Viewpoint from a Regional Adviser

Within Pacific island countries, fresh water is essential to human existence and a major requirement in agricultural and other commercial production systems. The water resources of small island countries are fragile due to their small size, lack of natural storage and competing land use. They are extremely vulnerable to natural and anthropogenic hazards, including droughts, cyclones and urban pollution.

Kiribati is one of the small island developing states in the Pacific, consisting of 33 islands spread over a territorial area of over 3 million square kilometres. The total land area amounts to only 726 square kilometres and all but one of the 33 islands are low-lying coral atolls. South Tarawa supports the highest proportion of the Kiribati population with 43 per cent, approximately 45,000 people, living on a stretch of land of around 18 square kilometres.

South-Tarawa's water supply is sourced from groundwater lenses pumped from galleries on water reserves allocated by the government on adjacent islands. The potable water supply from the existing system, which is based on only 30 L/capita/day, is insufficient. Most of the freshwater lenses on South Tarawa have been polluted and augmentation by rainwater collection at the household level is not widespread enough. The occurrence of water-born diseases such as diarrhoea can be attributed to people still using shallow, open hand-dug wells which are contaminated by leaking sewage systems, soak pits or pig pens.

Given the rising demand for a sustainable urban water supply, the development of additional water resources is a government priority. Land issues compounded by the reality of land shortage and complex family land ownership has meant that the water reserves set aside for public water supply have been under increasing pressure from squatters and agricultural uses, leading to conflicts and vandalism of public assets.

Groundwater studies are currently executed to study the feasibility of creating additional water reserves on two other islands. This provided an excellent opportunity for the team of CIRAD and ANU to study the social impact of this development and assist the Government of Kiribati and other stakeholders to avoid the problems encountered on the existing reserves.

The authors have shown that a useful dialogue can be generated through innovative approaches such as multi-agent-based simulations coupled with role-playing games. They demonstrated that the complex situation of the management of Tarawa's water resources can be captured in a model that allows the collection, understanding and merging of viewpoints from different stakeholders.

Small island hydrology may be considered as relatively simple, using straightforward water balance models to determine the sustainable yield from a freshwater lens that forms naturally under an island according to the Ghyben-Herzberg principle. In contrast, the management of water resources on a densely populated island such as South-Tarawa is quite complex due to the specific socio-political and cultural structures relating to traditional community practices, rights and interests, which are interwoven with colonial and 'modern' practices and instruments.

The surveys carried out in the first stage of the project resulted in a better understanding of people's perception of water management and sanitation issues. This provided a good basis for the agent-based model developed in stage 2 and the role-playing game of stage 3 that managed to engage government as well as local community stakeholders in a difficult though meaningful dialogue. I will be eager to learn of the outcomes of stages 4 and 5, which will see the formalisation of different scenarios and final discussions with the different stakeholders.

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12. AtollGame: A Companion Modelling Experience in the Pacific

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Abstract

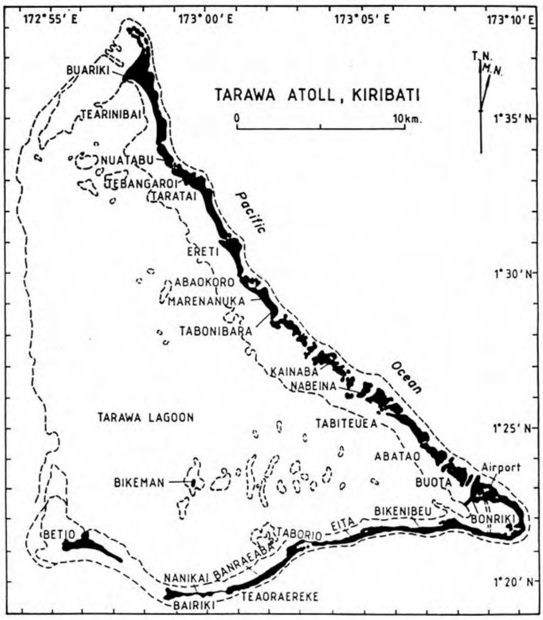
Multi-Agent Systems (MAS) have been developed to study the interaction between societies and the environment. Here we use MAS in conjunction with a Companion Modelling (ComMod) approach to develop a Negotiation Support System for groundwater management in Tarawa, Republic of Kiribati. In agreement with the complex and dynamic nature of the processes under study, the ComMod approach requires a permanent and iterative confrontation between theories and field circumstances. Therefore, it is based on repetitive back and forth steps between the model and the field situation. The methodology applied in Tarawa relies on 3 successive stages. First, a Global Targeted Appraisal focus on social group leaders in order to collect different standpoints and their articulated mental models. These collective models are partly validated through Individual Activities Surveys focusing behavioural patterns of individual islanders. Then, these models are merged into a single conceptual model that is further simplified in order to create a role-playing game. This game is played during iterative sessions, generating innovative rules and scenarios. Finally, when the rules become too complex, a computer based version of the game replaces the board version. Stakeholders can explore the possible futures of freshwater management in Tarawa and eventually agree on an equitable collective solution.

Introduction

Low coral islands are heavily dependent on groundwater for freshwater supplies. The availability, quality, and management of groundwater are central to sustainable development and poverty alleviation in many developing small island nations. Increasing populations, growing per capita demand and restricted land areas limit water availability and generate conflicts (Falkland and Brunel 1993).

This study is carried out in the Republic of Kiribati, on the low-lying atoll of Tarawa (Figure 12.1). The water resources are predominantly located in freshwater lenses on the largest islands of the atoll. The water table is typically 0.8 m to 1.6 m below ground surface. Groundwater is supplemented by rainwater on most of these islands. South Tarawa is the capital and main population centre of the Republic. The water supply for the urban area of South Tarawa is pumped from horizontal infiltration galleries in groundwater protection zones called *water reserves* on Bonriki and Buota islands. These currently supply about 1300 m^3/day, equivalent to about 30 l/capita/day of freshwater, representing 60 per cent of the needs of South Tarawa's communities. Rainwater tanks and local private wells supply the rest (White et al. 2002).

Figure 12.1. Tarawa Atoll (Bonriki and Buota islands are on the lower right of the atoll)



The government's declaration of water reserves over privately owned land has lead to conflicts, illegal settlements and vandalism of public assets. Water consumption per capita tends to increase towards western-like levels, threatening the sustainability of the system. As well, pollution generated by the 45,000 inhabitants of South Tarawa has already contaminated all the freshwater lenses, with the exception of Buota and Bonriki reserves (White et al. 1999).

The government is now conducting intensive groundwater investigations on the islands of Abatao and Tabiteuea in order to delineate the freshwater lenses and to provide more accurate estimates of the sustainable yields from these islands. Depending on the results of the investigations and community discussions, the groundwater resources could be partly used to supplement the water supplies from Bonriki and Buota to South Tarawa. However, already available information underlines the necessity to take into account the social impact of such implementation, in order to avoid the problems encountered on Bonriki and Buota.

