A Multi-Attribute Tradeoff Analysis for Water Resource Planning: A Case Study of the Mendoza River

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Abstract

This thesis presents the application of a Multi-Attribute Tradeoff Analysis to the water resources planning problem associated with the Mendoza river. A conjunctive water use model that represents the Mendoza river basin was developed. The model simulates the performance of several different strategies available for managing both water supply and demand. More efficient water distribution and improved irrigation technologies are compared with large infrastructure projects. Relevant attributes are calculated and presented on tradeoff curves to communicate the performance of different strategies to the organizations with vested interests. The initial results provide a basis from which a forum can be created to discuss the water management options available.

The results demonstrate the viability of several structural and non structural alternatives available to manage the supply and demand for water. Among the latter are those alternatives that incorporate water conservation and improved efficiency in the distribution system. These in turn require the development and implementation of policies which rectify the economic problems associated with an improperly valued resource. The effects of water pricing on farmer behavior are investigated and the results reveal that pricing is feasible. Unfortunately water pricing will not create demand for new irrigation technologies, but proper pricing can generate revenues necessary to improve the efficiency of the distribution system. The results indicate that novel water use policies for the Mendoza river can be beneficial if the responsible agencies commit themselves to work as a team and ultimately reach consensus on the implementation of acceptable water management strategies.

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Chapter 1. Background Information on the Mendoza River Basin and the Multi-Attribute Tradeoff Analysis

Introduction

This thesis examines an arid region in northern Mendoza, a Province of Argentina. The region considered is comprised of the city of Mendoza, several smaller towns, and agricultural areas. The inhabitants receive their water supply from the Mendoza river. The Mendoza river primarily supplies water to an agricultural area of between 50,000 and 80,000 hectares. The river also recharges a large ground water aquifer located in the area where agricultural activities transpire. In response to a drought in the 1960's, farmers in the region began to pump large quantities of ground water from the aquifer to meet their demands. Thereafter ground water has been used to supplement river water supplies. Extensive simultaneous use of surface and ground water has occurred without a suitable conjunctive use plan or recognition of the renewable capacity of the river basin. Unmanaged use has exacerbated the contamination of ground water with salt.

Numerous studies have been completed analyzing the economic viability of a dam and reservoir project proposed on the Mendoza River. Additionally, several studies have been completed identifying the potential harm that could be created by the construction of a dam and reservoir. Other regions of the province have experienced notable problems ostensibly associated with sediment settling in reservoirs leading to increased water infiltration in irrigation canal distribution systems. Several different organizations have generated reports, though one organization has control over both the ground water and river water supply. The controlling organization has polarized its efforts and concentrated solely on a proposed dam project. The current situation has resulted in an environment where conflict and disagreement have been insurmountable.

The Mendoza River Basin provides opportunities for the construction of dams. The river has an average yearly flow of 50 m^3/s and flows through a region of the Andes Mountains where there is substantial elevation change. The river provides water for irrigation, industry, sewerage, and human consumption in the northern part of the Province of Mendoza. Various officials in the Province, and at times the national government, suggest that the river be controlled by the construction of a dam. A dam can provide water regulation enhancements and additional electricity supply to the region, but the construction of a dam may produce a number of different problems. Vitally important water and energy policy questions require evaluation prior to the execution of a large scale project with uncertain costs and benefits.

This thesis examines water management policy options in Mendoza and their impact on resource consumption. The analysis demonstrates the application of a multi-attribute tradeoff analysis to the Mendoza River basin. A water use simulation model developed specifically for the Mendoza River basin calculates parameters associated with water resource planning problems. (electricity generation, water storage and infiltration, etc.) The capacity of the system is investigated for different irrigation water demands. The results are displayed graphically to permit those with vested interests (stakeholders) in Mendoza to examine the outcomes of different development strategies. These tradeoff graphs provide a basis from which stakeholders can actively discuss and evaluate the performance of different water management policies. The results, combined with existing data characterizing farmer behavior, are utilized to answer the following two questions: (i) Is it possible to establish a price for water in Mendoza? and (ii) If a price is charged for water will new irrigation technologies be demanded? The results establish an affirmative answer to the former question and a negative answer to the latter. Most importantly the analysis reveals the numerous options available to Mendozans to improve the use of water.

Background

Basis of the Research Effort

The objective of the research in this thesis is to evaluate the future interactions of water and energy resources in the Province of Mendoza, Republic of Argentina. M.I.T. executed an agreement with the Universidad Nacional de Cuyo (UNC) and the Provincial Government of Mendoza which provided a framework for collaborative research projects. The specific project that provided the impetus for this thesis has been the transfer of the multi-attribute trade-off (MATA) analysis technique to a research group in Mendoza established for this project. This was achieved through a demonstration application of the MATA analysis under the auspices of the project: Evaluacion por Multi-Atributo de los Recursos Hidricos y Energeticos de Mendoza. (EMARHE)

The project was divided into two components: energy and water. The emphasis on energy and water for this research effort was a result of several changes in the country of Argentina. The most significant change was the creation of a wholesale electricity market. Prior to 1992, the supply of electricity in the country of Argentina was controlled by government owned and operated organizations. These were referred to as State Society companies. Between 1989 and 1992 these organizations were privatized through government sanctioned sales. In conjunction with the privatization process a new framework for the electricity industry was developed and promulgated.[1] This framework consists of a wholesale market operated by an independent organization with government involvement and government regulated transmission and distribution companies.

These changes fundamentally restructured the previous methodology that the government had utilized to plan the future supply of electricity. During several preceding decades the government owned and operated two state societies: Aqua y Energia and Hidronor. These organizations coordinated numerous studies throughout Argentina to identify all possible locations for the development of hydroelectric electricity. While these companies existed several hydroelectric projects were constructed; as a result, the installed Argentine electricity capacity is approximately 50% hydroelectric. (Bastos 1993)

In addition to hydroelectric projects constructed primarily to supply electricity, there have been several facilities constructed in river basins where water is utilized simultaneously for electricity generation and irrigation. In many river basins the construction of a dam provides numerous benefits. These benefits may include:

- Electricity generation;
- Intertemporal water storage;
- Tourism;
- Flood control;
- Improved agricultural yields;
- Ground water pumping reductions, etc.

The Province of Mendoza is a region where rivers present the opportunity for multiple benefit water resource development projects.

The privatization of Agua y Energia and Hidronor substantially changed the way electricity supply planning occurred in Argentina. The role of the State is now envisioned to be minimal, while the wholesale market is expected to generate the signals required to encourage the construction of new facilities. This fact is partly responsible for the Mendozan interest in examining the interaction of water and energy resources within the framework of the reformed electricity industry. The evaluation of electricity plants in Mendoza is complicated by hydroelectric facilities that provide both electricity and irrigation benefits. The viability of a hydroelectric project is different when compared with a fossil fuel plant.

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[1] Argentine Government, Law 24065, 1992.

The newly established wholesale market represents a source of uncertainty that impacts the planning process.

To confront this situation two models were developed to evaluate the future provision of electricity and water use in Mendoza. A model which examines the supply and demand of electricity in Mendoza was developed by one investigator at M.I.T. while I developed a computer model to study water resource planning options on the Mendoza River basin. The simultaneous use of these models allows the investigation of the future consumption of water and electricity. Various supply options can be analyzed not only from a financial perspective, but also as a function of their environmental effects, long run suitability, and performance when uncertainties are considered.

Water Resource Planning

Examination of pertinent information supplied by Mendozan researchers revealed that a major element of this research work encompassed water resource planning. The nature of the effort envisioned here was not as extensive as those executed by others during the 1960's and 1970's. (Maass et al 1962 and Major et al 1979) The Mendoza river basin has significant agricultural development in place as result of over 100 years of canal system construction. The question was therefore not related to examination of numerous sites for both hydroelectric and irrigation development, but how to utilize the existing system in a fashion which maximizes the benefits available in the context of the current water supply available and electricity market framework in Mendoza. To evaluate the situation a model facilitates the consideration of numerous options available to manage the delivery of water.

The distribution of water in Mendoza is managed by the Departmento General de Irrigación. (DGI) This organization was established under the constitution of the Province and enjoys substantial powers in its ability to deliver and regulate the usage of water in the Province. The DGI is charged with distributing the water from rivers in Mendoza to the land where crops are cultivated and to the organizations that distribute potable water or have industrial use permits. The department is also responsible for insuring that farm drainage networks are functional. During the previous two decades the department has supported the idea that a dam/reservoir should be constructed on the Mendoza river in order to enhance the supply of superficial water available during the spring season when river flows are minimal and irrigation demands are significantly in excess of the flow. (DGI 1970, 1980, 1986)

In addition to the supply of superficial water available to irrigate farms there is a substantial ground water aquifer available to supplement the river supply when necessary. The administration of the water extracted from the aquifer is also under the jurisdiction of the

DGI. The existence of two sources of water, combined with the fact that many farmers in the region have installed ground water pumps, creates a complex situation. The yearly endowment of the Mendoza river is naturally variable and there exists no guarantee that adequate supply will be available to satisfy the demand that the DGI is obligated to serve through supply rights established over several decades. Many farmers have recognized this potential shortage and have acted individually by installing their own ground water extraction wells.

These well installations have resulted in changes in the ground water quality and availability as the farmers are unable to take into account the effects their individual pumping has on the ground water system. In addition to problems caused by ground water pumping, increased salinity levels have been detected in certain portions of the ground water supply presumably as a result of extended agricultural activity in the region. This problem is exacerbated in areas where drainage of excess irrigation water is inadequate. Research work in Mendoza has revealed high salt concentrations in ground water aquifer layers near the surface while ground water located at deeper levels has a lower salt concentration. (Alvarez unpublished 1995) The researchers have reached the conclusion that the salt concentrations in deeper layers have increased as a result of water transmission between layers. Previously the deeper aquifer layers had lower salt concentrations. Substantial increases in ground water salt concentrations have been observed following the installation and operation of numerous wells. The increased ground water pumping can draw down the free water surface to the point where the transmisivity between two distinct ground water layers is artificially impacted by the cones of depression of the ground water wells. Ground water from an upper layer, nearer to the surface, subsequently mixes with ground water in a layer deeper in the earth.

This exploitation of the ground water, combined with the variability of the flows in the Mendoza river, results in a situation where water resource planning is critical. To date planning activities have concentrated on the investigation of the installation of a dam on the Mendoza river. The potential for multiple benefits exist. An important element of this thesis is the modeling of water resources in this region in order to compare the benefits of several different potential projects. The viability of the water projects that generate electricity is important. Hydroelectric projects can be compared with other electricity sources in order to examine the costs and benefits of both sources of electricity supply. The multiple benefit nature of a hydro-project requires an extensive analysis when contrasted with a fossil fuel facility.

The model also permits the investigation of other methods of improving the supply of water. A planned conjunctive use is envisioned with the model. The recharge of the unconfined aquifer is compared with the volume of ground water pumping required. A global water balance is calculated to evaluate the conjunctive water use. Ground water pumping batteries are planned in regions where water with low salt concentrations exist. The batteries can replace supplies potentially available from a reservoir while allowing improvements in problem areas to commence.

Equally important is the mitigation of losses in the water distribution system and the potential for improved usage at the farm level. The distribution system is comprised of numerous earthen canals and the primary technique employed for application is gravity distribution. This system supplies a much larger quantity of water than is required to achieve effective irrigation of the land in question. The current method of distributing the water does not take into account the exact quantity a farm may require, but is delivered on the basis of legal rights to the water whether it is needed or not. This can create substantial waste as there exists no mechanism to equate the supply with demand or to provide an incentive for reduced levels of use. A means of countering this problem is explored through the potential application of water pricing which reflects its opportunity cost. This is a central issue in this thesis as the question posed is whether a water usage policy, including pricing based on scarcity, would modify consumptive patterns sufficiently to materially assist in managing the long term water supply for Mendoza?

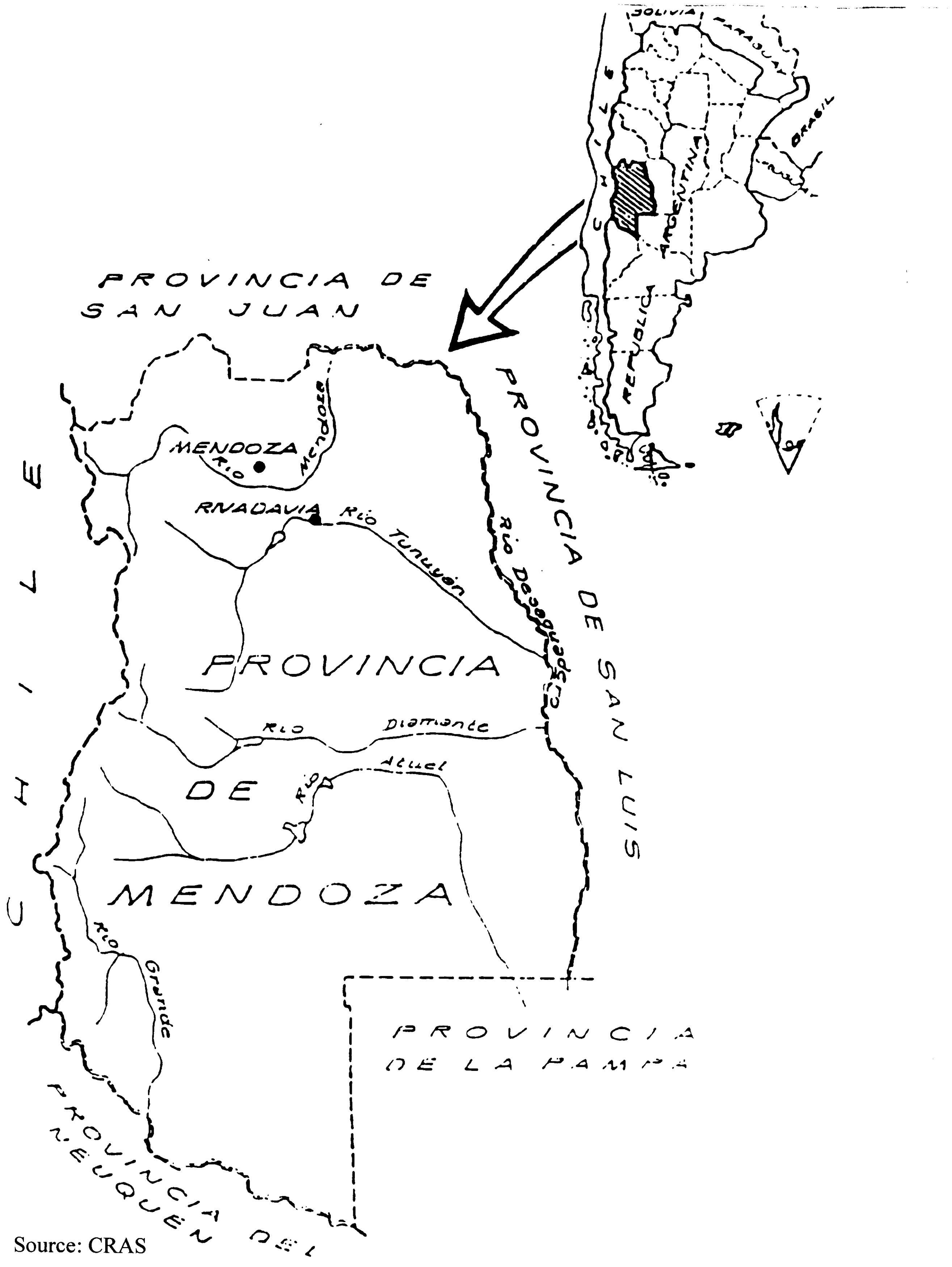
Through the use of a simple simulation model the impacts of improved supply management with large and small scale projects is studied. Equally the positive effect of demand management is explored to permit a fair comparison of the options available. Combinations of various projects are analyzed to explore the alternatives. The objective of insuring a guaranteed supply of water is envisioned throughout the analysis. Policies that could be exercised by the DGI are proposed as a means of achieving the desired goal of a low cost, properly employed source of water for the region.

Situation in Mendoza

There are four significant rivers in Mendoza whose water is distributed by the DGI. (see Figure 1.1) The Mendoza and Tunuyan rivers which are located in the north, and the Diamante and Atuel rivers located just south of the center of the Province. The Diamante and Atuel rivers have several man-made works. The focus of the research in this thesis is on the Mendoza river, but it is beneficial to discuss other experiences elsewhere in the province as many relevant concerns result from previous river basin developments.

The current state of affairs in Mendoza is complex and results from more than 100 years of agricultural development in the region. In order to familiarize one with the water use

Figure 1.1: Rivers in the Province of Mendoza



Source: CRAS

issues in the region a brief discussion of pertinent matters is presented. The first issue relates to the administration of water in the region. This is followed by examples of water works previously constructed in Mendoza to control the distribution of water. The concluding portion relates to the effects of large scale water diversion and distribution on the local environment.

Departmento General de Irrigación

The DGI is charged with the distribution of water to all users. This responsibility includes operation and maintenance of the entire water distribution system for the Province of Mendoza.

The DGI operates as a function of their establishment by the provincial constitution, law #322 and the Water Law of 1884.[2] The structure and hierarchy are defined by the constitution. The structure contains the following elements: appeals council; administrative commission; superintendent; water sub delegations; honorary assemblies; and the irrigation channel inspection group. The primary power of the DGI is vested in the superintendent. The responsibilities of the superintendent are defined by Provincial Law and Articles 3 and 6 of Law # 322.. These functions are the following:

- Administer the water of the Province;
- Exercise police powers when investigations are necessary relating to the water supply, the natural river channels, river banks, and service zones;
- Dictate all measures necessary to insure effective use and realization of benefits from the resource;
- Resolve administrative questions that arise due to the distribution of the water, drainage, or staff;
- Respond to complaints and claims made against employees of the DGI;
- Establish the distribution allotments in times when water is scarce;
- Impose sanctions on those who violate the prescriptions of the Water Law. These sanctions can be a simple fine and elevate to a revocation of the right to the water;
- Understand all original paperwork associated with applications for concessions for irrigation, industrial, and energy rights;

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[2] Constitucion de la Provincia de Mendoza, Ley General de Aguas, 1884, Ley No. 322.

- Know about appeals and in final instances the resolutions of the sub delegates of water and the inspectors where sub delegations do not exist.

The sub delegates are organizationally beneath the superintendent and are in charge of the administration of each particular river, carrying out the same functions in their respective regions; the equitable distribution of water for irrigation and remaining uses. These groups are responsible for the governing, administration, and policing of water in their respective jurisdiction. They have responsibility for direction and control of the diversion works and the canal systems. Additionally, they are in charge of administrative paperwork and accounting in their region as well as the implementation of small projects that modify elements of the distribution system. They are permitted to modify rights to the water in times of emergency or danger.

The Honorary Assemblies of Irrigators collaborate with the sub delegations to obtain optimum management of the river water and to achieve a smooth interaction amongst irrigators in each jurisdiction. The assembly consists of the Sub delegate, a zone advisor, and three irrigators elected to the assembly of inspectors. Their functions are limited to the advising and supervision of the workings of the irrigation works, drainage, and the cleaning and conservation of the canals as well as suggesting when canal lining is desirable. The intent should always be to improve the distribution and utilization of the water.

The final group, Inspectors of the channels, is responsible for the physical operation of the system. Their responsibilities include the operation of the canal system insuring proper distribution of water, administration of funds resulting from fines, payment of staff who clean and maintain the works, and financing of small projects. They are also permitted to adjudicate conflicts between users up to the point where the problem does not extend beyond 300 hectares. The election of these authorities is determined by the Laws # 2503 and 322. This group has several responsibilities and its function is a primary component of the decentralized management structure of the DGI.

These groups comprise the structure responsible for the management of the water distribution system. The creation of the DGI under the provincial constitution gives the organization substantial autonomy. Historic data indicate that the department has implemented few substantial capital projects during the most recent 25 years. (Braceli 1985) The importance of this organization in relation to this thesis is the fact that any policies developed for the improvement of water supply would be implemented by the DGI. Their history and administrative capacity must be carefully considered when proposing any water management policies.

Current Problems

Several administrative and physical problems have been identified by National and Mendozan agencies including: El Instituto Nacional de Ciencia y Téchnica Hídricas (INCYTH), El Centro de Economía, Legislación y Administración del Agua y del Ambiente (CELAA) and El Centro Regional de Agua Subterránea. (C.R.A.S.) A listing of several issues is as follows:

- The water rights system utilized in Mendoza insures the delivery of water to those with rights regardless of whether the water is actually utilized. The system is not regularly updated though significant information exists which indicates that several thousand hectares registered to receive water are not cultivated. This excess delivery reduces the supply available to those who could utilize it and exacerbates salinization problems.
- The lack of attention given to conjunctive use of ground water and surface water has perpetuated continued pumping of ground water. The result has been worsened salinization problems in the ground water aquifer. The DGI has prevented continued ground water extraction in certain regions, but this adversely affects farmers who do not receive their river water supply.
- Those people with rights to the water have no guarantee that water will be delivered due to seasonal and yearly stream flow variations. Many have acted individually and installed ground water pumps to insure an adequate supply. These actions have not been managed in conjunction with an understanding of the entire surface/subsurface water system.
- Few capital projects to reduce losses and improve use have been implemented.
- Enhanced ability to supply water from the river year round with a reservoir seems to have been emphasized with little attention given to supply management options.
- Many alternatives have been proposed, but few studies exist analyzing the potential improvements. This situation has been identified previously by Frederick in 1975.

Currently the Mendoza region has experienced two significant physical problems. The first problem is elevated salt concentrations in the ground water. The second problem arises due to the settling of sediment in a reservoir. Elaboration on each of these issues provides insight into the benefits that the formulation of an overall conjunctive use plan can provide to preclude future difficulties.

A problem associated with irrigation is that ground water salt concentrations tend to rise due to repeated application of water to the land. The river water salt concentrations vary between 500-1500 micromho/cm while concentrations as high as 5500 micromho/cm have been measured in the ground water. (Alvarez unpublished 1995) This problem has become more pronounced during the most recent twenty years due to increased exploitation of the ground water which has caused interaction between upper levels of ground water and levels located deeper in the earth. The region in question has two distinct ground water aquifers. The first is an unconfined aquifer located south west of the City of Mendoza. The second is a multi-layered, confined aquifer located north east of the City of Mendoza. (see Figure 1.2) The geology of the region creates these two distinctly different regions. The organization that has studied this area most significantly is the Centro Regional de Agua Subterranea. (CRAS) This group has generated numerous data which verify the existence of the two different ground water aquifer areas. The confined area contains at least three lenses of low permeability material that provide containment of water at substantial piezometric heads. The water quality in each of these regions has been monitored extensively and the increased salt concentrations have been observed in numerous locations.

Level I is the water located nearest to the surface (0-80 m), the second is between 80-200 m, and the third occurs at depths greater than 200 m. Elevated levels of salt in the ground water have been observed in the upper two levels while the third continues to be affected only minimally. In certain regions observations of considerable interaction between the upper level and the second level have been attributed to extensive ground water extraction in a region where the transmisivity between levels is relatively high. Exacerbating this situation has been the poor installation of numerous wells. These wells have casings that are known to leak due to corrosion of the materials used for construction of the wells and thereby transmit water between levels. The upper level has experienced serious elevations in the concentrations of salt in the water which is the result of extensive irrigation. This phenomena is observed in many regions throughout the world where irrigation continues for decades.

The second problem discussed commonly in Mendoza is a problem referred to as "Aguas Claras." Defined literally this term signifies "clear water" and involves the following phenomena: (i) sediment in the reservoir water settles to the bottom, (ii) water released from the reservoir has an increased capacity to transport sediment, (iii) the water enters unlined irrigation canals and carries away sediment accumulated in the canal, (iv) the rate of infiltration in the canal system rises, (v) the free surface of the ground water rises flooding irrigable land. This phenomenon has been observed in other parts of Argentina following the construction of dams.

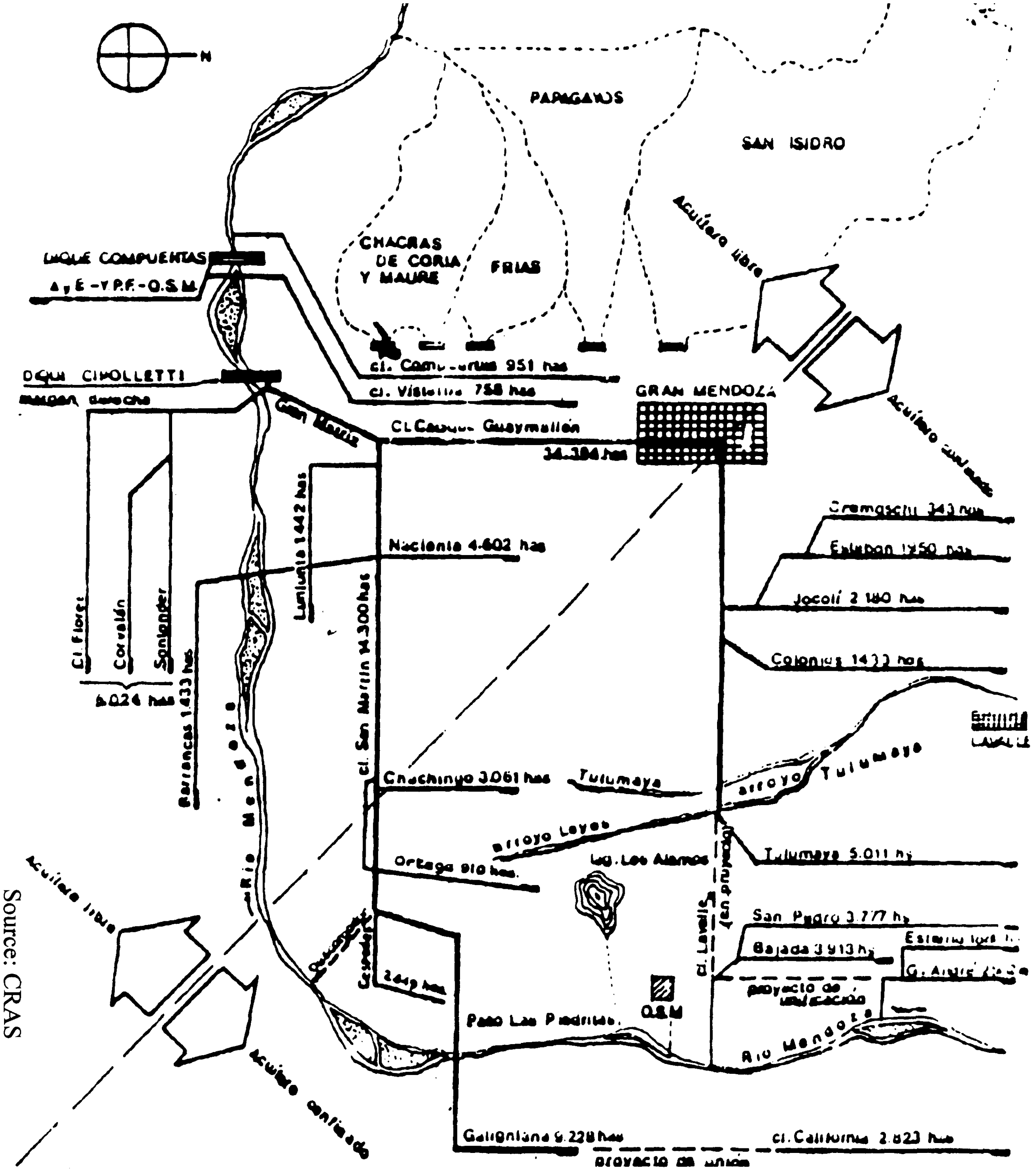

Figure 1.2: Depiction of the Unconfined/Confined Aquifer Division

Source: CRAS

The clear water problem is an important issue when considering the potential construction of a dam/reservoir in a location near the city of Mendoza referred to as Potrerillos. There is significant uncertainty associated with the quantification of the effects of clear water. CELA, INCYTH, and CRAS believe that the lining of several irrigation canals is necessary to combat this problem and limit infiltration. This problem is not treated explicitly in this thesis for the following reasons: (i) an accurate quantification of the problem does not exist, (ii) the exact cause of the problem has not yet been verified, (iii) mitigation of the increased infiltration requires lining of unlined canals and increases the cost of a dam/reservoir project substantially.

The increased costs of a dam/reservoir project reduce its economic viability considerably. Lack of inclusion of the clear water problem with a dam project creates more favorable results. The initial work presented in this thesis intends to demonstrate the tradeoff analysis and identify feasible water management strategies. To date numerous options have not been considered in Mendoza, nor has the critical requirement that conjunctive use of ground water and surface water be managed together. The results indicate that, of several projects examined to improve the supply of water to the farms, a large scale project has significantly higher risks with benefits that rely on uncertain forecasts. The clear water problem adds to the uncertainty. If a dam/reservoir project is part of the final set of interesting options then a more detailed analysis can be executed to attempt to precisely integrate the clear water problem.

Multi-Attribute Trade-Off Analysis (MATA)

Origin and Terminology

The past 25 years demonstrate the DGI's continued insistence that a multi-benefit dam project is the optimal solution to Mendozan water management problems. (DGI 1970, 1980, 1986) The DGI analyses consistently ignore other viable alternatives for water management. Other concerned agencies have identified and characterized potential problems associated with the construction of a dam, but no attempt has been made to unite interested parties in a forum that permits a thorough discussion of alternatives. The utilization of an open planning process presents the opportunity of identifying strategies for water management that are acceptable to each stakeholder.

Previous analyses executed by the DGI in Mendoza have focused on the construction of a dam in the town of Potrerillos. There seem to be several reasons to explain this emphasis. The multiple benefits available from a dam/reservoir project motivate the overwhelming interest. These multiple benefits include:

- Electricity generation;
- Water storage to meet irrigation demands;
- Flood control;
- Tourism;
- Potential improved agricultural production;
- Ground water pumping reductions, etc.

Additionally, a large infrastructure project provides jobs for the unemployed and tends to enhance the local economy during construction. Equally a dam project has risks. The clear water problem defined previously is a serious concern which is not well understood. Other environmental impacts will result when the tourism developments are initiated and increased numbers of people frequent the area.

The inability of all stakeholders to reach consensus on the effectiveness of a dam has been a problem. The rapid privatization of the electricity market in Argentina removed the emphasis on state led planning for electricity supply and forced provinces to carefully assess their local conditions. This renewed interest has presented the opportunity to formulate a MATA to analyze the problem.

The use of a MATA to assist in understanding the available alternatives presents an opportunity to examine the outcomes of numerous water management improvement strategies. The development of an effective long term strategy demands a multiple-issue, multiple-option planning framework which the MATA analysis offers. The complexity, controversy, and uncertainty inherent in large scale water resource system development has clearly been a primary reason for the paralysis evidenced in Mendoza: no substantial modifications have been implemented for 25 years though numerous problems have been identified. The MATA analysis is utilized here to demonstrate the outcomes of different infrastructure developments and to provide a forum for productive debate.

A succinct description of this analysis is given by Andrews 1990:

> "Scenario-based multi-attribute tradeoff analysis is a technique that allows negotiating parties to observe the performance of strategies, the effects of uncertainty, and the interactions among components of a complex system in multi-attribute space. This helps the group to invent better strategies having more of the characteristics that each party prefers, thus improving the potential for consensus. By involving the parties in the analysis, their creativity is harnessed, a shared understanding of both issues and options grows, and the results are more likely to be accepted by the group. The analyst plays a non-traditional role in facilitating the joint fact-finding effort among the parties."

The elements utilized to implement this methodology were initially outlined in work completed by Merrill and Schweppe (1984) and Geraghty, Lethrop and Merrill, et al (1984). This work developed as a result of placing emphasis on the choice of strategies in an open decision environment and the explicit analysis of various tradeoffs considering a wide range of uncertainty. These authors described a Multi-Objective Decision Analysis technique in which scenarios are conceived through the combinations of options (strategies) and uncertainties. The results are evaluated using decision analysis techniques and linear programming algorithms. The terms defined for describing the components of the analysis are as follows:

Strategies (options): A strategy represents a decision over which the parties have control and which can be implemented. These represent types of projects that can be either combined or solely executed to achieve water usage planning objectives.[3]

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[3] A combination of distinct projects can represent a strategy or a single project can equally represent a strategy. The defined strategies shown in Tables1.1 & 1.2 show the projects associated with a strategy. I use the words strategy and project interchangeably in many instances.

Uncertainties: An uncertainty is an event over which the parties do not have control. Uncertainties represent demand forecasts, stream flow variances, economic variations etc.

Scenarios: A scenario is a combination of a strategy with a set of uncertainties. A scenario is then evaluated using applicable analysis techniques.

Attributes: An attribute is a measure of the performance of a strategy. Attributes are defined by the stakeholders and utilized in assessing the merits or outcomes of a scenario's simulation.

The MATA retains the describing function defined by Merrill and Schweppe using strategies (options), uncertainties and attributes, though it eliminates the optimization algorithms from the analysis technique. This permits the technique to be more readily applied in an open decision environment. In the tradeoff analysis, computer simulation is used to analyze scenarios. Results are displayed graphically to identify inferior strategies and to assist in identifying reasonable compromises.

MATA in Mendoza

The planning of water use in Mendoza presents multiple attributes which provide a forum for productive interactions among the stakeholders. The MATA technique is useful in this situation where multiple attributes are definable and several investment strategies have been proposed though no effective means of analyzing these strategies has been formulated. Numerous stakeholders exist and notable conflict is apparent. Furthermore, there is a substantial amount of uncertainty in future forecasts which include both water demand variations and variable stream flows.

The use of the MATA envisions the identification of all attributes of interest prior to commencement of the analysis. When vital attributes are identified one develops several different scenarios which combine investment strategies with various futures. Each of these scenarios is analyzed and the values of the attributes associated with them are displayed graphically. Unfortunately the DGI was not involved in the attribute definition and model development which are a part of the study reported on herein. Attributes were defined with the Mendozan research group and follow-up analysis will be necessary when the DGI involvement increases.

