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Companion Modelling approach: the AtollGame experience in Tarawa atoll (Republic of Kiribati)

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Companion Modelling approach: the AtollGame experience in Tarawa atoll (Republic of Kiribati)

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EXTENDED ABSTRACT

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. The declaration by the Government of Kiribati of water reserves on the atoll of Tarawa, over privately owned land, has lead to conflicts, illegal settlements and vandalism of public assets. Beside, the water consumption per capita tends to increase towards western-like standards, threatening the sustainability of the actual exploitation system. Finally, pollution generated by the 45 000 habitants of South Tarawa has already contaminated all the freshwater lenses, with the exception of the existing reserves so far.

Our project, called AtollGame, aims at providing the relevant information to the local actors, including institutional and local community representatives in order to facilitate the dialogue and devise together sustainable and equitable water management practices. Multi-Agent Based Simulations (MABS) coupled with a Role-Playing Game have been implemented to fulfil this aim. 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 3-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 in order to explore different scenarii and their simulated outcomes.

Although game sessions delivered successful outcomes, the final stage of the project is characterised by the upheaval of contradictory Government stands that undermine the whole process. It is argued that heterogeneous viewpoints may be handled in a satisfactory manner during the gaming sessions, but that long-term hidden agendas may override the outcomes. Beyond the inherent question of legitimacy attached to such approaches, it is clear, from our experience, that some players – especially those representing Government or supra-national institutions – have to deal with constraints that are often genuinely first considered as external to the on-going negotiation process.

1. 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 (see Fig.1). The water resources are predominantly located in freshwater lenses on the largest islands of the atoll. The water table is typically 0.8 to 1.6m below ground surface. South Tarawa is the capital and main population centre of the Republic. Pollution generated by its 45 000 habitants has already contaminated most of the freshwater lenses. Hence, the water supply for South Tarawa inhabitants is pumped from horizontal infiltration galleries in protection zones with restricted access called « water reserves », on Bonriki and Buota islands. The galleries, connected to a reticulation system provide fresh water via individual taps all along South Tarawa. The Public Utility Board (PUB) is the Government owned corporation in charge of the water exploitation and water supply for South Tarawa.

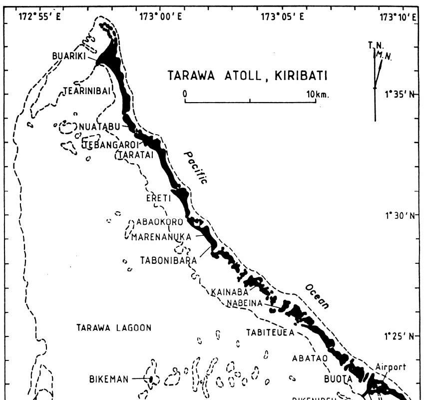

Figure 1: Tarawa Atoll. Bonriki and Buota islands are on the lower right of the atoll

The water reserves currently supply about 1300 m^3/day, equivalent to about 30L/capita/day of freshwater, representing 60% of the needs of South Tarawa's communities. The water consumption per capita tends to increase towards western-like standards, threatening the sustainability of the actual exploitation system. With an estimated 50% losses, the reticulated system is unable to meet the demand. Water is therefore supplied for only a few hours per day as a *de facto* demand management tool. Only a limited number of households have adopted rain harvesting technologies. Unfortunately, roof installations are often poorly managed (Carpenter *et. al.,* 2002). Traditional wells remain an essential source of freshwater although they are anything but reliable. They are excavated close to the dwellings, very often located next to the lagoon-side shore. Hence, during extended drought spells, freshwater lenses shrink and the wells become increasingly brackish.

Landownership and traditional landuse rights are central issues in the establishment of water reserves. As a matter of fact, land provides groundwater, food, attendant fishing rights and cash income from coprah harvesting (Jones, 1997). Traditional landownership includes underground resources, a fact poorly appreciated when water reforms were proposed. Thus, the creation of water reserves has lead to conflicts, illegal settlements and vandalism of public assets (White *et al.,* 1999). Payment of adequate compensation and restricted landuse are continuing contentious issues. Wider communities regard designated water reserves as common pool resources that can be easily plundered.

The Government of Kiribati has obtained in 1999 a loan from the Asian Development Bank in order to finance the US $10.24 million SAPHE project (SAnitation, Public Health and Environment). This project aims at improving the exploitation, distribution and sanitation system on South Tarawa. It is driven by a Steering Committee involving the PUB, the Ministry of Works and Energy, the Ministry of Environment, the Ministry of Finance, the Ministry of Health, and the Land Department. On the exploitation side, it was proposed to rehabilitate and extend the existing water reserves. Hence intensive groundwater investigations were conducted on the islands of Abatao and Tabiteuea (north of Bonriki and Buota) in order to delineate the freshwater lenses and to provide accurate estimates of the sustainable water yields. Although previous reports insisted on the necessity to take into account the social impact of the new water reserves - in order to avoid the problems encountered on Bonriki and Buota - not much attention was given to this issue. As a consequence, contrasted viewpoints arose within the Steering Committee regarding the legitimacy of these water reserves when cost-efficiency, social impacts and long-term sustainability were to be compared with alternate solutions.