Our project aims at providing the relevant information to the local actors, including institutional and local community representatives, in order to facilitate dialogue and to help devise together sustainable and equitable water management practices. Multi Agent-Based Simulations (MABS) coupled with a role-playing game have been implemented to fulfill this aim. They provide powerful tools for studying interactions between societies and their environment (Bousquet et al. 2002). They have the potential to greatly reduce conflict over natural resource management and resource allocation. In order to collect, understand and merge viewpoints coming from different stakeholders, the following 5-stage methodology is applied: collecting local and expert knowledge; blending the different viewpoints into a game-based model; playing the game with the different stakeholders; formalising the different scenarios investigated in computer simulations; and exploring the simulated outcomes with the different stakeholders. The first 3 stages are described successively in this chapter.

Collective knowledge

Theoretical assumptions

We acknowledge the constructivist theory in socio-psychology and believe that the nature of individual representations is socially constructed through people's interactions with their physical and social environment (Descola 1996). We agree on the fact that these adaptive mental models can be partly elicited through Knowledge Engineering-based techniques and translated into conceptual models (Becu et al. 2003). We assume that social groups carry collective representations of their environment and that these mental models can be partly elicited from wisely selected representatives. We argue that individuals belonging to the same group share the same representation, but their behaviour is driven by personal motivations and tacit knowledge. Thus, they can temporarily dismiss part of the shared representation.

Our methodology includes 2 sets of interview. The first , called Global Targeted Appraisal (GTA), is focusing on groups' representatives, or *Group Voices*, and its objective isto elicit representations rather then individual behaviours. The second, called Individual Activities Survey (IAS), is conducted with individuals belonging to the same groups.

Global targeted appraisal

Prior to the interviews, a short survey helped selecting relevant spatial and social groups, and understanding their hierarchical links in order to identify 30 *Group Voices* belonging to different religious, cultural, administrative, educational and gender groups. They were then interviewed individually at their place through semi-structured interviews, in order to highlight their understanding of the main interactions between local people and water resources. The interview was divided into three exercises:

- exercise 1: photo interpretation dealing with Tarawa overall features and issues;
- exercise 2: cognitive mapping focusing on the interviewee's home island; and
- exercise 3: card game focusing on water cycle and human use interactions.

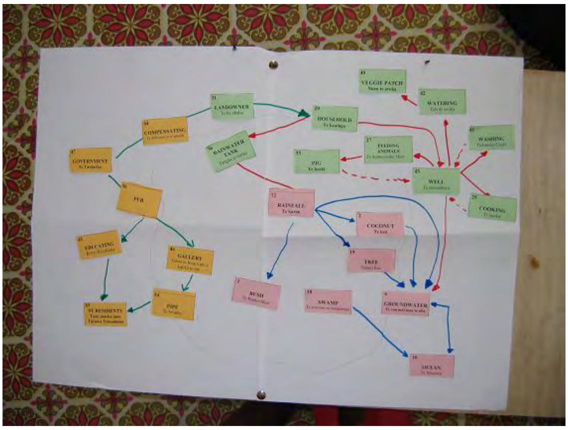
For the first exercise, 4 successive groups of photos referring to different aspects of Tarawa's environment and activities were given to the interviewee. For each group, the interviewer first gave the general topic of discussion and asked the interviewee to describe important elements in the photos related with the topic (Figure 12.2). The topics to be discussed with the interviewee were: population, landuse and landownership; social and economic activities; climate and environment; water resources and water use; and environmental pollution and water quality.

Figure 12.2. Elder man in Abatao commenting on photos of economic activities

For the second exercise, the interviewee was provided with a sheet of paper and asked to draw the location or the spatial distribution of the island's key features. Key features were grouped according to topics largely overlapping the ones described for South Tarawa. The interviewer interacted directly on the map with the interviewee. When one group of key features had been displayed on the map, prompting questions used during the first step were reused in order to crosscheck information consistency and to outline the island's specificities.

The third exercise focused on the way the interviewee understood and represented water management processes. Water management included natural water cycles along with human activities (consumption, pollution, protection). It was based on a card game between the interviewer and the interviewee (Figure 12.3). The interviewer had 60 cards in his hands, representing elements that seemed important for water management processes. At first, the cards *Coconut*, *Rainfall* and *Groundwater* were displayed on a board, and the interviewee was asked to provide other elements in order to complete the natural water cycle. The interviewee was also asked to draw links between cards (action, relation, impact) and to describe them in a few words. The second set of cards displayed was: *Household*, *Pig* and *Vegetable Crop*. The topic was about direct water management from local settlers. The last set of cards included *Government*, *PUB* (the local water agency) and *South Tarawa Residents*. This part focused more on water management at the institutional level.

Figure 12.3. Example of Card Game's flowchart



natural water cycle elements (pink), human activity elements (green), and institutional elements (orange)

Individual activities survey

The objectives of this second field survey were to partly validate the models elicited during the Global Targeted Appraisal (GTA) and to quantify some relationships already described by the *Group Voices*. In order to achieve these objectives, 24 people were selected from among the 4 islands and submitted to specific individual interviews. This time, the interview relied upon a more structured questionnaire form, focusing on local facts and personal activities and behaviour. Interviews were generally held in the central house or shelter with viewing distance to the well and other domestic facilities. Questions were grouped within 5 topics, which were very similar to the ones used in the GTA: demography and landownership; activities and landuse; water resource and water use; improving water-use and sanitation; and water reserve.

Processing elicited knowledge

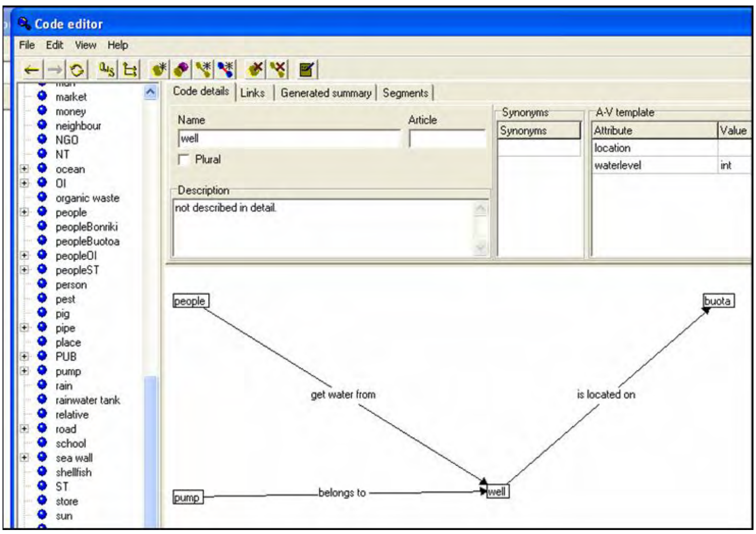
Results from the GTA

First exercise

The first exercise of the GTA intended to establish confidence with the interviewees and to let them browse general topics without focusing immediately on sensitive local issues. Thus, we started from demographic evolution and constraints and ended with global problems of pollution on South Tarawa. From a psychological viewpoint, we wanted to confirm the ability of the interviewees to develop dynamic rationales from static material (photos). A second objective was to test our ability to elicit their mental constructs.

