4 USING THE GROUNDWATER GAME APPS

There are two Groundwater Game apps: the Groundwater Manager App and the Groundwater Player App.

The manager app, which must be installed on the game manager computer, is used to manage the input of data from players and sharing of outcomes information with each player. The player app is used by players to send their decisions to the manager app and also to display outcomes information received from the manager app. There are two versions of the player app, one for Windows computers and one for Android phones. Each team must have one device (laptop or phone) with the player app installed.

The Groundwater Manager and Player apps communicate on the local Wi-Fi network which should be setup beforehand (see section 4.1.1).

4.4.1 The groundwater manager app

4.4.1.1 Installation

1. Download the 'GroundwaterMgrInstaller.msi' file from the Groundwater Game web page (https://www.un-igrac.org/special-project/groundwater-game).
2. Double click 'GroundwaterMgrInstaller.msi' to begin installation.
3. Click through the installation window prompts in to install the Groundwater Manager App. This will create a desktop link and start menu entries for the app.

4.4.1.2 Groundwater manager app overview

Players' inputs to the game, reflecting their farming decisions (e.g. the area to crop), are made using the Groundwater Player App. This player app transmits the data to the Groundwater Manager App, which updates the Excel spreadsheet under the control of the game manager. In the Excel spreadsheet a series of hydrogeological and economic results are calculated in different worksheets.

The Game Manager App consists of two tabbed panels labelled 'Admin' and 'Game'.

The Admin panel (Fig. 7) contains three control panels:

- Game Setup: this creates new games or restarts existing games.
- Server Control: this starts and stops the server which the players' apps will connect with to upload game data.
- Player Monitor: this monitors players' login status and can be used to log players out and reset passwords.

The lower panel displays an event log for the app.