Addressing a demand from the Ministry of Works and Energy seeking for new participatory approaches, our project aims at providing the relevant information to the local actors, including institutional and local community representatives in order to facilitate the dialogue and devise together sustainable and equitable water management practices. A Role-Playing Game coupled with an computer-based simulator is implemented in order to fulfil this aim. This coupled approach provides powerful means for studying interactions between societies and their environment (Bousquet et. al. 2002). It has demonstrated its capacity to promote discussion amongst stakeholders with contrasted and eventually conflicting viewpoints (D'Aquino et. al., 2003). The success of the approach is inherently correlated with the ability of the players to identify their own mental constructs with the game's features. Thus, it appears essential to format the game according to stakeholders' standpoints. However, Becu *et. al*. (2003) showed that using knowledge elicitation techniques to infer formal ontologies was anything but trivial.

Dray et al. (2004, *in press*) describe the methodology developed to collect, understand and merge viewpoints coming from different stakeholders in order to build a shared representation of the system through a conceptual model using *Unified Modeling Language* (UML). Applying a semi-automatic process using qualitative analysis softwares, it is possible to create from individual and fragmented narratives, a collective and consensual UML-based representation of the system. The common representation is used to build the essential elements of the role-playing game while conflicting issues are incorporated into the flexible design of the playing sessions.

2. Conception of the computer-assisted RPG

2.1 Conceptual framework

The RPG is designed as a medium of communication based on the existing conceptual model. It is meant for opening or developing the communication between stakeholders. In a well-designed RPG, 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 RPG to generate collective scenarios that will explore new management avenues. In order to achieve these tasks, the RPG must represent simplified features and processes encountered in the reality. In particular, biophysical processes, social interactions and spatial descriptions should be understood and accepted by all players as plausible assumptions. The RPG must also 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 to build self-confidence and to advocate their viewpoints. The RPG should create opportunities for players to comment, modify and improve the rules. Indeed, the game is intentionally designed with a rudimentary set of rules that needs improvement. Thus, players come progressively from playing against each other to a situation where they appropriate the game collectively.

Finally, when players have realized the collective benefit of the game, they tend to explore more complex situations and to implement many more rules. Most of the time, the increasing complexity tends to bring together the artificial game and the real environment. What is at stake with this approach is to give stakeholders the capacity to build their future together. Of course, manipulation, lobbying, struggle for power are inherently part of the process, but in an armless and controlled environment.

2.2 Game boards and virtual landscape

The set of the game is composed of two maps displayed on separated tables. Both maps represent a 80 acres virtual island, based on a regular spatial grid with hexagonal cells. Concurrently, a similar computer-based environment is created with VisualWorks©, using the CORMAS© platform (Bousquet et al., 1998). These environments include generic features without direct references to actual islands in order to avoid any threatening feeling among players.

Island 1 (Fig. 2) corresponds to a scarcely populated island (50 families) where the government is already pumping freshwater. The water reserve is delineated with a red line and pumping galleries are explicitly represented. Island 2 (Fig. 2) corresponds to an overcrowded island (200 families), already polluted and equipped with a distribution pipe for drinking water.

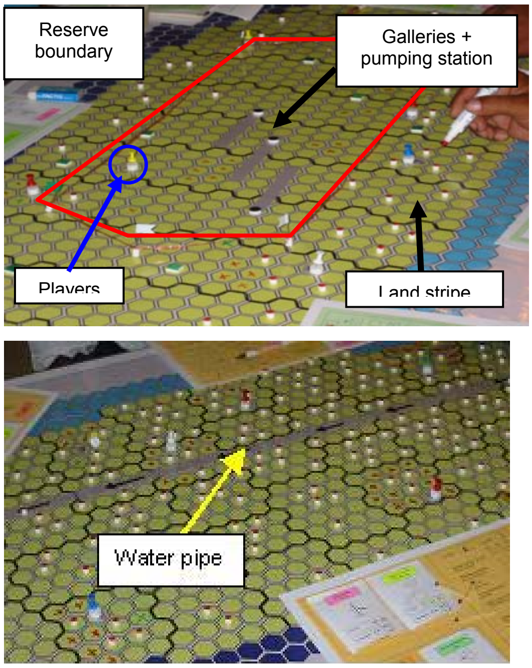

Figure 2: Island 1 (top) and Island 2 (bottom)