Some interviewees made extensive use of the photos during the interview, others focused mainly on one of them to develop their rationale. On several occasions, interviewees developed their ideas without referring to the photos at all, in some sort of story telling mode. Pre-selected prompting questions were instrumental in keeping the discussion alive during most of the interviews. The *Transcript Analysis* technique was adapted and applied to each recorded interview (Newell 1982; Shadbolt and Milton 1999). Three lists of elements (words or group of words) were completed: social/institutional elements, spatial/geographical elements, and passive/biological elements. Semantic links between these elements were defined according to the grammatical structure of the transcript (Figure 12.4).

Figure 12.4. Partial view over an associative network



Codes and links are individually labelled

All interviewees were fully aware of the population increase on South Tarawa and its impact on society and environment. Increased pollution, land pressure and alcoholism linked with unemployment were the main issues described. Most interviewees stressed the fact that climate pattern and weather features had changed over time, but concerns about coastal erosion and sea level rise issues were not yet shared in the population. The concepts of soil water infiltration and groundwater recharge were well admitted by a large majority of the interviewees. However, the concept of evaporation was still fairly vague.

Even if the traditional view *my land/my well/my water* was still recognised, the science-driven concept of *one island/one water* was widely accepted. The impact of tidal wave and flood/drought on the water lens had often been mentioned and discussed. Illegal tapping into the PUB pipes, and illegal settling on the water reserves, were issues openly discussed by several interviewees. With regard to pollution, most interviewees mentioned solid waste in the first place, especially cans and tins. They also acknowledged the impact of pigs on the environment, as they were causing bad smells and spreading disease. Only half of the interviewees perceived the direct link with water lens contamination. Human wastes were often not mentioned at all.

Second exercise

The second exercise of the GTA intended to focus on specific issues related to the interviewee's island. Most of the time, it was mainly an update of more general considerations expressed during the first exercise, and the discussion often concentrated on the specific features of the island's society and environment. From a psychological viewpoint, our objective was to confirm the interviewees' ability to represent spatial entities, to manipulate these entities on the map and to describe dynamic processes directly on the map. These were essential elements to validate the use of a role-playing game later on. A striking outcome from the exercise was that the 4 islands not only constituted a spatial continuum between South and North Tarawa, they represented a temporal bridge between present and past time as well. Social, environmental and economic evolution on Bonriki was largely replicated on the 3 other islands. It was especially true regarding land tenure issues.

Regarding water issues—remembering that we didn't ask the interviewees about their own feelings but more generally about the thoughts of local people—the situation was contrasted. Where water reserves already existed, angry and happy people coexisted. The opposition mainly focused on the level of financial compensation (land lease), but one has to recognise that this claim was strongly backed by a barely sustainable pressure on land tenure. This pressure had already boosted the land market to unexpected levels. Access to their water through the PUB reticulated system was also described as a fair claim. On Abatao and

Tabiteua, the fears crystallised around the landownership issues. Beyond the financial bargaining game, traditional livelihood and environmental harmony were genuine arguments. Bonriki and Buota cases were often taken as examples of the way things shouldn't be done.

Third exercise

The last exercise was meant to directly elicit individual knowledge of water management processes. The card game was designed to disaggregate these representations into unit elements and causal links. As mentioned previously, some of the elements had been discussed during the first exercise (in a broader context), and it was interesting to observe whether these elements might reappear during the card game. From a psychological viewpoint, beyond the ability of the interviewees to disaggregate their mental constructs into basic elements, we were interested in verifying their acceptance to play the game by the rule and their capability of justifying a given choice. Again, these hints were valuable in the perspective of a role-playing game implementation.

The story was divided into 3 stages of evolution (pristine island, remote settlers and interconnected islands), and cards were distributed at each stage. A first analysis consisted in counting the number of cards and noting the elements cited. Overall, the interviewees took an average of 28 cards out of 60, and most of them were much more comfortable with the second theme. The reference to their daily life obviously helped to build useful analogies, whereas the level of abstraction required with themes 1 and 3 was more challenging. An interesting outcome was the fact that a large majority of people were able to describe an infiltration-like process linking the rainfall input with the groundwater recharge. The freshwater lens itself was seldom perceived as a specific entity, but rather an attribute of the soil itself (*water in the soil*). The sanitation elements were often skipped from the representation as if they were not part of the water cycle. This was relatively surprising as most of these people referred, when prompted, to pollution mechanisms during the photo interpretation exercise. Finally, the interaction with South Tarawa was described through engineering elements and links. The institutional and legal aspects were merely represented through negotiation between landowners and government (*Compensation* card).

Different table breakdowns gave more details about specific socio-cultural subgroups (Figure 12.5). First, higher educated people had a better understanding of complex processes (*Evaporation, Taxation*), and a better awareness of modern technologies *(Pump, Gallery*). This group hardly overlaps with a precise age group. If the young/middle age group mentioned *Evaporation* more often then their elders, this group was mainly characterised by a strong focus on financial negotiations with the government about the water reserves (*Landowner and Compensation* elements).

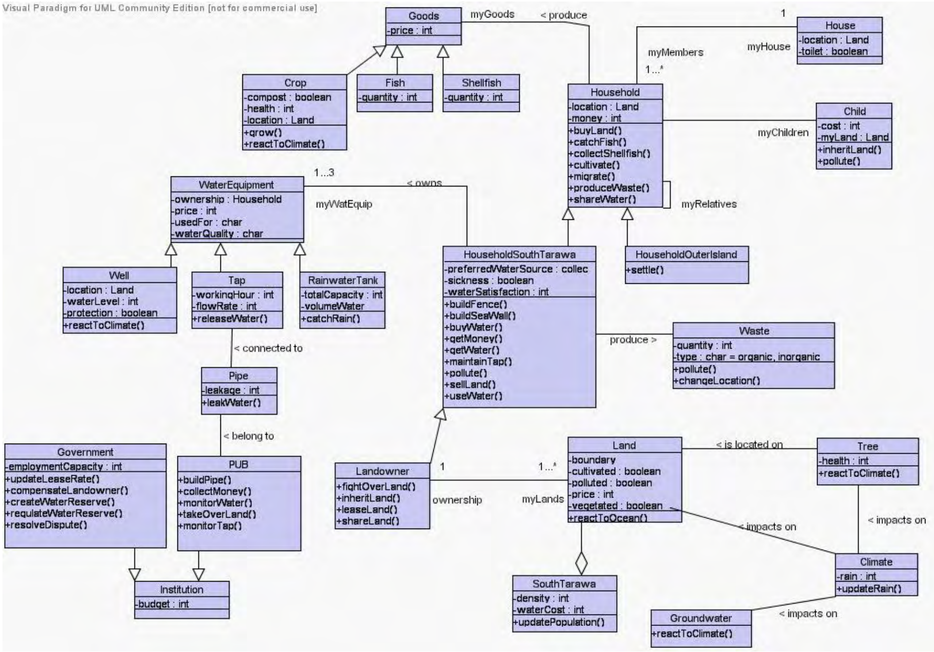
Figure 12.5. Overall table ranking most quoted elements during the card game