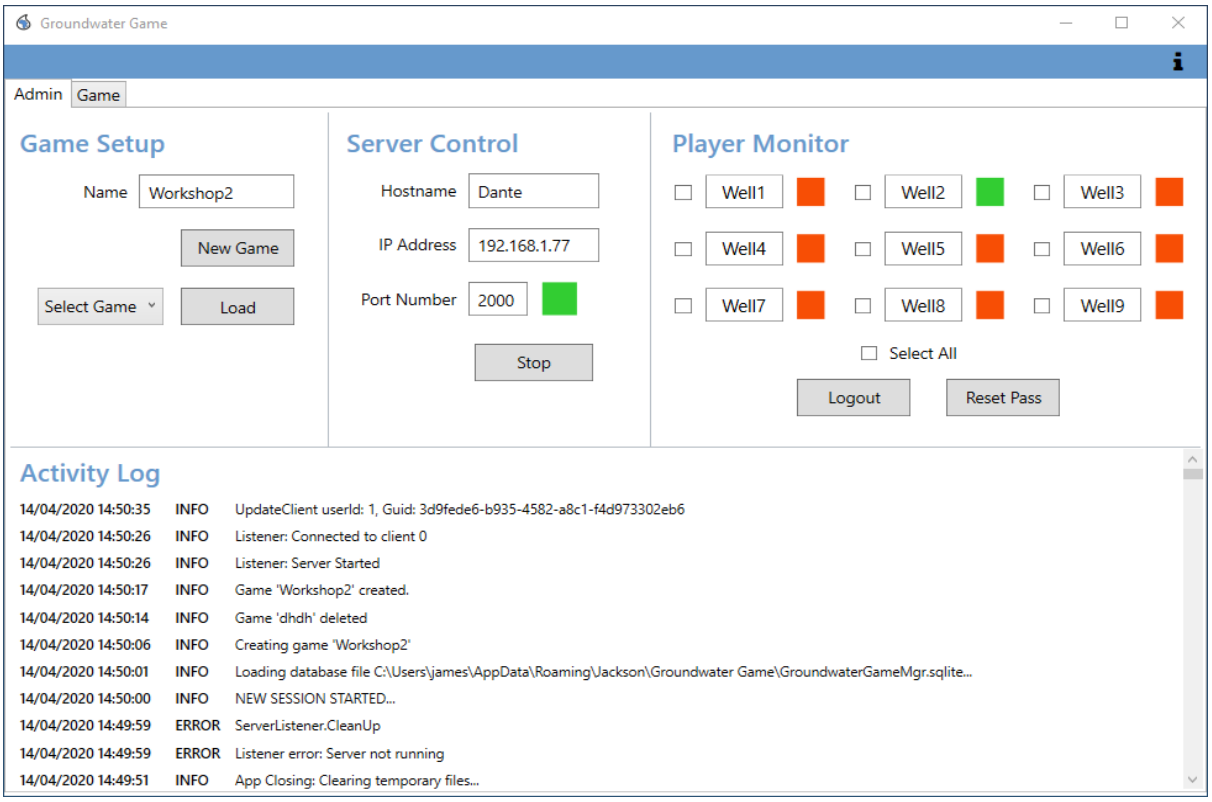

Figure 7 - Groundwater manager app admin panel

The Game panel (Fig. 8) is used to run the game. The upper grid displays the login status of each player and highlights the data input for the current round.

The lower panel displays instructions relevant to the game stage (e.g. at the outset information on getting the participants setup and connected to the server, then instructions for the current round). There are buttons for committing player data (when all well data has been entered), transmitting the cap limit and cap penalty to players and, if required, rolling the game back to the previous round.

Note: The Groundwater Manager opens the Groundwater Game Excel file when starting a new game and will save a copy of the Excel file to a folder "Groundwater Game\Saved Games" in the Documents directory when the Game Manager App is closed at the end of the workshop.

During each round, as players send data from the Groundwater Player App, the appropriate input cell changes color from amber to green (Fig 9).