A water use simulation model is utilized to provide quantified values for the attributes. Trade-off graphs are constructed and provide a means by which the results of the analysis can be discussed amongst the constituencies interested in the strategies under consideration. The graphic displays are plots of attributes in two dimensional space. This permits one to display significant features of the project in a fashion where people can easily understand their relevance. Attributes selected initially for this study are the following:

- Average quantity of ground water pumped calculated over a 25 year period[4];
- Electricity generated by facilities existing or proposed ;
- Quantity of water that recharges the unconfined aquifer;
- Quantity of water that infiltrates on the farms;
- Electricity consumed to pump ground water;
- Economic benefits associated with dam/reservoir projects;
- Present value costs of scenarios;
- Internal rates of return for scenarios;
- Net present values.

One important attribute related to water resource planning has not been considered. Typically in a water resource analysis one examines the ability to meet demand in each period. Penalties are conceived when the system is incapable of satisfying the water requirements. The initial analysis executed for the Mendoza river assumes that the demand is always satisfied with a combination of surface water and ground water and thus no penalties for failure to meet demand are considered. The analysis can be broadened to include scenarios that make greater demands on the water supply such that the ground water is mined. The analysis presented in this thesis demonstrates the initial application of the MATA and the fact that a conjunctive use can be planned for the water resource. A more extensive analysis can be developed utilizing this initial work as its basis

Changes in the values of the attributes are examined under several different futures by analyzing the scenarios with the water usage model. Table 1.1 provides examples of strategies and futures combined into scenarios as well as example results that provide values for some of the relevant attributes. A brief explanation of the key elements of the strategies is as follows:

0. Construction of a dam at Potrerillos with a useful reservoir capacity of 250 hm^3.
1. Construction of a dam at Potrerillos with a useful reservoir capacity of 500 hm^3.

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[4] The 25 year period was identified by the Mendozan research group as the time period of interest.

2. Construction of a dam at Potrerillos with a useful reservoir capacity of 250 hm^3 and an assumed increase in infiltration due to clear water of 15 %
3. Construction of a dam at Potrerillos with a useful reservoir capacity of 250 hm^3 and an assumed increase in infiltration due to clear water of 30 %
4. Construction of a dam at Potrerillos with a useful reservoir capacity of 250 hm^3 and construction of the marginal canal.[5]
5. Construction of the marginal canal.
6. Construction of the marginal canal and an enlargement of the electricity generation facility at Condarco.
7. Construction of the marginal canal and a reduction in canal losses of 12 %.
8. Construction of the marginal canal and a reduction in canal losses of 24 %.
9. 24 % reduction in canal losses.
10. 12 % reduction in canal losses.
11. 12 % reduction in canal losses and 10 % loss reduction on farms.
12. Scenario 11 with Construction of the marginal canal

An example of a tradeoff graph is presented in Figure 1.3 to illustrate the process in which one compares the attributes resulting from the analysis of numerous scenarios. In Figure 1.3 a graph of two attributes is presented. The present value costs of each strategy analyzed for future #1 are plotted versus the average yearly volume of ground water pumped during the 25 year analysis period. The MATA is characterized by studying the values of the relevant attributes plotted in this two dimensional space. The axes are designed so that the origin represents the most desirable location for a point to be located. As points move away from the origin, in either direction, there is a worsening of the performance of one or both attributes. The interpretation of the performance of one scenario compared with another involves drawing a vertical and horizontal line from each point in a direction that represents a degradation of the attribute. Any point that lies above and to the right, within the box defined by the vertical and horizontal lines, is considered inferior when compared with the point from which the lines are drawn. For example, in Figure 1.3 a vertical and horizontal line are drawn from scenario 8 to illustrate the dominance of 8 over scenarios 6, 11, and 12.

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[5] The marginal canal is a proposed project that would remove water from the river at Condarco and transport it to Cipolletti. This canal eliminates the infiltration in this tract of the river.

Table 1.1: Multi-Attribute Trade-Off Analysis Scenarios

Scenarios Considered for Managing the Supply and Distribution of Water (1996-2021)

Strategy	FUTURE #1 Water Demand Variations			Water Loss Variations			
	Potable (OSM)	Industrial	Irrigation	Canal Marginal	Canal Lining	Aguas Claras (Clear Water)	Improved Usage
Existing Cach/Con Arrangement	6/95 Forecast	Constant	74,500 hectares	No	No	No	No
0.) Potrerillos	6/95 Forecast	Constant	74,500 hectares	No	No	No	No
1.) Potrerillos w/ 500hm3 Util.	6/95 Forecast	Constant	74,500 hectares	No	No	No	No
2.) Potrerillos w/clear water (15%)	6/95 Forecast	Constant	74,500 hectares	No	Yes	Yes (15%)	No
3.) Potrerillos w/clear water (30%)	6/95 Forecast	Constant	74,500 hectares	No	Yes	Yes (30%)	No
4.) Potrerillos w/ Marginal Canal	6/95 Forecast	Constant	74,500 hectares	Yes	No	No	No
5.) Marginal Canal	6/95 Forecast	Constant	74,500 hectares	Yes	No	No	No
6.) Marginal Canal with Enlarged Condarco	6/95 Forecast	Constant	74,500 hectares	Yes	No	No	No
7.) Marginal Canal plus 12% Reduction in Canal Losses	6/95 Forecast	Constant	74,500 hectares	Yes	Yes (12%)	No	No
8.) Marginal Canal plus 24% Reduction in Canal Losses	6/95 Forecast	Constant	74,500 hectares	Yes	Yes (24%)	No	No
9.) 24% Loss Reduction in Canals	6/95 Forecast	Constant	74,500 hectares	No	Yes (24%)	No	No
10.) 12% Loss Reduction in Canals	6/95 Forecast	Constant	74,500 hectares	No	Yes (12%)	No	No
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	6/95 Forecast	Constant	74,500 hectares	No	Yes (12%)	No	Yes (10%)
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	6/95 Forecast	Constant	74,500 hectares	Yes	Yes (12%)	No	Yes (10%)

Notes: 1) Estimates of impact of clear water problem are ARBITRARY and are offset by loss reductions through canal lining and/or marginal canal;

Uknowns: Extent and exact cause of the clear water problem; Historical variations in the free surface groundwater level in the area of the farms;
Accurate estimates of canal losses for a full year.

Scenarios Considered for Managing the Supply and Distribution of Water (1996-2021)

Scenario	Pertinent Results Compiled From Multiple Model Runs					
	Total Quan. of GW Pmpd(hm3)	Total Infiltration (hm3)		Ave.quan.of GW pumped (hm3/yr)	Ave. quan. of Elec. (Gwh/yr)	Total Cost PV ($000)
		Farms/Canals	Cach-Clp			
Existing Cach/Con Arrangement	4682.11	6935.95	5170.8	187.28	245.84	N.A.
0.) Potrerillos	2419.8	6935.95	5251.17	96.79	876.17	238,862
1.) Potrerillos w/ 500hm3 Util.	1575.67	6935.95	5273.81	63.03	938.8	360,356
2.) Potrerillos w/clear water (15%)	2658.4	6935.95	6023.13	106.34	877.56	241,559
3.) Potrerillos w/clear water (30%)	2922.64	6935.95	6789.8	116.9	879.5	244,919
4.) Potrerillos w/ Marginal Canal	1443.39	6935.95	1774.58	57.74	861	247,711
5.) Marginal Canal	3777.68	6935.95	3142.72	151.11	245.84	24,370
6.) Marginal Canal with Enlarged Condarco	3774.8	6935.95	2531.68	150.99	304.52	62,227
7.) Marginal Canal plus 12% Reduction in Canal Losses	3442.55	6159.12	3142.72	137.7	245.84	27,067
8.) Marginal Canal plus 24% Reduction in Canal Losses	3088.23	5278.26	3142.72	123.53	245.84	30,427
9.) 24% Loss Reduction in Canals	3903.6	5278.26	5170.75	156.14	245.84	21,578
10.) 12% Loss Reduction in Canals	4308.5	6159.1	5170.75	172.34	245.84	18,218
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	3989	5465.5	5170.75	159.57	245.84	96,393
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	3162.25	5465.5	3142.72	126.49	245.84	105,242
	Total Demand (hm3)	22908				

A frontier is defined by the points located nearest to the attribute axes. These points do not strictly dominate each other and represent those scenarios where there are tradeoffs between attributes. The selection of the most suitable strategy occurs through an open decision-making process in which a group of stakeholders examine the results together and discuss the impacts of the tradeoffs depicted by the graphs. Several tradeoff graphs are generated to permit an examination of the performance of the different attributes. Scenarios that consistently are located on the frontier, when compared with other attributes, are those that form the potential group that stakeholders consider. Inferior scenarios are subsequently eliminated.

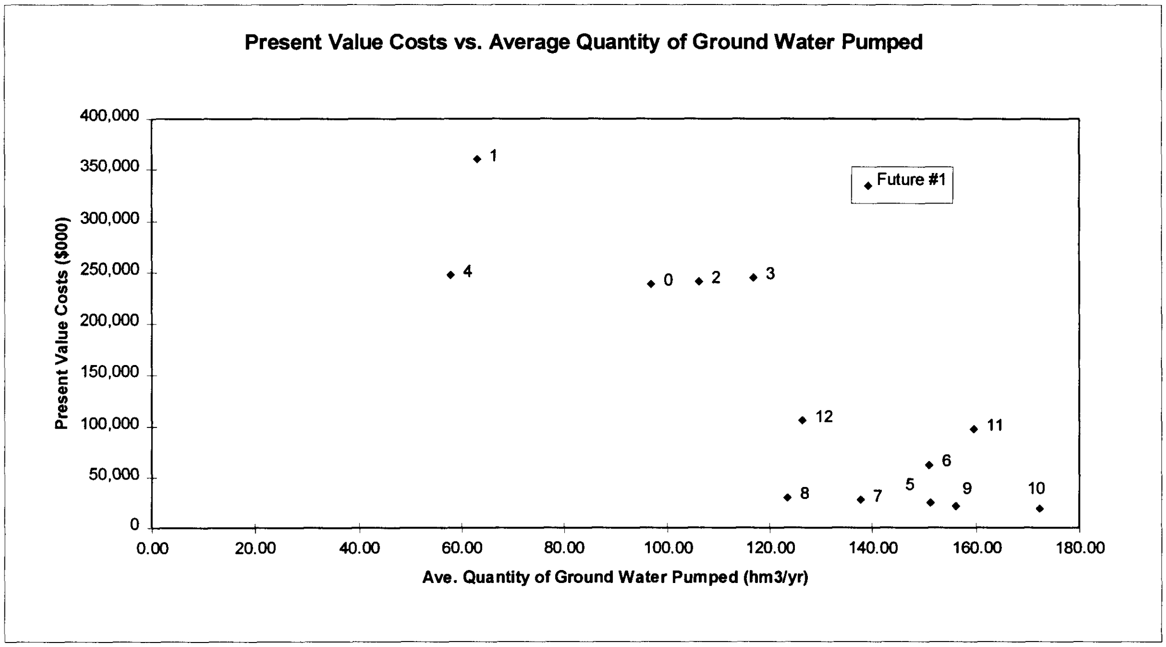

Figure 1.3: Example Trade-Off Graph

Scenarios that consistently yield desirable results are considered "robust." The stakeholder group then determines whether better scenarios can be invented and, if so, these are then analyzed and added to the graphs. The analysis presented in this thesis constitutes the first step in the tradeoff analysis. With the assistance of the Mendozan team 13 strategies and 5 futures were identified for this initial analysis. The continued definition of strategies and futures would comprise the next activity in the MATA. Those new scenarios would then be analyzed to determine if they represent better solutions.

Chapter 2. Irrigation Methodology

The primary method of irrigation used in Mendoza is distribution of water by gravity. The water is applied to the fields either in furrows or by flooding. This method of water distribution typically results in an efficiency of 60 to 70 percent, indicating that 60 to 70 percent of the water applied to the field is used by the crop for evapotranspiration while 30 to 40 percent is lost. Losses are characterized by either deep percolation into the soil at the root zone or runoff from the field. In this thesis the lost water is not considered available for irrigation. The water that percolates into the soil ultimately mixes with water at an elevated salt concentration. This ground water located near to the surface of the land has high salt concentrations and is unable to be utilized for irrigation. Water that runs off the field is also unavailable for use. This water either infiltrates into the contaminated upper layer of ground water or evaporates. There is no evidence that excess water returns to the river. The water losses on the fields can be reduced through the use of modern irrigation technologies for the application of irrigation water.

Modern irrigation technologies achieve an application efficiency of 85 to 100 percent. (Verplancke 1992) The highest efficiencies can be obtained from a drip irrigation system. Significant improvements can also be realized utilizing a sprinkler or aspiration system. The strategies analyzed in the water usage model that envision improved use assume the utilization of these modern irrigation technologies. A conservative estimate of the reduction in losses is made to represent the additional water available through improved application. Reasonable estimates of the capital costs of new systems are employed. The technologies considered are currently available in Mendoza and the capacity to install and operate the systems correctly is considered in the implementation of the policies.

Irrigation Technologies

The province of Mendoza has investigated and applied several types of pressurized irrigation technologies which deliver water to the plants more efficiently. The primary objective is to accurately estimate the quantity of water demanded by the crop being irrigated and to deliver a quantity of water that just meets this demand. The methodology requires estimates of the crop demand and a thorough knowledge of the physical characteristics of the irrigation technology considered. A suitable system design is developed as a function of the quantity of land requiring irrigation. The vital element for insuring success of these systems is the ability of the farmers to operate them effectively. Pressurized irrigation systems are examined in the water use model as a means to improve the efficiency of water use while simultaneously conserving the supply.

Three different systems have already been implemented on a limited scale in Mendoza: sprinkler systems, micro-aspiration, and drip irrigation. The systems utilize pressurized water with the major differences being the method of delivery of the water and the distribution system required. A description of the requirements of each of these systems and an estimate of the installation and operational costs were obtained from actual experiences in the Province of Mendoza.

Micro-Aspiration

Micro-aspiration is a system that provides small volumes of irrigation water to the crops. The water is emitted as a spray over an area of between 3-7.5 meters in diameter. The primary components of the system are the following: pump and filtration element, pressure control device, principal and secondary water distribution networks, lateral delivery piping, and spray nozzles.

The pump extracts water from either a collection pond, a tank or a ground water well. The appropriate design of the water collection source is a function of the property being irrigated The discharge pressure is monitored and adjusted to insure proper operation of the system as a function of the demand. This control system permits flow and pressure regulation and compensates for any losses in the filtration elements. After the water flows through the pump/filter/control system it is delivered to the distribution network. The primary and secondary distribution network deliver the water to smaller lateral piping. These smaller pipes contain spray nozzles that atomize the water and apply it to the crops.

The spray nozzles can have moving parts or consist of only a nozzle. The precise quantity of distribution elements depends on the type of crop irrigated. The spray nozzles can be obtained with a pressure control that permits constant flow above a specified inlet pressure. Typically the nozzles are not equipped with pressure controls and the flow varies as a function of the system design.

The application of this system demands careful attention to the design parameters. The operational costs can vary significantly if the system is designed incorrectly. The extensive water distribution network creates frictional losses. These losses, in combination with the nozzle pressure requirements and filter specifications, must be analyzed properly to select an adequate pump. Frictional losses in the piping can be considerable if piping is improperly sized. Errors can increase the operational costs of the system considerably. This situation must be specifically analyzed as a function of the area that will be irrigated.

Drip Irrigation

The drip irrigation system is comprised of the same major components as a micro-aspiration system. The difference arises in the method of delivery of the water to the crops. The drip system utilizes a mechanism that delivers the water to the soil in drips as opposed to the spray of the micro-aspiration system. The design of the system accounts for the pressure requirements of the drip elements. These can be specified to automatically regulate flow or to deliver a flow which is a function of the pressure at the distribution element. The costs of the drip and micro-aspiration systems are similar, though the aspiration system delivers more water through its nozzles when compared with the drip system.

Sprinkler Irrigation

The sprinkler irrigation system is distinctly different than the micro-aspiration and drip irrigation systems. The distribution of the water is achieved with a larger scale distribution network that can provide water to a more significant area. The major components required parallel those of the micro/drip systems, however they differ in the secondary distribution network piping. For sprinkler irrigation this piping is larger and transports water to sprinklers that are erected vertically in the fields. This permits the irrigation of a much larger area with fewer distribution elements.

Several different types of sprinkler irrigation systems are available. There are systems where the sprinklers are supplied water through flexible hose permitting manual positioning. Systems that have piping that is installed permanently with movable sprinkler heads are available. The employment of a complete system permanently installed is also an option. The capital costs of the more permanent systems are higher, though the labor requirement for operation is less. The amount of area requiring irrigation is an important factor in selecting a suitable system. In many instances the demands of the crops dictate the available options. The proper design of the system is critical to insure proper functionality.

In Mendoza, studies of the operational characteristics of each of these systems exist and provide guidelines for designers. Failures of systems tested previously have resulted from improper designs and inadequate training of those individuals responsible for the operation of the equipment. (INCYTH 1993) These experiences emphasize the importance of carefully considering the system design requirements so that successful implementation of a system is achieved. The irrigation techniques currently employed have not been modified for more than a century. A formidable cultural barrier exists and must be overcome if water users are to be convinced that new technologies will function acceptably. This barrier will only be more difficult to surmount if improperly designed systems are installed.

System Cost Estimates

The costs of previously installed pressurized irrigation systems in the provinces of Mendoza and San Juan provide a basis for the cost estimates utilized in the analysis. The data are shown in Table 2.1.

Table 2.1: Pressurized Irrigation System Cost Estimates

Irrigation System	Capital Cost ($/ha)	Operational Cost ($/ha/yr)
Sprinkler	9,000	100-500
Micro-Aspiration/Drip	6,000-13,000	100-500

Source: Instituto Nacional de Ciencia y Téchnica Hídricas, Seminario Nacional de Riego Presurizado, Centro Regional Andino, Mendoza, Argentina 1993.

The figures presented in Table 2.1 are obtained from distinct experiences or preliminary estimates available in Mendoza. These values should not be considered highly accurate, but only representative of the level of costs associated with the implementation of the technologies investigated. The costs can vary considerably as a function of specific circumstances. For example, the applicable electricity tariff affects the operational cost significantly. The operational cost differences shown are derived from electricity tariffs between .03 and .085 $/kwh. Equally the installation of the pumping system can affect costs considerably. If a system employs a ground water pump the costs are lower when compared to the extensive development required to install a system that utilizes water provided from a canal system. In the latter case a storage facility is required to permit proper pump operation.

The installation of pressurized irrigation systems results in a more efficient use of the water. (Verplancke 1992) This improved utilization permits conservation of the available supply by applying a volume of water that is commensurate with the crop requirement. The potential improvements realized through the use of these systems is investigated with the water usage model. The quantity saved is available to fulfill the water usage rights of those farmers who do not always receive adequate amounts.

Chapter 3. Water Use Model

Description of the Model

A model was developed to evaluate the water supply available from the Mendoza river. The model facilitates the evaluation of supply and demand in the Mendoza river basin on a monthly basis over a 25 year horizon.[6] The model incorporates the supply available from the river, supply available from the ground water aquifer, demands made upon the supply, infiltration realized during the distribution of the water, and potential projects which could be implemented to insure that the supply and demand are equated. The model allows one to investigate multiple options for improving the supply and managing the demand. The results calculated are the attributes used to evaluate the performance of strategies. The results can be presented in several different forms depending on the interest of the audience reviewing the output.

In order to facilitate the analysis of different types of projects two similar models are employed simultaneously to yield useful output. One model is a representation of the system without a dam/reservoir arrangement while the other is a representation of the system with a dam/reservoir arrangement. Flow diagrams for each version are shown on Figures 3.1 and 3.2. The employment of two separate versions facilitates the comparison between the current exploitation of the river and projects which could feasibly be constructed on the river. A single output file compiles the results from the two models and permits economical storage of the data. The basic idea is to repeatedly execute the models and examine the attribute values resulting from different strategies. Attributes are then presented on trade-off curves and/or as variations depicted graphically over a twenty five year period. The following sections separately describe each part of the model and the relevant assumptions incorporated in the analysis.

Supply

The Mendoza river basin offers two significant sources of water supply. The river provides an annual average quantity, measured over the period 1909-1994, of approximately 1600 hm^3. (Secretaría de Energía 1994) In addition, a large ground water aquifer has been created by the infiltration of river water during many centuries. The exact quantity

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[6] The 25 year period was identified by the Mendozan research group as the time period of interest.

Figure 3.1: Water Use Model Diagram with Dam

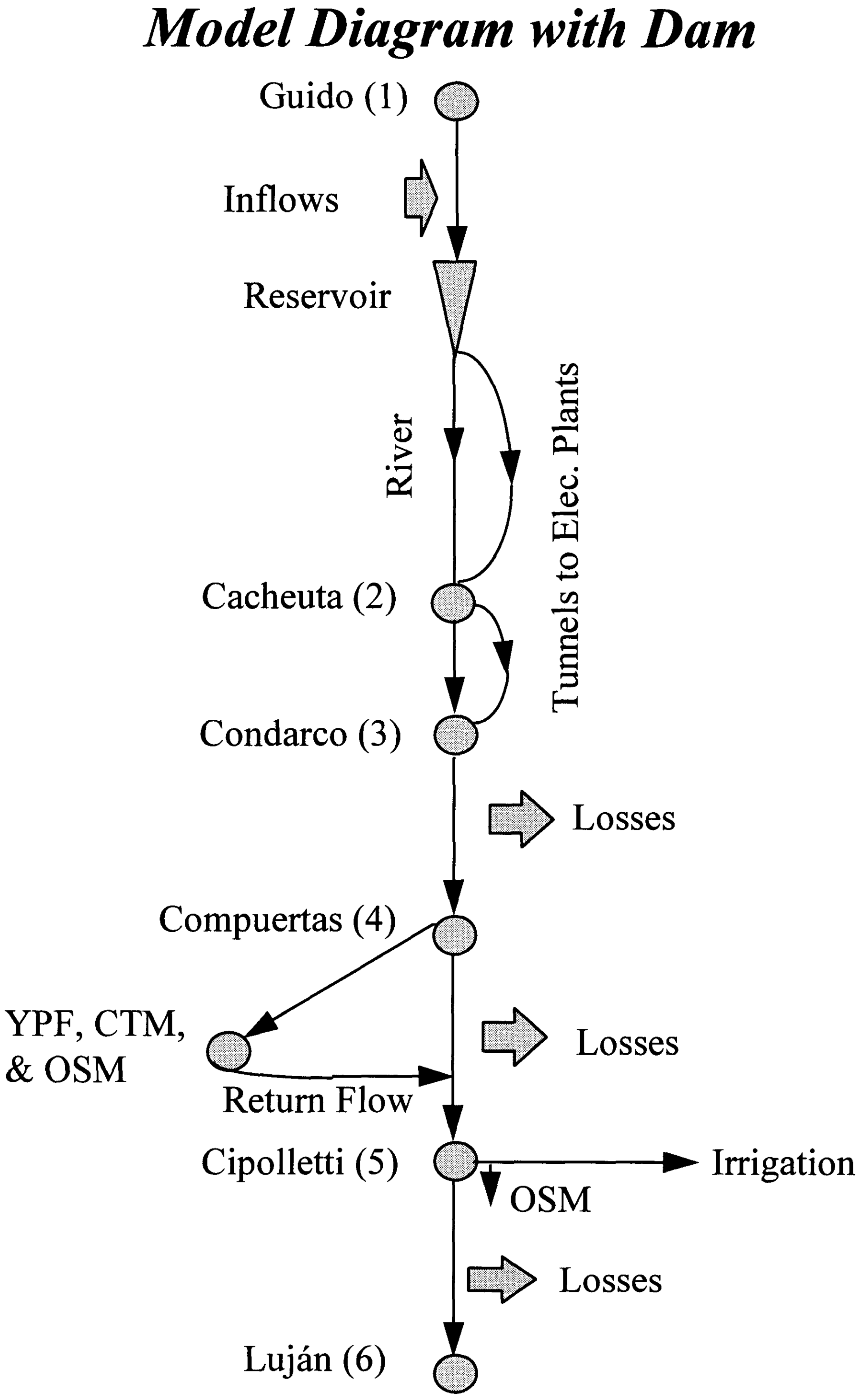
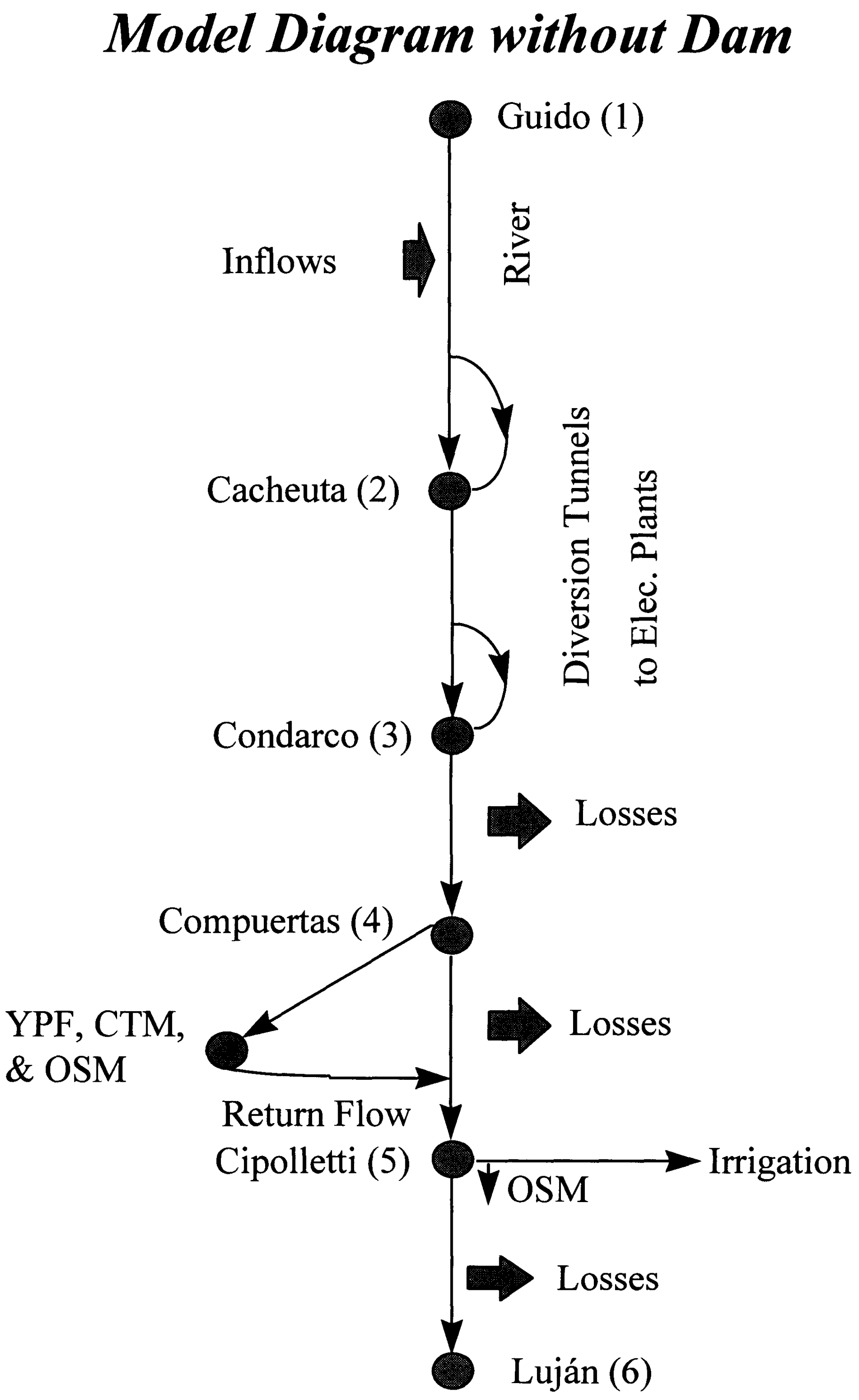


Figure 3.2: Water Use Model Diagram without Dam



stored in the aquifer is difficult to estimate, but ground water hydrologists in Mendoza have suggested that its total volume is 20,000 hm^3 with an exploitable volume of 5,000 hm^3. (Alvarez unpublished 1995) During the most recent 30 years, thousands of ground water pumps have been installed to exploit this source when droughts occurred. This has created one source of concern in the region as the extraction is not managed in conjunction with the superficial supply.

The primary river flow input to the model is the flow measured at the Guido river gauging station. This flow is manually entered in the model on the worksheet that represents the year being analyzed. (see appendix) This flow has been measured primarily by a government agency responsible for monitoring river flows throughout Argentina. The average monthly data have been published for several decades. (Secretaría de Energía 1994) The flows utilized as inputs are the values measured between 1969-1994. This historical sample exhibits 3 to 1 variations in the annual flows measured in the Mendoza River. (see Figure 3.3) This sample is acceptable and is used as a forecast for an initial analysis.

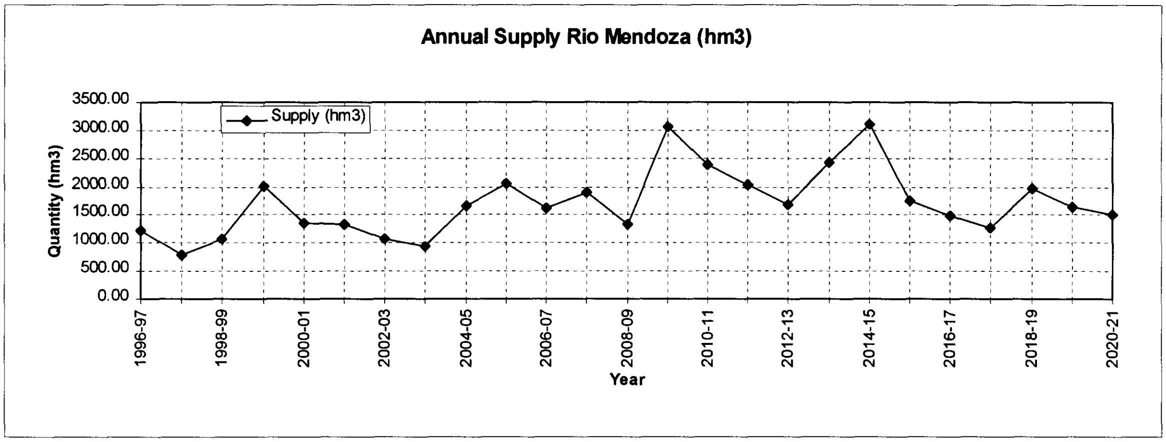


Figure 3.3: Mendoza River Average Annual Flows

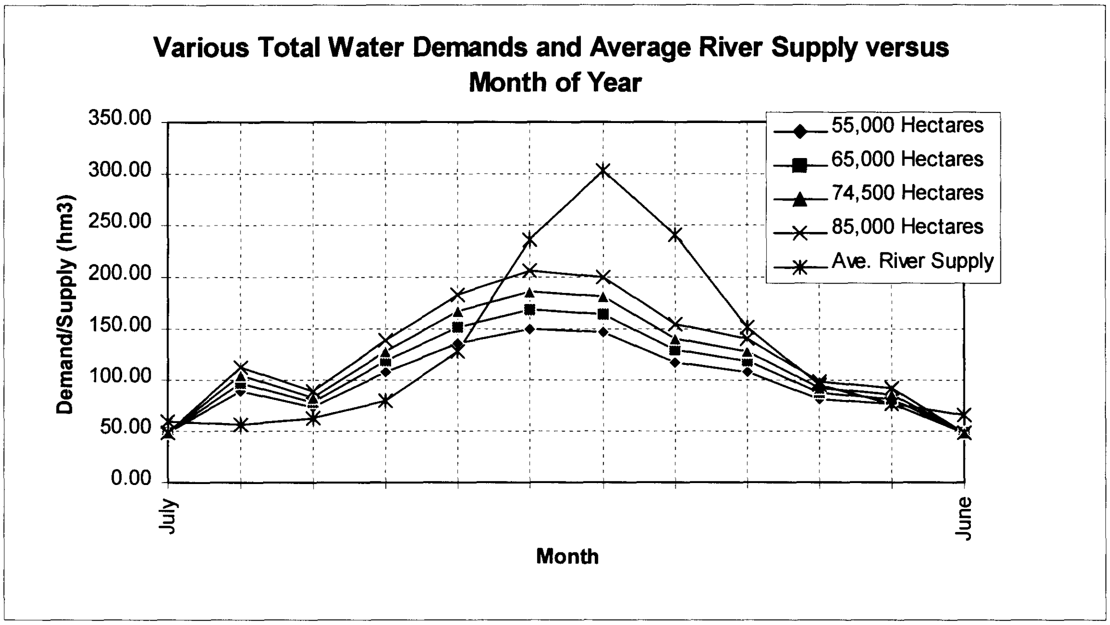
The flow at Guido is utilized in an equation which relates the flow at this location with the flow at a downstream location referred to as Cacheuta. The source of this equation is a statistical analysis performed on the flows at Guido and Cacheuta during several decades. The flow at Cacheuta has been recorded for the longest period of time (1909-1996), but during the 1980's a change in the data measured at Cacheuta was observed.

A description of the data difference is as follows: (i) the flow values measured at Guido have usually been slightly less than the concurrent flow values measured at Cacheuta, (ii) there are some months when the flow is slightly larger at Guido, but the difference generally indicates that water is lost to the river bed between Guido and Cacheuta. In the 1980's large variations appeared contrary to this previously observed pattern. The flow measured at Cacheuta was suddenly much lower than normally observed when compared with the flow at Guido. Prior to the observation of this new pattern, the Mendoza river flooded. Mendozan researchers believe the channel in the river bed where the flow is measured was physically modified during the flood. Therefore, these large variations were considered a result of a measurement error and prompted a statistical correlation of the flows measured at Guido and Cacheuta. To replace the unreliable flow values measured at Cacheuta an equation was developed at the Universisdad Nacional de Cuyo. It relates the flows between Guido and Cacheuta during the period prior to the observation of an anomaly. (UNC 1994) This equation is:

$$\text{Flow at Cacheuta } (hm^3/mnth) = 1.559 + 1.06 * \text{Flow at Guido } (hm^3/mnth) \quad (1)$$

Monthly demand and river flow variations observed during a given year are equally important and were carefully reviewed for several different historical variations in the river flows. The Mendoza river provides inadequate flow in the spring months, and considerable excess flow in the summer. This is depicted in Figure 3.4 where various demands associated with different quantities of irrigated land are plotted versus the historical average monthly river flows recorded at Cacheuta.