Overall	Stage 1		Stage 2		Stage 3	
	mean	top elements	mean	top elements	mean	top elements
overall (26)	9	Tree 85% Soil 69% Ocean 69% Infiltrating 50% Evaporating 46%	12	Watering 100% Well 96% Cooking 96% Washing 88% Feeding 85%	8	Pipe 96% PUB Tap 65% Gallery 65% Compens. 65% Reserve 62%

We were interested also in checking whether the government expert and council member groups would display specific features. So far, the latter group didn't show any specificity compared with the overall results, but the first group clearly demonstrated its (partial) belonging to the high education group (*Evaporation* and *Taxation* elements). Beyond this characteristic, the experts were almost the only ones to mention the pollution and sanitation elements in the water cycle (*Pollution*).

In conclusion, the GTA allowed us to collect valuable first-hand information. This information was used to design a bottom-line model of freshwater management on the atoll. A Unified Modelling Language (UML) based version of this model was used as a template to build a role-playing game, called *AtollGame* (Figure 12.6). A critical question was whether people shared equivalent representations of the hydrogeological processes. The GTA successfully demonstrated that almost everybody was able to describe an infiltration process leading to the recharge of an island-wide freshwater lens. This was of prime importance in order to step into the next phase of the negotiations.

Figure 12.6. UML-based Class Diagram representation of the common ontology



Finally, the ability of the interviewees to explain their mental constructs, to manipulate spatial entities on the map, to break down complex systems into simple elements and to accept to play games by the rules, confirmed the potential of success of a role-playing game during the next phase.

Results from the IAS

As mentioned in the methodology, the IAS was designed to partly validate the models elicited during the GTA, and to quantify some relationships described during the GTA. 24 people, all but 3 of whom were landowners, were interviewed.

Family members ranged from 3 to 18 on Tabiteua and Abatao, and from 3 to 16 on Buota and Bonriki. On an average, each family was composed of 8 members. We considered family to be the close family living in the same compound and sharing some facilities. Most of the time it included 3 generations from direct descend. The average size of a block of land was 2.5 acres. Most of the time, the blocks were collectively owned by different members of the family (between 2 and 10). The maximum size of a block was approximately 6 acres. Very often, other related families, according to the *extended family* concept, also occupied these blocks. On average, 3 other families were living on the same block as the interviewee, although the average value does not express the diversity (between 0 and 10).

In terms of employment, there was a huge difference between Tabiteua/Abatao where only one interviewee relied on a regular job and Buota/Bonriki, where nearly 75 per cent of the families had at least one regular income. On average, they generated AU$425 of monthly income. Subsistence economy was based on fishing (fish, shellfish), local product manufacturing (thatching, string), or local food marketing (coconut, papaya, toddy). On average, they generated a mere AU$140/week, but it was fairly hazardous to extrapolate this figure into a monthly income as most of these activities are irregular and subject to fundraising initiatives. Special attention was given to vegetable cropping activities. They mainly concerned Abatao (100 per cent of interviewees) and Bonriki (50 per cent of interviewees), where the average income jumped towards AU$250/week with a more regular pattern controlled by market niches (schools, hospital, and restaurants).

Each interviewee, with one exception, had access to a personal well. Again, there was a large difference in the use of alternative water sources between Tabiteua/Abatao (only one person collecting rainwater in drums) and Buota/Bonriki, where water collection was more diversified (38 per cent use of drums, 19 per cent use of PUB water, and 11 per cent use of rainwater tanks). On an average, families used 460 l of water daily. Given an average family size of 8 people, the consequent 58 l/person/day represented a rather high estimate of the usual figures quoted in the literature (between 30 and 50 l/person/day). One has to remember that most of the interviewees didn't face any problem of water availability, and that most of them enjoyed very good water quality. Hence, a resource with free access didn't limit consumption.

Furthermore, most interviewees confessed that everyone in the family, including children, was getting water from the well on an instant demand basis (90 per cent of cases). Consumption from families regularly watering their vegetable plots jumped to an average 100 l/person/day. Nearly 95 per cent of the interviewees considered their water as safe and didn't recall any health incident linked with water quality. Nobody on Tabiteua/Abatao considered that their island faced pollution problems, whereas 45 per cent on Buota/Bonriki complained about an increasing threat. It was an interesting that:

- 95 per cent recognised that grey water was just thrown away around the house;
- 25 per cent recognised that they were discarding solid waste on the beach; and
- 30 per cent recognised that they were discarding solid wastes in the bush (pit, hole).

Only a few interviewees mentioned watering the garden with grey water or composting the domestic waste. Nevertheless, 29 per cent admitted to regularly burning solid wastes. Regarding the Water Reserve issues, responses were slightly different for Tabiteua /Abatao (forecasted) and Buota/Bonriki (implemented). 44 per cent of the interviewees on Buota/Bonriki remembered that the government provided information about pumping, 31 per cent were not present at that time and only 25 per cent denied receiving any information. Nevertheless, nearly 50 per cent were not satisfied with the implementation by the government, 19 per cent had no comment, and only 31 per cent were satisfied with the implementation. In order to agree on the actual pumping, 31 per cent mentioned higher financial compensation, 19 per cent access to PUB water and facilities, 19 per cent requested the recognition of their rights. 44 per cent expressed strong doubts about the government's ability to manage properly the water pumping and distribution, whereas 25 per cent felt fairly confident about it, and 31 per cent had no opinion. On Tabiteua/Abatao the situation was clearer as we were discussing an ongoing process. All of the interviewees recognised that the government informed them beforehand, but 63 per cent disagreed with the implementation as they felt forced into it. While 50 per cent of the interviewees would like to enter financial negotiations with the government, 38 per cent remained strongly opposed to any move towards a water reserve on their island.

In conclusion, we would like to underline the fact that the IAS confirmed the fact that sanitation issues were largely disconnected from the water management consideration for most of the interviewees. Hence, we confirmed that the gap in the mental constructs elicited during the GTA largely overlapped with the behavioural models displayed during the IAS.

AtollGame: the model

Elements of design

As previously stated, the agent-based model and the corresponding role-playing game were designed according to the different viewpoints, converging or conflicting, recorded during the interviews. Freshwater lenses were perceived as global and undivided resources on each island, but few interviewees described the lens entity and its properties. Therefore, we decided to implement a very simple reservoir-like entity in the model. Through different descriptions, water infiltration into the soil is acknowledged by a majority of interviewees. Water uptake by vegetation and evapotranspiration processes were perceived far less and so we decided to use a very simple water balance model linking the groundwater with the atmosphere. Seasonality of the climate was differently perceived, and we decided to create a quasi-random rainfall allocation rule. Sea level rise and global change influences were kept as scenarios to explore.