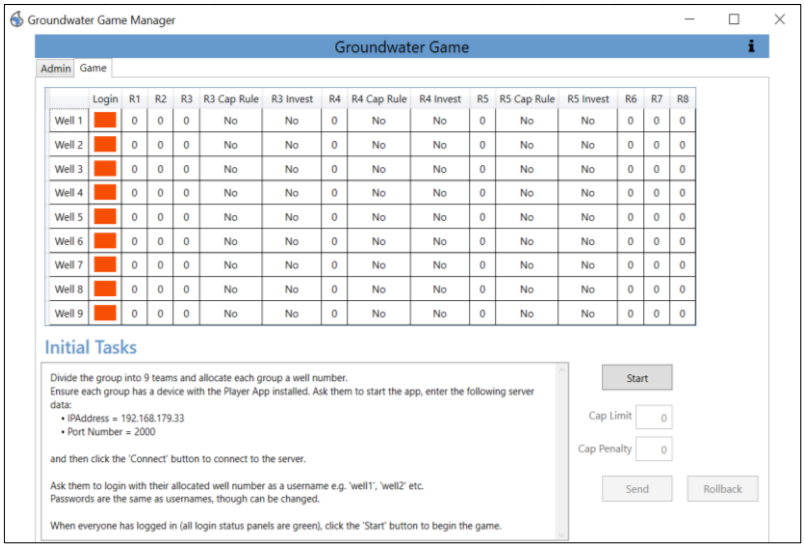

Figure 8 - Groundwater manager app game panel

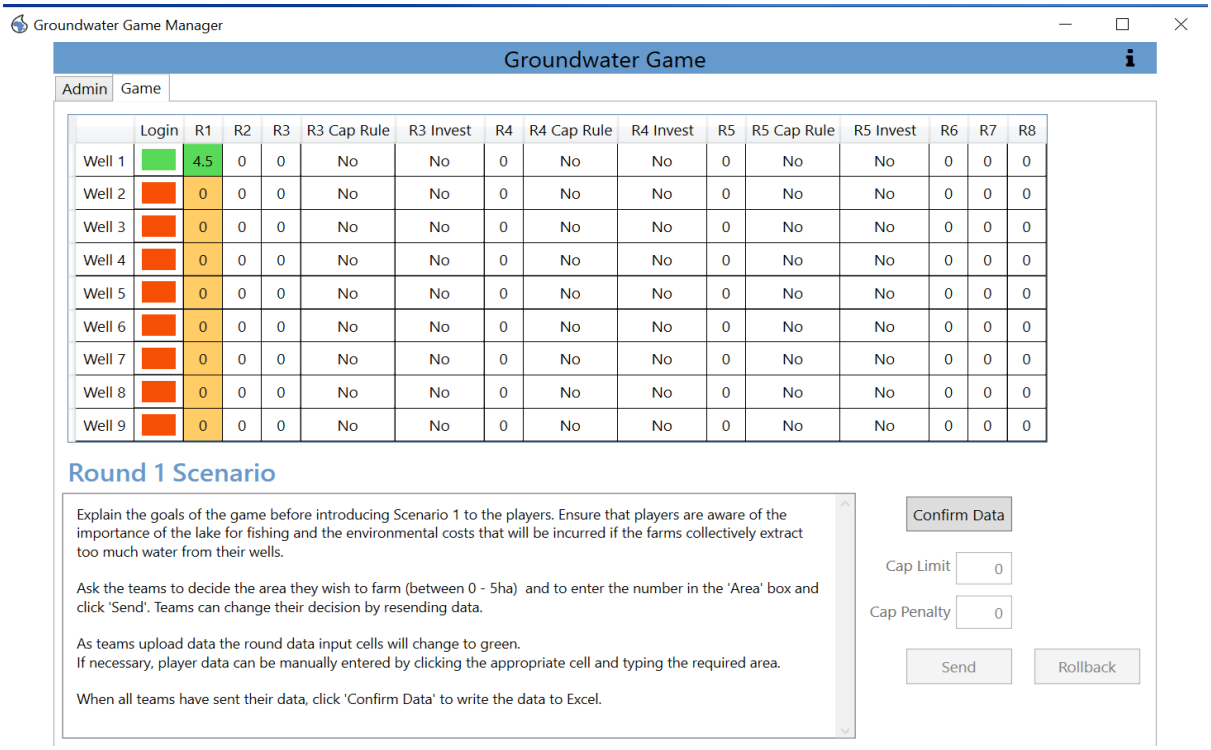

Figure 9 - Groundwater manager app game panel showing data input

Data can also be manually entered by the game manager, to cover situations where the local Wi-Fi network is interrupted or unavailable for any reason (in this situation use forms in Appendix 1). To manually add area data, click on the appropriate cell and enter the required number. The 'Cap Rule' and 'Invest' entries are toggled by clicking on the cell.

When all data for the round has been entered, click the Confirm Data button. This initiates several actions:

1. The data is written to the Excel spreadsheet, triggering the well data calculations.
2. The players' apps are updated with the outcomes of their decisions.
3. The round is moved forward to the "Review" stage.
4. The instructions in the tasks panel are updated.

Note that players can change their data right up until the Confirm Data is pressed.

It is at this point in the round (starting from Round 2) that the PowerPoint links need to be updated, **but this will be indicated in the task panel instructions**.

If for any reason the Groundwater Player App is not used or there is a network interruption, the data outcomes can be read directly from the Scn1_outp, Scn2_outp and Scn3_outp worksheets and distributed to the players using the paper forms for Scenario 1 (Appendix 1) or share the results in the power point presentation in Scenarios 1 and 2.

For Scenarios 2 and 3, values for the 'Cap Limit' and 'Cap Penalty' (Scenario 3 only) should be entered and the Send button clicked to update the Groundwater Player Apps, once these numbers have been agreed by the players. Note that this is done before players enter data. If the Cap Limit and Penalty data has not been sent for the round and the Game Manager attempts clicks the 'Conform Data' button, a confirmation window will be displayed before the players' data is written to the Excel file.

4.4.2 The groundwater player app

Players' inputs to the game and the display of outcomes data are managed by the Groundwater Player App, which is installed on an Android smartphone or Windows computer.

4.4.2.1 Installation

Installation (Windows)

1. Download the 'GroundwaterPlayerInstaller.msi' files from the Groundwater Game web page. (https://www.un-igrac.org/special-project/groundwater-game).
   Double click 'GroundwaterPlayerInstaller.msi' to begin installation.
2. Click through the installation window prompts in to install the Groundwater Player App. This will create a desktop link and start menu entries for the app.