Figure 3.4: Monthly Water Demands and River Water Flows



The shortfall in supply that occurs during the winter and spring months (approx. August to December) can either be satisfied by a reservoir with storage capacity or, when this option is inadequate or does not exist, fulfilled with ground water. In both versions of the model the option of extracting ground water is available in the event there is insufficient supply. In each scenario without a dam/reservoir arrangement, it is assumed that 400 new ground water pumps are installed. These pumps extract water from the unconfined aquifer and deliver it directly to the canal system. Their combined capacity of approximately 65 hm^3 /month satisfies the typical spring shortages shown in Figure 3.4. The model with a reservoir utilizes existing ground water pumping capacity when no water remains stored in the reservoir. It is assumed that the reservoir is full when the simulation is commenced.

These assumptions do not precisely represent the actual usage in the region. There are agricultural regions that are not connected to the river water distribution network. These areas utilize ground water on a continuous basis to irrigate their farms. In the model the irrigated acreage is considered as a single quantity and the farms that use only ground water are not separated. The difficulty with this assumption arises in two places: (i) when there is adequate flow in the river, in which case the model indicates ground water is unnecessary, and (ii) when a reservoir is present and groundwater pumping is also unnecessary. In both these instances the quantity of groundwater pumped is underestimated.

In the case where a reservoir is present the results will overestimate the financial savings associated with the reduction in ground water pumping. The ground water pumping necessary is underestimated by 10-20 % depending on the irrigation demand. The financial benefits associated with a reduction in pumping are 10-15 % of the total benefits accrued when a reservoir exists. Therefore, the net effect is to reduce the benefits by 1-3%; this difference does not significantly alter the results. Without a reservoir present, ground water is required each year in order to satisfy the demand. Therefore, as long as the ground water demanded is greater than the quantity required to irrigate the acreage that is exclusively supplied with ground water, there exists no discrepancy. This situation prevails in most years, and when an underestimate occurs, it can be similarly argued that the difference in benefits does not significantly alter the results.

Demand

The models incorporate three types of demand for water: (1) industrial water uses, (2) water works requirements (potable and sewerage), and (3) water to irrigate farms. These three demands comprise the major uses of the water from the river. The demand is presented on a separate table included on the worksheet for the year analyzed. (see appendix) Both models incorporate the same demands in order to insure proper comparisons of the results. Each demand has different characteristics and is discussed separately.

Industrial demands are the simplest to explain. In Mendoza the rights to utilize water from the river are awarded under the sanction of the Water Law. There are currently only two industrial organizations which are allowed to utilize river water. The first organization operates a thermal power plant adjacent to the river. They are permitted to divert 12 m^3/s. A portion of this flow--5.5 m^3/s--is returned to the river while the balance is then delivered to the second industry, an oil refinery. These industrial flows are removed by a dike located at Compuertas and depicted on the model diagram. The incorporation of future variations in the demand can be achieved by modifying the input table.

Potable water is delivered to Obras Sanitarias de Mendoza. (OSM) This company is responsible for the distribution and provision of potable water of acceptable quality. They receive a large quantity of their required water from the dike located at Compuertas while a smaller quantity is obtained from the diversion at Cipolletti. The potable demand can be varied by modifying the input table.

Irrigation requirements are satisfied with a large diversion works which diverts water from the Mendoza river into a large canal system at Cipolletti. Irrigation demands tend to be the most complex to estimate and incorporate into the models. This is due to the difficulty in obtaining data which accurately represent the acreage currently cultivated and potential changes in the future demand. Fluctuations in the quantity of land cultivated are related to the ability of the farming community to realize sufficient profits given the crop mixture selected. The most accurate estimates of cultivated land are obtained from the DGI; their estimates have been utilized with the water demand per hectare as a function of crop distribution to determine irrigation water demand. Uncertainty in the total demand is incorporated in the model by varying the quantity of land irrigated.

Simplifying the input of the agricultural demand was important as the information available is not always abundant. The basic procedure employed by the irrigation department is to examine a moment in time and utilize the crop distribution determined by census to develop the demands. The crop distribution is available as a function of three primary areas where irrigation water is delivered. In Mendoza these areas are referred to as Superior, Medio, and Inferior tracts. The three tract delineation is utilized in the model to separate the demands.

In Table 3.1 and Figure 3.5 the monthly variations in demand as a function of crop type are presented. The amount of water typically required to satisfactorily generate an acceptable yield has been calculated by Instituto Nacional de Technología Agropecuario

(INTA). These data, shown in Table 3.1 and Figure 3.5, are available by crop type in mm/mnth.

Table 3.1: Typical Water Requirements for Various Crops in Mendoza

Analysis of Typical Agricultural Water Requirements for Various Crops in Mendoza													
Crop	Monthly Evapotranspiration[1] (mm)												
	July	August	September	October	November	December	January	February	March	April	May	June	Total
Grapes	0	82	36	83	121	157	161	131	126	69	50	0	1016
Veges	12	19	24	81	120	119	112	63	0	0	9	10	569
Olives	15	32	46	81	113	141	143	118	124	80	63	35	991
Fruit	0	50	52	97	134	164	164	130	122	65	50	0	1028
Alflafa	24	51	74	118	158	200	200	153	122	65	0	0	1165
Trees	0	0	52	97	134	163	163	130	122	65	50	0	976

1. Source: R. Bagini, Como, Cuando, Cuanto Regar, Instituto Nacional de Technologia Agropecuaria, 1988.

Table 3.1 reveals that the variations in yearly demand are not large when different crops are considered. Though the yearly demand does not vary significantly, the monthly demands do vary considerably as shown in Figure 3.5. The crop structure must change considerably to affect the monthly demands shown. It is assumed that a rapid crop structure change is unlikely and that these data sufficiently represent crop variations for the 25 year analysis period.

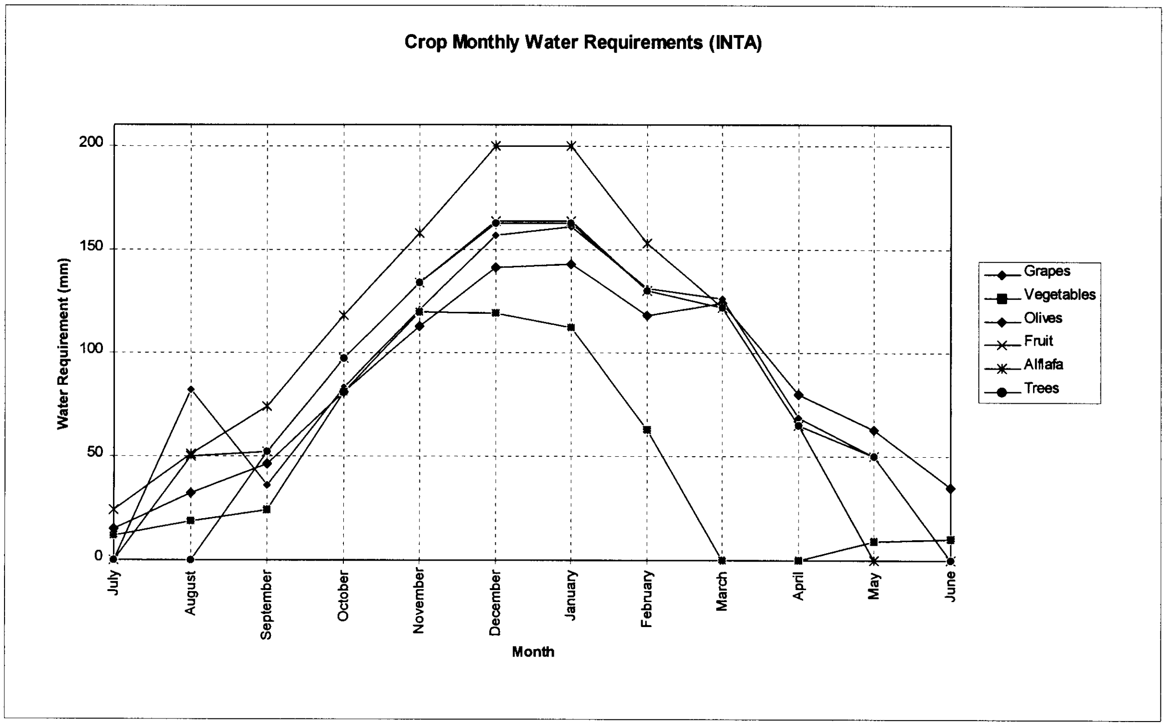


Figure 3.5: Monthly Crop Water Requirements

The INTA data are used to calculate the water demand for each hectare cultivated. Table 3.2 presents water demand data as a function of the crop distributions of the three tracts recently determined by census. The data in Table 3.2 are utilized to generate a weighted demand that takes into account the different demands of the land cultivated as a function of the crop structure. (see example calculation in Table 3.2) These values are then added to obtain a quantity of water demanded for each month as a function of a given crop distribution. The monthly demands per tract are manually input to the water use model.

The conditions of the market are difficult to estimate and therefore the potential to vary demand is incorporated in the model by varying the quantity of land irrigated, though the actual quantity of land being irrigated is a function of the markets for the agricultural products.

Table 3.2: Monthly Irrigation Water Demands

Irrigation Water Demands Expressed as a Function of the Most Recently 0bserved Crop Distribution Compiled by the Associated Region														
Tramos Superiores		**Irrigation Water Demand^2 (m^3/ha)**												
Crop^3	% of Total	July	August	September	October	November	December	January	February	March	April	May	June	Total (m^3/ha/yr)
Grapes	47.9	0	393	172	398	580	752	771	627	604	331	240	0	2726
Veges	23.4	28	44	56	190	281	278	262	147	0	0	21	23	2319
Olives	9.5	14	30	44	77	107	134	136	112	118	76	60	33	977
Fruits	11.4	0	57	59	111	153	187	187	148	139	74	57	0	1328
Trees	2.2	5	11	16	26	35	44	44	34	27	14	0	0	215
Animal Feed	5.6	0	0	29	54	75	91	91	73	68	36	28	0	0
	Monthly Totals	48	536	377	855	1230	1487	1491	1142	956	531	405	57	9114
	Effec. Precip.	40	25	50	127	160	238	286	300	224	122	50	45	1667
	Net Demand	8	511	327	728	1070	1249	1205	842	732	409	355	12	7447
2. This number is obtained as follows: e.g. - for grapes in August ; .479 (%) * 82 ~~mm~~ * 1 m/1000~~mm~~ * 10000 m^2/ 1 ha = 393 m^3 /ha														
Tramos Medios		**Irrigation Water Demand (m^3/ha)**												
Crop^3	% of Total	July	August	September	October	November	December	January	February	March	April	May	June	Total (m^3/ha/yr)
Grapes	49.7	0	408	179	413	601	780	800	651	626	343	249	0	2828
Veges	18.8	23	36	45	152	226	224	211	118	0	0	17	19	1863
Olives	16.4	25	52	75	133	185	231	235	194	203	131	103	57	1686
Fruits	13.3	0	67	69	129	178	218	218	173	162	86	67	0	1549
Alfalfa	1.4	3	7	10	17	22	28	28	21	17	9	0	0	137
Trees	0.4	0	0	2	4	5	7	7	5	5	3	2	0	0
	Monthly Totals	51	569	381	847	1218	1488	1498	1163	1014	572	437	76	9314
	Effec. Precip.	40	25	50	127	160	238	286	300	224	122	50	45	1667
	Net Demand	11	544	331	720	1058	1250	1212	863	790	450	387	31	7647
Tramos Inferiores		**Irrigation Water Demand (m^3/ha)**												
Crop^3	% of Total	July	August	September	October	November	December	January	February	March	April	May	June	Total (m^3/ha/yr)
Grapes	65.9	0	540	237	547	797	1035	1061	863	830	455	330	0	3750
Veges	11	13	21	26	89	132	131	123	69	0	0	10	11	1090
Olives	1.6	2	5	7	13	18	23	23	19	20	13	10	6	164
Fruits	14	0	70	73	136	188	230	230	182	171	91	70	0	1631
Alfalfa	5.3	13	27	39	63	84	106	106	81	65	34	0	0	517
Trees	2.2	0	0	11	21	29	36	36	29	27	14	11	0	0
	Monthly Totals	28	663	394	869	1248	1560	1579	1243	1112	607	430	17	9751
	Effec. Precip.	40	25	50	127	160	238	286	300	224	122	50	45	1667
	Net Demand	0	638	344	742	1088	1322	1293	943	888	485	380	0	8084
3. Source: Juan Gustavo Satlari, La Demanda Agricola en al Area de Riego del Rio Mendoza, DGI, 1994.														

This analysis is designed to screen the effects of different changes in the supply methodology employed and does not examine the markets for agricultural goods. The lower and upper bounds utilized for the quantity of land irrigated are derived from historical information on the regional economy during different eras. The model can be easily modified to incorporate varying crop structures, as a function of market demands, if a more detailed analysis is desired.

Infiltration

Infiltration is a significant source of water losses in the distribution system, the river bed between Cacheuta and Cipolletti, and on the farms themselves where the usage efficiency is low. The first significant source of infiltration encountered is in the river bed between Cacheuta and Cipolletti. An equation has been developed by C.R.A.S. to represent this infiltration. (Hernández, 1987) This equation relates the losses due to infiltration to the flow at Cacheuta and is used in the model:

$$\text{Infiltration (hm}^3\text{/mnth)} = 1.086 * (\text{Flow at Cacheuta (hm}^3\text{/mnth)})^{.58} \quad (2)$$

Though the study on which this equation is based measured the infiltration between Cacheuta and Cipolletti, the primary zone where infiltration occurs is between Condarco and Cipolletti.[7] Therefore in the model we have chosen to neglect any infiltration between Cacheuta and Condarco. The water volume lost according to equation (2) is then apportioned into two parts: the tract between Condarco and Compuertas and the tract between Compuertas and Cipolletti. This separation is effected by calculating the losses as a function of the length of the river bed through which the water flows. This lineal distance is then divided by the total distance between Condarco and Cipolletti and this fractional quantity is multiplied by the losses as calculated by equation 2. This permits the calculation of a distinct flow at the Compuertas location.

This section of the river bed is the only location where significant infiltration has been observed and carefully measured. There is infiltration in the river bed downstream of Cipolletti, but the primary extraction point for irrigation water is the dike installed at Cipolletti. The losses between Cipolletti and Lujan are estimated to be 14 % of the flow in the river, but data based on measurements do not exist. The model calculates this loss using the estimate of 14 % to incorporate the fact that there is infiltration. Realistically, little flow

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[7] Personal communication with Amilcar Alvarez.

passes downstream of Cipolletti, though there is a location where water can be diverted to supply portions of the Inferior tract. It appears that when water is available it is diverted, and at other times those who cultivate this land utilize ground water.

Infiltration in the canal system is a significant source of water losses. There are numerous earthen distribution canals that have no defense against infiltration. Currently the losses are assumed to be a percentage of the total water demanded for irrigation. The DGI has been utilizing an estimate of losses due to infiltration of 50 % of the agricultural demand. (DGI 1995) An additional source of information has been a report written by C.R.A.S. that analyzes losses in the secondary canal network. (Hernández 1982) The C.R.A.S. report only investigates three months of the year and measurements of the quantity of water lost due to infiltration vary considerably. The extension of the results to represent a full year produces a value for total losses twice as large as the acknowledged total. Incorporating the specific results of the CRAS study directly substantially overestimates the amount of losses that occur in the canal network. The CRAS report does state that generally 15-20 % of water delivered to secondary canals is lost, but this value is an estimate.

Specific findings in the CRAS study are in agreement with canal losses measured in other parts of the world. The variance in the losses is large and losses in earthen canals can be as low as 5 percent or as high as 50 percent. (Kraatz 1977) Numerous variables affect the actual losses: sediment concentration of the water in the canal, canal material, wetted area, flow rate, and plants growing in the canal are some of the important variables. These facts emphasize the importance of measuring actual losses prior to making an assumption of the losses that can be mitigated by canal lining. The analysis performed herein to approximate losses provides acceptable estimates, but insufficient information is available to specifically identify individual canal losses.

Losses in the canals and on the farms were estimated in the model as presented in Table 3.3. The estimates were derived by examining the amount of land irrigated by individual canals and the volume of water delivered to the canals. These data were obtained from reports published by the DGI. The amount of land corresponds to the acreage registered to receive water from the river. The acreage associated with each canal, with crop distributions as a function of tract, is multiplied by the demand per hectare shown in Table 3.3. This provides an estimate of the amount of water actually required to successfully irrigate the registered land. This is then compared with the volume of water that the DGI indicates is delivered to the specific canal on a yearly basis.

Table 3.3: Water Losses in Canals and on Farms

Derivation of Water Losses in Canals and on Farms										
		Irrigation Water Demanded by Crops and Delivered by Canal						Infiltration as % of Excess Flow		
Main System	Secondary Canal Names	Area Served (hectares)	Demand-Crops (m3/ha/yr)	Total Demand (hm3/yr)	Flow Delivered (hm3/yr)	Excess Flow (hm3/yr)	% of Total Delivered	Worst=1 (>40%)	Infiltr. on Farm 60%-hm3/yr	Infiltr. in Canals 40%-hm3/yr
Canal Cacique Guaymallen										
(Tramos	Lima/Lulunta	2217.5	7447	16.514	31.824	15.310	48.11%	1	9.186	6.124
Superiores)	Chacras de C. y la Falda	1223.3	7447	9.110	12.618	3.508	27.80%		2.105	1.403
	Sola./Moral./Vill./Cald.	1631.9	7447	12.153	14.066	1.913	13.60%		1.148	0.765
	2nd Guinazu	600.2	7447	4.470	17.098	12.628	73.86%	1	7.577	5.051
	Matriz Gil	3216	7447	23.951	41.653	17.702	42.50%	1	10.621	7.081
	Jarillal	2684.2	7447	19.990	47.046	27.056	57.51%	1	16.234	10.822
	Sobremonte	2277.3	7447	16.960	21.274	4.314	20.28%		2.589	1.726
	Mathus Hoyos	3824.4	7447	28.482	41.075	12.593	30.66%		7.556	5.037
	Tajamar/Tobar	1574.7	7447	11.727	10.083	n/a	-			
	Algarrobal	1418.5	7447	10.564	26.129	15.565	59.57%	1	9.339	6.226
	Estaben	1366.5	7447	10.177	11.845	1.668	14.08%		1.001	0.667
	Tulumaya	5603.2	7447	41.729	32.704	n/a	-			
	Jocoli	7551.9	7447	56.241	85.4	29.159	34.14%		17.495	11.663
Totals		35189.6		262.069						
Canal Matriz San Martin										
(Tramos	Barrancas/Espino	1440.8	7647	11.018	13.054	2.036	15.60%		1.222	0.815
Medios)	Naciente	4565.5	7647	34.912	51.118	16.206	31.70%		9.724	6.483
	Ortega	912.5	7647	6.978	13.123	6.145	46.83%	1	3.687	2.458
	Chachingo	2987.2	7647	22.843	42.349	19.506	46.06%	1	11.704	7.803
	Cespedes	2828.5	7647	21.629	26.915	5.286	19.64%		3.172	2.114
Totals		12734.5		97.379						
Gran Canal Matriz										
	2nd Vistalba	693.9	7647	5.306	7.607	2.301	30.25%		1.381	0.920
	!st Guinaz	220.8	7647	1.688	2.768	1.080	39.00%		0.648	0.432
Totals		914.7		6.995						
Tomas Dirs.	Compuertas& 1st Vistalba	1699.93	7647	12.999	20.011	7.012	35.04%		4.207	2.805
	Ramo Num. 1	32.1	7647	0.245		n/a	-			
Totals		1732.03		13.245						
Marg. Derec.										
	Flores	2773.3	7647	21.207	34.01	12.803	37.64%		7.682	5.121
	Corvalan-Santander	3203.3	7647	24.495	36.35	11.855	32.61%		7.113	4.742
Totals		5976.6		45.702						
Tramos										
Inferiores	Galign./Reina/M. Hoff	8010.7	8084	64.761	118.998	54.237	45.58%	1	32.542	21.695
	Villa Central	1168.3	8084	9.445		n/a	-			
	Bajada de Araujo	3844.5	8084	31.080	55.847	24.767	44.35%	1	14.860	9.907
	San Pedro y San Pablo	3829.4	8084	30.958	56.123	25.165	44.84%	1	15.099	10.066
	Conc. California	2826.5	8084	22.850	61.203	38.353	62.66%	1	23.012	15.341
	Natalio Estrella	1784.9	8084	14.430	25.924	11.494	44.34%	1	6.897	4.598
	Gustavo Andre	2723.3	8084	22.016	32.011	9.995	31.22%		5.997	3.998
Totals		24187.6		195.539					233.795	155.863
	Total Hectares	80735.03								
Demand										
Summary	Total-Crops (hm3/yr)	620.928								
	Total-Losses (hm3/yr)	389.658								
	Total - 80735 Ha	1010.586								
Source: DGI										

The difference between the amount delivered and the amount necessary is assumed to represent the losses. The result is between 40-50% of the total demand depending on the specific DGI data utilized to obtain the water volume delivered to the canals. The DGI records do not contain the same quantities on a yearly basis though variations are not considerable in most cases. It is impossible to determine the accuracy of these data. The data utilized were from years where there was in fact an ample quantity of water available to satisfy the demands as registered by the amount of land which has rights to the water. The general finding indicates that the estimates are in agreement with what is conventionally believed in

Mendoza. Those canals identified as having the highest losses are selected for lining in the strategies where lining is indicated.

The infiltration in the canals and on the farms is considered unrecoverable and subsequently unavailable for future usage. The free surface ground water table exhibits elevated salt concentrations and CRAS advises that this water does not appear to be rapidly transmitted to confined aquifers located deeper in the earth. A major concern with this source of infiltration is the resulting level of the ground water table. If the level is too close to the land surface the crops can be adversely impacted by the water. This is not currently a problem in the region irrigated by the Mendoza river, but is thought to be the origin of a substantial problem in regions where the clear water problem is observed. The resultant free surface level and the salt concentration need to be carefully considered in the ground water model. It is assumed that a reduction in infiltration on farms and in canals is acceptable. The ground water table should not rise when actual infiltration is reduced below current levels.

Strategy Analysis

The model has been developed to permit an examination of different types of strategies which affect the management of the water supply and its distribution. The performance of specific supply options is examined by varying the demand for water. The financial indicators, internal rate of return and net present value, are used to determine the financial performance of supply management options. The costs to implement a project are input on the worksheet and the benefits that result during the life of the project are either calculated by the model or input manually. Different projects can be studied and compared against the current way in which water is obtained from both the river and the ground water aquifer.

The costs input into the model are simply the costs associated with implementing a strategy. These are entered as negative cash flows in the years during which they occur. The sources of the cost estimates for the projects considered are the numerous documents that present multiple projects considered to be feasible. These data were provided by the research group in Mendoza and are referenced in this document.

The model output analysis contains numerous results associated with a defined scenario. These results permit the calculation and subsequent study of attributes associated with each scenario. The Mendoza river basin presents a situation where conjunctive water use is clearly an option. Planned conjunctive use demands careful attention to the ground water recharge and pumping volumes. The output of the model includes flows, infiltration, electricity generated, demands, water supplied from the river and the groundwater aquifer and quantifiable benefits. These outputs comprise the majority of the relevant attributes. The depiction of the output data is achieved with tradeoff graphs and graphs containing 25 year variations in flows, losses, and ground water consumption. The variation of yearly flows is utilized to examine the water supply in years of low precipitation. During these years the reliance on groundwater increases and adequate pumping capacity is necessary to meet demand. In this situation one can examine the actual performance of a project over 25 years as presented in specific graphs which display, for example, ground water pumped versus years. Examples of the graphs available are provided in the appendix.

The benefits associated with different strategies can be difficult to calculate accurately due to their dependence on assumptions. For example, different sources in Mendoza have calculated numerical values for benefits such as tourism, increased agricultural output, and flood control which are associated with the construction of a dam. Estimates of agricultural output and tourism benefits are highly susceptible to market behavior and, most importantly, the behavior of individual investors and land owners. As a result of this Mendozans have estimated different values for the benefits associated with a dam project, but do not agree amongst themselves with the monetary values utilized to quantify the benefits. Estimates of these benefits generated in Mendoza are utilized in scenarios with a proposed dam, but it is not possible to validate the accuracy of these data given the uncertainty associated with them.

Other benefits such as the cost savings when groundwater pumping is reduced or the value of the electricity generated are less contentious. These benefits are common to all scenarios analyzed, and when quantified, the selected value is used in each scenario. For example, a value for electricity generated is input and utilized by the model for an entire future. This permits a fair comparison of the performance of different scenarios. This methodology works well when examining the costs to extract ground water and the value of electricity generated.

The benefit most accurately represented is the value of electricity obtained from a hydroelectric power plant. This value will be a function of the prevailing value of electricity on the wholesale market in Argentina. This value is utilized in the electricity model described previously (Paz-Galindo 1996) and can be varied to examine the increase or decrease in benefits received from a hydroelectric facility. The value most commonly employed is $30/Mwh. This figure originates from careful examination of the forecasts provided by the company which operates the wholesale market, CAMMESA. (CAMMESA 1995) This value is subject to substantial debate, but is considered stable as a result of the extensive excess supply that currently exists in the country of Argentina. There is approximately an excess of supply over demand of 40%. This permits some degree of confidence in this assumption.

The quantity of electricity generated each month by the model is simply a function of the flow, density of water, and available head and is calculated by the formula:

$$\text{Electricity (Mwh)} = 2.73 * \text{Flow (hm}^3\text{/mnth)} * \eta * \text{Head (m)} \quad (3)$$

The coefficient, 2.73, is a conversion factor which includes the density of water and η is the efficiency of the turbine and associated electrical generation equipment. The head is relatively constant in the case of a plant where there is a small reservoir to collect the water. This type of plant is similar to the current facilities at Cacheuta and Condarco which are commonly referred to as run-of-the-river plants. The head is variable when there is a dam/reservoir associated with the generation facility. The variance is then calculated by averaging the minimum and maximum quantity of water in the reservoir for the month being examined. The change in volume is related to the head thorough the use of a reservoir volume/elevation relationship curve developed for each specific dam/reservoir project examined.

The electricity generated when a dam/reservoir exists is modeled as a function of the demand for water downstream. This assumes that the primary usage of the stored water is for irrigation and electricity is generated when irrigation water is released. Current and future forecasts of the wholesale electricity market have not indicated a substantial difference in peak and off-peak electricity values. If this situation were to change it might be important to analyze the highest value use of the stored water. The analysis in this thesis does not investigate a variety of reservoir operational rules. In the case of a run-of-the-river facility an operating rule is employed which limits the quantity of water diverted to the plant to no more than 80% of the average flow of the river during the month under consideration. This operating rule was derived by comparing model results with actual data. All plants analyzed have limits on the quantity of water which can be utilized to generate electricity during a month. This limit is the maximum flow rating of the equipment in hectometers cubed per month. The maximum flow ratings are either the nameplate capacities of existing equipment or the capacities of plant equipment proposed for future facilities.

The amount of electricity consumed to pump ground water is difficult to obtain accurately. The difficulty arises from a lack of information describing the actual installation of the wells and pumps, the flow rate achievable, and the actual lift required to elevate the water to the surface. The model determines the volume of ground water required monthly. This value can then be multiplied by a cost per unit of volume pumped to obtain total costs. The most comprehensive study available examining these costs was executed in 1995 by

University personnel. (Pizzi 1995) However, the amount of electricity required to pump ground water as predicted by the model is much lower than the quantity that the local utility, E.M.S.E., indicates is actually consumed. A possible explanation for this apparent discrepancy is found in the report of several Mendozans who indicate that several industries are utilizing ground water to cool equipment or in other industrial processes. Estimates by the writer indicate that half of the electricity consumed could be industrial users taking advantage of the subsidized tariff.

The model allows the comparison of different alternatives available to improve the supply of water. In each scenario investigated the value of interest is the difference in the quantity of ground water required to satisfy the demand. This difference is then multiplied by the cost per unit pumped to generate a financial benefit. The cost per unit pumped is the same in all the alternatives examined and therefore there is no bias in the results. The inaccuracy is that the magnitude of moneys expended to pump could be incorrect and should be the subject of further investigation in subsequent studies.

Analysis Limitations

The model concentrates on the implementation of global improvements assumed to result from a variety of smaller scale management options. The assumption is made that the capacity to execute these projects exists and that the only requirement is recognition of the need for a conjunctive use plan and appropriate policies to insure modifications. These could be questionable assumptions when one considers the history of the previous twenty years. (see Frederick 1975 and Braceli 1985)

The model does not attempt to include valuation of benefits from the realization of regional economic goals. For example, the value of improved agriculture is not analyzed quantitatively in the model. The assumption is that improved water supply creates the opportunity for improved cultivation. The potential benefits can be exploited under any scenario. Increased agricultural activity is incorporated by the ability to vary the quantity of land being cultivated. This variation affects the demand for water which then affects the performance of supply management options. Similarly a value for potential economic gains from tourism is not calculated by the model, however the scenarios which examine the performance of a reservoir do include estimates of these benefits. These estimates have been obtained from other studies performed in the region. These can not be neglected in the analysis of a reservoir, but it is important to recognize that the electricity value is the source of more than half of the revenue from a dam project. (see results in appendix)

These limitations do not prevent productive study of potential improvements of the supply. The costs of the improvements can be compared with quantifiable benefits as well as benefits related to improved management. Similarly, the risk of clear water problems from sediment settling in a reservoir, an issue which does not currently have quantitative definition, can be envisioned.

Model Operation

The computer code executed to operate the model is depicted graphically in Flow Charts 1 and 2 in the appendix. Flow Chart 1 depicts the methodology employed to analyze a situation where a dam/reservoir exists. Flow Chart 2 depicts the methodology utilized when there is no dam/reservoir. The significant difference is the analysis of storage in the version with a dam/reservoir. The code utilized to program the model is Visual Basic and the model operates satisfactorily in Microsoft Excel Version 5.0. The appendix contains examples of the code required to execute the scenarios examined.

The output for the model is generated on a year by year basis. The output table, located on a separate worksheet for each year analyzed, allows one to examine all pertinent information related to each node on a month by month basis. The nodes are defined as shown in Figures 3.1 and 3.2. A simple application of conservation of mass rules permits an individual to verify that the calculations are performed correctly. Additionally one can verify that the formulas have been executed correctly by making test calculations with a hand held calculator. A summary comparison of the output for two twenty five year periods is generated in a separate output analysis file.

Chapter 4. Analysis Results

The thirteen strategies presented in Tables 1.1 and 1.2 were analyzed over five different futures. Four of the futures studied concentrated on analyzing variations in the demand for water as a function of the amount of land receiving water for irrigation. One variation in the potable water demand was analyzed. In each future the water usage model equates supply and demand for all scenarios analyzed. The five futures investigated are shown on Table 4.1.

Table 4.1: Futures Analyzed with the Water Use Model

Future	Futures Considered Water Demand Variations		
	Potable (OSM)	Industrial	Irrigation
# 1	6/95 Forecast	Constant	74,500 hectares
# 2	6/95 Forecast	Constant	55,000 hectares
# 3	6/95 Forecast	Constant	65,000 hectares
# 4	6/95 Forecast	Constant	85,000 hectares
# 5	3% Growth per Year	Constant	74,500 hectares

A major difficulty with formulating futures was the limited participation of the DGI. At the beginning of the research effort it became apparent that the DGI was an extremely important stakeholder who did not have a representative involved in the project. Several attempts were made to obtain data from the DGI and to provide a detailed explanation of the tradeoff analysis. Unfortunately the DGI did not become an active participant until after preliminary results had been obtained. The writer was hesitant to act individually and define several futures without first reviewing the model with the DGI and discussing the assumptions. Thus, the initial analysis was conceived to demonstrate the tradeoff technique and provide preliminary output which supports the idea that options are available and must be considered. The futures and strategies were reviewed with those Mendozans who participated in the first phase of the research. When the DGI has the opportunity to understand the analysis, additional futures and strategies will undoubtedly be identified and can then be analyzed.

Preliminary runs of the model demonstrated that the quantity of land being irrigated significantly impacts the results. An increase in the acreage irrigated increases both the volume of water necessary to insure proper plant growth and the volume of water lost in the canals and on the farms. According to the DGI, 74,500 hectares is the approximate amount of land currently with water rights. Current estimates indicate that between 50,000 and 60,000 hectares are actually irrigated. The first phase is limited to 4 different acreage's that represent feasible possibilities. This permitted the analysis of substantial fluctuations in the demand.

The potable demand utilized in four futures was obtained from a 1995 forecast that Obras Sanitarias Mendoza had completed for the period 1995-2025. This forecast was developed assuming that a water metering system would be installed over the next few years. The system would permit OSM to charge customers on the basis of the volume utilized. The assumption is that demand will decrease when the system is implemented and begin to rise in later years. The forecast data were input into the model for the analysis. One future assumed a constant 3 percent yearly growth in potable water demand. This alternative permits an examination of how variations in potable demand compare with variations in land irrigated.

The amount of water consumed by industrial users was considered constant for all futures. This value was not varied because the endowments provided to industry have been the same for some twenty years. The current industrial uses are for the refinery and power plant located at the Compuertas diversion. There is no indication that these demands are going to change. Many industrial organizations either have ground water pumps or can install pumps if necessary. They are not completely dependent on the river, and when water is delivered they naturally use it since there is no electricity cost. There are other industrial organizations that pump groundwater, but information sufficient to evaluate their usage was unavailable. The industrial ground water pumping issue is discussed in Chapter 3.

The model calculated the nine attributes defined in Chapter 3 for 13 strategies over 5 futures or 65 scenarios. The attributes are as follows:

- Average quantity of ground water pumped calculated over a 25 year period[8];
- Electricity generated by existing or proposed facilities;
- Quantity of water that recharges the unconfined aquifer;
- Quantity of water that infiltrates on the farms;
- Electricity consumed to pump ground water;
- Economic benefits associated with dam/reservoir projects;
- Present value costs of scenarios;
- Internal rates of return for scenarios;

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[8] The 25 year period was identified by the Mendozan research group as the time period of interest.

- Net present values for scenarios.

These attributes were defined in conjunction with the Mendozan research group. The attributes represent important indices of scenario performance. Attributes allowing the determination of the limits of the water supply as well as economic benefits associated with the different scenarios are calculated and displayed. Future involvement of the DGI will surely identify other important attributes.