Daily water use was generally described in same terms. Only a few interviewees linked solid wastes and grey water production to the infiltration process. We decided to focus mainly on daily water demand, and to let the sanitation issues arise from the game playing sessions later. Landowners, traditional or new buyers, are the essential actors in the negotiations with the government and it was decided that each active agent in the model, or player in the game, had to become a local landowner. The connection between land tenure issues and water management was an essential element. It drives the land-use restrictions and land leases discussions. For this reason it was decided to design the model around conflicting land and water allocation rules.

The population increase, mainly through immigration, was perceived as a threat in terms of water consumption, pollution generation and pressure on the land, and it was decided to submit the agents/players to increasing numbers of new settlers on their land. Financial issues linked with water management mainly dealt with land leases, equipment investment and, seldom, with water pricing. It was decided to allocate different types of income to the agents/players in order to activate these mechanisms.

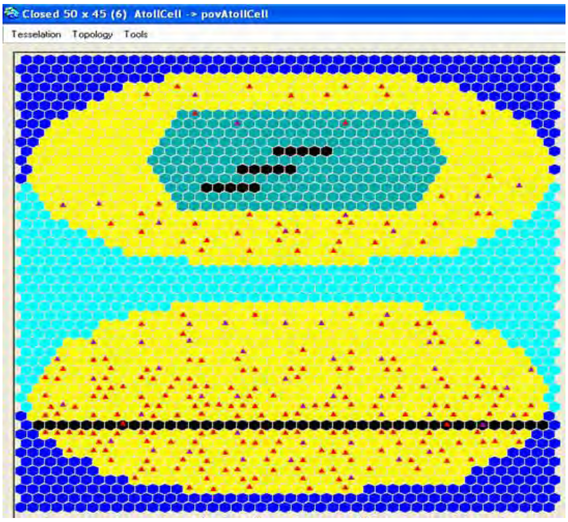
The virtual landscape

AtollGame was created with VisualWorks, using the CORMAS platform developed by Bousquet et al. (1998). AtollGame includes:

- Spatial active entities: *AtollCell;*
- Social entities: *Household* and *AgentPUB;* and
- Spatial passive entities: *Landuse, Wateruse* and *WaterBalance*.

Two 80 acre virtual islands were created, each one on a 25x45 regular spatial grid with hexagonal cells (Figure 12.7). Each unit cell corresponds to a 490m^2 land area. We decided to work on environments representing virtual islands in order to prevent stakeholders from feeling personally tackled. Island 1 corresponds to a low population island (50 families) where the government is already pumping freshwater. Island 2 corresponds to an overcrowded island (200 families), already polluted and depending on a freshwater adduction pipe for drinking water. Each hexagonal cell provides isotropy properties used to model freshwater lenses by generating isopiezometric circles. Each cell holds one *Landuse* passive entity, which can be tree, crop or bare soil type, and one *WaterBalance* passive entity.

Figure 12.7. AtollGame environment



AtollGame environment with top island featuring Water Reserve and pumping stations, and bottom island featuring a water distribution pipe. Triangles represent the landowners (in purple) and their relatives (in red).

The modelling time step corresponds to a 10 day period and the simulations are limited to 1 year. Several modelling viewpoints were created, directly accessible during the simulations, in order to represent key features of the system. The *Landuse viewpoint* visualises the eventual changes between the 3 land-use types. The *LensDepth viewpoint* allows the depth evolution of the Lens to be followed during the simulations. The *WellWater viewpoint* represents the water salinity evolution, varying between fresh, brackish and salty.

Water balance and hydro-geological models

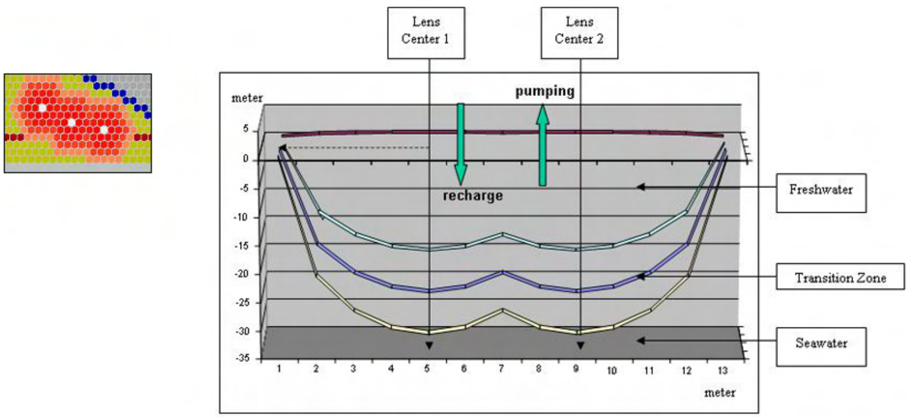
The recharge of the freshwater lenses is directly controlled by the infiltration rate through the unsaturated soil layers. The water balance is simulated within AtollGame using a slightly modified version of the mass-conservation driven model proposed by Falkland (1992) for South Tarawa. This 3-reservoirs-based model, called WATBAL, uses rainfall and Potential Evapotranspiration (PET) as input data. Runoff is not taken into account because of the high permeability of the coral sand soils. The first reservoir intercepts the rainfall at the vegetation level. The second reservoir corresponds to the soil water storage. The water entering the third reservoir corresponds to the recharge of the freshwater lens. Recharge of the lens may occur only after plants have satisfied their water requirements. Tree crops (mainly coconut trees in this case) are able to extract water directly from the lens. This model was adapted to AtollGame by bringing down the hydrological calculations at the level of each cell through its *Water-*

Balance and *Landuse* entities. Each instance of these two classes can operate its specific part of the water balance. Hence, AtollGame takes the spatial heterogeneity of the processes and their time dependence into account.

The shape and the depth of the freshwater lenses are calculated according to the model proposed by Volker et al. (1985). This model predicts the depth of the freshwater lens and the thickness of the transition zone from the recharge and uptake values, according to the maximum length of the lens. Two strong assumptions limit the use of this simple 2D-model: the recharge is constant, and the lens is in a steady-state condition. Hence, the model is often used for long-term predictions based on ten years averaged data. This vertical, 2D representation had to be adapted to the AtollGame distributed grid (Perez et al. 2003).

Some cells have been selected and designated as lens centres or nuggets. Using the isotropy property of the grid, each nugget is surrounded by concentric circles of isopiezometric cells. The orthogonal distance between the lagoon and ocean shores, crossing the nugget gives the value of the radius (L). The distance between 2 nuggets may be smaller than their respective radius; in this case, a common cell is given the deepest value calculated at each time step. The global shape of the lens corresponds to overlapping bowls (Figure 12.8).

Figure 12.8. Representation of the freshwater lens in AtollGame



Nuclei and izopiezometric areas (left), and corresponding volume (right)

The hydrological model, using outputs from the water balance model, provides an update of the cell's attribute *depth* at each time step. This attribute is then used to specify the water quality of the lens by updating the cell's attribute *wellWaterQuality* according to a simple rule: if the depth is lower than 1.6 m, the water is considered as salty, if the depth is higher than 3.1 m the water is said to be fresh, and in between the water is brackish.