Installation (Android)

Install from the Google Play Store - search for 'Groundwater Game Player': (https://play.google.com/store/apps/developer?id=JimJ) (see Fig. 10).

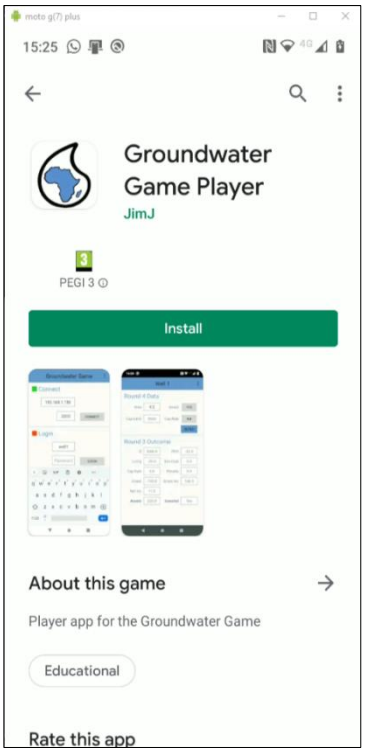

Figure 10 - Groundwater player app on Google Play

4.4.2.2 Groundwater player app overview

The User Interfaces for the Windows and Android versions of Groundwater Player App are slightly different (Figs. 11 and 12). In the Windows version the top left-hand panel contains controls for connecting to the server, logging in and changing password. The top right-hand panel contains the controls for sending well data, cap rule and investment decisions to the server and also displays the player's well number and the current round number. Below this is a panel which displays information on the outcome of the previous round and the overall status. The lower panel displays an event log.

In the Android version the server connection and login panel are displayed only when the player is not logged in to the server.

The content of the interface panels will change slightly as the game transitions to different scenarios.

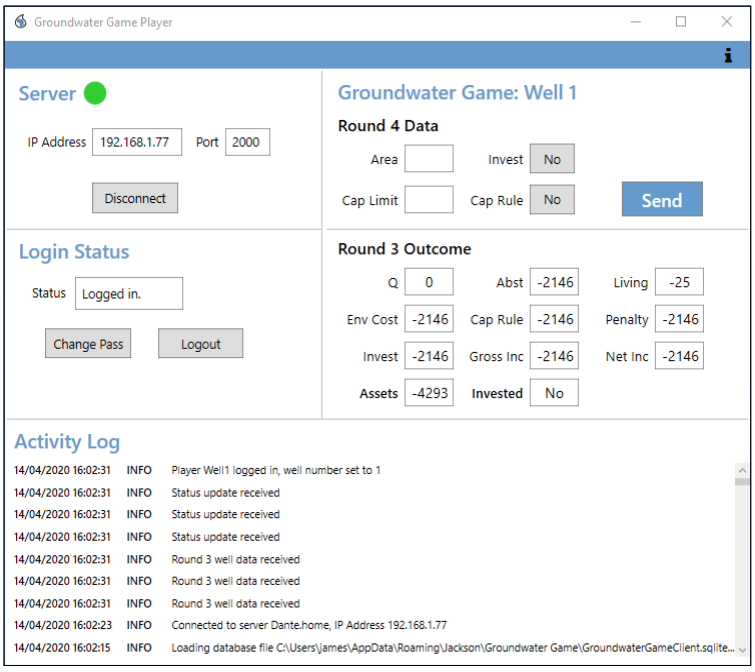

Figure 11 - Groundwater player app (Windows version, scenario 2)

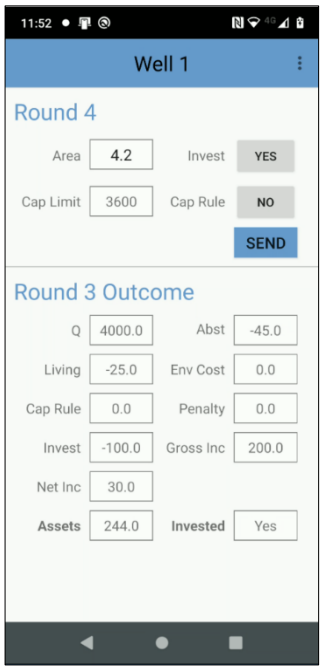

Figure 12 - Groundwater player app (Android version, scenario 2)