The results are presented on 6 tradeoff graphs for each of the 5 futures. The nine attributes are defined to insure that the origin of the graphs represents the optimal value of both attributes. This can create confusion and careful examination of the graphs is required to insure that the representation of the attribute is understood. The graphs listed below illustrate the definitions of the attributes necessary to insure the origin is optimal. The six tradeoff graphs presented are as follows:

- (1) 1 minus the electricity generation facility capacity factor versus average yearly quantity of ground water pumped over a 25 year period;
- (2) A measure of a strategy's financial performance (.35 minus internal rate of return (IRR))[9] versus average yearly quantity of ground water pumped over a 25 year period;
- (3) The net present value of the scenario versus .35 minus IRR;
- (4) The net present value of a scenario versus the water cost of the scenario;
- (5) Present value costs of strategies versus average yearly quantity of ground water pumped over a 25 year period;
- (6) Present value costs of strategies versus total quantity of ground water pumped during 25 years divided by the quantity that infiltrates into the unconfined aquifer between Cacheuta and Cipoletti.[10]

The following comments provide additional explanation of several of the specific attributes defined to construct the tradeoff graphs. The capacity factor (see attribute no. 1)is defined as the average yearly quantity of electricity generated by the facility divided by the maximum quantity of electricity the facility could generate if it was operated at full capacity

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[9] The selection of .35 is arbitrary and is based on the observed results. The definition of .35 - IRR is necessary to make the origin the optimal location when presenting this attribute graphically.

[10] The primary recharge of the confined aquifer has been identified by CRAS as the unconfined aquifer which receives the majority of its recharge from the river bed between Cacheuta and Cipolletti.

for an entire year. The capacity factor is subtracted from one to define the origin of the graph as the most desirable location. The water cost (see attribute no. 4)is obtained by dividing the net present value of a scenario by the total water demand for the 25 year period. Recognizing that the NPV's are negative for every scenario analyzed, the result can be thought of as the cost to provide water as a function of the scenario being analyzed. One can imagine this value as a representation of the water supply cost.

The ratio of total quantity of groundwater pumped to the quantity that infiltrates between Cacheuta and Cipolletti (see attribute no. 6)provides insight into the conjunctive use of the surface and ground water in Mendoza. CRAS indicates that the recharge source of the confined aquifers is the infiltration between Cacheuta and Cipolletti. The ground water pumps in the Mendoza river valley obtain water from the confined aquifer. This ratio represents a measure of whether or not the ground water is being mined. A value less than one signifies less pumping than infiltration while a value greater than one signifies excessive pumping. The infiltration volume does not include water that infiltrates into the unconfined aquifer from canals and farms situated on the land above the unconfined aquifer. This assumption must be reconsidered following a detailed analysis of the ground water flow currently underway by CRAS. The ground water model will permit a simulation of the entire ground water system for each scenario of interest. The best value for this attribute will be determined from the ground water flow model results. The current infiltration/pumping condition is assumed to be an initial indicator of an acceptable conjunctive use.

An example of the six graphs for one future is included here for discussion. The complete set can be seen in the appendix. It is important to recognize that the results presented in this thesis are sufficient to demonstrate the tradeoff analysis applied to the water resource management problem in Mendoza, but have not been generated with the intent of reaching final conclusions. The primary objective has been to incorporate more flexibility into the planning process and create a forum where different strategies can be discussed amongst stakeholders. The output represents the first phase of a comprehensive tradeoff analysis. Improvements are easily conceived and implemented to broaden the analysis and generate ample data to identify strategies that belong in the final decision set.

Examination of Figure 4.1 reveals that scenarios 1, 4, and 8 are those that lie along the frontier.[11] Results from futures 2-4 revealed that variations between scenarios 1 and 4 appear

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[11] Scenario 1 is Potrerillos, Scenario 4 is Potrerillos with the marginal canal, and Scenario 8 is the marginal canal combined with a reduction in canal water losses.

Figure 4.1: Trade-Off Graph 1

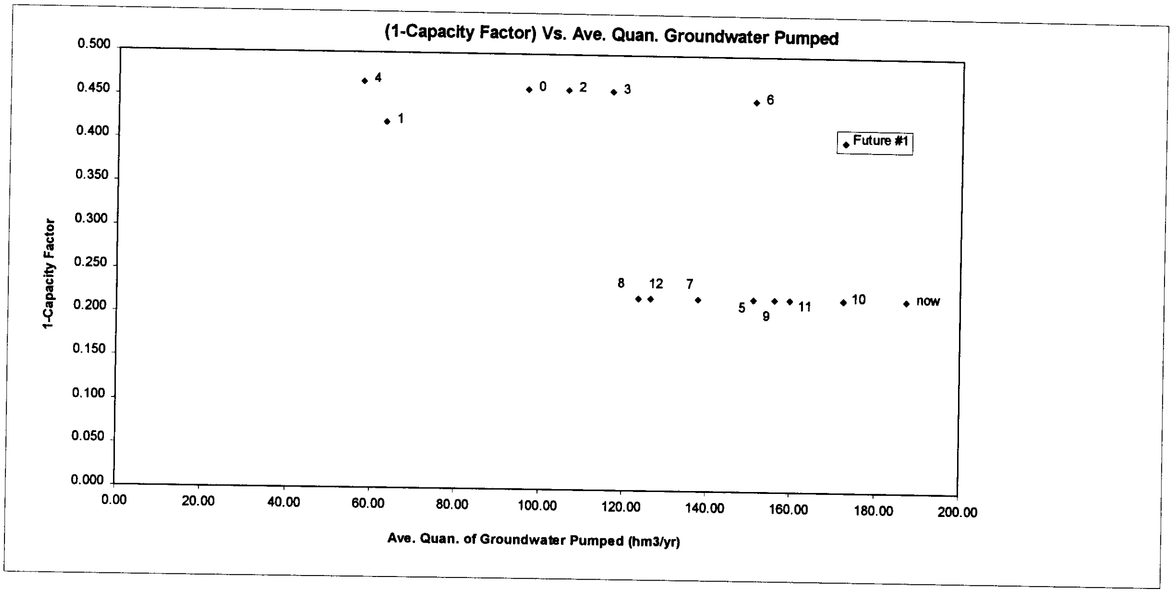


Figure 4.2: Trade-Off Graph 2

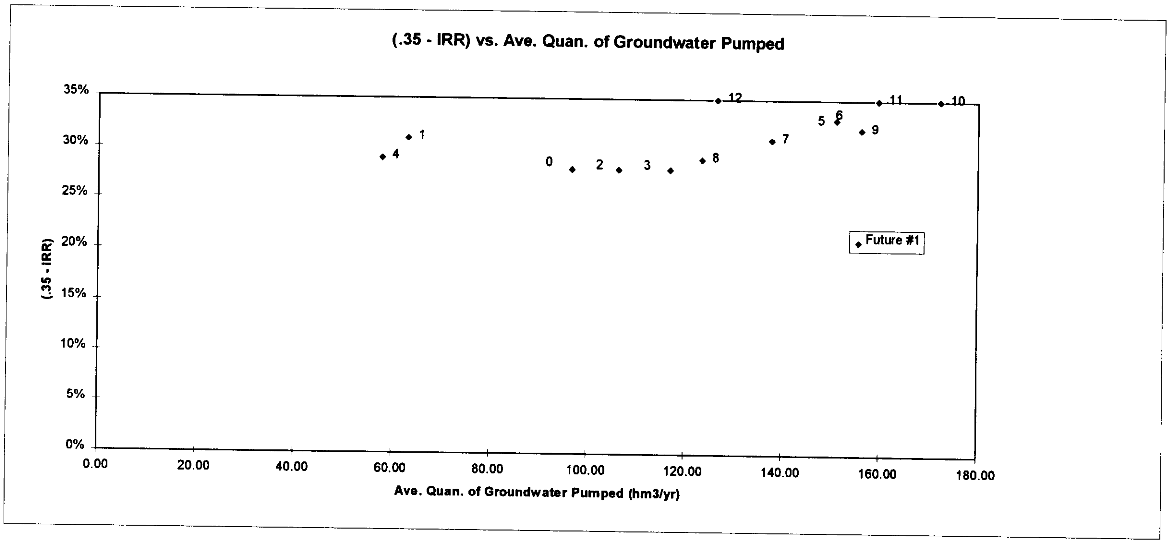


Figure 4.3: Trade-Off Graph 3

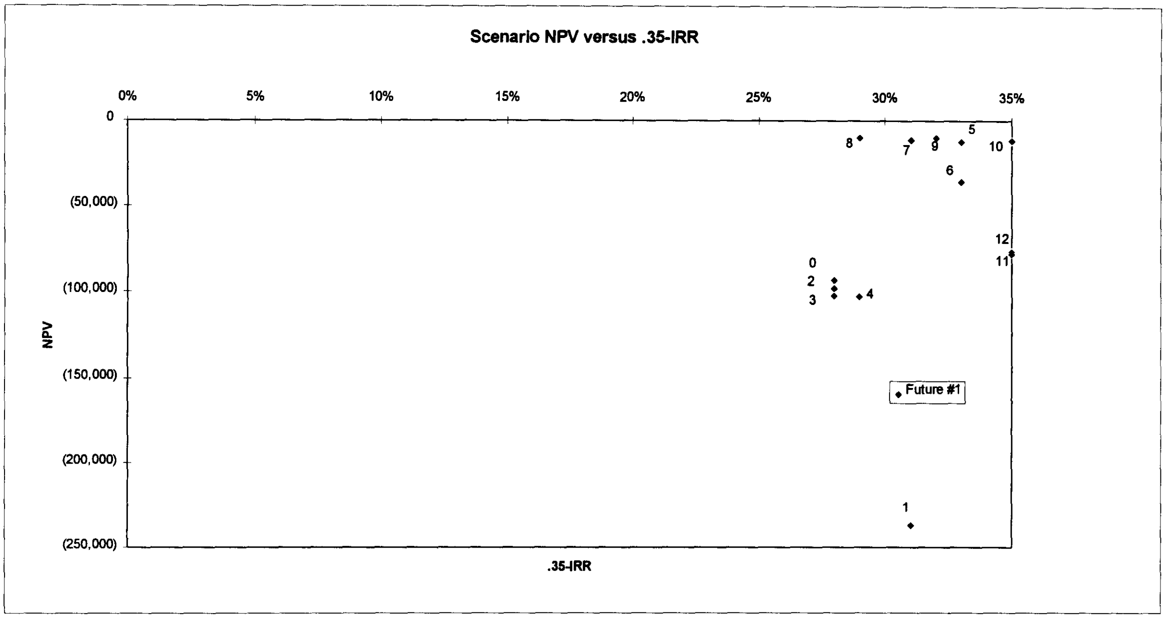
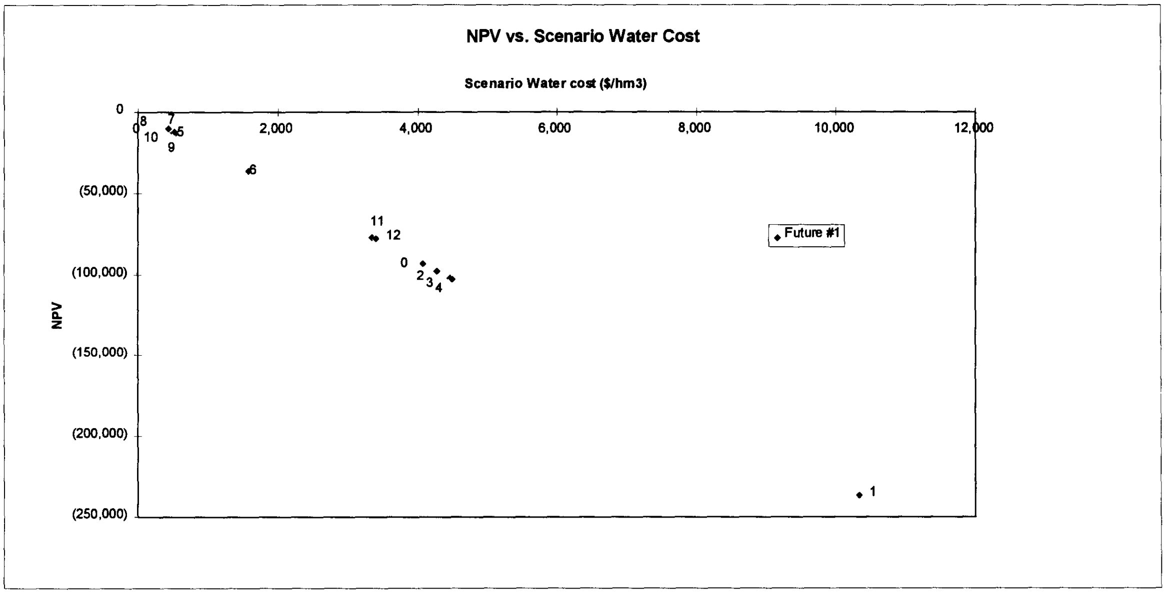


Figure 4.4: Trade-Off Graph 4



when water demand is varied. (see tradeoff graphs for futures 2-4 in Appendix) Scenario 4 is more effective when demand is high due to the presence of the marginal canal in this scenario. The marginal canal prevents infiltration and provides a greater supply in scenario 4 and the ground water pumping required is lower. Because the river can provide nearly ample flow in the spring when demands are small, the effectiveness of the marginal canal is reduced. The marginal canal is essentially desirable in the spring months when the demand is greater than the supply. In the summer there is typically sufficient river flow to satisfy demand and the marginal canal is unnecessary. Selecting 1 or 4 as the more dominant scenario of the two is not possible. Scenario 8 represents the tradeoff on the graph. The utilization of the electricity facility in scenario 8 is much greater that in scenarios 1 or 4, but the average yearly quantity of groundwater pumped is larger. The graph reveals the potential to invent other scenarios that might fall in between scenario 8 and scenarios 1 and 4. This stage of the analysis clearly indicates that scenarios 1, 4 and 8 are feasible.

Figure 4.2 does not clearly depict a frontier. Essentially scenarios 1 and 4 appear feasible, but the financial measure, internal rate of return, proved problematic in several of the scenarios. The source of these problems was the lack of significant benefits in the years following the initial investments. IRR can not be calculated when the net present values are negative for several discount rates. The future benefits associated with the scenario are very small when compared with the initial costs and there exists no discount rate for which the net present value is zero. This occurred regularly in future 2 where demand is very low and extensive ground water pumping is unnecessary. The scenarios with improved irrigation technologies require high initial costs, but produce small benefits in relation to costs. Internal rate of return is not a good indicator for these projects. Scenarios 1 and 4 perform well consistently though the financial measure does not permit a fair comparison of all scenarios.

Figure 4.3 compares the net present value with .35 minus the internal rate of return. This plot has the same problems identified previously, but presents more strategies that lie on a definable frontier. For the futures where acceptable results are obtained, scenarios 0, 2, 3 and 8 lie on the border. Scenario 4 becomes dominated by 0, 2 and 3 because the cost associated with the marginal canal produces a lower NPV, though the IRR is still comparable with the other scenarios. Scenario 8 has the least negative NPV, but the IRR is lower. The tradeoff between scenario 8 and scenarios 0, 2, and 3 was examined carefully for futures 2-4. (see tradeoff graphs for futures 2-4 in Appendix) Results from future 2 reveal a reduction in IRR for scenario 8 from 7% to 1 % when compared with future 1, while scenarios 0,2, and 3 remain at approximately 6%. The IRR for scenario 8 is observed to increase with the water demand. The NPV's do not vary significantly though IRR is sensitive to the water demand for the future. Taking into consideration different futures the results show that the position of scenario 8 changes significantly.

The presentation of NPV versus water cost in Figure 4.4 represents a result in which scatter is not observed. These attributes are directly related: i.e., the water cost is the NPV divided by the 25 year water supply. The result is a grouping of scenarios 5, 7, 8, 9, 10 near the origin. These scenarios all have the most desirable NPV's and therefore the lowest water costs. The relation of the attributes renders this plot insignificant and it is ignored.

Figure 4.5: Trade-Off Graph 5

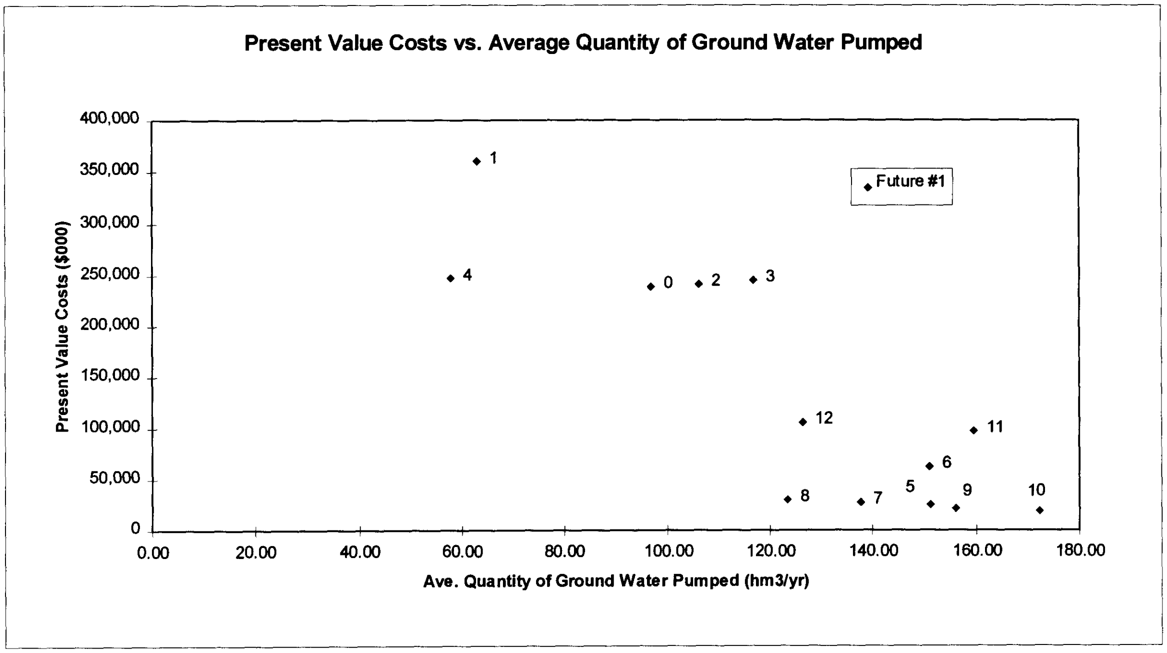


Figure 4.6: Trade-Off Graph 6

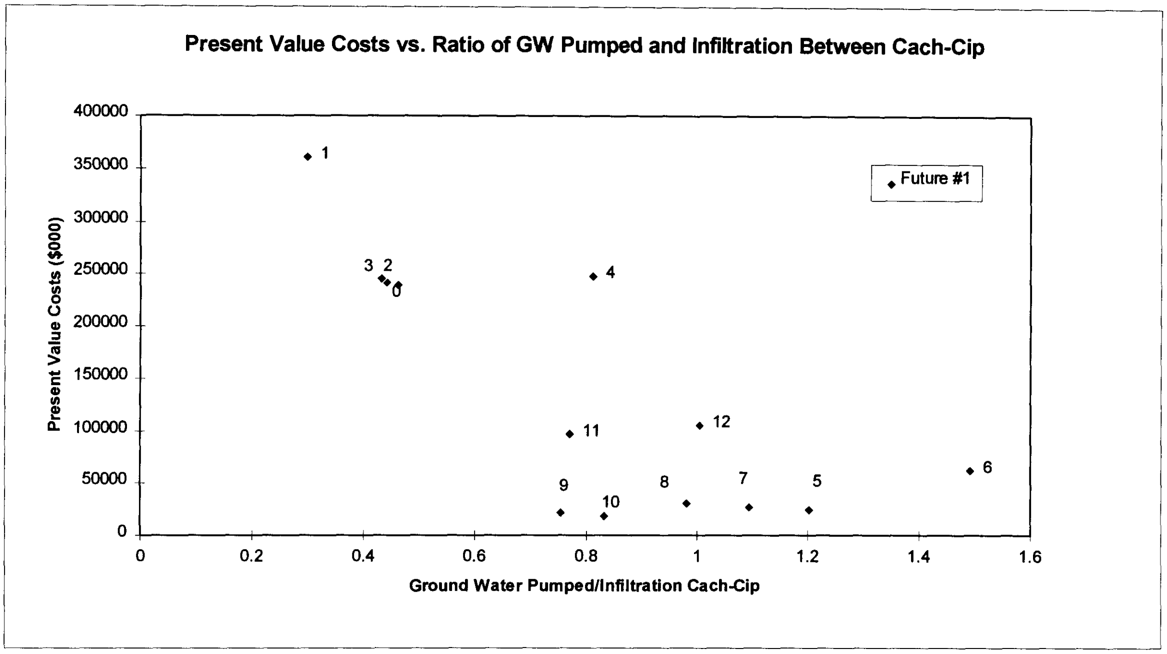


Figure 4.5 compares the present value costs with the average yearly quantity of groundwater pumped. Scenarios 4 and 8 consistently define the frontier for these attributes. Scenario 8 represents a very low cost option when compared to scenario 4. (Potrerillos w/ marginal canal) The tradeoff is between making a large risky investment to lower average yearly ground water pumping approximately 30 hm^3 or making a much smaller investment that requires more careful water distribution management. A similar graphic representation would be obtained if the attribute was total ground water pumped compared with present value costs. In many cases attributes can exhibit colinearity and the set of those that permit complete analysis can be reduced.

An interesting observation can be seen on the final tradeoff graph, Figure 4.6. The attribute on the abscissa defines a limit on the conjunctive use of the water supply in the Mendoza river basin. Points greater than 1 represent ground water pumping that is greater than the recharge in the unconfined aquifer. Several scenarios lie on the frontier of this tradeoff graph. This plot provides insights into which futures demand more water than the available supply. If demand grew to large values there would not be adequate supply even with conjunctive use. A new source would be necessary if more water usage was envisioned. The opportunity cost of additional supply would then need to be determined.

The initial results demonstrate the important tradeoff that exists between a large scale infrastructure project (Potrerillos) and a much smaller scale conservation effort that emphasizes demand side management and distribution system improvements. The ultimate decision between the identified tradeoffs would be reached in a forum where the stakeholder group actively discusses the pros and cons associated with the tradeoffs. Typically, further analysis needs to be identified and executed to search for more desirable strategies. In this research project the discussion forum and inventing sessions are the next steps. This analysis only sets the stage for a productive debate.

An important idea investigated in this analysis is the utilization of the higher quality source of water available in the unconfined aquifer in conjunction with the river to permit the elimination of excessive ground water pumping in those areas where salinization and interaction between ground water levels is occurring. The elimination or reduction of ground water pumping in low water quality regions is vital to create the opportunity for water quality improvement. These benefits are not valued in the analysis, but clearly exist if the proposed shift in ground water pumping is permissible and implemented

These preliminary results concentrate on identifying and presenting alternative options for the usage of water in Mendoza. It is hoped that they will generate substantial commentary in Mendoza, and they will certainly require some degree of additional analysis for perfection and acceptance by all those involved in this project.

Chapter 5. Economics of Water in Mendoza and Water Policy Options

A well functioning market is the normal efficient mechanism to allocate resources among users. To function acceptably markets require certain fundamental conditions to be met. For example, property rights over the resource must be clear and secure. A resource must enter an active market that determines a price according to supply and demand. Actions should not have deleterious side effects. Competition is vital. Uncertainty should be eliminated. When these conditions are not met, resource allocation is non optimal. The absence of a market for water in the Mendoza river basin is the source of problems that currently exist. Identifiable market failures associated with water distribution in Mendoza provide insight into the nature of the problems and permit identification of potential improvements.

The following are some relevant sources of market failure:

- poorly defined or nonexistent property rights
- unpriced resources and absent or thin markets
- spillover effects or externalities
- public goods that cannot or should not be provided by the private sector

In Mendoza water is considered a public good. The distribution of the resource is meant to proceed so that the overall welfare of the society is maximized. When water was available in ample quantities this method of distribution was functional. As water became scarce the absence of a market was more apparent and significant problems surfaced. Clearly the lack of a market is a primary concern, but the desire to provide water as a public good overrides the impetus to create a market. In this situation it is useful to study the problems associated with an incomplete or absent market and propose measures that can improve the allocation of a resource which is considered a public good. Given that the DGI is legally responsible to distribute water, what actions can be taken to confront existing disparities and improve the overall allocation of water?

The tradeoff analysis yields results that provide information to the stakeholders concerned with the allocation of water. The water use model simulates a market by equating the supply and demand over a 25 year horizon. The model simplifies the interaction amongst agents by assuming all demands are satisfied: i.e. ample water is available in all scenarios analyzed. The analysis is a tool which is employed to permit groups with varied viewpoints to actively discuss the impacts of their specific interests on the performance, in this case, of a conjunctive water use plan. The results provide relevant information useful for formulating proposals to confront the typical problems associated with an absent market. For example: (i) the water supply costs of different infrastructure developments can be compared, and (ii) the capacity of the ground water and surface water supplies are determined. The results provide information which is otherwise unavailable due to the absence of a market.

Throughout the balance of this chapter the assumption is made a priori that the DGI manages and administrates any changes proposed to improve water allocation and consumption. The argument is made that a more centralized management of the ground water and surface water is necessary to ultimately eradicate the problems described in this thesis. The DGI acts as a monopoly provider of the resource and water price regulation is required. This suggestion may conflict with the idea that water should be a public good, but its historic provision as a free resource has resulted in several problems. (see chapter 1)

Specific Market Failures in Mendoza

Numerous reports have been written investigating the links between irrigation water distribution and economic welfare of the region. Specifically, the impacts of excessive ground water pumping and elevated salt concentrations have been investigated by Mendozan economists. (Zapata 1969, Llop 1992) Two important issues have been carefully examined: (i) the effects of externalities created by the farmers' individual use of ground water wells, and (ii) the demand for water under conditions of elevated salt concentrations. These two matters represent significant problems for the province of Mendoza through their potential impact on the local economy.

The salinity and individual pumping problems are related to the absence of a market. The lack of a market price for water reduces incentives to use the resource optimally and prohibits internalization of externalities. Excess use of water results in increased soil and ground water salinity. Externalities caused by individual ground water pumping that disregards the state of the ground water aquifer, and others who use it, can not be mitigated. To address these problems, the establishment of a price for water should be considered. Furthermore, in this situation where the DGI would manage the supply, there must be a guarantee to the consumers that a reliable supply exists. The current variability could not be tolerated if investments are made to improve supply, and a pricing system is implemented.

The current water rights system in Mendoza can be described as operating on the principle of prior appropriation. This system provides sustained historic access to river water irrigation rights. These rights are a function of the quantity of land a farmer owns and are envisioned to provide the supply of water necessary to successfully grow the crop. The rights do not address the stochastic variation in water supply, varying costs in the provision of water, the quality of the water, or the changes in use that naturally occur as time passes. Practically, the water right offers little guarantee that the quantity of water stipulated will be delivered.

The farmers' response to water right uncertainty has been the DGI sanctioned installation of ground water pumps. The ground water pumping right is fundamentally different than the river water use right. The landowner is permitted to pump an unlimited quantity of groundwater regardless of the effects on the aquifer. This lack of consistency between water rights substantially affects the farmers' access to a primary input to their production process. Water right inconsistencies combined with the size and crop distribution differences between farms create a situation where the capacity for farmers to generate acceptable profits varies considerably. The inconsistencies in the water rights system must be rectified to permit recipients of the water equal opportunities to successfully cultivate crops. A secure, defined property right is necessary.

These water allocation inconsistencies were recognized and measures were incorporated into the tradeoff analysis to eliminate distribution inadequacies. The scenario analyses equate supply and demand through centralized management of the ground water. New ground water pumping batteries--strategically situated to optimize ground water withdrawal--are incorporated into the scenarios. The DGI would manage the ground water supply and exercise their authority over the ground water to encourage better utilization. The primary difference is that those farmers with water rights will have certainty that water of acceptable quality will be delivered when required as opposed to the current situation where farmers have no certainty that water will be available. The argument that changes are feasible, given the current situation, is presented to provide the foundation necessary to suggest positive changes. The first important element is an evaluation of the current system of water charges.

Current Water Charges and Costs

Ground Water and River Water

In Mendoza the DGI is responsible for collecting fees for the delivery of water to the farms and for maintenance of the distribution system. The fee associated with the water right (as described previously) is \$35/ha/yr. The costs for canal cleaning and administration are managed by the inspection groups.[12] The fees are collected by the inspection groups from the areas they represent. A \$250 fee is charged for the use of a ground water pump. Thus, for

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[12] Information on the magnitude of these costs was unavailable.

example, if a farm consists of 10 hectares, and has a ground water pump in addition to surface water rights, the fee charged by the DGI would be \$600/yr. If the 10 hectares requires 8000 m^3/ha/yr, the fee per hm^3 is \$7,500/hm^3.[13] Clearly this figure varies considerably with the smaller farms effectively facing a higher rate.

The pump fee is in addition to the electricity consumed by the pump motor during its operation. An estimate of the cost to pump ground water is simple to calculate, but the costs vary considerably between farms. The source of the differences are: (i) the water depths in the wells vary and therefore different size pumps are required, and (ii) the efficiency of the older pumping systems is much lower when compared with the newer pumping systems. These facts create significant problems in accurately estimating the actual costs to pump the ground water. The estimate utilized herein as an initial approximation was developed to represent a conservative estimate of the cost given known conditions.

The primary source of data necessary to estimate the cost is obtained from the Pizzi report (1995) which estimates ground water pumping costs. Information on the ground water pumps installed in Mendoza is collected by the DGI and entered into a ground water pump data base. The year when the pump was installed and its location are included in this information. These data are available for all the pumps situated in the Mendoza river basin.

Pizzi compiled the number of pumps as a function of the installation year. The pumps are then divided into three groups: (i) those older than 20 years, (ii) those between 10 and 20 years old, and (iii) those less than 10 years old. Information on the technology available in the era when the pumps were installed provides an estimate of the efficiency, while location provides information on the pump size required to insure adequate lift. Even with knowledge of the location, actual depths to the water tables are not always known with certainty. To overcome this problem a conservative estimate of 60 meters of depth to the ground water level in the well was assumed. This value is the highest value typically observed and produces a conservative estimate of the water pumping energy requirement. The efficiency value was varied as a function of the age of the pumps. A weighted average energy demand was calculated for the 60 m depth. The energy requirement combined with the electricity tariff yielded a marginal ground water pumping cost of \$16,048/hm^3. Because this cost only represents the energy required to run the pump, it is referred to as the marginal cost.

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[13] This value is obatined as follows: 8000 m^3/ha/yr *10ha = 80,000m^3/yr = .08 hm^3/yr and \$600/yr/.08 hm^3 = \$7,500/yr.

Two points are important in relation to the derived cost. First, the electricity tariff obtained from the local electricity distribution company is subsidized. The subsidized value of .0398 cents/kwh is utilized to determine the marginal pumping cost. An unsubsidized electricity cost would approach .10 cents/kwh. Second, the cost is assumed to be the same for all the farmers that have ground water pumps. To simplify the study the marginal cost disregards the costs associated with the installation of the wells. This assumption is supported by the fact that the majority of the pumps (> 85%) were installed more than ten years ago and several were subsidized with government funds. (Pizzi 1995, Frederick 1975)

Conjunctive Water Use Supply Costs

The investigation of conjunctive water use supply costs is facilitated with the water use model. The net present value (NPV) of each scenario is calculated. The NPV is used to derive what is effectively a long range marginal cost for the provision of water. It is important to recognize that the NPV for all the scenarios analyzed is negative. The NPV is divided by the water demand over the 25 year period analyzed to yield the volumetric cost to supply water. The supply cost represents the long run cost of the scenario assuming the demand is satisfied with a combination of surface and ground water. The supply cost is useful for comparing the different scenario volumetric water costs with the marginal cost to pump water. The supply cost is not a true marginal cost: it combines estimates of the DGI operational costs with water supply system infrastructure investments. Because accurate DGI operational costs were unavailable, an estimate was made from historical data. The DGI budget varies considerably and actual cost are difficult to identify accurately. (Braceli 1985) Additional research is required to accurately determine costs and benefits.

Supply costs calculated by the water use model are combined with DGI operational costs and compared with the price the farmer is willing to pay to pump ground water. DGI operational costs are estimated at \$250/hm^3. The scenario water supply costs calculated by the model vary from \$300-400/hm^3 to as much as \$10,000-12,000/hm^3. The scenarios that yield high costs are those that include construction of a dam. Values of \$3,000-4,000/hm^3 are obtained for those scenarios that envision the implementation of new irrigation technologies. The lowest values obtained emerge from scenarios with the marginal canal and canal infiltration reductions. The farmers' current marginal cost to pump ground water as presented previously is \$16,000/hm^3.

This comparison reveals two important facts: (i) the supply costs for all scenarios are lower than the farmers' marginal cost to pump ground water, and (ii) a feasible price for water can be conceived that incorporates observed behavior and actual supply costs. Those farmers who primarily pump ground water are exposed to higher costs than necessary and are not facing prices that internalize externalities. The costs associated with ground water table lowering and increased salinity in regions are internalized in the water use model. Farmers with river water irrigation rights are not provided a guaranteed supply, but actually may pay more than necessary considering the uncertainty they confront.

A significant concern associated with these cost observations is that farmers are treated in the model as a homogenous group which is, of course, not strictly correct. The production optimization process clearly varies when individuals are faced with water supplies that have different costs and qualities. Furthermore, those farmers who have rights to river water are not guaranteed a supply. Even though the water costs may be lower, there is no certainty that the water will be supplied. An equalization of the water costs faced by all farmers would create a situation where each individual farmer can make optimal production decisions.

A Price for Water?

The critical issue associated with a proposal to define a price for water in Mendoza is the potential deleterious effects an improper price could have on some farmers. Several different types of crops are cultivated and numerous different size farms exist. The derivation of a price that properly charges all those who receive water is a significant challenge. As a first approximation the price should reflect the cost of supplying the water, or even better, the willingness to pay for the water. In Mendoza the farmers' willingness to pay is demonstrated by their ground water pumping. The marginal cost is a surrogate for their actual willingness to pay for the water. Preliminary long range marginal supply costs are estimated with the water use model. The data presented here demonstrate that a price can be developed , though a more detailed analysis of the welfare effects is necessary to precisely quantify the long term benefits.