2.3 Water balance and hydro-geological models

Biophysical processes and landuse dynamics are encapsulated into the computer-based simulator. According to the field interviews, freshwater lenses were perceived as global and undivided resources on each island. Water infiltration into the soil was acknowledged by a majority of interviewees. Runoff was not a concern due to the very high permeability of the coral-sand soils. Water uptake by vegetation and evapotranspiration processes were far less perceived. Therefore, we opted for a simple reservoir-like water balance model for our computer-based simulator. The model, called WATBAL (Falkland, 1992), uses 10-day period values of rainfall and potential evapotranspiration (PET). The first reservoir intercepts the rainfall at the vegetation level ; the second reservoir corresponds to the unsaturated soil storage and the third reservoir corresponds to the freshwater lens. Recharge of the lens may occur only after plants have satisfied their water requirements. Pumping galleries, traditonal wells, and coconut trees are able to extract water directly from the lens. Using the Cellular Automata capacities of our simulator, the water balance is calculated for each cell allowing the spatial heterogeneity of the processes and their time dependence to be taken into account.

The shape and the depth of the freshwater lens is 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 (radius). Two strong assumptions limit the use of this simple 2D model: (1) the recharge is constant, and (2) 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 2D model was modified into a 3D-like simulator using the isotropic properties of the mesh (Perez et al., 2003). To do so, some cells were selected and designated as lens nucleus, surrounded by concentric circles of isopiezometric cells. The orthogonal distance between the lagoon and ocean shores, crossing a nucleus gives the value of the corresponding radius (L). The elongated lens is approximated by a succession of these elementary units. The global volume of the lens corresponds to overlapping bowls.

For a given cell, the freshwater thickness is given by the attribute *depth*. The hydrogeological model calculates each individual depth after averaging inputs and outputs over the whole freshwater lens. This attribute is then used to specify the water quality by updating the cell's attribute "*wellWaterQuality*" according to a simple rule: if the *depth* is lower than 1.6m, the water is considered salty, if the *depth* is higher than 3.1m the water is considered fresh, and in between the water is declared brackish. This salinity index is visually accessible to the players at any time.

2.4 Players

According to the field interviews, the connection between land tenure issues and water management was a paramount element in the negotiations with the government. Beside, the population increase - mainly through immigration - was perceived as a threat in terms of water consumption, global pollution and pressure on the land. Thus, it was decided to design the game around land and water allocation conflicting rules. Each player, at the beginning of the game, becomes a local landowner having to accommodate an increasing number of incoming settlers.

Each game board welcomes 8 players in order to facilitate playful interactions. This even number of players does not respect the real population densities in North and South Tarawa. These differences were taken into account with the creation of Household entities unevenly distributed among the two islands. They are represented by red pawns on the game boards. The corresponding agents in the computer-based simulator are divided into *landowners* or *relatives*.

Field interviews also showed that financial issues linked with water management mainly dealt with land leases, equipment investment and, seldom, with water pricing. Thus, it was necessary to allocate different types of income to the players in order to activate these mechanisms. Players can either be public servant, seamen or unemployed and are given corresponding tokens at the beginning of each round. The relatives settling on their land can cost the players money or provide some additional income. At the beginning of the game, each player randomly draws a card that defines his/her personal profile in the game: land location, type of job, and family size.

2.5 Players' objective

Players are given the task to provide enough water to their family at each round in order to minimize the number of angry or sick people in their house. People become angry if they didn't have enough water to drink and sick if they drank unhealthy water (salty or polluted). Spatially distributed salination processes are calculated and displayed by the computer-based simulator. As far as pollution processes remain conflictual among stakeholders, it was decided to introduce them as an arbitrary *Pollution* event during the game.

In order to provide drinking water to their families, players are given *buckets* at the beginning of the game that can store 20 L/day roughly equivalent to daily individual needs. On purpose, the initial number of buckets is lower then the players' needs. Thus, they have to buy equipments (pump, rainwater tank or PUB tank) that will increase their storing capacity. Usually, the rainwater tanks and PUB tanks automatically refill at the end of each round unless insufficient rainfall occurs. Players can decide to farm vegetable gardens in order to increase their income providing they have enough money and sufficient water storing capacity for irrigation at each round. The profit from the crop depends on the climate.

2.6 Duration

The game consists in 2 sessions of four rounds, each equivalent to a 3-month season. Initially, on Island 1, the pumping rate from the government is steady and corresponds to a 150 m3/day. On Island 2, the government is providing the local residents 150 m3/day through the pipe. As a matter of fact, in order to secure the consistency of the hydrogeological model, the computer-based simulator ran on a 10-day time step basis. Therefore, one round in the game accounts for 9 time steps in the model.

2.7 Playing rounds

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 water equipments and/or decide to crop. The raining 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 side, 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 two tables.