4.4.3 Pre-game preparation

There are several tasks that the game manager needs to complete shortly before starting the game:

1. If not done beforehand, ensure that the Groundwater Manager App is installed on the game manager PC and that the Groundwater Player App is installed on the laptops or phones of the players (only one installation per team is required, if more than one player is managing a well). Note: Ensure the app has been installed before the players' devices are connected to the local Wi-Fi network as the local Wi-Fi network will not have internet access.
2. Power on the router and connect the game manager's computer to the local Wi-Fi network.
3. Start the Groundwater Manager App by double clicking on the Desktop link.
4. Create a new game or load an existing game. To create a new game, enter a name in the box and click New Game. If restarting an existing game select the game from the dropdown panel and click Load.
5. The Game Panel will be added to the user interface.
6. Click the Start button on the Server Control panel to start the server and then select the 'Game' tab to open the Game panel.
7. Open the PowerPoint presentation and edit the 'Network Connection' slide (slide 2) to add the IP Address and Port Number of the server (both can be found in the Server Control panel or task panel). This will give the players the data needed to connect their computers or smartphones to the Wi-Fi network and to connect to the Game Manager server.
8. You are now ready to start the game.

4.4.4 Running a game

After you have completed the pre-game tasks outlined above and the players are assembled:

1. Allocate well numbers (1 – 9) to each player or team.
2. Ask the players to connect to the network and server using the data you have entered in the 'Network Connection' slide (you can use WPS if supported by your router).
3. Ask the players to login to the server – the usernames are 'well' followed by the allocated well number e.g. 'well1', 'well2' etc. The passwords are the same as the usernames, though can be changed if desired.
4. When all players are logged in (in the Groundwater Manager App check all status icons are green), click Start to begin round 1.

Note: if a player tries to login during a game and receives a message 'Well X already logged in', click on the Admin tab and select the appropriate checkbox in the Player Monitor panel and click 'Logout' to reset the player's login status.

Instructions to help you complete the tasks for each round will be displayed in the task panel.

For Scenario 1, the players simply upload area information to the server (Fig. 13).

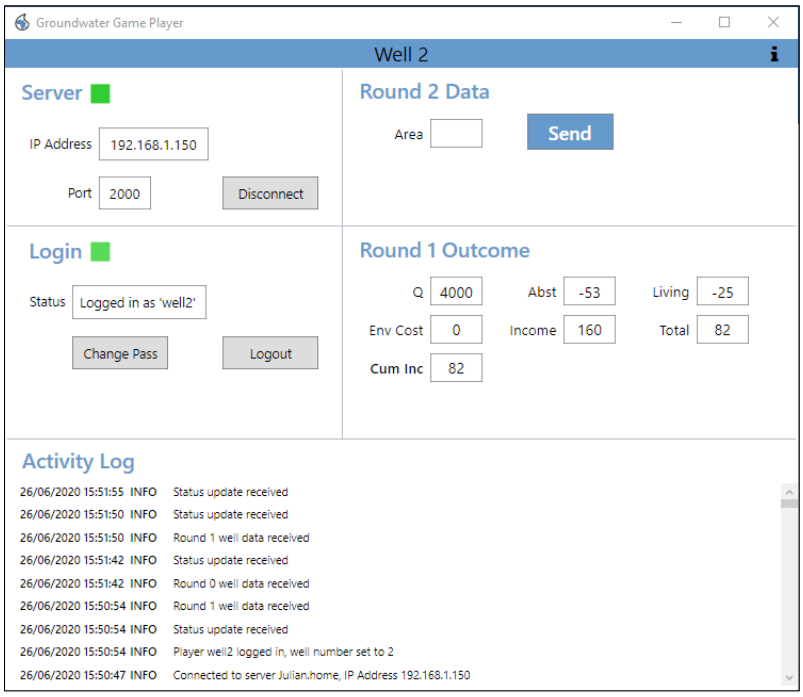

Figure 13 - Groundwater player app - scenario 1 data input (Windows)