The current conjunctive usage of the surface and ground water provides an opportunity to measure the farmer's willingness to pay for water. Many farmers have ground water pumps and utilize the pumps regularly to supplement the surface water supply. (Llop 1992) An analysis was performed by Llop to evaluate the farmers' response under the conditions of elevated salinity. The analysis was executed in regions where ground water is either the primary source of irrigation water or is utilized a significant part of the year due to inadequate availability of river water. Marginal costs for pumping ground water in different regions were determined as a function of the electricity cost. In each region surveyed price elasticities were determined from the cross sectional data sample obtained from farm level interviews.

The price elasticities are a measure of the sensitivity of the farmers' water demand to the cost of pumping ground water. The quantity demanded in the price elasticity analysis is the amount of ground water pumped per hectare. In the situation where ground water is the only water source, and the capital cost of the pump has been absorbed, the price in the elasticity is a representation of the marginal cost of water to the farmer. The elasticities used are point elasticities and are useful as an initial measure of the farmers' potential response to price changes. The available analysis does not contain adequate information to examine the long run impacts of price changes.

The fact that farmers can be observed pumping ground water at a known cost permits one to envision a structure where the farmers pay for river water as a function of the volume delivered. The potential to charge a price for water which is commensurate with its value is critically important. Equally important is the idea of defining guaranteed water rights. The guarantee would provide a farmer with the security that a primary input to the production process is available. This security is essential if a central organization charges a price for the product delivered: there must be a guarantee that the water will be available if more than a nominal fee is charged.

Will the farmers pay a price for the water? The data presented conclusively demonstrate that farmers will pay for the water; indeed they currently invest some \$16,000/hm^3 to pump groundwater. All of the supply improvement strategies that were analyzed provide water at a lower cost. A price can easily be derived that permits the establishment of a more efficient supply management system while eliminating the most detrimental externalities through centralized allocation of ground water and river water.

A price system will insure a more structured usage of the ground water and surface water, improve water quality, and provide farmers with greater certainty that water will be available intertemporally. The current differences in the prices of surface water and ground water preclude an optimal conjunctive use. The externalities associated with individual ground water pumping are not accounted for and the external effects are observable. The opportunity to implement beneficial changes can no longer be ignored.

Will New Irrigation Technologies be Demanded?

To consider whether or not farmers would demand advanced irrigation technologies the farmers' price elasticities with respect to ground water pumped are utilized to study potential changes in demand under various water pumping costs. Ground water pumping cost increases are assumed and the effect on demand is studied through the price elasticities. The analysis only analyzes local movements along the demand curve near the point where the elasticity is defined. It does not take into account potential shifts in the demand curve due to price changes. The values are a rough estimate of the demand change with respect to the price to pump ground water. The change in demand is quantified and compared with the costs of installing a more efficient irrigation system.

The farmers' price elasticity presented in Mendozan publications ranges from -.48 to -.66. (Llop 1992) These values are very inelastic and large variations in price do not change demand considerably. Assuming that the elasticity estimates are accurate, it is apparent that price increases will not change demand significantly in the short run. Demand will decrease, though minimally. For example, a 50% increase in the price results in approximately a 23% decrease in the demand. These elasticity figures are used to ask if new irrigation technologies will be demanded.

Assume a high technology irrigation system installation cost of \$9000/ha and a yearly system operations cost of \$300/yr. (see Table 2.1) A farm size of 10 hectares is estimated to have a water demand of 80,000 m^3/yr or .08 hm^3/yr. If the new irrigation system is 90 percent efficient then the farmer requires .088 hm^3/yr. Assuming the previous application efficiency was 60 percent, then .112 hm^3/yr was demanded. This results in a net savings of .024 hm^3/yr. The installation cost of a 10 hectare irrigation system amortized for 20 years at 10 percent interest is \$10,575/yr. The water saved valued at the marginal cost to pump is .024 hm^3/yr * \$16,000/hm^3 which equals \$384/yr. The difference between these two costs is greater than an order of magnitude. Higher water prices may reduce demand, but will not generate interest in new irrigation technology. This example demonstrates conclusively that advanced irrigation systems must produce benefits far in excess of water savings to be attractive.

Farmers will not demand new irrigation technologies unless significant additional benefits are realized. The installation of an advanced irrigation system generates benefits that are not included in this analysis. Some of these benefits are: (i) lower farm production costs, (ii) reduced irrigation labor requirements, and (iii) higher yields as a result of improved water application. The quantification of these benefits requires the analysis of farm production costs and is beyond the scope of this thesis. If these additional benefits are large enough to compel farmers to install pressurized irrigation systems then water savings are possible. The historical absence of advanced irrigation systems in Mendoza attests to a degree of non-profitability.

Beyond the benefits each individual farmer would consider when analyzing the installation of a pressurized irrigation system are the benefits the farming community would realize if water quality is improved. Newer irrigation technologies reduce the amount of water applied to the field. This reduction lowers infiltration and makes water available to those who may not receive reliable supplies currently. Reduced infiltration will eventually result in reduced ground water aquifer salinity. The need to examine global benefits is obvious and is one of the important refinements necessary to improve the tradeoff analysis results.

Water Management Policy Considerations

The results of the water use model have demonstrated the viability of a variety of water management options available for the Mendoza river basin. Regardless of the infrastructure development and water use options identified, and ultimately selected through the tradeoff analysis process, water management policy modifications are necessary to adequately address the current water problems. Specific sources of market failure associated with the distribution and management of water from the Mendoza river were identified previously in this Chapter. These market failures must be considered in parallel with infrastructure improvements in order to insure a coherent approach to rectifying water use problems in the Mendoza river basin. Traditional water management policy suggestions directed at rectifying the specific Mendoza market failures are presented in this section. Though these specific suggestions can be considered subjective, the problems they are combating are very real.

An effective policy must contain clear objectives which can be implemented. Objectives formulated here are developed from analyzing the existing water allocation system and current ground water quality data. The feasibility of their implementation is supported in part by the results of the tradeoff analysis. For example, results from the analysis combined with existing observations of farmer behavior demonstrate that water can be priced. As a result of these considerations the primary objectives established are as follows:

1. The provision of water to all those with water rights must be guaranteed;
2. The water delivered to those with rights must be of acceptable quality;
3. The external effects of individual farmer ground water pumping must be internalized to prevent further ground water contamination and/or excess use;
4. Potential adverse impacts on individuals as a result of policy changes must be foreseen and mitigated;
5. A more efficient use of water is desirable to reduce system losses.

The fulfillment of these objectives in Mendoza requires significant changes in the current system of water management. Modifications to the water right allocations and the management of the ground water aquifer withdrawals are vital to achieve the identified objectives. Legislative action may be necessary to implement a new water management policy.

The first element of a successful policy is a modified system of water rights. The current system of water rights does not endow all those individuals with access to the same resource. The disparity results in part from an antiquated system that does not permit dynamic adjustment to changing conditions. Moreover, ground water use rights are separate from the primary river water rights. Those that utilize ground water possess a different right when compared with those with river water rights. Farmers with both river water rights and ground water rights have distinct advantages when compared to those with rights to only one or the other.

A water right system developed on the basis of the principle of symmetric treatment of sources can eliminate the problems inherent in the current inequitable system. The symmetric treatment principle requires that rights to water resources be specified in terms of water of common characteristics. The rights need not be directly linked to the source. The idea of symmetric treatment of the resource is to promote economic efficiency in conjunction with the value system of the irrigating society. Economic welfare must be of value to the society for this system to be accepted. Adoption of symmetric treatment of the resource will equalize the value of the water across all different users.

The current bond between land ownership and water rights must be severed to allow equal access to irrigation water. Water rights can either be modified such that a market for rights is created or water can be supplied as a function of actual demand and not land ownership. The current water supply and demand analysis demonstrates that an adequate supply is available. Initial establishment of rights can proceed without contention. A price can be charged for water on a volumetric basis as delivered to those with rights. Water availability must be guaranteed to convince farmers that changes are desirable. The responsibility of insuring that water is delivered would fall upon the DGI. The DGI similarly must guarantee the quality of the water.

The internalization of the externalities related to individual ground water pumping wells would be achieved by the central management of the water supply. The DGI will evaluate ground water pumping locations and determine the most favorable areas to install and operate wells. The DGI has the authority to retract ground water pumping rights. Control of ground water extraction is critical to eliminate aquifer contamination and lower salt concentrations. The DGI must guarantee an alternate source of water for the farmers and provide the water at a comparable cost. Farmers will need to be convinced that water will be available if they are to accept a modified system.

A modified water right system that guarantees availability will establish a price for water that reflects its scarcity. Currently it is impossible to determine a price for water. Access to water and its unreliable availability and quality prohibit the development of a fair system for allocation. If each user is guaranteed that water will meet certain guidelines, their observed behavior indicates they will be willing to pay for the water. The current pumping of ground water by farmers concretely demonstrates this willingness to pay for a reliable water source.

The implementation of water policy management modifications will be arduous. The water use problems in Mendoza have developed during a period of several decades. Modifications require the commitment of all stakeholders in Mendoza. The role of the DGI will change considerably and modified organizational structures will have to be created. A detailed discussion of specific changes necessary to implement the proposals is beyond the scope of this Thesis, but can not be overlooked.

Chapter 6: Conclusions

The tradeoff analysis presented herein to study water resource planning options in the Mendoza river basin yields many important results. Of these, most significant is that several strategies exist to insure that demand is satisfied. Important tradeoffs exist between scenario costs and a renewable supply of water. Scenarios that require the construction of a dam and reservoir have high costs, but provide over year storage of water. This storage reduces ground water pumping requirements, but does not exploit the potential for water conservation and a planned conjunctive use. Scenarios that emphasize conservation and more controlled conjunctive use make greater demands on the ground water supply, but have the potential to eliminate several localized ground water aquifer problems. The analysis demonstrates that the installation of the marginal canal combined with irrigation canal lining lies on the frontier with the construction of Potrerillos. These scenarios represent very different options and the tradeoff between them can not be ignored.

Regardless of the tradeoffs between scenarios, the current problems associated with the absence of a water market promise to persist if allowed to continue unchecked. Water use must improve to mitigate problems associated with externalities and localized salinization problems. The installation of a dam, such as Potrerillos, does not address the real irrigation water system difficulties: lack of incentives to improve use and equalization of the benefits all farmers receive from the irrigation water. The current system of charges and uncontrolled ground water pumping have been shown to create large inequities amongst users.

The potential to use insights obtained from the water use model to price water and improve use is extremely important. The derivation of an applicable pricing system, combined with guaranteed water rights, is necessary to encourage better usage and mitigate long term problems attributable to absent markets. Water right modifications will not be easily accepted. A concentrated group effort is necessary to identify acceptable modifications to the current system while recognizing the future benefits. Short term solutions, like the installation of numerous ground water pumps in the early 70's, have proven detrimental. The obvious need is clear water use policy.

The derivation of a price for water will not produce a demand for advanced irrigation technologies. A more detailed analysis at the farmer production level is necessary to determine if such systems are potentially beneficial. If at this level the systems still are unattractive, it is necessary to examine potential global benefits. If global benefits beyond the water savings are favorable, then a program to assist the deployment of these systems may be desirable.

The data presented in this thesis are preliminary. The application of the tradeoff analysis yields insights, but at the same time generates numerous questions. The investigation into the economic issues only brushes the surface of the problem. The fact that certain policy options must be considered is concretely demonstrated. The gathering of more detailed data in order to quantify the farm level effects of these proposals requires additional analysis. The analysis presented herein emphasizes identifying options and proposing suitable policies. An examination of social welfare and the pursuit of "optimum" developments is beyond the scope of this thesis. On the contrary the emphasis in this thesis is to examine the numerous strategies available and create a forum where all stakeholders can participate. History demonstrates that there is never a single optimal plan that satisfies everyone; however, it is important that there be a process by which the essential features of each individual's ideal plan are considered and evaluated.

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Appendix

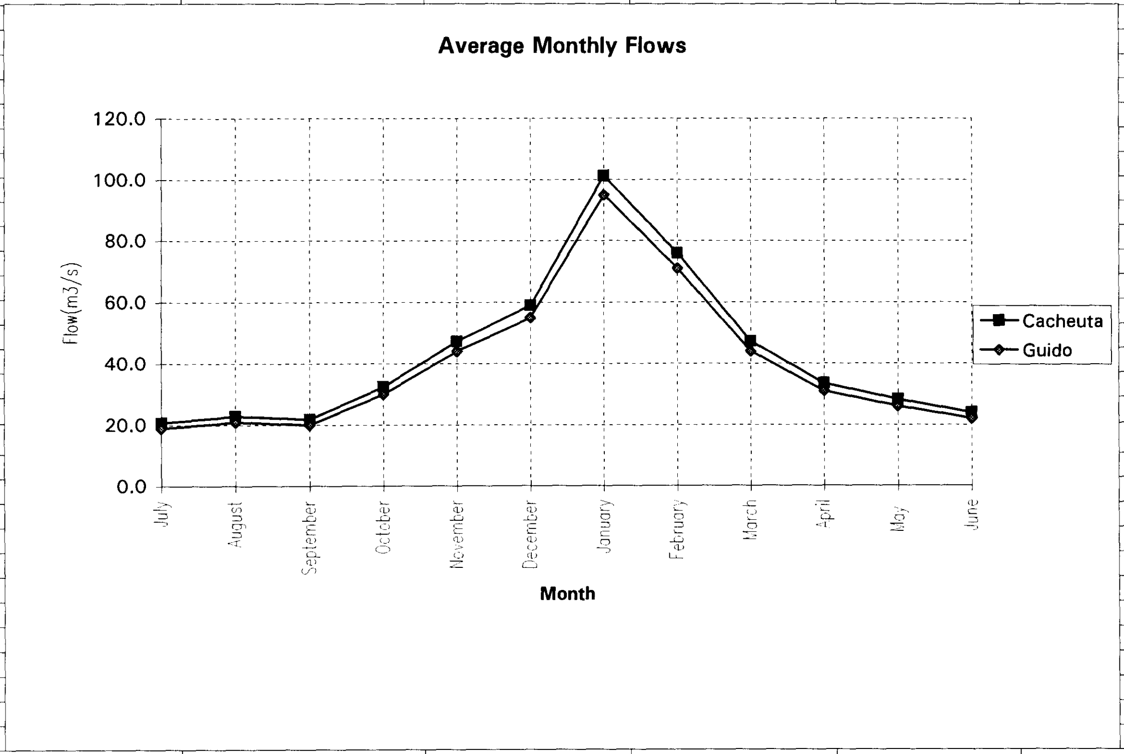
Water Use Model

RIVER WATER SUPPLY

INPUTS-AVERAGE MONTHLY RIVER FLOW

For the year 1996-1997

Month	**Cacheuta** **Flow (m3/s)**	**Guido**
July	13.3	12
August	12.3	11
September	14.4	13
October	15.4	14
November	32.4	30
December	101.3	95
January	86.5	81
February	75.9	71
March	48.3	45
April	33.5	31
May	23.9	22
June	19.7	18


Average Monthly Flows

WATER DEMANDS (hm3)

	Consumptive Demands									Non-Consumptive Demands (Cacheuta & Compuertas)			
	IRRIGATION				Tract Demands		Compuertas	Potable Water	Total	INDUSTRIAL (YPF,CTM,OBRAS)		Net Demand	Electricity
Month	demand/ha	# of hectares	total(hm3)	Superior	Medio	Inferior	(6.5 m3/s)			CTM(12m3/s)	Consumed (6.5m3/s)	(Compuertas)	(Cacheuta)
July	8	74500	1	0	0	0	16.84	16.28	33.72	31.10	-16.84	14.26	26.76
August	511	74500	38	19.30	6.40	12.37	16.84	16.28	71.19	31.10	-16.84	14.26	26.76
September	327	74500	24	12.35	4.09	7.92	16.84	16.28	57.48	31.10	-16.84	14.26	26.76
October	728	74500	54	27.50	9.11	17.63	16.84	16.28	87.36	31.10	-16.84	14.26	26.76
November	1070	74500	80	40.42	13.39	25.91	16.84	16.28	112.84	31.10	-16.84	14.26	26.76
December	1249	74500	93	47.18	15.63	30.24	16.84	16.28	126.17	31.10	-16.84	14.26	26.76
January	1205	74500	90	45.51	15.08	29.18	16.84	16.28	122.89	31.10	-16.84	14.26	26.76
February	842	74500	63	31.80	10.54	20.39	16.84	16.28	95.85	31.10	-16.84	14.26	26.76
March	732	74500	55	27.65	9.16	17.72	16.84	16.28	87.65	31.10	-16.84	14.26	26.76
April	409	74500	30	15.45	5.12	9.90	16.84	16.28	63.59	31.10	-16.84	14.26	26.76
May	355	74500	26	13.41	4.44	8.60	16.84	16.28	59.57	31.10	-16.84	14.26	26.76
June	12	74500	1	0	0	0	16.84	16.28	34.01	31.10	-16.84	14.26	26.76
Yearly Total	-	-	554.88	281.32	93.22	180.33	202.08	195.36	952.32	373.20	-202.08	171.12	321.12

Output Data for 1996-97

Month	Nodes	Flow hm3/Mnth	Loss/Gain hm3/Mnth	Demand hm3/Mnth	Storage hm3	Electricity Mwh	Storage Release/Add. hm3/Mnth	Flow in the River Bed hm3/Mnth	Flow Through Turbines for Elec. Gener. hm3/Mnth	Spill Release hm3/Mnth
July	1-Guido	31.10	3.43							
	2-Cacheuta	34.53	0.00		420.00	18581.75	-15.49	5.00	45.02	0.00
	3-Condarco	50.02	-1.77			9356.54		50.02	45.02	
	4-Compuertas	48.25	-2.23	16.84						
	5-Cipolletti	29.19	-1.68	34.01						
	6-Lujan	10.33	-0.30							
	Groundwater	0.00								
August	1-Guido	28.51	3.27							
	2-Cacheuta	31.78	0.00		404.51	38017.23	-67.44	5.00	94.23	0.00
	3-Condarco	99.23	-1.77			19582.23		99.23	94.23	
	4-Compuertas	97.46	-2.23	16.84						
	5-Cipolletti	78.39	-0.70	90.22						
	6-Lujan	4.31	-19.03							
	Groundwater	0.00								
September	1-Guido	33.70	3.58							
	2-Cacheuta	37.28	0.00		337.06	28826.19	-41.39	5.00	73.66	0.00
	3-Condarco	78.66	-1.77			15309.01		78.66	73.66	
	4-Compuertas	76.90	-2.23	16.84						
	5-Cipolletti	57.83	-0.70	69.66						
	6-Lujan	4.31	-12.18							
	Groundwater	0.00								
October	1-Guido	36.29	3.74							
	2-Cacheuta	40.02	0.00		295.68	30794.83	-45.68	5.00	80.70	0.00
	3-Condarco	85.70	-1.77			16771.04		85.70	80.70	
	4-Compuertas	83.93	-2.23	16.84						
	5-Cipolletti	64.87	-0.70	114.47						
	6-Lujan	4.30	-27.12							
	Groundwater	37.77								
November	1-Guido	77.76	6.22							
	2-Cacheuta	83.98	0.00		250.00	29737.77	0.00	5.00	78.98	0.00
	3-Condarco	83.98	-1.77			16414.68		83.98	78.98	
	4-Compuertas	82.22	-2.23	16.84						
	5-Cipolletti	63.15	-0.70	152.69						
	6-Lujan	4.30	-39.86							
	Groundwater	77.70								
December	1-Guido	246.24	16.33							
	2-Cacheuta	262.57	0.00		250.00	68122.12	80.88	5.00	176.70	0.00
	3-Condarco	181.70	-1.77			36721.56		181.70	176.70	
	4-Compuertas	179.93	-2.23	16.84						
	5-Cipolletti	160.86	-0.70	172.70						
	6-Lujan	4.31	-46.53							
	Groundwater	0.00								
January	1-Guido	209.95	14.16							
	2-Cacheuta	224.11	0.00		330.88	68684.88	47.33	5.00	171.78	0.00
	3-Condarco	176.78	-1.77			35699.70		176.78	171.78	
	4-Compuertas	175.01	-2.23	16.84						
	5-Cipolletti	155.95	-0.70	167.78						
	6-Lujan	4.31	-44.89							
	Groundwater	0.00								
February	1-Guido	184.03	12.60							
	2-Cacheuta	196.63	0.00		378.20	61401.10	41.80	5.00	149.84	0.00
	3-Condarco	154.84	-1.77			31139.07		154.84	149.84	
	4-Compuertas	153.07	-2.23	16.84						
	5-Cipolletti	134.00	-3.31	127.21						
	6-Lujan	20.32	-31.36							
	Groundwater	0.00								
March	1-Guido	116.64	8.56							
	2-Cacheuta	125.20	0.00		420.00	49816.41	0.00	5.00	120.20	0.00
	3-Condarco	125.20	-1.77			24979.57		125.20	120.20	
	4-Compuertas	123.43	-2.23	16.84						
	5-Cipolletti	104.36	-0.88	114.92						
	6-Lujan	5.40	-27.27							
	Groundwater	0.00								
April	1-Guido	80.35	6.38							
	2-Cacheuta	86.73	0.00		420.00	34318.26	-1.10	5.00	82.83	0.00
	3-Condarco	87.83	-1.77			17213.38		87.83	82.83	
	4-Compuertas	86.06	-2.23	16.84						
	5-Cipolletti	66.99	-0.70	78.83						
	6-Lujan	4.31	-15.24							
	Groundwater	0.00								
May	1-Guido	57.02	4.98							
	2-Cacheuta	62.00	0.00		418.90	31638.94	-19.79	5.00	76.79	0.00
	3-Condarco	81.79	-1.77			15959.28		81.79	76.79	
	4-Compuertas	80.03	-2.23	16.84						
	5-Cipolletti	60.96	-0.70	72.79						
	6-Lujan	4.31	-13.22							
	Groundwater	0.00								
June	1-Guido	46.66	4.36							
	2-Cacheuta	51.01	0.00		399.12	18454.68	0.99	5.00	45.02	0.00
	3-Condarco	50.02	-1.77			9356.54		50.02	45.02	
	4-Compuertas	48.25	-2.23	16.84						
	5-Cipolletti	29.19	-1.62	34.46						
	6-Lujan	9.95	-0.45							
	Groundwater	0.00								

Output Summary

Total Groundwater Pumped (hm3/yr)	115.47		Annual River Supply (hm3)	1235.86
Electricity Generated at Cacheuta (Mwh)	478394.15		(at Cacheuta)	
Electricity Generated at Condarco (Mwh)	248502.59			
Total Electricity Generated (Mwh)	726896.75			
Total Water Infiltration in Canal System (hm3/yr)	-277.44			
Total Water Infiltration between Cach-Cippoll.	-47.93			

```
'Procedure which calculates water usage as a function of demands-Copyright Joseph Cavicchi 1996

'Declare Module variables

Dim FlowCach, FlowGuid, Demcons, Demnoncons, LossCachCon, LossConCom
Dim DemCon, DemNCon, DemCip, StorCa, ElecCa, FlowCip, FlowLu, FlowGrwat
Dim LossCaCip, LossCipLu, LossCanals, LossComCip, StorReCa, SpillRe, DemConCom
Dim StorAdd, StorSp, ElecFlowCa, ElecFlowCon, ReExc, LossCaCipMin, GainGuCa
Dim FlowCon, FlowCom, ElecCon, DemNConCom, DemNConCach, StorAddRe, FlowRivCa,
FlowRivCon

'Declare constants

Const VolConv = 2.592
Const StorMin = 250
Const FlowLuMin = 5
Const StorMax = 420
Const ElecFlowMax = 207
Const LF = 0.5
Const AC = 1

'Procedures

Sub WaterUsageCalcs()

Static StorCanext(0 To 300) As Variant
StorCanext(0) = StorMax

'Loops are begun to index model through both sheets and months

For J = 1 To 25 Step 1
   Sheets(J).Select

   For I = 0 To 11 Step 1

'River water flows are taken from the input table to the water usage model

   FlowGuid = Cells(43 + I, 12) * VolConv

'Determine the flows at Cacheuta/Condarco and the increase in flow between
'Guido and Cacheuta

   FlowCach = 1.559 + 1.06 * FlowGuid
   GainGuCa = FlowCach - FlowGuid
   FlowCon = FlowCach

'Operational decisions are made as a function of reservoir constraints

'Insert Storage value at beginning of period into model
```

```
   StorCa = StorCanext(((J - 1) * 12) + I)
   StorSp = StorMax - StorCa

'Consumptive and non-consumptive demands are calculated or taken from demand table
'Note: Non-Consumptive demand is used during June and July

   DemNConCom = Cells(6 + I, 29)
   DemNConCach = Cells(6 + I, 30)
   DemNCon = DemNConCach + DemNConCom
   DemConCom = Cells(6 + I, 24)
   LossCanals = Cells(6 + I, 21) * LF * -1 + _
            Cells(6 + I, 22) * LF * -1 + _
            Cells(6 + I, 23) * LF * -1
   DemCon = Cells(6 + I, 26) - LossCanals


'Determine the minimum losses that will occur between Cacheuta and Cipolletti
'for usage in determining storage releases or additions

   If DemCon > DemNCon And DemCon > ElecFlowMax Then
   LossCaCipMin1 = ((DemCon + FlowLuMin) ^ 0.58 * 1.086) * 1.1 * AC
   Else
   LossCaCipMin1 = (FlowLuMin ^ 0.58) * 1.086 * AC + 1.24
   End If
'Check to see if demands are greater than electric station capacities

   If DemCon + LossCaCipMin1 / 1.1 + FlowLuMin > ElecFlowMax Then

     LossCaCipMin = ((FlowLuMin + DemCon + (DemCon + LossCaCipMin1 _
              - ElecFlowMax)) ^ 0.58 * 1.086) * 1.05 * AC

   Else
      LossCaCipMin = LossCaCipMin1

   End If


'Determine release from or addition to storage for the current period

'Examine situations where consumptive demand is greater than non-consumptive demand

'Determine if a release is required:

   If DemCon > DemNCon And FlowCach < DemCon + FlowLuMin + LossCaCipMin _
      And StorCa - StorMin > DemCon + FlowLuMin + LossCaCipMin - FlowCach _
      Then
      StorReCa = DemCon + FlowLuMin + LossCaCipMin - FlowCach
      StorAdd = 0
```

```
   ElseIf DemCon > DemNCon And FlowCach < DemCon + FlowLuMin + LossCaCipMin _
      And StorCa - StorMin < DemCon + FlowLuMin + LossCaCipMin - FlowCach _
      Then
      StorReCa = StorCa - StorMin
      StorAdd = 0
   End If

'Determine if an addition should occur:

   If DemCon > DemNCon And FlowCach > DemCon + FlowLuMin + LossCaCipMin And _
      FlowCach - DemCon - FlowLuMin - LossCaCipMin > StorSp _
      Then
      StorAdd = StorSp
      StorReCa = 0
   ElseIf DemCon > DemNCon And FlowCach > DemCon + FlowLuMin + LossCaCipMin And _
      FlowCach - DemCon - FlowLuMin - LossCaCipMin < StorSp _
      Then
      StorAdd = FlowCach - DemCon - FlowLuMin - LossCaCipMin
      StorReCa = 0
   End If

'Examine situations where non-consumptive demand is greater than consumptive demand

'Determine if a release is required:

   If DemCon < DemNCon And FlowCach < DemNCon + FlowLuMin + LossCaCipMin _
      And StorCa - StorMin > DemNCon + FlowLuMin + LossCaCipMin - FlowCach _
      Then
      StorReCa = DemNCon + FlowLuMin + LossCaCipMin - FlowCach
      StorAdd = 0
   ElseIf DemCon < DemNCon And FlowCach < DemNCon + FlowLuMin + LossCaCipMin _
      And StorCa - StorMin < DemNCon + FlowLuMin + LossCaCipMin - FlowCach _
      Then
      StorReCa = StorCa - StorMin
      StorAdd = 0
   End If

'Determine if an addition should occur:

   If DemCon < DemNCon And FlowCach > DemNCon + FlowLuMin + LossCaCipMin And _
      FlowCach - DemNCon - FlowLuMin - LossCaCipMin > StorSp _
      Then
      StorAdd = StorSp
      StorReCa = 0
   ElseIf DemCon < DemNCon And FlowCach > DemNCon + FlowLuMin + LossCaCipMin And _
      FlowCach - DemNCon - FlowLuMin - LossCaCipMin < StorSp _
      Then
      StorAdd = FlowCach - DemNCon - FlowLuMin - LossCaCipMin
      StorReCa = 0
```

```
    End If



'Caculate the quantity of water that is in storage at the end of the period

    StorCanext(((J - 1) * 12) + I + 1) = StorCa - StorReCa + StorAdd

'Generate a release/addition value for the output table

    If StorReCa = 0 Then
    StorAddRe = StorAdd
    Else
    StorAddRe = -StorReCa
    End If

'Determine the quantity of electricity generated at Cacheuta

   If FlowCach - StorAdd + StorReCa - FlowLuMin > ElecFlowMax Then

    ElecCa = ElecFlowMax * 0.87 * 2.73 * _
          (174.5 - (StorMax - (StorCanext(((J - 1) * 12) + I + 1) + StorCa) / 2) * 0.094)

    Else
    ElecCa = (FlowCach + StorReCa - StorAdd - FlowLuMin) * 0.87 * 2.73 * _
         (174.5 - (StorMax - (StorCanext(((J - 1) * 12) + I + 1) + StorCa) / 2) * 0.094)

    End If

'Determine the quantity of electricity generated at Condarco

    If FlowCon - StorAdd + StorReCa - FlowLuMin > ElecFlowMax Then

    ElecCon = ElecFlowMax * 0.87 * 2.73 * 87.5

    Else
    ElecCon = (FlowCon + StorReCa - StorAdd - FlowLuMin) * 0.87 * 2.73 * 87.5

    End If

'Determine what quantity of water was spilled during the current period

    If FlowCach - StorAdd + StorReCa - FlowLuMin > ElecFlowMax And _
      StorCanext(((J - 1) * 12) + I + 1) = 420 Then
      SpillRe = FlowCach - StorAdd + StorReCa - ElecFlowMax - FlowLuMin
    Else
    SpillRe = 0
    End If
```

```
'Determine flow through the Cacheuta electricity station for the month

  If FlowCach - StorAdd + StorReCa - FlowLuMin > ElecFlowMax Then
    ElecFlowCa = ElecFlowMax
  Else
    ElecFlowCa = FlowCach + StorReCa - StorAdd - SpillRe - FlowLuMin
  End If

'Determine flow through the Condarco electricity station for the month

  If FlowCon - StorAdd + StorReCa - FlowLuMin > ElecFlowMax Then
    ElecFlowCon = ElecFlowMax
  Else
    ElecFlowCon = FlowCon + StorReCa - StorAdd - SpillRe - FlowLuMin
  End If

'Determine the flow that was in the river bed starting at dam gates during the period

  If SpillRe = 0 Then
     FlowRivCa = FlowCach + StorReCa - StorAdd - ElecFlowCa
  Else
     FlowRivCa = SpillRe + FlowLuMin
  End If

  LossCachCon = 0

'Determine the flow in the river at the outlet of the Condarco power station

  FlowRivCon = FlowRivCa + LossCachCon + ElecFlowCon


'Calculate the losses between Condarco and Compuertas

  LossConCom = (FlowRivCon - ElecFlowCon) ^ 0.58 * 1.086 * -1 * 0.64 * AC



'Determine the flow at Compuertas

  FlowCom = FlowRivCon + LossConCom


'Calculate the flow at Cipolletti and the losses between Compuertas and Cipolletti

  If FlowCom > ElecFlowCon + DemConCom + FlowLuMin Then
  LossComCip = (FlowCom - ElecFlowCon) ^ 0.58 * 1.086 * -1 * 0.36 * AC
  FlowCip = FlowCom + LossComCip - DemConCom
  Else
```

```
    LossComCip = (FlowCom - (ElecFlowCon - DemConCom)) ^ 0.58 * 1.086 * -1 * 0.36 * AC
    FlowCip = FlowCom + LossComCip - DemConCom
    End If
'Determine quantity of water to be pumped from aquifer

    If FlowCip < DemCon - DemConCom + FlowLuMin Then
    FlowGrwat = DemCon - DemConCom + FlowLuMin - FlowCip
    Else
    FlowGrwat = 0
    End If

'Calculate the flow at Lujan
'(Note: FlowGrwat is in this formula to adjust consumptive demand)

    LossCipLu = 0.14 * -1 * (FlowCip - (DemCon - DemConCom) + FlowGrwat)
    FlowLu = FlowCip + LossCipLu - (DemCon - DemConCom) + FlowGrwat

'Insert all values from the current period into the output table

Cells(43 + I, 11).Value = FlowCach / VolConv
Cells(77 + 7 * I, 42).Value = FlowGuid
Cells(78 + 7 * I, 42).Value = FlowCach
Cells(79 + 7 * I, 42).Value = FlowRivCon
Cells(80 + 7 * I, 42).Value = FlowCom
Cells(81 + 7 * I, 42).Value = FlowCip
Cells(82 + 7 * I, 42).Value = FlowLu
Cells(83 + 7 * I, 42).Value = FlowGrwat
Cells(77 + 7 * I, 43).Value = GainGuCa
Cells(78 + 7 * I, 43).Value = LossCachCon
Cells(79 + 7 * I, 43).Value = LossConCom
Cells(80 + 7 * I, 43).Value = LossComCip
Cells(81 + 7 * I, 43).Value = LossCipLu
Cells(82 + 7 * I, 43).Value = LossCanals
Cells(80 + 7 * I, 44).Value = DemConCom
Cells(81 + 7 * I, 44).Value = DemCon
Cells(78 + 7 * I, 45).Value = StorCa
Cells(78 + 7 * I, 46).Value = ElecCa
Cells(79 + 7 * I, 46).Value = ElecCon
Cells(78 + 7 * I, 47).Value = StorAddRe
Cells(78 + 7 * I, 48).Value = FlowRivCa
Cells(79 + 7 * I, 48).Value = FlowRivCon
Cells(78 + 7 * I, 49).Value = ElecFlowCa
Cells(79 + 7 * I, 49).Value = ElecFlowCon
Cells(78 + 7 * I, 50).Value = SpillRe

    Next I
Next J
End Sub
```