Social entities

Two classes of social entities were defined. On Island 1, 50 *Household* agents have been created. They all represent a family but only 11 are *landowners*, the rest are *relatives*. On Island 2, there are 200 *Household* agents, 42 of whom are *landowners*. The initial locations of the households are saved in the environment. The main attributes of each *Household* are: the size, the drinking and domestic water requirements, a list of *Wateruse* equipment, and a consumption satisfaction index. Theoretical demands are set up to estimated levels of 20 l/day/person for drinking water on Island 1, and 40 l/day/person on Island 2. For both islands, the domestic water consumption has been fixed at 40 l/day/person. Households are all provided with a well, some are given a rainwater tank and some, only on Island 2, have a connection to the water pipe. The decision process dealing with water consumption follows a simple rule: households satisfy their drinking water needs from their rainwater or PUB connection, if any, and supply their domestic water demand from their well. If they only have a well, they use it for both purposes, taking the risk of drinking brackish or salty water according to their well water quality. The water availability is updated at each time step according to the type of equipment. Groundwater extraction from individual wells is limited by a maximum depletion rate in the vicinity of the well.

One process accounts for population growth through the introduction of new relatives at the beginning of each time step. The *AgentPUB* class contains only one instance representing the Public Authority Board, in charge of the water distribution among the population. At this stage of the model, social interactions focus only on the competition for water between households and the management decisions from PUB. The *AgentPUB* is characterised by the volume of water pumped from Island 1 and given to Island 2. The pumping rate is initialised at 150 m^3/time step. The distribution among the different households on Island 2 is driven by their ranking distance along the main pipe. The *AgentPUB* can modify its pumping rate according to the average recharge rates.

AtollGame: the role-playing game

Conceptual framework

A role-playing game has been designed as a medium of communication based on the existing conceptual model. It is meant to open or develop the communication between stakeholders. In a well-designed role-playing game, players are aware of the issues at stake, but allow themselves to express their views and behave accordingly to their beliefs. Another fundamental characteristic is the ability of the role-playing game to generate collective scenarios that will explore new management avenues. In order to achieve these tasks, the role-playing game must:

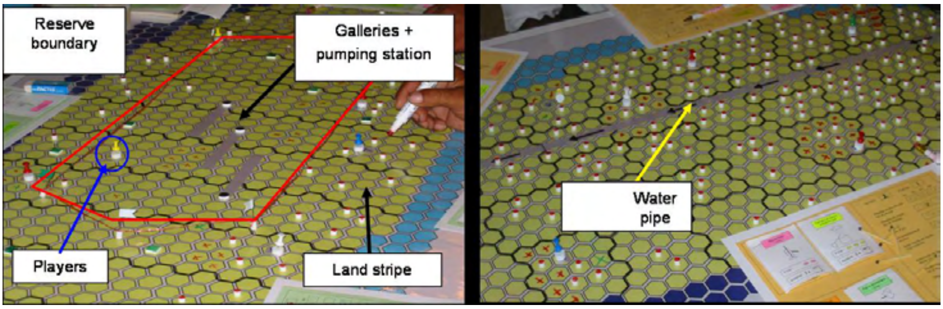
- *represent* simplified features and processes encountered in reality (in particular, biophysical processes, social interactions and spatial descriptions should be understood and accepted by all players as plausible assumptions);
- *secure*, at every stage of the game, the neutrality of the selected rules and of the Game Master decisions (this *fair game* is instrumental in helping players build self-confidence and advocate their viewpoints); and
- *create* opportunities for players to comment, modify and improve the rules (the game is intentionally designed with a rudimentary set of rules that needs improvement).

Thus, players come progressively from playing against each other towards a situation where they appropriate the game collectively. Finally, when players have realised the collective benefit of the game, they tend to explore more complex situations and to implement more rules. Most of the time, the increasing complexity tends to bring the artificial game and the real environment together. What is at stake with this approach is to give the local stakeholders the capacity to build their future together. Instead of asking foreign expertise to provide an hypothetical best solution, this expertise is used to help local people adopt equitable management of the resource. Of course, manipulation, lobbying, struggle for power are inherently part of the process, but in an armless and controlled environment.

The game

Two game boards, identical to the computer-based visual maps, are used. Board 1 represents a scarcely populated island where the government is already pumping freshwater. Board 2 represents an overcrowded island where the government needs to provide drinking water (Figure 12.9). On each island, 8 players are allocated numbered locations. On the first board, the water reserve boundaries, and pumping galleries are physically represented. On the second board, the main pipe is delineated by a stripe of adhesive. Each player takes the role of a landowner who needs to provide enough water to his/her family during the game. In order to do so, players have to invest wisely in different types of equipment.

Figure 12.9. Island 1 (left) and Island 2 (right)



The players

At the beginning of the game, each player randomly draws a card that defines his/her personal profile in the game. The players' profile includes: job type, family size, water needs and initial equipment. On Island 1, amongst the 8 players, 1 is a public servant, 3 are seamen and 4 have no job. On Island 2 the distribution is slightly different: 3 public servants, 3 seamen and 2 have no job. They earn virtual money from their jobs (2–6 tokens) in the form of matches. The relatives living or arriving on their land at the beginning of each round can cost them money (–2 or –1 tokens), or provide some additional income (0–2 tokens).

The duration

The game spreads over 2 daily sessions. Within each daily session, 4 rounds (each equivalent to a 3-month season) are to be played. The first round corresponds to a good rainy season (550 mm), the second one to a very bad season (190 mm), the third and fourth rounds only replicate the data from the first round. On Island 1, the pumping rate from the government is steady and corresponds to a 150 m^3/day. On Island 2, the government is providing the local residents 150 m^3/day through the pipe.

The objective

The individual objective of the players is to minimise the number of angry or sick people in their household. People may become *angry* because they didn't have enough water to drink during the round. People may become *sick* if they drank unhealthy water during the round. Unhealthy water is when the water is polluted or salty. *Pollution* depends on the number of people living on the island, and contaminating the freshwater lens. *Salty water* depends on the recharge rate of the freshwater lens and the location of the players on the island. Rainfall and pumping rates affect the level of recharge. Rainwater or water from the adduction pipe are safe to drink.

In order to provide drinking water to their family, players are given *buckets* at the beginning of the game. One bucket can store 20 litres each day. One person is supposed to need 20 litres of drinking water each day. The initial number of buckets is lower then the family's needs by 2 or 3 buckets. In order to provide enough water to their family, the players have to *buy* equipment that will increase their storing capacity, counted in equivalent-buckets. A manual *pump* costs 2 tokens and provides 2 more buckets of storing capacity. A *rainwater tank* costs 3 tokens and provides 5 more buckets of storing capacity. A *PUB tank* costs 3 tokens and provides 5 more buckets of storing capacity.