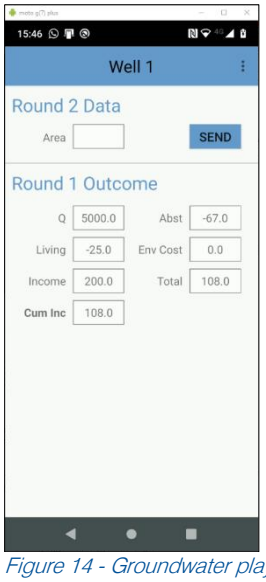

Figure 14 - Groundwater player app - scenario 1 data input (Android)

However, in Scenario 2 Cap Rule and Investment decisions must also be made (Fig. 11) and the game manager must send 'Cap Limit' data to players, if at least 5 players have agreed to set a cap rule. When a cap limit has been agreed, enter the value in the textbox and click Send (Fig. 12).

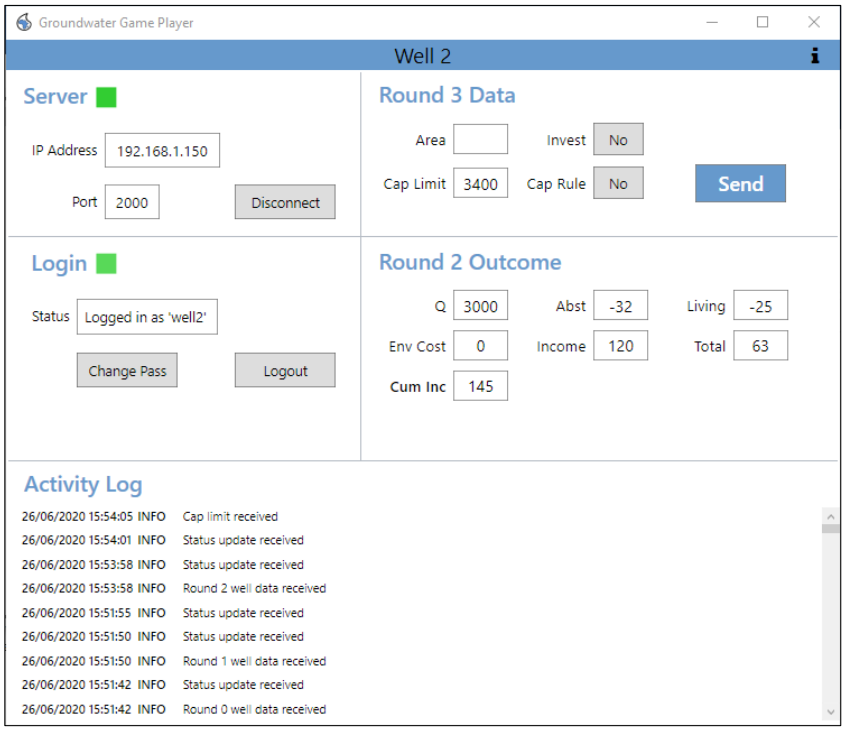

Figure 15 - Groundwater player app - scenario 2 data input (Windows)

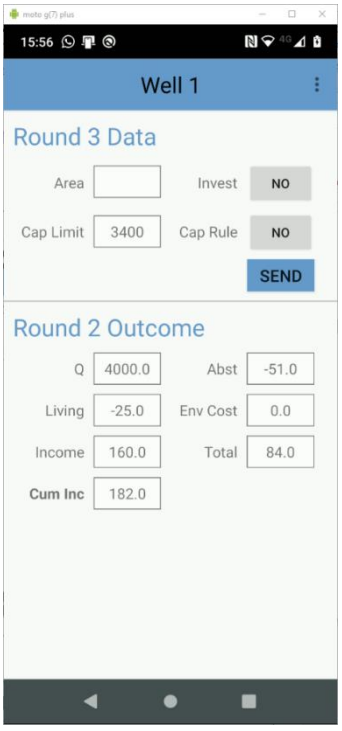

Figure 16 - Scenario 2 data input (Android)