Output Data for 1996-97 (No Dam)

Month	Nodes	Flow hm3/Mnth	Loss/Gain hm3/Mnth	Demand hm3/Mnth	Storage hm3	Electricity Mwh	Storage Release hm3/Mnth	Flow in the River Bed hm3/Mnth	Flow Through Turbines for Elec. Gener. hm3/Mnth	Spill Release hm3/Mnth
July	1-Guido	31.10	3.43							
	2-Cacheuta	34.53	0.00		0.00	1830.47	0.00		27.62	0.00
	3-Condarco	34.53	-2.13			5593.11			27.62	
	4-Compuertas	32.40	-2.32	16.84						
	5-Cipolletti	13.23	-0.70	33.78						
	6-Lujan	4.30	-0.22							
	Groundwater	8.71								
August	1-Guido	28.51	3.27							
	2-Cacheuta	31.78	0.00		0.00	1684.82	0.00		25.43	0.00
	3-Condarco	31.78	-2.03			5148.06			25.43	
	4-Compuertas	29.75	-2.30	16.84						
	5-Cipolletti	10.61	-0.70	75.28						
	6-Lujan	4.30	-14.05							
	Groundwater	52.82								
September	1-Guido	33.70	3.58							
	2-Cacheuta	37.28	0.00		0.00	1976.12	0.00		29.82	0.00
	3-Condarco	37.28	-2.23			6038.16			29.82	
	4-Compuertas	35.05	-2.35	16.84						
	5-Cipolletti	15.86	-0.70	60.10						
	6-Lujan	4.30	-8.99							
	Groundwater	32.40								
October	1-Guido	36.29	3.74							
	2-Cacheuta	40.02	0.00		0.00	2121.78	0.00		32.02	0.00
	3-Condarco	40.02	-2.32			6483.21			32.02	
	4-Compuertas	37.70	-2.38	16.84						
	5-Cipolletti	18.48	-0.70	93.18						
	6-Lujan	4.30	-20.02							
	Groundwater	62.86								
November	1-Guido	77.76	6.22							
	2-Cacheuta	83.98	0.00		0.00	4452.21	0.00		67.19	0.00
	3-Condarco	83.98	-3.57			13603.98			67.19	
	4-Compuertas	80.41	-2.81	16.84						
	5-Cipolletti	60.76	-0.70	121.40						
	6-Lujan	4.30	-29.43							
	Groundwater	48.79								
December	1-Guido	246.24	16.33							
	2-Cacheuta	262.57	0.00		0.00	6593.40	0.00		99.50	0.00
	3-Condarco	262.57	-13.34			20146.49			99.50	
	4-Compuertas	249.23	-7.60	16.84						
	5-Cipolletti	224.79	-14.77	136.16						
	6-Lujan	90.71	-34.35							
	Groundwater	0.00								
January	1-Guido	209.95	14.16							
	2-Cacheuta	224.11	0.00		0.00	6593.40	0.00		99.50	0.00
	3-Condarco	224.11	-11.41			20146.49			99.50	
	4-Compuertas	212.69	-6.58	16.84						
	5-Cipolletti	189.27	-10.30	132.53						
	6-Lujan	63.28	-33.14							
	Groundwater	0.00								
February	1-Guido	184.03	12.60							
	2-Cacheuta	196.63	0.00		0.00	6593.40	0.00		99.50	0.00
	3-Condarco	196.63	-9.88			20146.49			99.50	
	4-Compuertas	186.75	-5.78	16.84						
	5-Cipolletti	164.13	-10.97	102.59						
	6-Lujan	67.41	-23.16							
	Groundwater	0.00								
March	1-Guido	116.64	8.56							
	2-Cacheuta	125.20	0.00		0.00	6593.40	0.00		99.50	0.00
	3-Condarco	125.20	-4.57			20146.49			99.50	
	4-Compuertas	120.63	-3.22	16.84						
	5-Cipolletti	100.57	-3.35	93.51						
	6-Lujan	20.55	-20.13							
	Groundwater	0.00								
April	1-Guido	80.35	6.38							
	2-Cacheuta	86.73	0.00		0.00	4597.86	0.00		69.39	0.00
	3-Condarco	86.73	-3.64			14049.03			69.39	
	4-Compuertas	83.10	-2.84	16.84						
	5-Cipolletti	63.41	-1.87	66.86						
	6-Lujan	11.52	-11.25							
	Groundwater	0.00								
May	1-Guido	57.02	4.98							
	2-Cacheuta	62.00	0.00		0.00	3286.99	0.00		49.60	0.00
	3-Condarco	62.00	-2.99			10043.59			49.60	
	4-Compuertas	59.01	-2.60	16.84						
	5-Cipolletti	39.57	-0.70	62.41						
	6-Lujan	4.30	-9.76							
	Groundwater	11.00								
June	1-Guido	46.66	4.36							
	2-Cacheuta	51.01	0.00		0.00	2704.39	0.00		40.81	0.00
	3-Condarco	51.01	-2.67			8263.40			40.81	
	4-Compuertas	48.34	-2.49	16.84						
	5-Cipolletti	29.01	-1.64	34.11						
	6-Lujan	10.10	-0.33							
	Groundwater	0.00								

Output Summary

Total Groundwater Pumped (hm3/yr)	216.58
Electricity Generated at Cacheuta (Mwh)	49028.23
Electricity Generated at Condarco (Mwh)	149808.48
Total Electricity Generated (Mwh)	198836.72
Total Water Infiltration in Canal System (hm3/yr)	-204.82
Total Water Infiltration between Cach-Cippoll.	-104.08

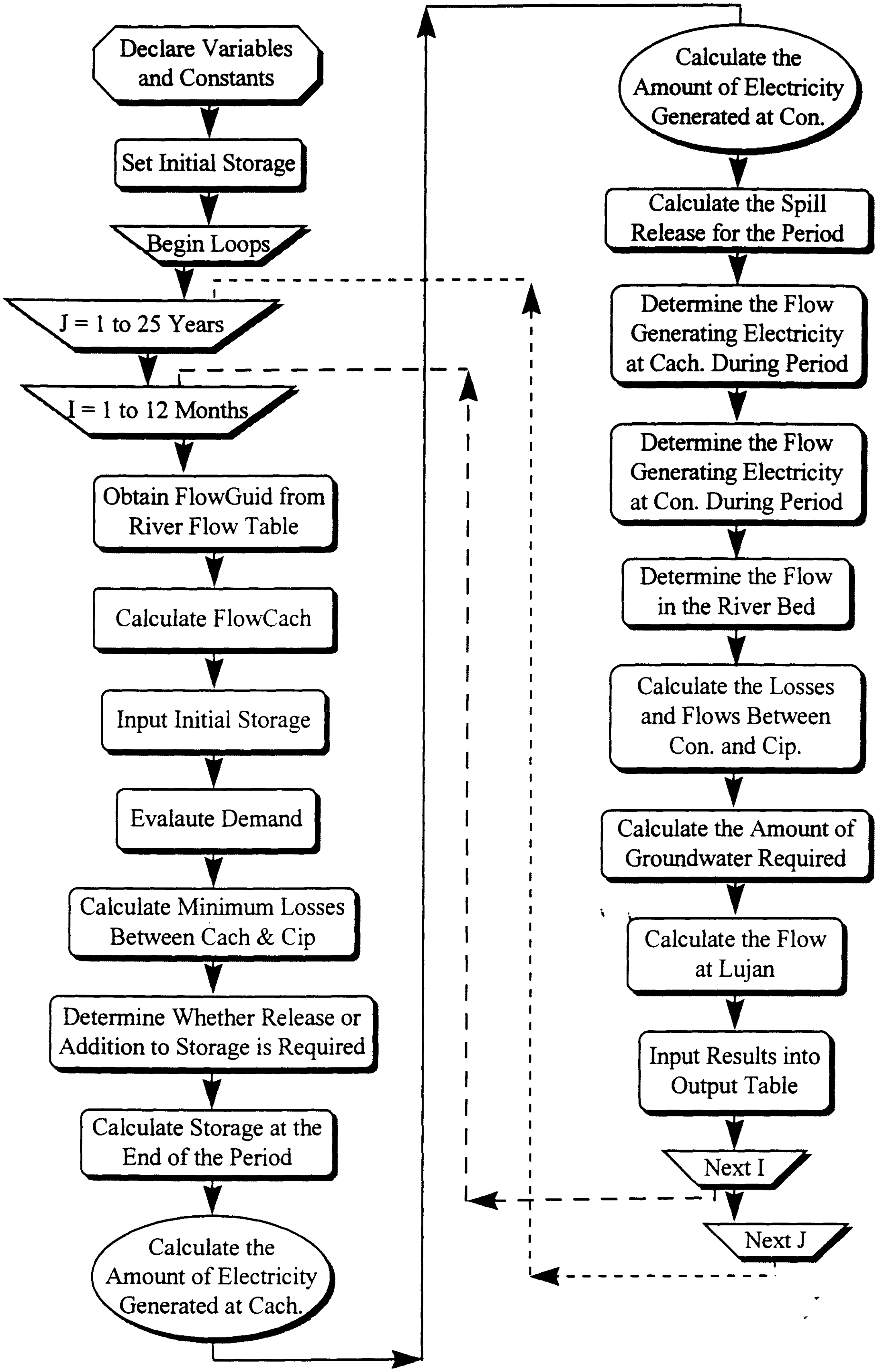
```
'Procedure which calculates water usage as a function of demands-Copyright Joseph Cavicchi
1996

'Declare Module variables

Dim FlowCach, FlowGuid, Demcons, Demnoncons, LossCachCon, LossConCom
Dim DemCon, DemNCon, DemCip, StorCa, ElecCa, FlowCip, FlowLu, FlowGrwat
Dim LossCaCip, LossCipLu, LossCanals, LossComCip, StorReCa, SpillRe, DemConCom
Dim StorAdd, StorSp, ElecFlowCa, ElecFlowCon, ReExc, LossCaCipMin, GainGuCa
Dim FlowCon, FlowCom, ElecCon, DemNConCom, DemNConCach

'Declare constants

Const VolConv = 2.592
Const FlowLuMin = 5
Const LF = 0.5
'Define Maximum flow through electricity generation equipment

Const ElecFlowMaxCach = 99.5
Const ElecFlowMaxCon = 99.5

'Procedures

Sub WaterUsageCalcsNoDam()

'Specify value of variables which are not used

SpillRe = 0
StorReCa = 0
StorAdd = 0
StorCa = 0

'Loops are begun to index model through both sheets and months

For J = 1 To 25 Step 1
   Sheets(J).Select

   For I = 0 To 11 Step 1

'River water flows are taken from the input table to the water usage model

   FlowGuid = Cells(43 + I, 12) * VolConv

'Determine the flows at Cacheuta/Condarco and the increase in flow between
'Guido and Cacheuta

   FlowCach = 1.559 + 1.06 * FlowGuid
   GainGuCa = FlowCach - FlowGuid
```

```
'Consumptive and non-consumptive demands are calculated or taken from demand table
'Note: Non-Consumptive demand is used during June and July

   DemNConCom = Cells(6 + I, 29)
   DemNCon = DemNConCom
   DemConCom = Cells(6 + I, 24)
   LossCanals = Cells(6 + I, 21) * LF * -1 + _
            Cells(6 + I, 22) * LF * -1 + _
            Cells(6 + I, 23) * LF * -1
   DemCon = Cells(6 + I, 26) - LossCanals

'Examine the flow for the month to determine amount which can be used to generate electricity
'I have decided that 80% can be used to generate electricity

'Determine the quantity of electricity generated at Cacheuta

  If FlowCach > ElecFlowMaxCach * 1.2 Then

   ElecCa = ElecFlowMaxCach * 0.87 * 2.73 * 27.9

   Else
   ElecCa = (FlowCach * 0.87 * 2.73 * 27.9) * 0.8

   End If
'Determine flow through the Cacheuta electricity station for the month

   If FlowCach > ElecFlowMaxCach Then
     ElecFlowCa = ElecFlowMaxCach
   Else
     ElecFlowCa = FlowCach * 0.8
   End If

'Calculate the losses between Cacheuta and Condarco

  LossCachCon = 0

'Determine the flow at Condarco

   FlowCon = FlowCach + LossCachCon

'Determine the quantity of electricity generated at Condarco

   If FlowCon > ElecFlowMaxCon * 1.2 Then

   ElecCon = ElecFlowMaxCon * 0.87 * 2.73 * 85.25

   Else
   ElecCon = (FlowCon * 0.87 * 2.73 * 85.25) * 0.8
```

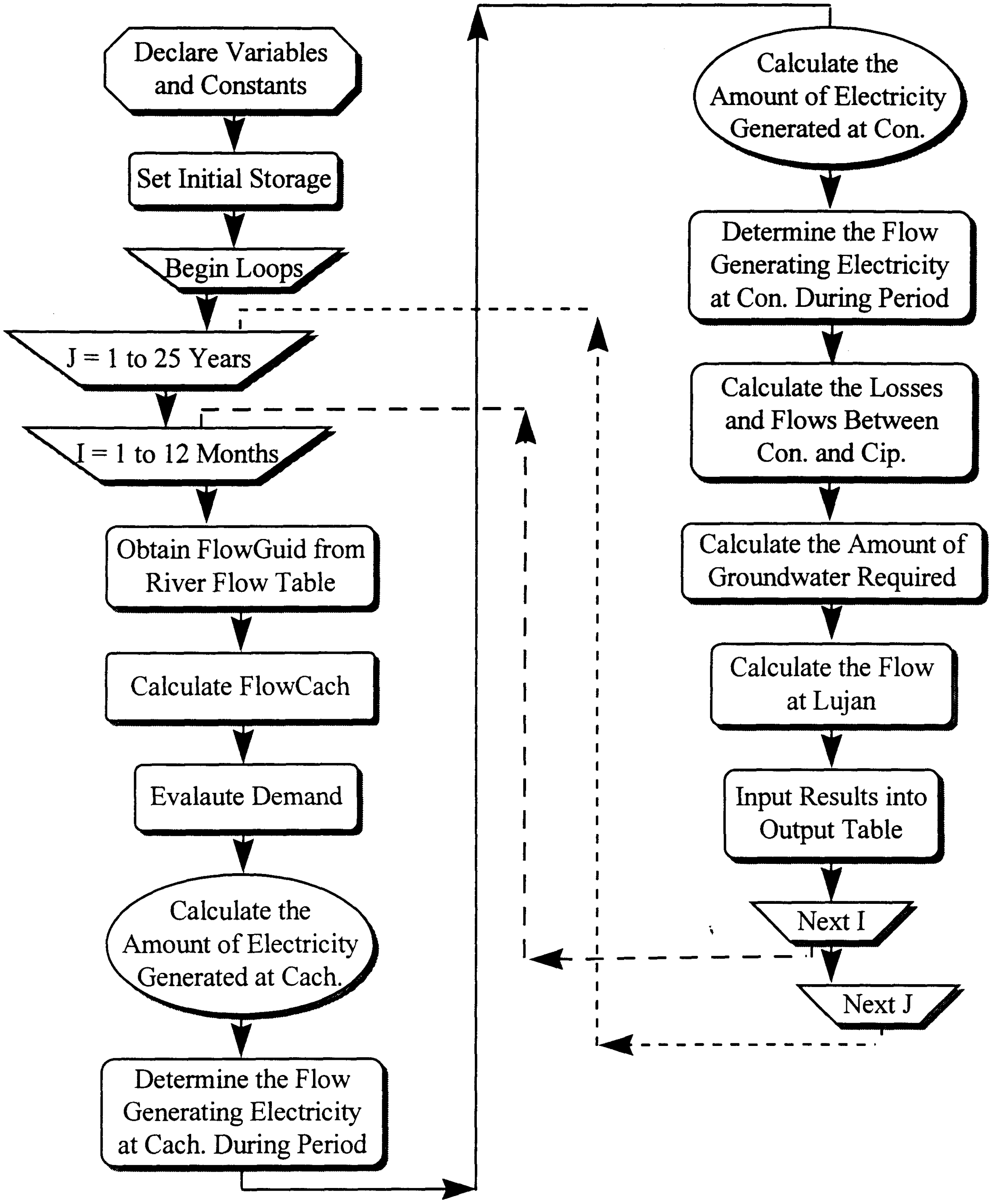
```
   End If

'Determine flow through the Condarco electricity station for the month

   If FlowCon > ElecFlowMaxCon Then
     ElecFlowCon = ElecFlowMaxCon
   Else
     ElecFlowCon = FlowCon * 0.8
   End If

'Calculate the losses between Condarco and Compuertas

  LossConCom = (FlowCon - ElecFlowCon) ^ 0.58 * 1.086 * -1 * 0.64

'Determine the flow at Compuertas

   FlowCom = FlowCon + LossConCom


'Calculate the flow at Cipolletti and the losses between Compuertas
' and Cipolletti

   LossComCip = (FlowCom - (ElecFlowCon - DemConCom)) ^ 0.58 * 1.086 * -1 * 0.36
   FlowCip = FlowCom + LossComCip - DemConCom

'Determine quantity of water to be pumped from aquifer

   If FlowCip < DemCon - DemConCom + FlowLuMin Then
   FlowGrwat = DemCon - DemConCom + FlowLuMin - FlowCip
   Else
   FlowGrwat = 0
   End If

'Calculate the flow at Lujan
'(Note: FlowGrwat is in this formula to adjust consumptive demand)

   LossCipLu = 0.14 * -1 * (FlowCip - (DemCon - DemConCom) + FlowGrwat)
   FlowLu = FlowCip + LossCipLu - (DemCon - DemConCom) + FlowGrwat

'Insert all values from the current period into the output table

Cells(43 + I, 11).Value = FlowCach / VolConv
Cells(77 + 7 * I, 42).Value = FlowGuid
Cells(78 + 7 * I, 42).Value = FlowCach
Cells(79 + 7 * I, 42).Value = FlowCon
Cells(80 + 7 * I, 42).Value = FlowCom
Cells(78 + 7 * I, 44).Value = Empty
Cells(81 + 7 * I, 42).Value = FlowCip
```

```
Cells(82 + 7 * I, 42).Value = FlowLu
Cells(83 + 7 * I, 42).Value = FlowGrwat
Cells(77 + 7 * I, 43).Value = GainGuCa
Cells(78 + 7 * I, 43).Value = LossCachCon
Cells(79 + 7 * I, 43).Value = LossConCom
Cells(80 + 7 * I, 43).Value = LossComCip
Cells(81 + 7 * I, 43).Value = LossCipLu
Cells(82 + 7 * I, 43).Value = LossCanals
Cells(80 + 7 * I, 44).Value = DemConCom
Cells(81 + 7 * I, 44).Value = DemCon
Cells(78 + 7 * I, 45).Value = StorCa
Cells(78 + 7 * I, 46).Value = ElecCa
Cells(79 + 7 * I, 46).Value = ElecCon
Cells(78 + 7 * I, 47).Value = StorReCa
Cells(78 + 7 * I, 49).Value = ElecFlowCa
Cells(79 + 7 * I, 49).Value = ElecFlowCon
Cells(78 + 7 * I, 50).Value = SpillRe

   Next I
Next J
End Sub
```

Flow Chart - Model with Dam



Flow Chart - Model without Dam

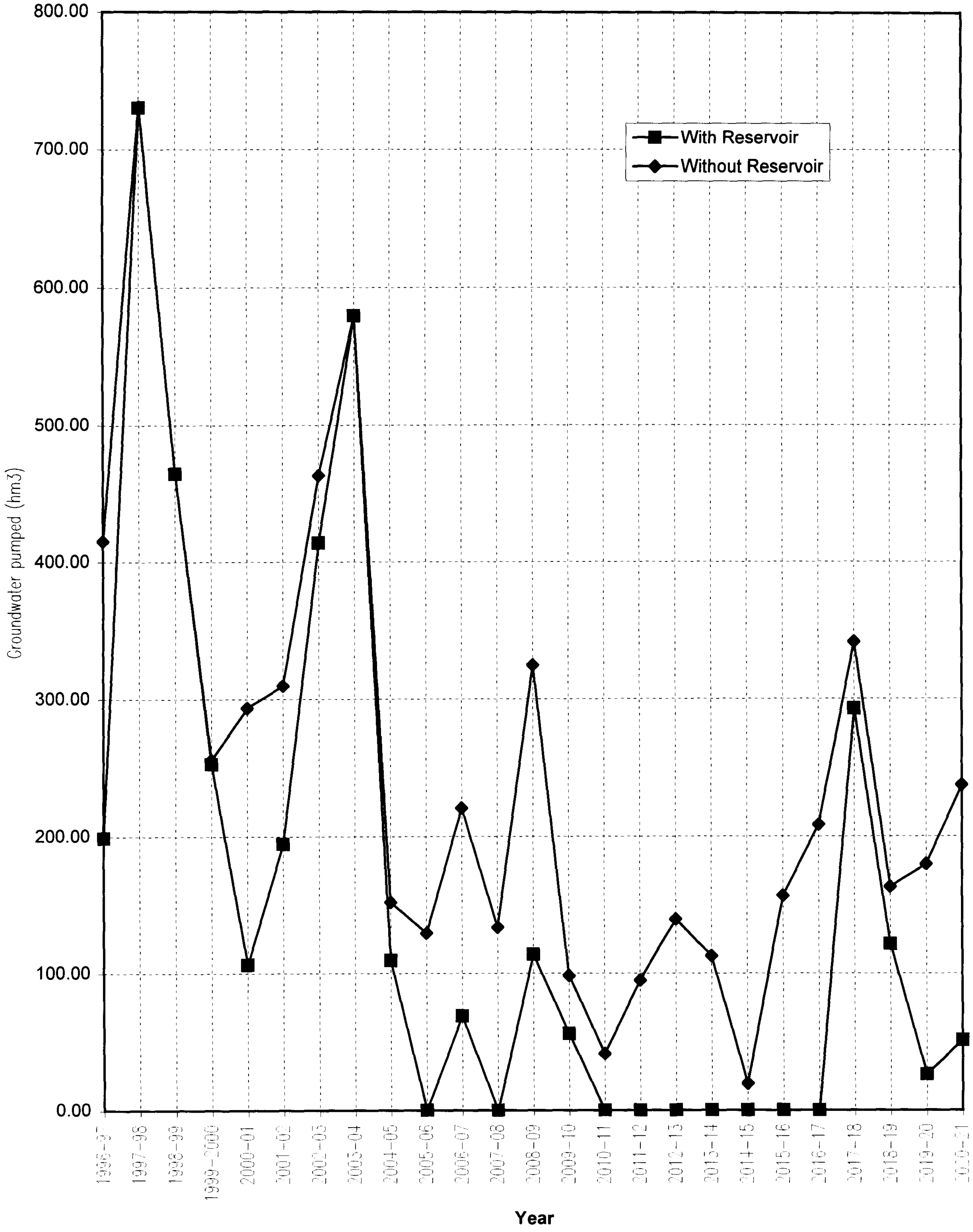


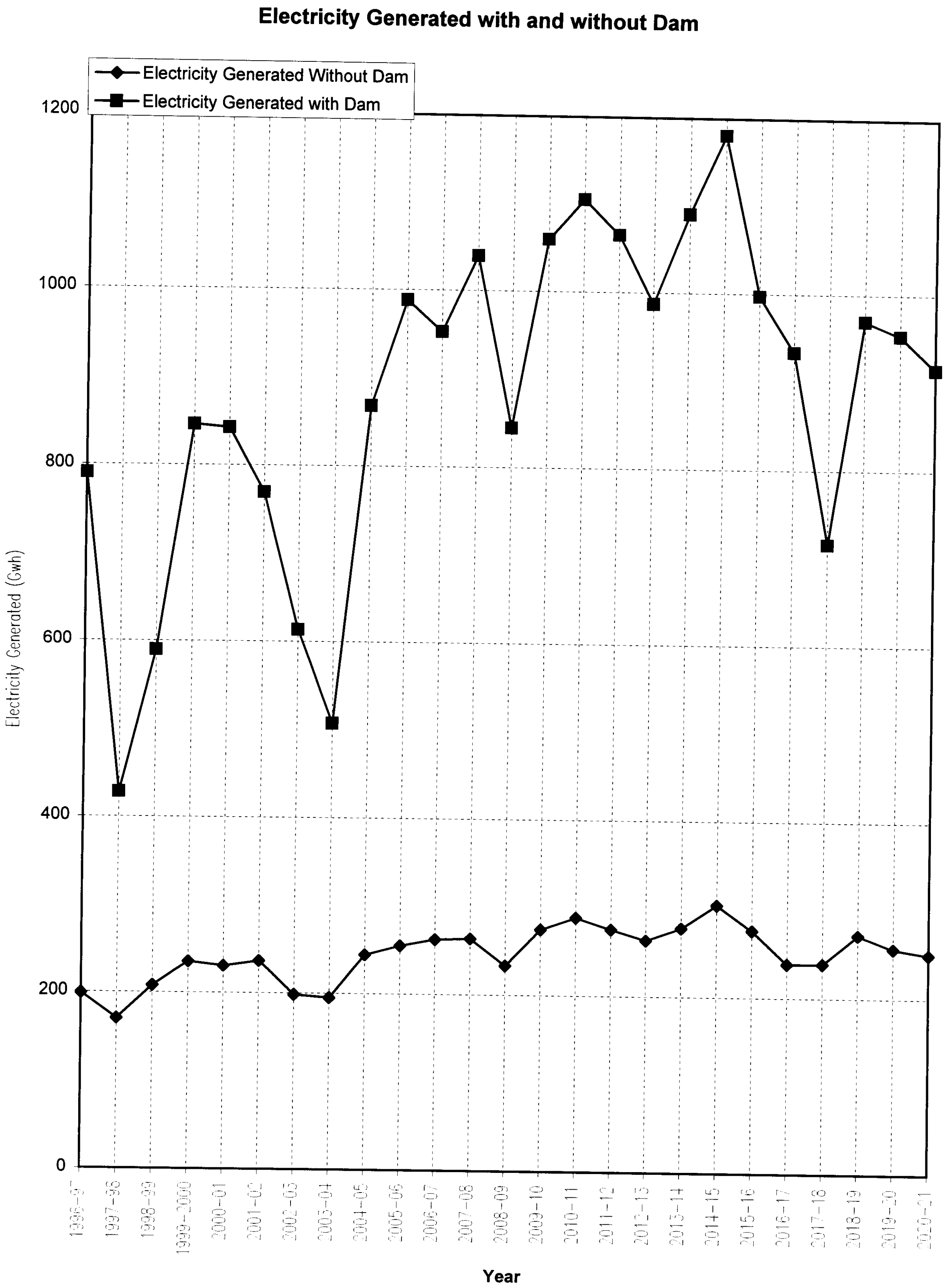
Year	***Investment ($000)***				***Benefits ($000)***			
	Dam Projects	Interest during Construction		10%				
		Discount rate		12%	Benefit Factor	1		1
					Elec.Value			
					($/Mwh)	30		
	Potrerillos (state)	Potrerillos (Inves.)		Total	Electricity	Tourism	Floods	Agriculture(net)
1	-69,695	-6,969	0	-6,969	0	0	0	
2	-32,952	-10,265	0	-10,265	0	0	0	
3	-87,191	-18,984	0	-18,984	0	0	0	
4	-72,903	-26,274	0	-26,274	0	0	0	
5	-28,869	-29,161	0	-29,161	11,364	0	0	
6		-48,866	-1,441	-50,307	15,842	7,983	1,000	412
7		-48,866	-1,441	-50,307	10,522	7,983	1,000	1,036
8		-48,866	-1,441	-50,307	11,514	7,983	1,000	1,888
9		-48,866	-1,441	-50,307	17,745	7,983	1,000	2,200
10		-48,866	-1,441	-50,307	17,032	7,983	1,000	874
11		-48,866	-1,441	-50,307	16,055	7,983	1,000	903
12		-48,866	-1,441	-50,307	15,088	7,983	1,000	768
13		-48,866	-1,441	-50,307	9,398	7,983	1,000	2,040
14		-48,866	-1,441	-50,307	17,558	7,983	1,000	2,088
15		-48,866	-1,441	-50,307	20,699	7,983	1,000	1,595
16		-48,866	-1,441	-50,307	20,915	4,160	1,000	1,960
17		-48,866	-1,441	-50,307	21,658	4,160	1,000	2,303
18		-48,866	-1,441	-50,307	16,376	4,160	1,000	1,943
19		-48,866	-1,441	-50,307	23,714	4,160	1,000	2,836
20		-48,866	-1,441	-50,307	24,038	4,160	1,000	2,634
21		-48,866	-1,441	-50,307	22,132	4,160	1,000	2,510
22		-48,866	-1,441	-50,307	20,501	4,160	1,000	1,948
23		-48,866	-1,441	-50,307	22,725	4,160	1,000	2,622
24		-48,866	-1,441	-50,307	25,974	4,160	1,000	2,888
25		-48,866	-1,441	-50,307	20,039	4,160	1,000	1,729
26		-48,866	-1,441	-50,307	19,114	0	1,000	3,213
27		-48,866	-1,441	-50,307	15,291	0	1,000	4,550
28		-48,866	-1,441	-50,307	21,451	0	1,000	4,894
29		-48,866	-1,441	-50,307	20,449	0	1,000	3,657
30		-48,866	-1,441	-50,307	19,291	0	1,000	3,316
NPV	($238,862.17)	($279,047.04)	($11,301.96)	($317,164.54)	$91,098.49	$33,475.08	$4,984.46	$13,007.56

Canal Impermiabilization/Infiltration Mitigation ($000)					***Groundwater Pumping Batteries ($000)***							***Totals ($000)***	
					Note: Costs are input in $/hm3 at an average derived from multiple wells, weighted numerically,							***(State Scheme)***	Investor Scheme
					Pumping from 60m at 60, 70, 80 % efficiency								
					High Tariff is assummed-$.0853/kwh								
					cost ($/hm3)	35,100							
Marginal Canal	Canal Lining(12%)	Canal Lining(12%)		Investor Total			Cost (-) or Saving (+) ($000/yr)						
							0					-69,695	-6,969
							0					-32,952	-10,265
							0					-87,191	-18,984
-4,675				-468			0					-77,578	-26,274
-4,675				-935			0					-22,180	-29,161
				-1,185			8,224					32,020	-18,031
				-1,185			7,946					27,046	-23,005
				-1,185			3,656					24,600	-25,450
				-1,185			982					28,469	-21,582
				-1,185			7,613					33,061	-16,990
				-1,185			7,899					32,399	-17,652
				-1,185			10,454					33,853	-16,198
				-1,185			3,086					22,066	-27,985
				-1,185			1,616					28,804	-21,246
				-1,185			2,889					32,725	-17,326
				-1,185			5,599					32,194	-17,857
				-1,185			3,096					30,776	-19,274
				-1,185			8,424					30,462	-19,589
				-1,185			2,591					32,859	-17,191
				-1,185			703					31,094	-18,957
				-1,185			2,073					30,434	-19,617
				-1,185			3,167					29,335	-20,715
				-1,185			2,493					31,560	-18,491
				-1,185			302					32,883	-17,168
				-1,185			3,039					28,526	-21,524
				-1,185			5,585					27,472	-22,579
				-1,185			7,684					27,083	-22,967
				-1,185			4,306					30,210	-19,841
				-1,185			4,491					28,156	-21,895
				-1,185			5,762					27,927	-22,124
							$26,237.28				NPV	($89,711.56)	($169,749.71)
											IRR	7%	#NUM!