Normally, the rainwater tank and the *PUB tank* automatically refill at the end of each round. But, if the rainfall during the round was not sufficient, the rainwater tanks remain empty. The same happens with the PUB tanks if the adduction pipe cannot provide enough water during the round.

Players can decide to farm vegetable gardens in order to increase their income. Each *crop* card costs 1 token and needs 4 extra buckets of water for irrigation at each round. The profit from the crop depends on the climate. If the round was rainy, then the crop provides 2 extra tokens to the player. If the round was dry, the crop failed and there is no extra income.

Playing rounds

First session

During the first session, dedicated to individual strategies, players have to accommodate new relatives on their land and adjust their income correspondingly. According to their available cash, they may choose to invest on new equipment and/or decide to crop. The rainfall conditions influence groundwater salinity, storage in rainwater tanks and crop yields. This session allows players to perceive the impact of the location on their well's water quality: the closer to the lagoon or ocean, the saltier groundwater becomes during drought periods.

At the end of the first session, one player on Island 1 is given the opportunity to sell part of his land to a new (virtual) settler, he can accept or not. At the same time, on Island 2, one player is given the opportunity to leave his land and to relocate on Island 1 if he can make a deal with another player on that island. This is meant to introduce the first interaction between the 2 tables.

Second session

The second session is dedicated to collective decision-making. First, the game master introduces one collective event card on each island. On Island 1, the card mentions that the government has decided to get rid of all the settlers and crops located on the reserve. Players have to relocate their relatives and they loose the removed crops. On Island 2, the card mentions that the government has decided to raise a connection fee from each dwelling connected to the pipe. One player, selected randomly, is given the task of fulfilling the government decisions. This player leaves his *landowner* role and becomes a *Water Agency* player. As such, he freely negotiates with players on both islands. His task is amplified with the introduction, at the second round, of one collective event on Island 2: due to financial issues, the government cannot maintain the distribution pipe properly. As a consequence, the discharge falls to 75 m^3/day. Another event is introduced on Island 1 during the third round: due to water shortage on Island 2, the government decides to increase the pumping rate from 150 m^3/day to 250 m^3/day.

Within the computer-based simulator, the *AgentPUB* entity represents the water agency in charge of the water distribution among the population. The *AgentPUB* controls the volume of water pumped from Island 1 and transferred to Island 2. The initial pumping rate on Island 1 is adjusted according to the demand. The distribution on Island 2 is driven by the Household entity's position along the pipe.

Outcomes from the role-playing game

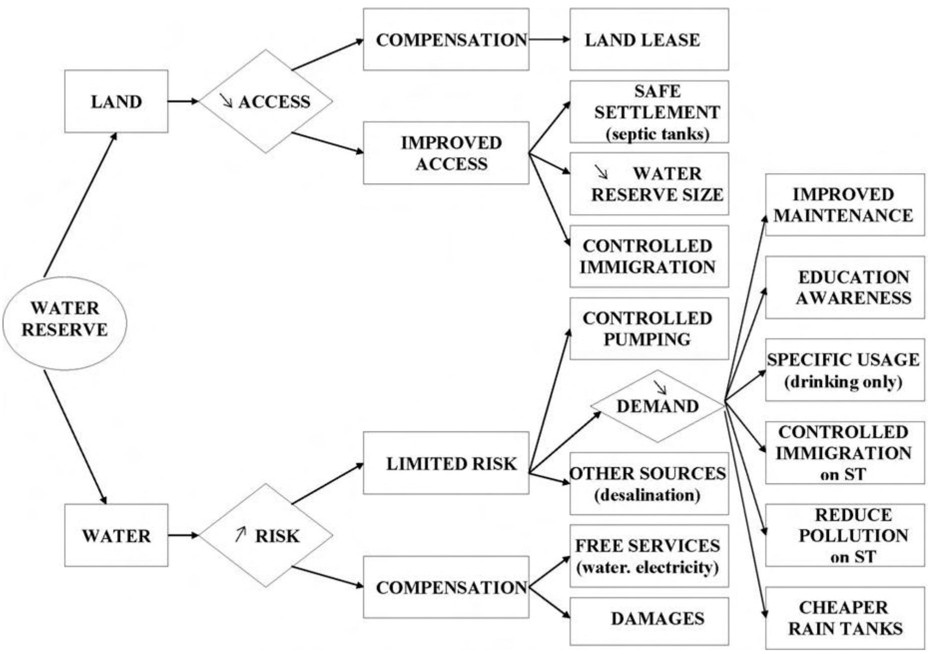
At first, it was encouraging to see that representatives from the different islands displayed different viewpoints about the water reserves. The group meetings organised in the villages prior the workshop allowed for a really open debate. On the institutional side, the position of the different officers attending the workshop demonstrated a clear commitment to the project. All the participants showed the same level of motivation either to express their views on the issue or to genuinely try to listen to other viewpoints. Participants also accepted to follow the rules proposed by the Game Master, especially the necessity to look at the problem from a broader perspective.

During the first session, the players quickly handled the game and entered into interpersonal discussions and comparisons. The atmosphere was good and the game seemed playful enough to maintain the participants' interest. Most players experienced the fact that individual strategies were strongly dependent on environmental uncertainties. Interaction between the 2 tables started when one player from the Island 2 was given the opportunity to move to Island 1. The bargaining process that emerged from this new situation illustrated the actual tensions existing around the land tenure market in the real situation. The connection between water management and land allocation issues was clearly demonstrated by the players' behaviour.

The second day, the introduction of a water agency and the selection of its director created a little tension among the participants. But, after a while, the players accepted the new situation as a gaming scenario and started to interact with the newly created institution. On Island 1, the decision to remove crops and settlers from the water reserve immediately generated animated discussions among players. On Island 2, the recovery of service fees from the players connected to the distribution pipe had the same effect. At that stage, players started to merge arguments based on the game with other ones coming directly from reality. On Island 1, players entered direct negotiations with the Director of the water agency. On Island 2, opposing discussions occurred between players willing or not to pay the fee.

Finally, the Game Master introduced the fact that the water agency was no longer able to maintain the reticulated system due to a poor recovery of the service fees. It had the immediate consequence of a sharp decrease of the quantity of water offered on Island 2. At this stage, all players gathered around Island 1 and entered a collective debate on the water reserve management. Consequently, players were asked to go back to their table and to list solutions to improve the situation on their island. When the 2 lists were completed, the Game Master helped the participants to build a flowchart of financial, technical and social solutions (Figure 12.10), taking into account issues from both islands.

Figure 12.10. Flowchart of financial, technical and social solutions



Exploring scenarios

A collective analysis of the flowchart concluded that the actual situation was largely unsustainable either from a financial or social viewpoint. The government relies on the land leases (top part of the flowchart in Figure 12.10) in order to secure social acceptance of the water reserves. The land market already pushes land prices to levels that can't be matched by government leases. Beside, other technical solutions (desalination plants or improved distribution) are not yet directly linked with the water exploitation issues on the islands. Some local residents claim that the environmental risks created by the pumping in the water reserves should be compensated as well. These *Damages* (bottom part of the flowchart) should be given to all the permanent residents of the island, besides the land leases granted to the concerned landowners. But fewer claims were made for negotiated and regulated use of the water reserves, somehow weakening the environmental risk claim.