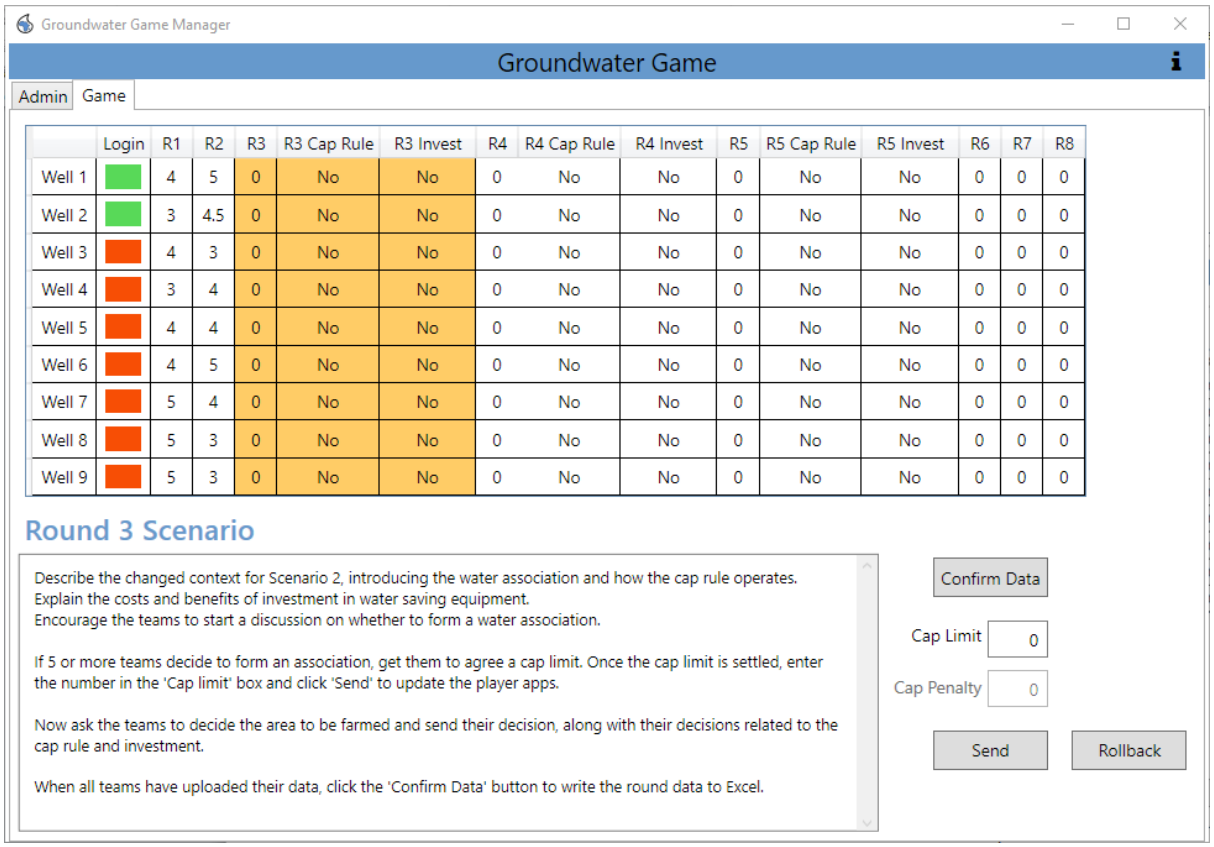

Figure 15 - Groundwater manager app - cap limit data input

In Scenario 3, in addition to the Cap Limit, Cap Penalty data must also be sent to players once they have agreed on the amount.

4.5 FINISHING THE GAME

At the end of the game, show players a general summary of the overall benefits and present the winner(s). Together with the players analyze the generated charts and emphasize the key moments of the game session. Use the worksheet "CUM_Graph" to show the players the cumulative benefits throughout the game. If the graph shows an increasing tendency this will indicate that the objectives were met, and the farmers ended with a positive income. Emphasize the impact of new elements and rules coming from the developing organization of the village.