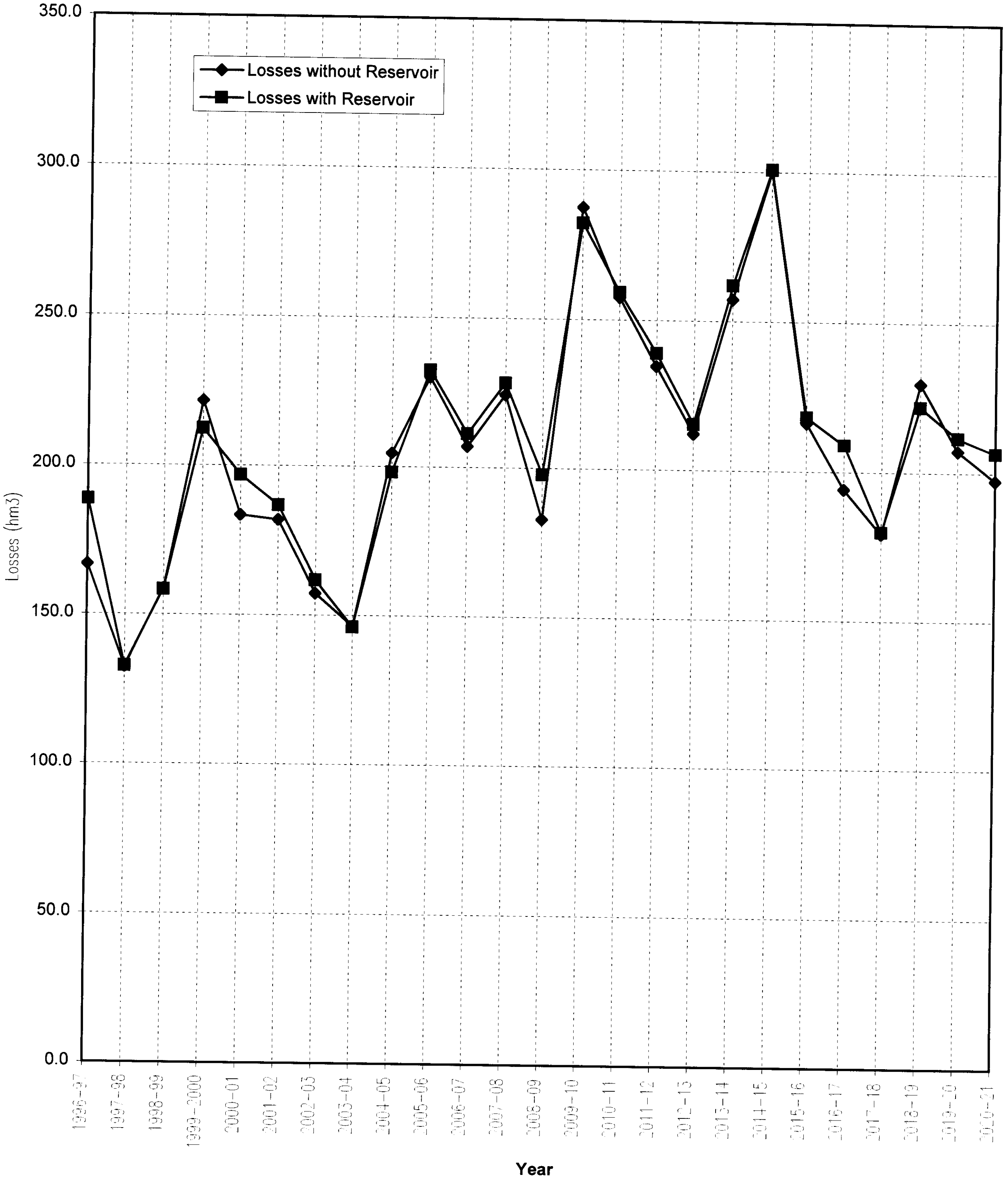
	Investment($000)		Interest rate	10%									
			Discount Rate	12%						*Groundwater Pumping Batteries (costs to improve system included in price)*			
Year	Marginal Canal	Canal Lining(12%)	Canal Lining(12%)	Condarco Enlarg.	Investor	Electricity Benefit Value ($/Mwh)	35	Note: Costs are input in $/hm3 at an average derived from multiple wells with three different levels and weighted numerically	High Tariff is assumme	Note: Costs to improve system included in pumping cost per reports Cost (-) or Saving (+) ($000/yr)		Total (State)	Total (Investor)
1	-4,675				-468	0				0		-4,675	-468
2	-4,675				-935	0		cost ($/hm	35,100	0		-4,675	-935
3					-1,185	0				814		814	-371
4					-1,185	0				2,411		2,411	1,226
5					-1,185	0				1,817		1,817	632
6					-1,185	0				843		843	-341
7					-1,185	0				1,026		1,026	-159
8					-1,185	0				1,090		1,090	-94
9					-1,185	0				1,311		1,311	126
10					-1,185	0				1,367		1,367	182
11					-1,185	0				349		349	-835
12					-1,185	0				629		629	-556
13					-1,185	0				881		881	-303
14					-1,185	0				472		472	-713
15					-1,185	0				1,143		1,143	-42
16					-1,185	0				460		460	-724
17					-1,185	0				83		83	-1,101
18					-1,185	0				183		183	-1,001
19					-1,185	0				444		444	-740
20					-1,185	0				551		551	-633
21					-1,186	0				0		0	-1,185
22					-1,185	0				564		564	-620
23					-1,185	0				963		963	-222
24					-1,185	0				1,232		1,232	47
25					-1,185	0				769		769	-416
26					-1,185	0				637		637	-548
27					-1,185	0				966		966	-218
28													
29											NPV	($1,203)	($1,871)
30													
											IRR	9%	#NUM!

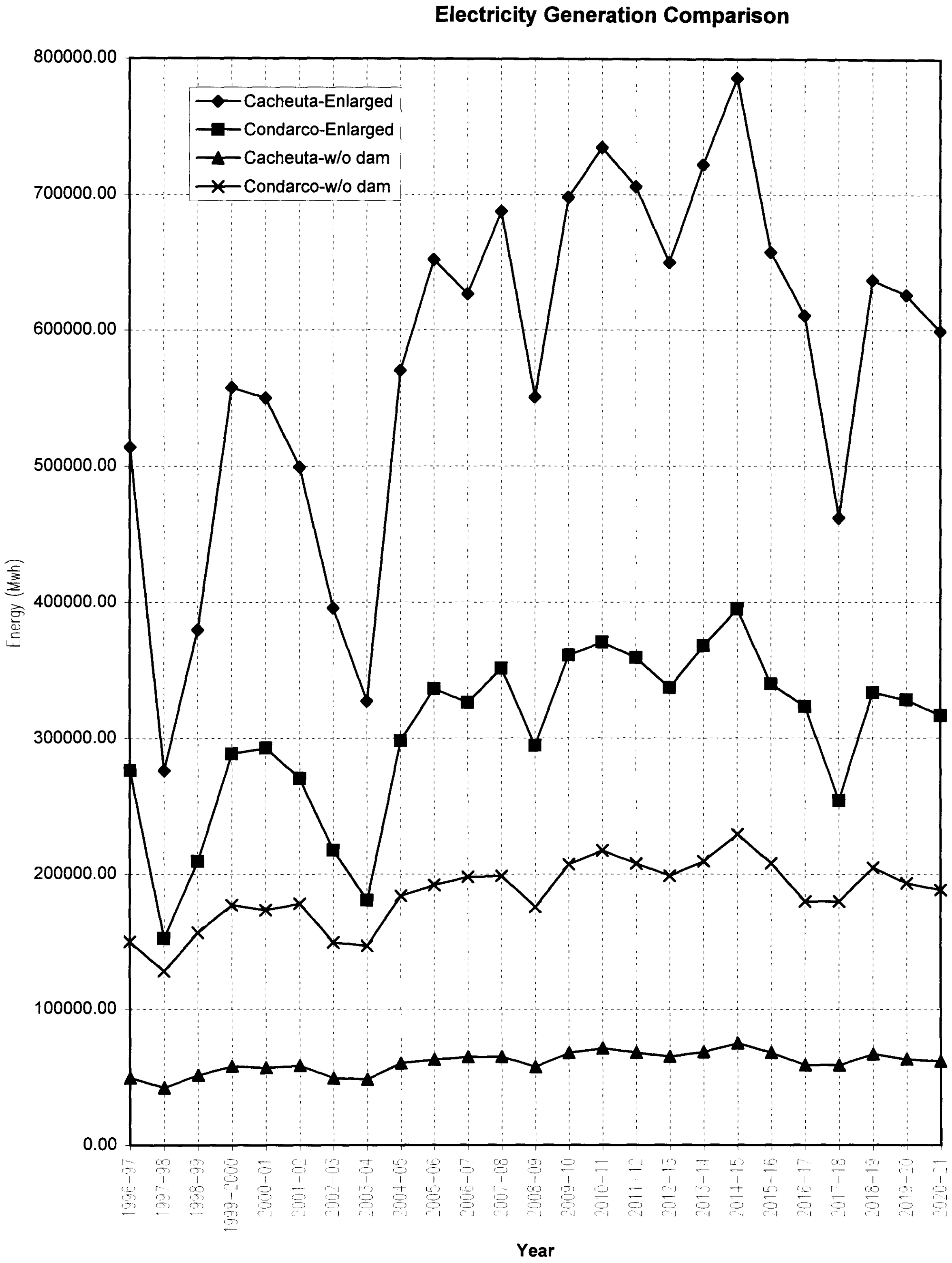
Groundwater Pumped with and without Reservoir




Electricity Generated with and without Dam
Electricity Generated Without Dam
Electricity Generated with Dam
1200
1000
800
600
400
200
0
Electricity Generated (Gwh)
1996-97
1997-98
1998-99
1999-2000
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
Year

Losses: Cacheuta to Cipolletti

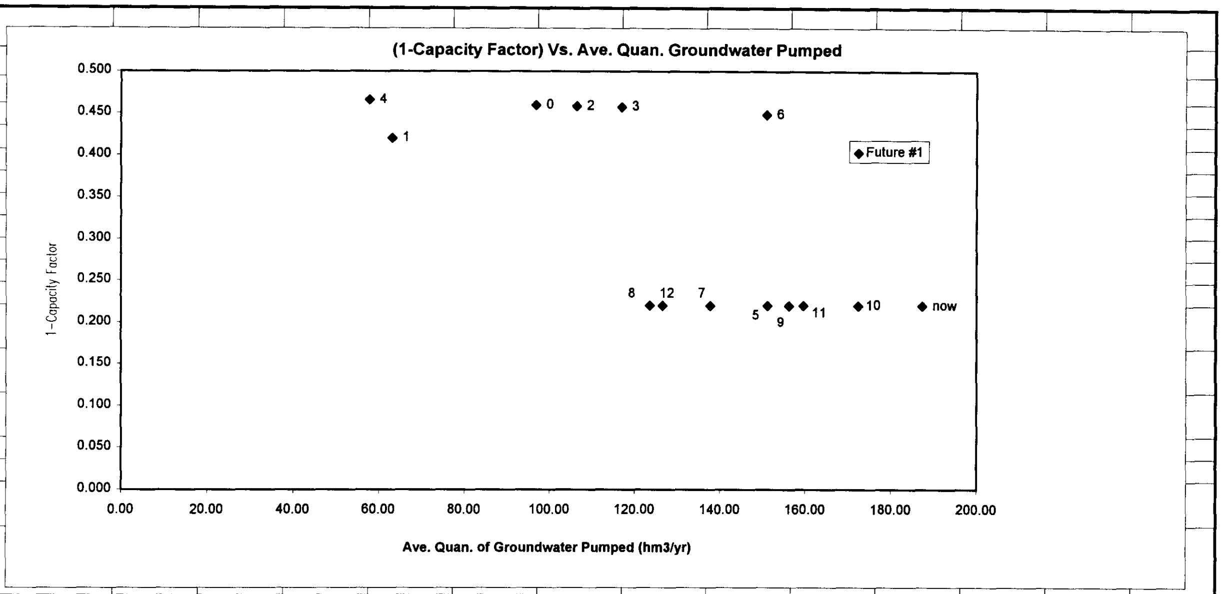


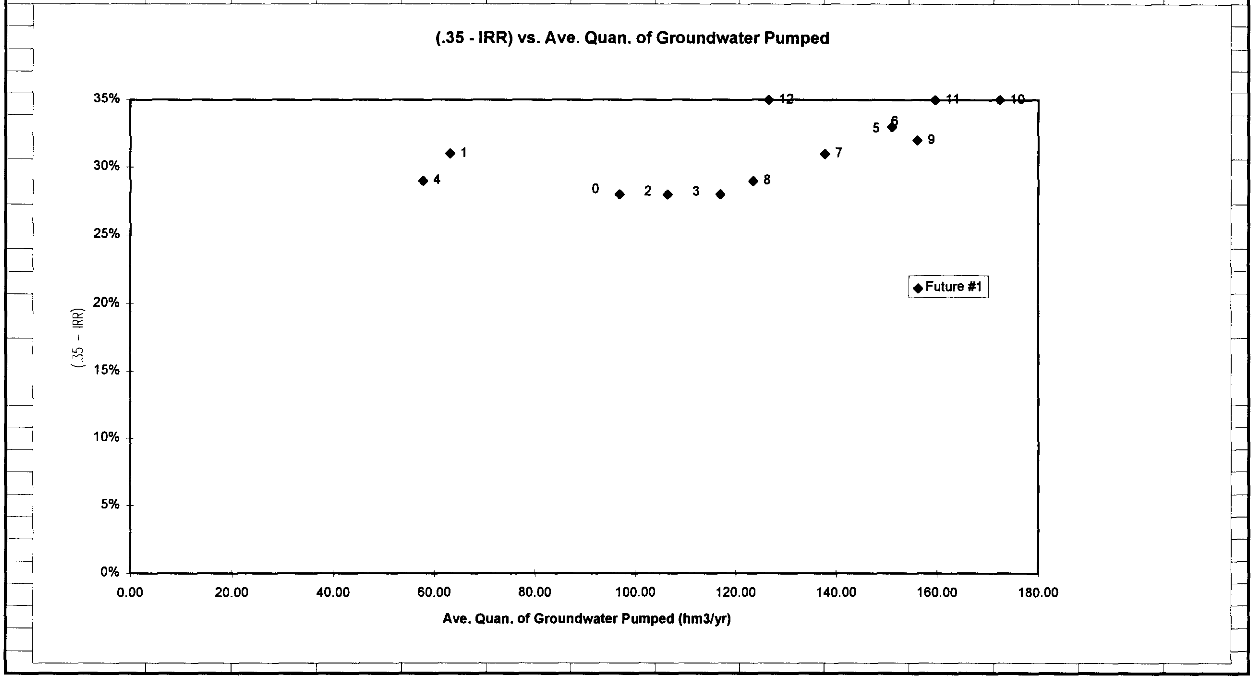

Electricity Generation Comparison
Cacheuta-Enlarged
Condarco-Enlarged
Cacheuta-w/o dam
Condarco-w/o dam
Energy (Mwh)
800000.00
700000.00
600000.00
500000.00
400000.00
300000.00
200000.00
100000.00
0.00
1996-97
1997-98
1998-99
1999-2000
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
Year

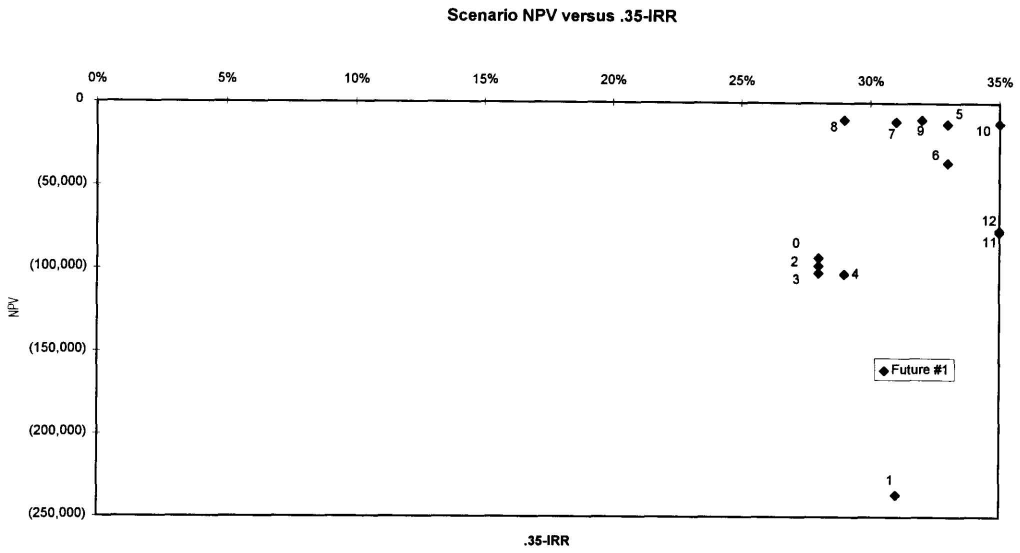
Results

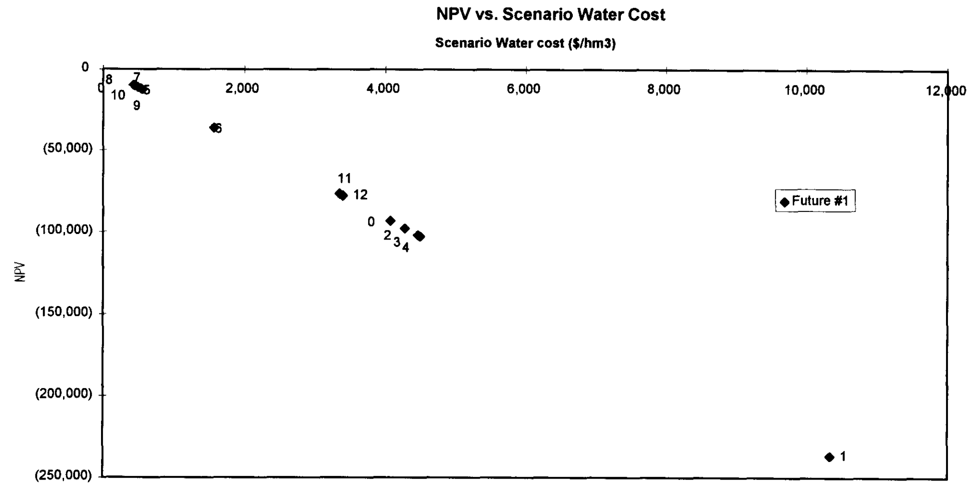
Scenario	FUTURE #1 Water Demand Variations			Water Loss Variations				
	Potable (OSM)	Industrial	Irrigation	Canal Marginal	Canal Lining	Aguas Claras (Clear Water)	Improved Usage	Total Quan. of GW Pmpd(hm3)
Existing Cach/Con Arrangement	6/95 Forecast	Constant	74,500 hectares	No	No	No	No	4682.11
0.) Potrerillos	6/95 Forecast	Constant	74,500 hectares	No	No	No	No	2419.8
1.) Potrerillos w/ 500hm3 Util.	6/95 Forecast	Constant	74,500 hectares	No	No	No	No	1575.67
2.) Potrerillos w/clear water (15%)	6/95 Forecast	Constant	74,500 hectares	No	Yes	Yes (15%)	No	2658.4
3.) Potrerillos w/clear water (30%)	6/95 Forecast	Constant	74,500 hectares	No	Yes	Yes (30%)	No	2922.64
4.) Potrerillos w/ Marginal Canal	6/95 Forecast	Constant	74,500 hectares	Yes	No	No	No	1443.39
5.) Marginal Canal	6/95 Forecast	Constant	74,500 hectares	Yes	No	No	No	3777.68
6.) Marginal Canal with Enlarged Condarco	6/95 Forecast	Constant	74,500 hectares	Yes	No	No	No	3774.8
7.) Marginal Canal plus 12% Reduction in Canal Losses	6/95 Forecast	Constant	74,500 hectares	Yes	Yes (12%)	No	No	3442.55
8.) Marginal Canal plus 24% Reduction in Canal Losses	6/95 Forecast	Constant	74,500 hectares	Yes	Yes (24%)	No	No	3088.23
9.) 24% Loss Reduction in Canals	6/95 Forecast	Constant	74,500 hectares	No	Yes (24%)	No	No	3903.6
10.) 12% Loss Reduction in Canals	6/95 Forecast	Constant	74,500 hectares	No	Yes (12%)	No	No	4308.5
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	6/95 Forecast	Constant	74,500 hectares	No	Yes (12%)	No	Yes (10%)	3989
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	6/95 Forecast	Constant	74,500 hectares	Yes	Yes (12%)	No	Yes (10%)	3162.25

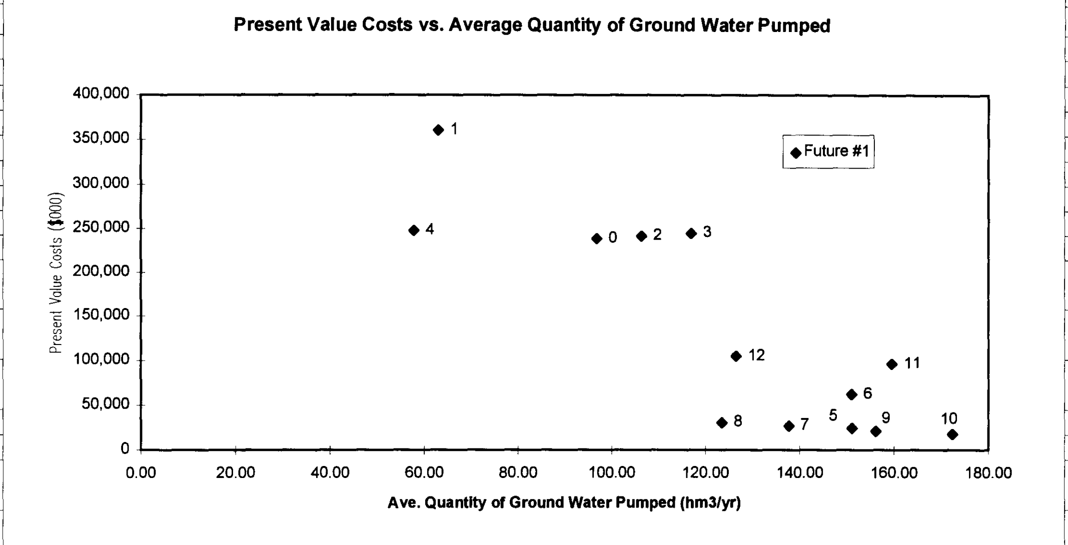
Scenario	Pertinent Results Compiled From Multiple Model Runs							
	Total Infiltration (hm3)		Ave.quan.of G pumped (hm3/y	Ave. quan. of Elec. (Gwh/yr)	NPV Investor	NPV State Finan.	Total Cost NPV ($000)	IRR State Finan.
	Farms/Canals	Cach-Cip						
Existing Cach/Con Arrangement	6935.95	5170.8	187.28	245.84	N.A.	N.A.	N.A.	N.A.
0.) Potrerillos	6935.95	5251.17	96.79	876.17	(173,622)	(93,190)	238,862	7%
1.) Potrerillos w/ 500hm3 Util.	6935.95	5273.81	63.03	938.8	(365,703)	(236,722)	360,356	4%
2.) Potrerillos w/clear water (15%)	6935.95	6023.13	106.34	877.56	(178,154)	(97,872)	241,559	7%
3.) Potrerillos w/clear water (30%)	6935.95	6789.8	116.9	879.5	(182,330)	(102,167)	244,919	7%
4.) Potrerillos w/ Marginal Canal	6935.95	1774.58	57.74	866	(182,891)	(102,853)	247,711	6%
5.) Marginal Canal	6935.95	3142.72	151.11	245.84	(14,360)	(12,519)	24,370	2%
6.) Marginal Canal with Enlarged Condarco	6935.95	2531.68	150.99	304.52	(40,594)	(35,908)	62,227	2%
7.) Marginal Canal plus 12% Reduction in Canal Losses	6159.12	3142.72	137.7	245.84	(13,087)	(11,057)	27,067	4%
8.) Marginal Canal plus 24% Reduction in Canal Losses	5278.26	3142.72	123.53	245.84	(12,370)	(10,086)	30,427	6%
9.) 24% Loss Reduction in Canals	5278.26	5170.75	156.14	245.84	(11,473)	(9,857)	21,578	3%
10.) 12% Loss Reduction in Canals	6159.1	5170.75	172.34	245.84	(13,451)	(12,089)	18,218	-
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	5465.5	5170.75	159.57	245.84	(83,923)	(76,656)	96,393	-
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	5465.5	3142.72	126.49	245.84	(85,658)	(77,723)	105,242	-


(1-Capacity Factor) Vs. Ave. Quan. Groundwater Pumped
1-Capacity Factor
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
◆ Future #1
4
1
0
2
3
6
8
12
7
5
9
11
10
now

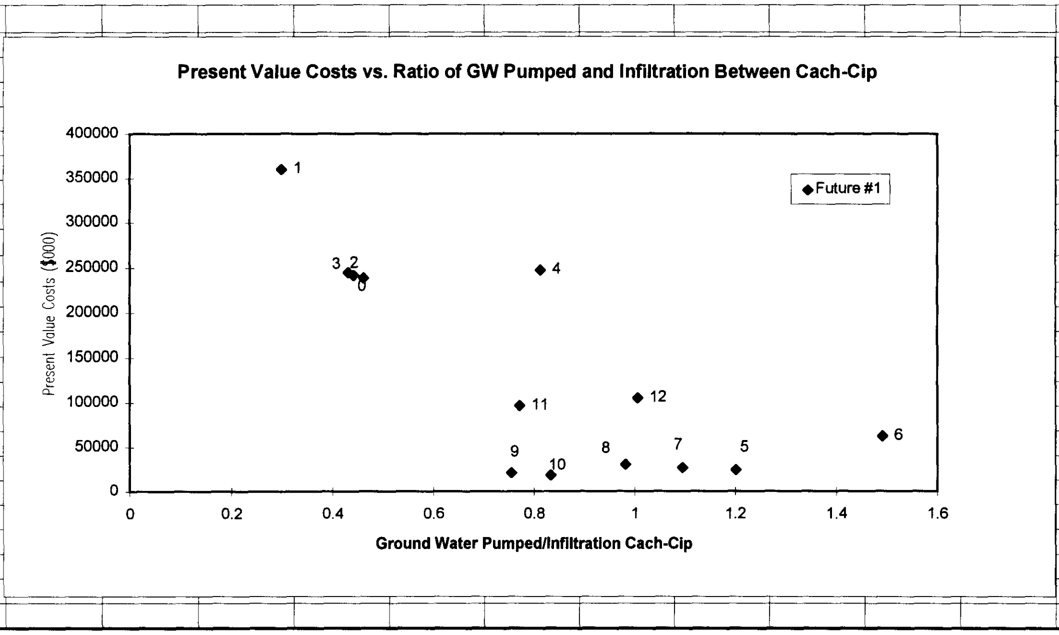

(.35 - IRR) vs. Ave. Quan. of Groundwater Pumped
(.35 - IRR)
35%
30%
25%
20%
15%
10%
5%
0%
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
◆ Future #1
12
11
10
5
6
9
1
7
4
0
2
3
8


Scenario NPV versus .35-IRR
0%
5%
10%
15%
20%
25%
30%
35%
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
NPV
.35-IRR
8
7
9
5
10
6
12
11
0
2
3
4
1
◆ Future #1


NPV vs. Scenario Water Cost
Scenario Water cost ($/hm3)
0
2,000
4,000
6,000
8,000
10,000
12,000
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
NPV
8
7
10
5
9
6
11
12
0
2
3
4
1
◆ Future #1



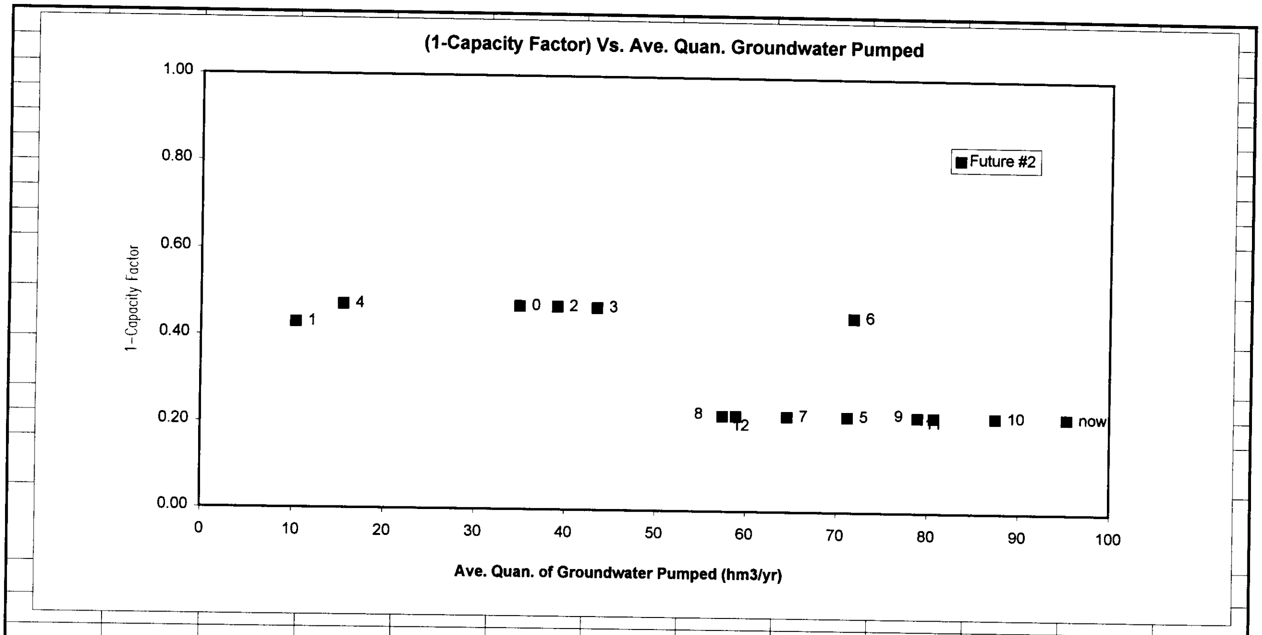
Present Value Costs vs. Average Quantity of Ground Water Pumped



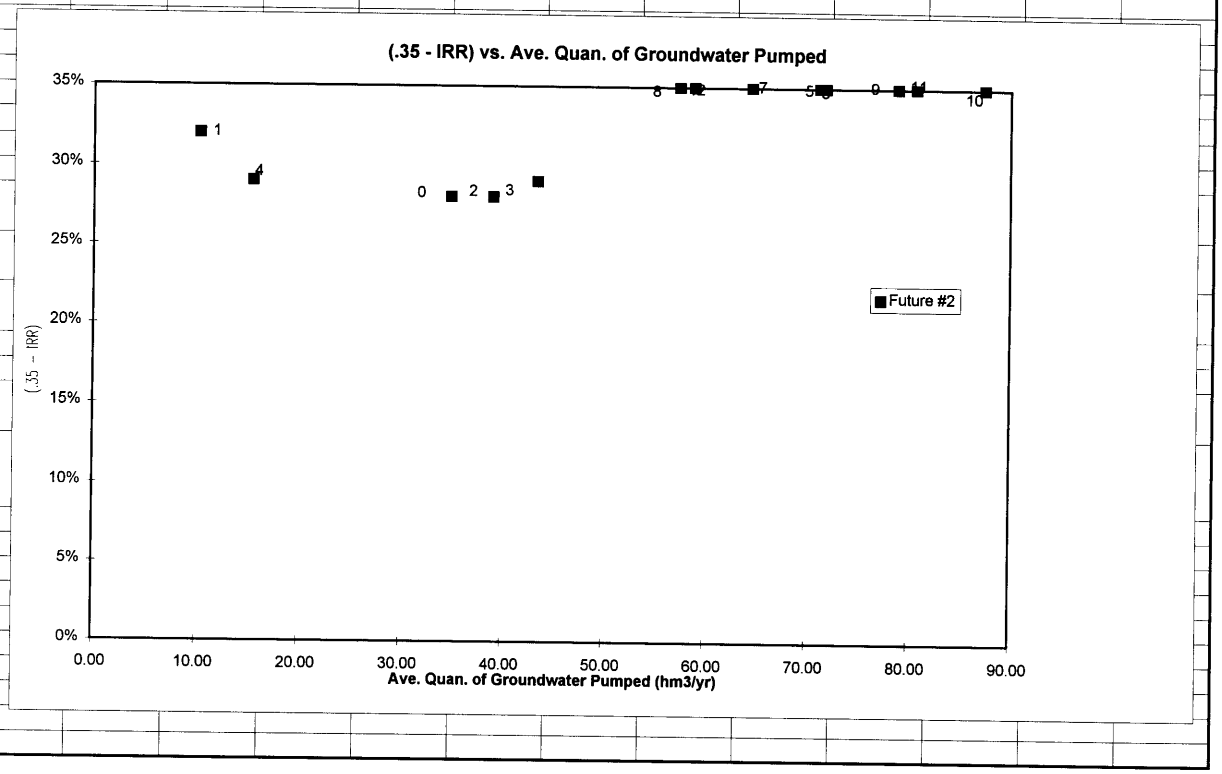
Present Value Costs vs. Ratio of GW Pumped and Infiltration Between Cach-Cip

Scenario	FUTURE #2 Water Demand Variations			Water Loss Variations				
	Potable (OSM)	Industrial	Irrigation	Canal Marginal	Canal Lining	Aguas Claras (Clear Water)	Improved Usage	Total Quan. of GW Pmpd(hm3)
Existing Cach/Con Arrangement	6/95 Forecast	Constant	55,000 hectares	No	No	No	No	2383
0.) Potrerillos	6/95 Forecast	Constant	55,000 hectares	No	No	No	No	873.89
1.) Potrerillos w/ 500hm3 Util.	6/95 Forecast	Constant	55,000 hectares	No	No	No	No	258.72
2.) Potrerillos w/clear water (15%)	6/95 Forecast	Constant	55,000 hectares	No	Yes	Yes (15%)	No	977.69
3.) Potrerillos w/clear water (30%)	6/95 Forecast	Constant	55,000 hectares	No	Yes	Yes (30%)	No	1087.3
4.) Potrerillos w/ Marginal Canal	6/95 Forecast	Constant	55,000 hectares	Yes	No	No	No	388.46
5.) Marginal Canal	6/95 Forecast	Constant	55,000 hectares	Yes	No	No	No	1781.04
6.) Marginal Canal with Enlarged Condarco	6/95 Forecast	Constant	55,000 hectares	Yes	No	No	No	1796.78
7.) Marginal Canal plus 12% Reduction in Canal Losses	6/95 Forecast	Constant	55,000 hectares	Yes	Yes (12%)	No	No	1614.68
8.) Marginal Canal plus 24% Reduction in Canal Losses	6/95 Forecast	Constant	55,000 hectares	Yes	Yes (24%)	No	No	1436.35
9.) 24% Loss Reduction in Canals	6/95 Forecast	Constant	55,000 hectares	No	Yes (24%)	No	No	1973.9
10.) 12% Loss Reduction in Canals	6/95 Forecast	Constant	55,000 hectares	No	Yes (12%)	No	No	2187.07
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	6/95 Forecast	Constant	55,000 hectares	No	Yes (12%)	No	Yes (10%)	2018.62
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	6/95 Forecast	Constant	55,000 hectares	Yes	Yes (12%)	No	Yes (10%)	1473.16