The flowchart (Figure 12.10) provides a set of interdependent solutions that should be explored in order to gradually unlock understanding of the present situation. Whether we look at already existing or forecasted water reserves, the following guidelines are highly relevant:

- the financial solutions could be mitigated with technical solutions including regulated access to the water reserves or participatory management of pumping;
- the water exploitation issues could be more strongly linked with the water distribution ones, and eventually with the sanitation ones (keeping in mind that the latter are generally disconnected from the other issues for most people).
- exploring the middle part of the flowchart would enable more *consensual* stakeholders to participate in negotiations that are presently dominated by more extremist views; and
- management issues on the existing water reserves (Bonriki and Buota) and implementation issues on the forecasted ones (Abatao and Tabiteuea) are inherently interrelated. On one side, creating new water reserves without confronting the actual problems on the existing ones is not viable. On the other side, the introduction of new actors in the debate helps reduce the actual bipolar confrontation between landowners and the government on the existing water reserves.

Discussion and perspectives

Instant debriefing

At the end of the 2-day workshop, the project team held what we called an *instant debriefing*. Beyond our satisfaction of having conducted a playful and fruitful exercise, our analysis focused on the ways to transform the scenario-flowchart into a viable road map for the government. Careful study of the memos (videos, notes, and game spreadsheets) revealed the existence of 2 types of strategic behaviour among players that would strongly influence the outcomes. Final discussions around the flowchart were highjacked by a minority of *pseudo-players*. These were local stakeholders who came with a strong agenda in mind and tried to enforce their views throughout the game. As requested, they were indeed outspoken representatives but were not prepared to compromise. The role-playing game failed to modify their position and, for example, they locked the discussions into endless arguing about financial compensations. However, the game helped more consensual players to move some distance from these extremist views and to advocate a more flexible approach to future negotiations.

In contrast, some representatives of government agencies appeared to be *virtual-players*, without any mandate for taking a decision to their home institution. As previously mentioned, only one player was part of the SAPHE Steering Committee, all others were not directly involved in the decision making process regarding the water reserves issues. These players played a fair game but hardly attempted to defend their agency's policy. Hence, the role-playing game was only perceived as a mere exercise in communication.

It was highly recommended that the next steps involve a sequential process for interactions. First, experts from the relevant government agencies should be confronted with a new version of the computer-based simulator, including most of the options present in the existing flowchart. The experts would help select affordable scenarios for the government and tune the parameters. Then, these scenarios should be presented in the different villages through collective meetings where people would have the opportunity to interact with the computer simulations. Evaluation of the government criteria and scenarios would lead to the creation of newly modified ones. At last, the government experts and the island's representatives should meet again to assess the remaining options and hopefully agree on an equitable management scenario.

Distant debriefing

At the end of May 2004, the project team returned to Tarawa to implement the strategy outlined above. Unfortunately, soon after our arrival, we were informed that the SAPHE Steering Committee had decided to organise meetings with the local communities on Tabiteuea and Abatao. The official objective of these meetings was to present the design of the pumping galleries to the local residents and to seek their agreement in principle. During separate meetings with members of the Steering Committee, the project team tried to underline the inherent risk linked to this hasty decision:

- The SAPHE Steering Committee relied on a design extracted from a technical report (Falkland 2003) that was not meant to be a final blueprint for implementation. The report carefully investigated the hydro-geological conditions prevailing on Abatao and Tabiteuea and provided some guidance in terms of positioning (distance to actual settlements). There was no mention of land ownership issues, demographic growth or pollution control.

- The SAPHE Steering Committee was not yet able to provide complete information to the local communities about financial arrangements, land use constraints or other compensation claims eventually raised by some local residents. Beyond, the local negotiation issue, these elements are instrumental in evaluating the economic viability of such a technological option. Falkland (2003) was very cautious regarding this specific aspect in his recommendations.
- The SAPHE Steering Committee didn't take into account the outcomes of the role-playing game workshop, which provided a tentative road map for further negotiations, including financial and technical aspects. It was obvious that an upfront confrontation would re-ignite the water lease issue. Besides, the present state of mind of a majority of residents on Abatao needed to be dealt with cautiously in order to avoid any more damage.

Despite the concerns above, the SAPHE meetings were confirmed but the Steering Committee accepted that our project team attend the meetings as observers. As expected, the meetings held in Tabiteuea and Abatao would have benefited from a careful analysis and better understanding of the outcomes of the role-playing game workshop. Whether they agreed with the water reserve, local residents constantly referred to our final flowchart. These meetings resulted in back-stepping and a sterile process in which a majority of local residents focused again on the financial aspects of the question.

The reason for this apparent backlash from the Steering Committee is partly to be found in the absence of crucial *meta-players* during the role-playing game sessions. As shown on Figure 12.7, the Asian Development Bank (ADB), the project contractor, and the government cabinet control the financial, technical, and political agendas of the SAPHE project. One year before the end of the loan-based project, technical delivery from the contractor became essential in order to secure the last payments and to turn on the loan reimbursement countdown. At the political level, the Cabinet was entangled in multiple discussions with the ADB and other funding agencies. The Steering Committee, instead of being a driving force, had become an arena for external and conflicting pressures.

Despite our genuine claim that the results from the role-playing game were far from being detrimental to the SAPHE project, and that further negotiations with local communities would need far less than 6 months, the financial and technical agendas prevailed. Beyond the timing issue, it is also assumed that acknowledging the results of our project would have been considered by some members of the Steering Committee as a recognition of their incapacity to tackle the problem in the first place.

The incapacity at the political level to handle the uncertainty of the situation was demonstrated by a first decision to freeze the SAPHE project (October 2004), and then to accept its implementation (January 2005) without modification. The frustrating consequences were that more than 6 months were lost in the process and that the local communities ended up as frustrated as usual. An interesting final twist is the actual willingness of PUB to resume collaboration with our research team in order to develop a more participatory approach in the future. This struggle between centralised and decentralised management is epitomised in the concept of polycentric institutions developed by Ostrom in her most recent work (2005). Technical agencies such as PUB often rely on deductive scientific approaches to reach outcomes that would need more inductive and flexible solutions. But flexibility means that one must assume some uncertainty during the implementation and give up hope of deterministic and predictable solutions (Bradshaw and Borchers 2000). What is true at the technical level becomes paramount at the political one.

There is a need for integrating not only the participation but, more importantly, the engagement of local communities in projects that concern their future. Following Aslin and Brown (2004), we argue that local communities need to be involved not only in the analysis of the results (consultation) or the choice of the possible scenarios (participation), but in the knowledge creation itself (engagement). This is the *post-normal* way chosen, for example, by colleagues working on Companion Modelling approaches (Bousquet et al. 2002).

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