Finish the game session with a plenary session on the final outcomes, discuss with the players the lessons learned through the game and listen to everyone's conclusions and comments. In the PowerPoint the final slides are specifically prepared to target concepts such as drawdown, depletion, groundwater management and governance.

NOTE: When the Groundwater Manager App is closed the game's Excel spreadsheet will be automatically saved as an Excel file with the game name in the Documents directory folder 'Groundwater Game\Saved Games'.

5.0 REFERENCES

- FAO, UNESCO-IHP, IAH, GEF & World Bank, 2012: Regional Diagnostic Report for Sub-Saharan Africa Region. Groundwater Governance – A Global Framework for Action. Internet http://www.groundwatergovernance.org/regional-consultations/sub-saharan-africa/en/
- Hardin, G., 1968: The Tragedy of the Commons. Science Journal Vol. 162 no. 3859 pp. 1243-1248
- Pietersen, K., H.E. Beekman & M. Holland, 2011: South African Groundwater Governance Case Study. WRC Report No. KV 273/11 ISBN 978-1-4312-0122-8
- Mendler de Suarez, J., P. Suarez & C. Bachofen 2012: Games for a New Climate: Experiencing the Complexity of Future Risks. Pardee Center Task Force Report. Boston: The Frederick S. Pardee Center for the Study of the Longer-Range Future, Boston University

6.0 APPENDIXES

APPENDIX I

Input and output players decisions.

WELL 1								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (Ⱥ)	Living cost (Ⱥ)	Abst cost (Ⱥ)	Env cost (Ⱥ)	Total (Ⱥ)	Cumulative (Ⱥ)
1				-25				
2				-25				

WELL 2								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (Ⱥ)	Living cost (Ⱥ)	Abst cost (Ⱥ)	Env cost (Ⱥ)	Total (Ⱥ)	Cumulative (Ⱥ)
1				-25				
2				-25				

WELL 3								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (Ⱥ)	Living cost (Ⱥ)	Abst cost (Ⱥ)	Env cost (Ⱥ)	Total (Ⱥ)	Cumulative (Ⱥ)
1				-25				
2				-25				

WELL 4								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (Ⱥ)	Living cost (Ⱥ)	Abst cost (Ⱥ)	Env cost (Ⱥ)	Total (Ⱥ)	Cumulative (Ⱥ)
1				-25				
2				-25				

WELL 5								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (Ⱥ)	Living cost (Ⱥ)	Abst cost (Ⱥ)	Env cost (Ⱥ)	Total (Ⱥ)	Cumulative (Ⱥ)
1				-25				
2				-25				

WELL 6								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (₳)	Living cost (₳)	Abst cost (₳)	Env cost (₳)	Total (₳)	Cumulative (₳)
1				-25				
2				-25				

WELL 7								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (₳)	Living cost (₳)	Abst cost (₳)	Env cost (₳)	Total (₳)	Cumulative (₳)
1				-25				
2				-25				

WELL 8								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (₳)	Living cost (₳)	Abst cost (₳)	Env cost (₳)	Total (₳)	Cumulative (₳)
1				-25				
2				-25				

WELL 9								
Scenario 1 round no.	Area (ha)	Q (m^3)	Income (₳)	Living cost (₳)	Abst cost (₳)	Env cost (₳)	Total (₳)	Cumulative (₳)
1				-25				
2				-25				

Scenario 2 - Well 1			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 2			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 3			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 4			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 5			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 6			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 7			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 8			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well 9			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 2 - Well ____			
Round no.	Area (ha)	Cap rule 0 =no 1 =yes	Investment 0=no 1=yes
3			
4			
5			

Scenario 3 - Well 1	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 2	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 3	
Round.	Area (ha)
6	
7	
8	

Scenario 3 - Well 4	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 5	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 6	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 7	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 8	
Round	Area (ha)
6	
7	
8	

Scenario 3 - Well 9	
Round	Area (ha)
6	
7	
8	

Scenario 3 – Well___	
Round.	Area (ha)
6	
7	
8	