The second session is dedicated to collective decision-making. On Island 1, the game master mentions the fact 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 government has decided to raise a connection fee from each dwelling connected to the pipe. One player, selected randomly, is given the task to fulfil the government decisions and becomes a "Water Agency" player. As such, he freely negotiates with players on both islands.

3. IMPLEMENTATION OF THE COMPUTER-ASSISTED RPG

3.1 Convocation

In April 2004, the 2-day workshop held in Tarawa gathered 16 representatives: 1 from the Public Utility Board, 1 from the Ministry of Environment, 1 from the SAPHE project, 1 from the Land Department and 3 from each of the concerned islands (Bonriki, Buota, Abatao and Tabiteuea). For the representatives of the aforementioned islands, the selection was entirely handled by the local communities, taking into account only two requests from our project team: (i) selecting outspoken individuals and (ii) expressing contrasted viewpoints within the community. A formal invitation was sent to members of the SAPHE Steering Committee. They were given the choice to come themselves or to delegate the task to another representative of their Ministry. Only one out of four (i.e. the SAPHE Project manager) came, all others chose to delegate.

3.2 Outcomes

At first, it was encouraging to see that representatives from the different islands displayed different viewpoints about the Water Reserves. 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. Most players experienced the fact that individual strategies were strongly dependent on environmental uncertainties. Interaction between the two 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, in the reality, around the land tenure market. 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 vivid 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 the reality. On Island 1, players entered direct negotiations with the Director of the Water Agency. On Island 2, discussions opposed 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 for immediate consequence a sharp decrease of the water quantity 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 two lists were completed, the Game Master helped the participants to build a flowchart of financial, technical and social solutions (Fig.3), taking into account issues from both islands.

3.3 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 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, improved distribution) are not yet directly linked with the water exploitation issues on the islands.

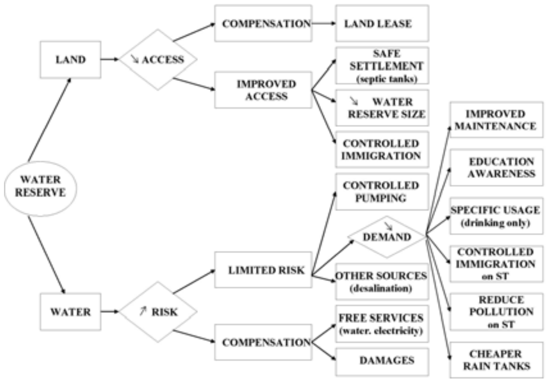

Figure 3: Flowchart of financial, technical and social solutions

The flowchart above provides a set of inter-dependent solutions that should be explored in order to gradually unlock 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 the 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 later are generally disconnected from the others by 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. 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 reducing the actual bipolar confrontation between landowners and the Government on the existing Water Reserves.

4. Discussion and Perspectives

4.1 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 two 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 not prepared to compromise. The RPG failed modifying their position and, for example, they locked the discussions into endless arguing about financial compensations. However, the game helped more consensual players to take some distance from these extremist views and to advocate a more flexible approach of the future negotiations.

On the contrary, some representatives of Government agencies appeared to be *virtual-players*, without any mandate for decision back 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 RPG was only perceived as a mere exercise of communication.

Hence, 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 selecting affordable scenarios for the government and tuning 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.

4.2 Distant debriefing

End of May 2004, the project team came back to Tarawa in order to implement the aforementioned strategy. Unfortunately, soon after arrival, we were informed that the SAPHE-Steering Committee had decided to organize 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 for 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 blue-print 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 landownership 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 that 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. Beside, the present state of mind of a majority of residents on Abatao needed to be dealt cautiously with in order to avoid any more damages. Despite the concerns above, the SAPHE meetings were confirmed but the Steering Committee accepted our project team to 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 or not with the water reserve, local residents constantly referred to our final flowchart. These meetings resulted in a back-stepping and sterile process where a majority of local residents focused again on the financial aspects of the question.

The reason of this seemingly backlash from the Steering Committee is partly to be found in the absence of crucial *meta-players* during the RPG sessions. 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 to 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. As a matter of fact, the Steering Committee, instead of being a driving force, had become an arena for external and conflicting pressures.

Despite our genuine claim (i) that the results from the RPG were far from being detrimental to the SAPHE project, and (ii) 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 own project would have been considered by some members of the Steering Committee as a recognition of incapacity to tackle the problem in the first place. The incapacity of 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 centralized and decentralized management is epitomized in the concept of polycentric institutions developed by Ostrom in her most recent work (2004). Technical agencies - like PUB – very 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 on deterministic and predictable solutions (Bradshaw and Borchers, 2000). What is true at the technical level becomes paramount at the political one.

Hence, 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).

5. ACKNOWLEDGEMENT

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