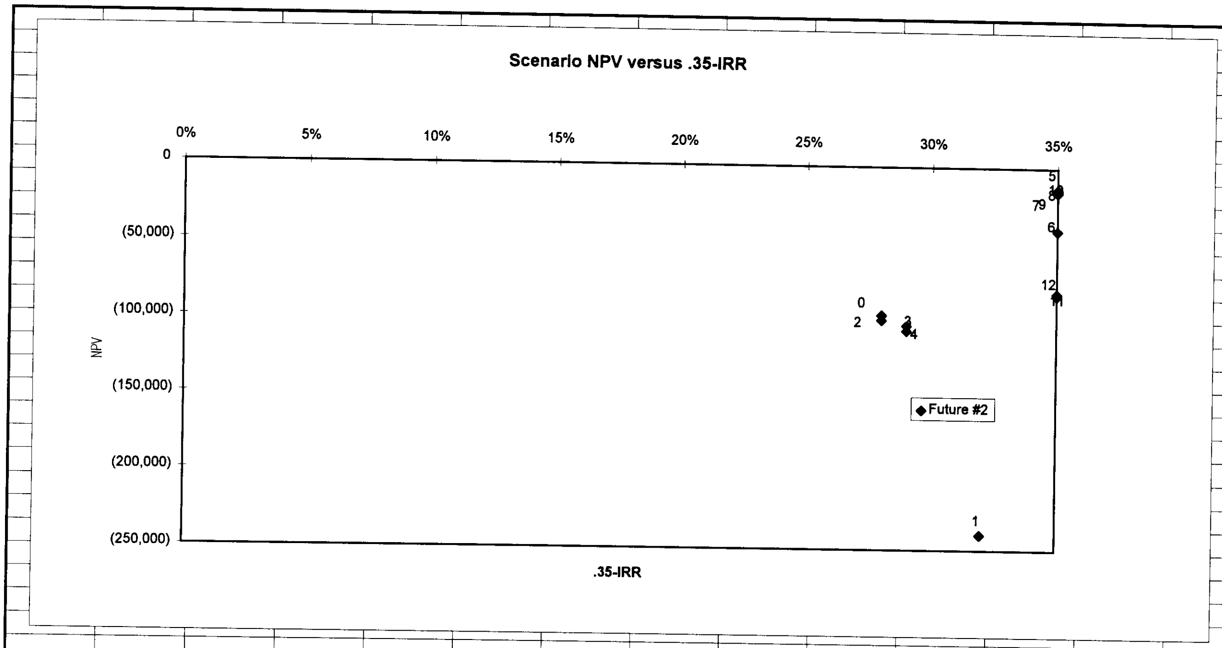
Scenario	Pertinent Results Compiled From Multiple Model Runs							
	Total Infiltration (hm3)		Ave.quan.of G pumped (hm3/y	Ave. quan. of Elec. (Gwh/yr)	NPV Investor	NPV State Finan.	Total Cost NPV ($000)	IRR State Finan.
	Farms/Canals	Cach-Cip						
Existing Cach/Con Arrangement	5120.5	5170.8	95.32	245.84	N.A.	N.A.	N.A.	N.A.
0.) Potrerillos	5120.5	5227.5	34.96	860.10	(176,987)	(96,554)	238,862	7%
1.) Potrerillos w/ 500hm3 Util.	5120.5	5249.5	10.35	925.25	(368,901)	(239,920)	360,356	3%
2.) Potrerillos w/clear water (15%)	5120.5	5994	39.11	861.4	(180,071)	(99,759)	241,559	7%
3.) Potrerillos w/clear water (30%)	5120.5	6758.6	43.49	863.11	(183,628)	(103,466)	244,919	6%
4.) Potrerillos w/ Marginal Canal	5120.5	1841	15.54	857.82	(186,812)	(106,774)	247,711	6%
5.) Marginal Canal	5120.5	3142.72	71.24	245.84	(16,868)	(15,027)	24,370	n/a
6.) Marginal Canal with Enlarged Condarco	5120.5	2531.68	71.87	304.52	(45,924)	(41,034)	62,227	0%
7.) Marginal Canal plus 12% Reduction in Canal Losses	4547	3142.72	64.59	245.84	(17,249)	(15,218)	27,067	0%
8.) Marginal Canal plus 24% Reduction in Canal Losses	3896.7	3142.72	57.45	245.84	(18,266)	(15,982)	30,427	0%
9.) 24% Loss Reduction in Canals	3896.7	5170.8	78.96	245.84	(15,957)	(14,342)	21,578	n/a
10.) 12% Loss Reduction in Canals	4547	5170.8	87.48	245.84	(15,183)	(13,821)	18,218	n/a
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	4034.95	5170.8	80.74	245.84	(88,929)	(81,663)	96,393	n/a
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	4034.95	3142.72	58.93	245.84	(91,180)	(83,245)	105,242	n/a

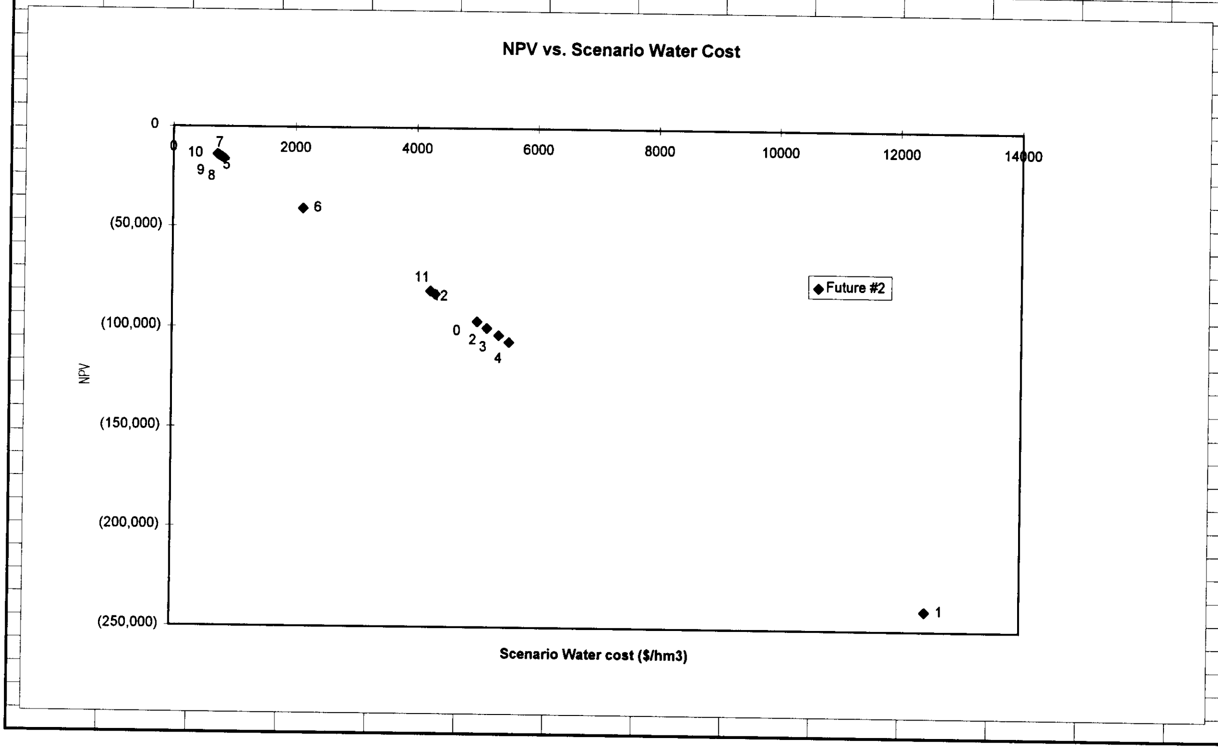


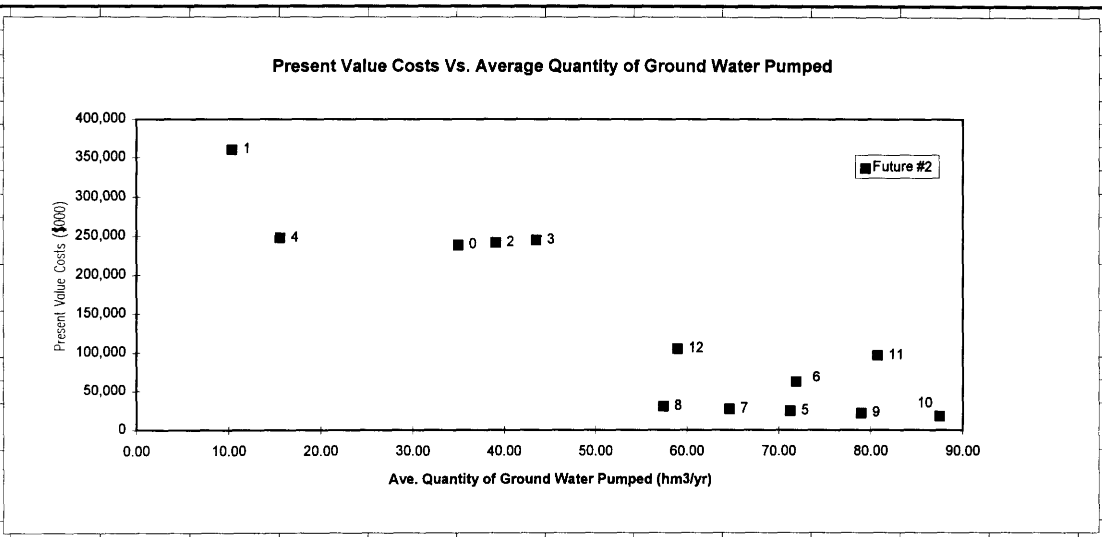
(1-Capacity Factor) Vs. Ave. Quan. Groundwater Pumped



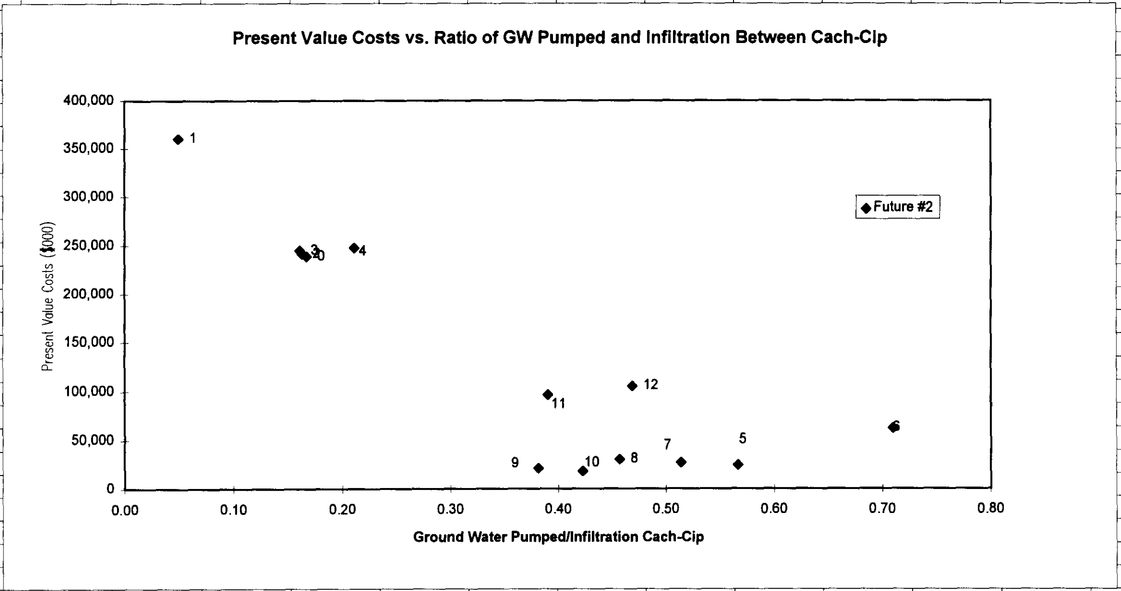
(.35 - IRR) vs. Ave. Quan. of Groundwater Pumped


Scenario NPV versus .35-IRR
0%
5%
10%
15%
20%
25%
30%
35%
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
NPV
.35-IRR
◆ Future #2
5
10
8
79
6
12
11
0
2
3
4
1


NPV vs. Scenario Water Cost
0
2000
4000
6000
8000
10000
12000
14000
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
NPV
Scenario Water cost ($/hm3)
◆ Future #2
10
7
9
8
5
6
11
2
0
2
3
4
1



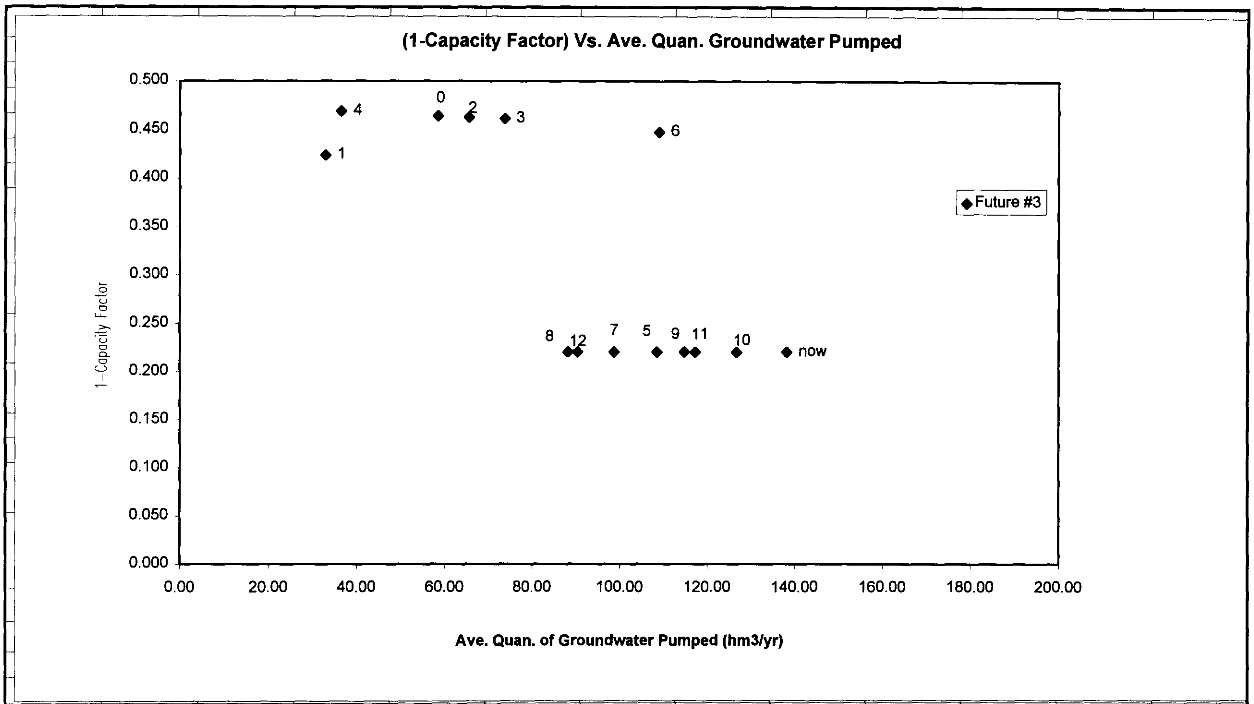
Present Value Costs Vs. Average Quantity of Ground Water Pumped

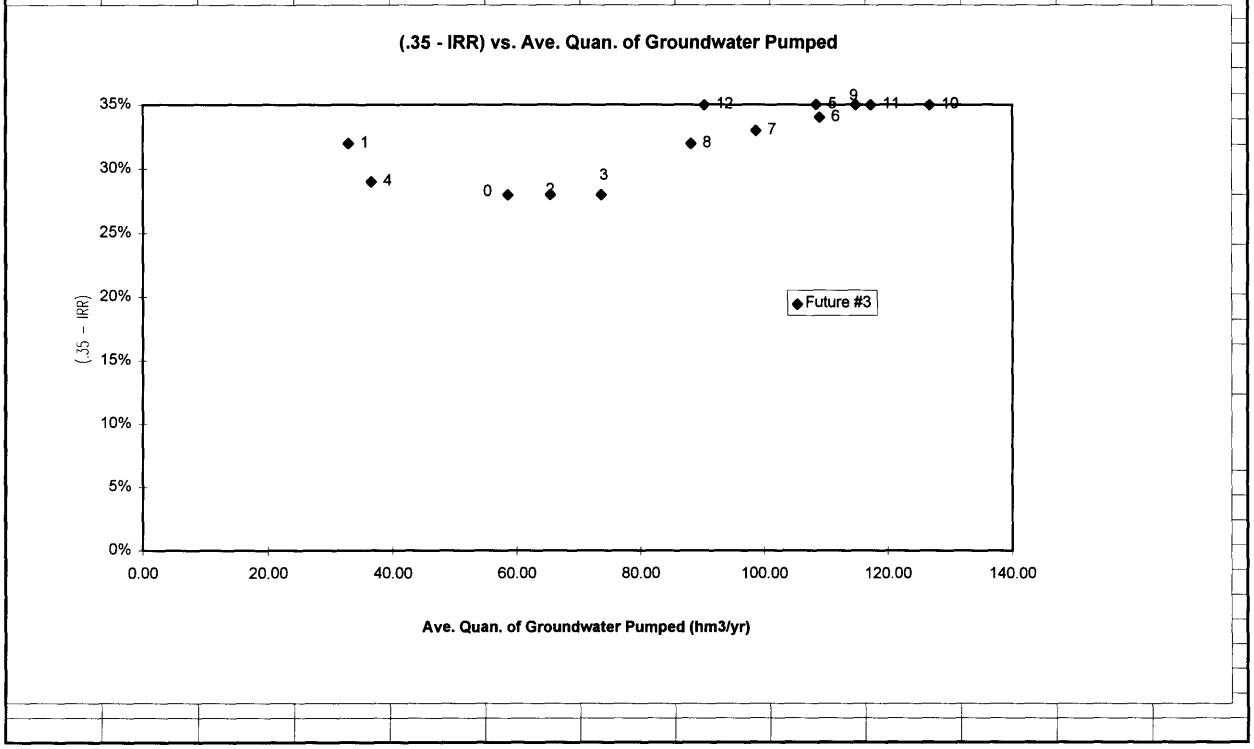


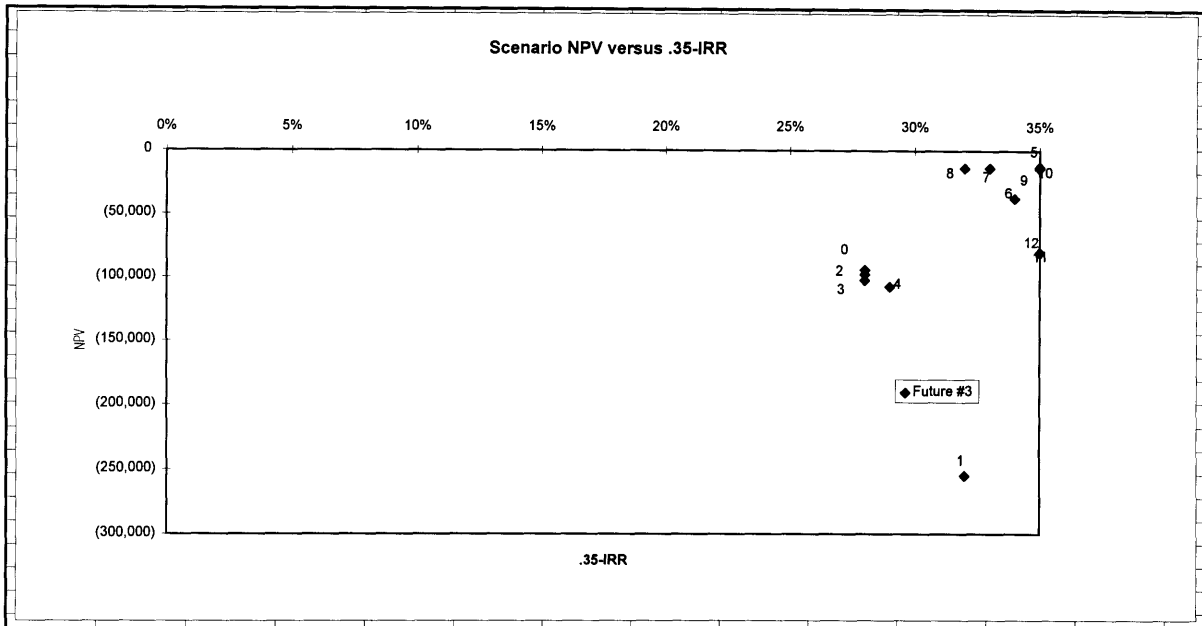
Present Value Costs vs. Ratio of GW Pumped and Infiltration Between Cach-Cip

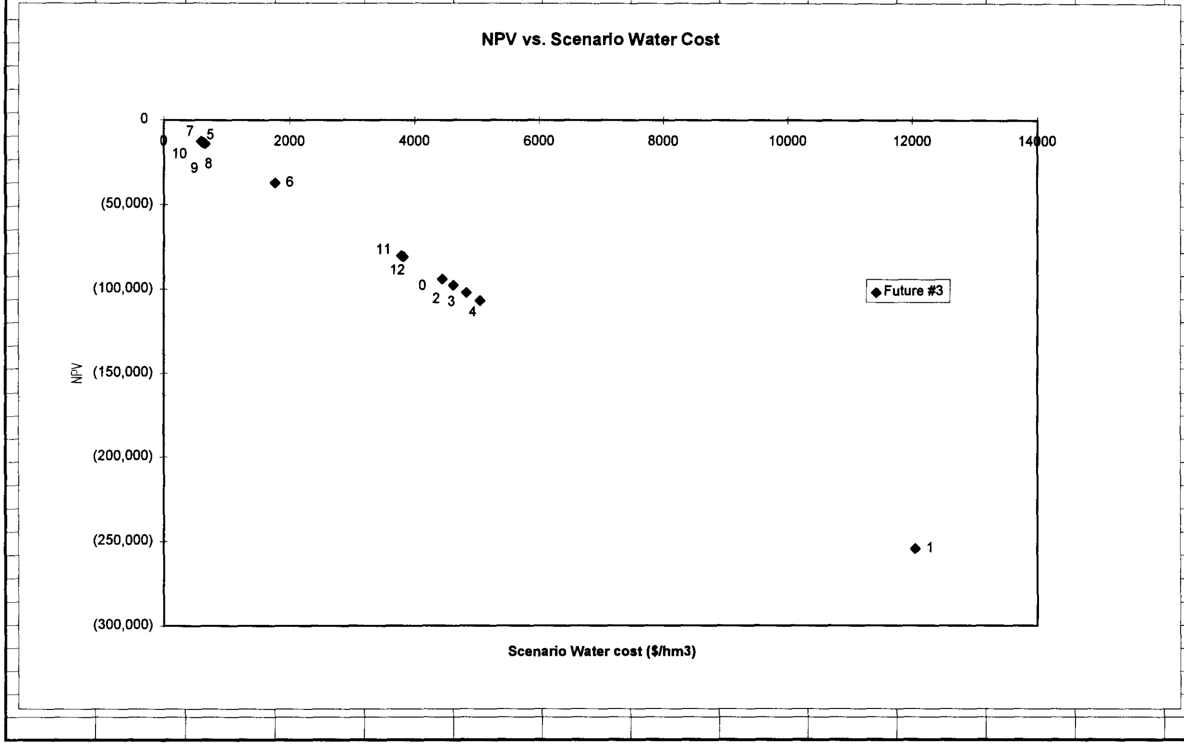
Scenario	FUTURE #3 Water Demand Variations			Water Loss Variations				
	Potable (OSM)	Industrial	Irrigation	Canal Marginal	Canal Lining	Aguas Claras (Clear Water)	Improved Usage	Total Quan. of GW Pmpd(hm3)
Existing Cach/Con Arrangement	6/95 Forecast	Constant	65,000 hectares	No	No	No	No	3454.23
0.) Potrerillos	6/95 Forecast	Constant	65,000 hectares	No	No	No	No	1464.5
1.) Potrerillos w/ 500hm3 Util.	6/95 Forecast	Constant	65,000 hectares	No	No	No	No	821.88
2.) Potrerillos w/clear water (15%)	6/95 Forecast	Constant	65,000 hectares	No	Yes	Yes (15%)	No	1637
3.) Potrerillos w/clear water (30%)	6/95 Forecast	Constant	65,000 hectares	No	Yes	Yes (30%)	No	1843.1
4.) Potrerillos w/ Marginal Canal	6/95 Forecast	Constant	65,000 hectares	Yes	No	No	No	913.38
5.) Marginal Canal	6/95 Forecast	Constant	65,000 hectares	Yes	No	No	No	2711.8
6.) Marginal Canal with Enlarged Condarco	6/95 Forecast	Constant	65,000 hectares	Yes	No	No	No	2725.4
7.) Marginal Canal plus 12% Reduction in Canal Losses	6/95 Forecast	Constant	65,000 hectares	Yes	Yes (12%)	No	No	2466.47
8.) Marginal Canal plus 24% Reduction in Canal Losses	6/95 Forecast	Constant	65,000 hectares	Yes	Yes (24%)	No	No	2204.23
9.) 24% Loss Reduction in Canals	6/95 Forecast	Constant	65,000 hectares	No	Yes (24%)	No	No	2869.4
10.) 12% Loss Reduction in Canals	6/95 Forecast	Constant	65,000 hectares	No	Yes (12%)	No	No	3167.8
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	6/95 Forecast	Constant	65,000 hectares	No	Yes (12%)	No	Yes (10%)	2931.79
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	6/95 Forecast	Constant	65,000 hectares	Yes	Yes (12%)	No	Yes (10%)	2258.83

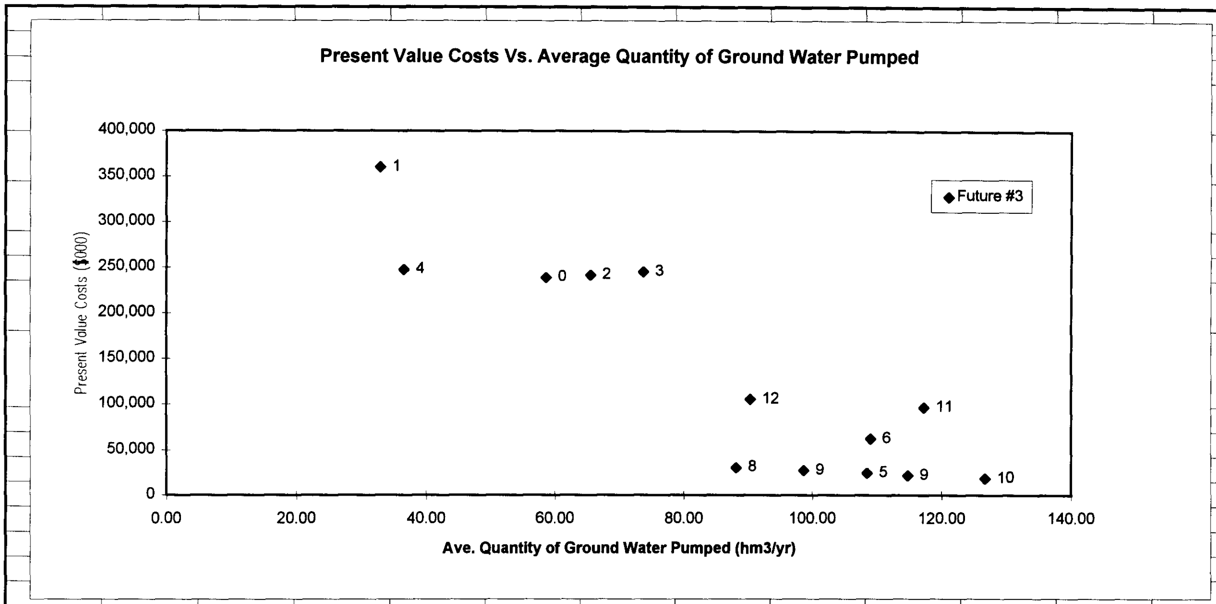
Scenario	Pertinent Results Compiled From Multiple Model Runs							
	Total Infiltration (hm3)		Ave.quan.of G	Ave. quan. of	NPV	NPV	Total Cost	IRR
	Farms/Canals	Cach-Cip	pumped (hm3/y	Elec. (Gwh/yr)	Investor	State Finan.	NPV ($000)	State Finan.
Existing Cach/Con Arrangement	6051.5	5170.8	138.17	245.84	N.A.	N.A.	N.A.	N.A.
0.) Potrerillos	6051.5	5239.52	58.58	867.81	(174,399)	(93,966)	238,862	7%
1.) Potrerillos w/ 500hm3 Util.	6051.5	5261.31	32.88	932.91	(383,665)	(254,684)	360,356	3%
2.) Potrerillos w/clear water (15%)	6051.5	6010.5	65.48	870	(177,965)	(97,653)	241,559	7%
3.) Potrerillos w/clear water (30%)	6051.5	6777.34	73.72	871.88	(182,208)	(102,045)	244,919	7%
4.) Potrerillos w/ Marginal Canal	6051.5	1818.44	36.54	859.55	(186,812)	(106,774)	247,711	6%
5.) Marginal Canal	6051.5	3142.72	108.47	245.84	(15,728)	(13,887)	24,370	0%
6.) Marginal Canal with Enlarged Condarco	6051.5	2531.68	109.02	304.52	(42,111)	(37,425)	62,227	1%
7.) Marginal Canal plus 12% Reduction in Canal Losses	5373.7	3142.72	98.66	245.84	(15,335)	(13,304)	27,067	2%
8.) Marginal Canal plus 24% Reduction in Canal Losses	4605.2	3142.72	88.17	245.84	(15,529)	(13,245)	30,427	3%
9.) 24% Loss Reduction in Canals	4605.2	5170.8	114.8	245.84	(14,228)	(12,612)	21,578	-
10.) 12% Loss Reduction in Canals	5373.7	5170.8	126.71	245.84	(14,305)	(12,943)	18,218	-
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	4768.58	5170.8	117.27	245.84	(87,381)	(80,114)	96,393	-
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	4768.58	3142.72	90.35	245.84	(88,619)	(80,684)	105,242	-

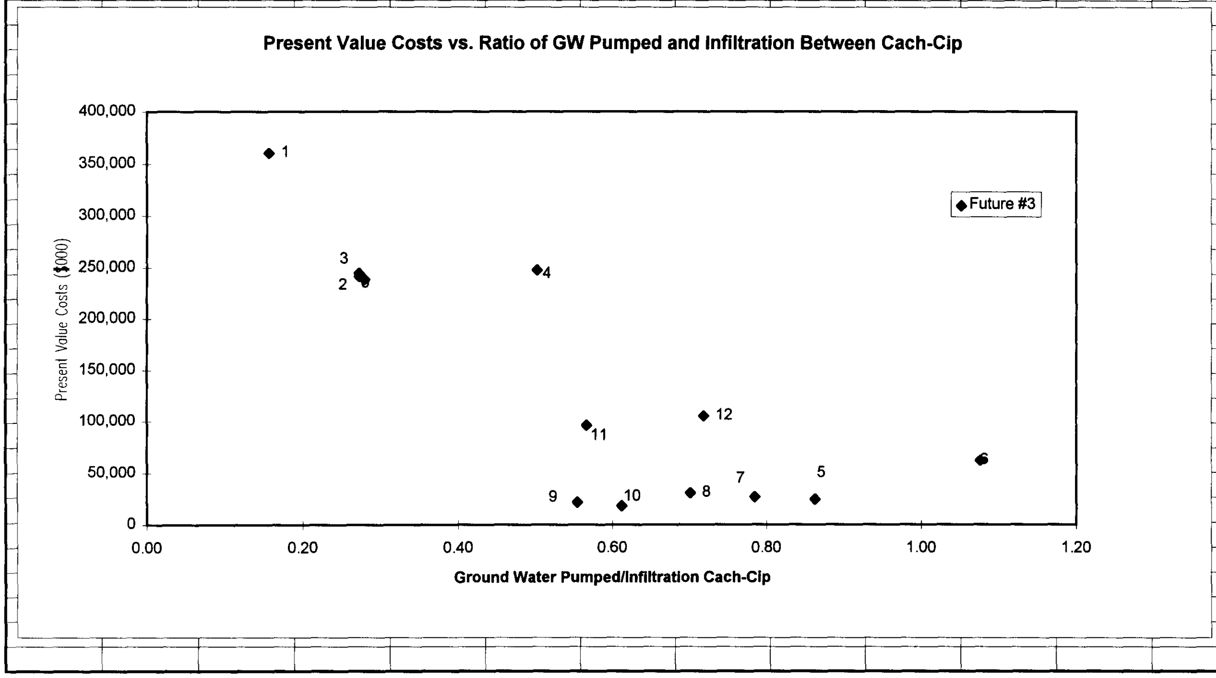

(1-Capacity Factor) Vs. Ave. Quan. Groundwater Pumped
1-Capacity Factor
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
◆ Future #3
4
0
2
3
6
1
8
12
7
5
9
11
10
now


(.35 - IRR) vs. Ave. Quan. of Groundwater Pumped
(.35 - IRR)
35%
30%
25%
20%
15%
10%
5%
0%
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
◆ Future #3
12
5
9
11
10
6
7
1
8
4
0
2
3


Scenario NPV versus .35-IRR
0%
5%
10%
15%
20%
25%
30%
35%
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
(300,000)
NPV
.35-IRR
8
7
9
5
10
6
12
11
0
2
3
4
1
◆ Future #3

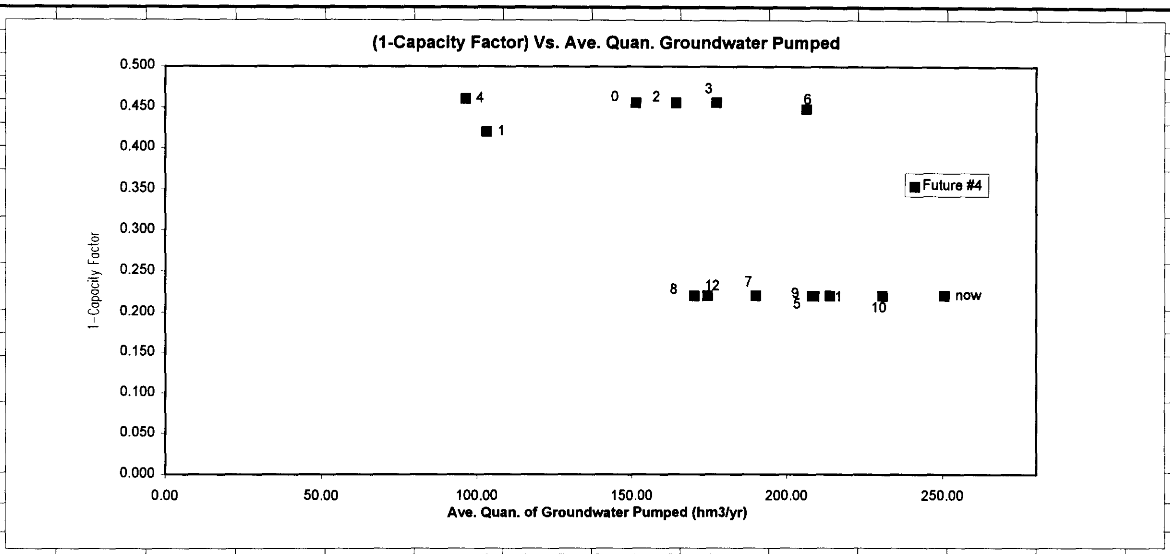

NPV vs. Scenario Water Cost
0
2000
4000
6000
8000
10000
12000
14000
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
(300,000)
NPV
Scenario Water cost ($/hm3)
7
5
10
9
8
6
11
12
0
2
3
4
1
◆ Future #3

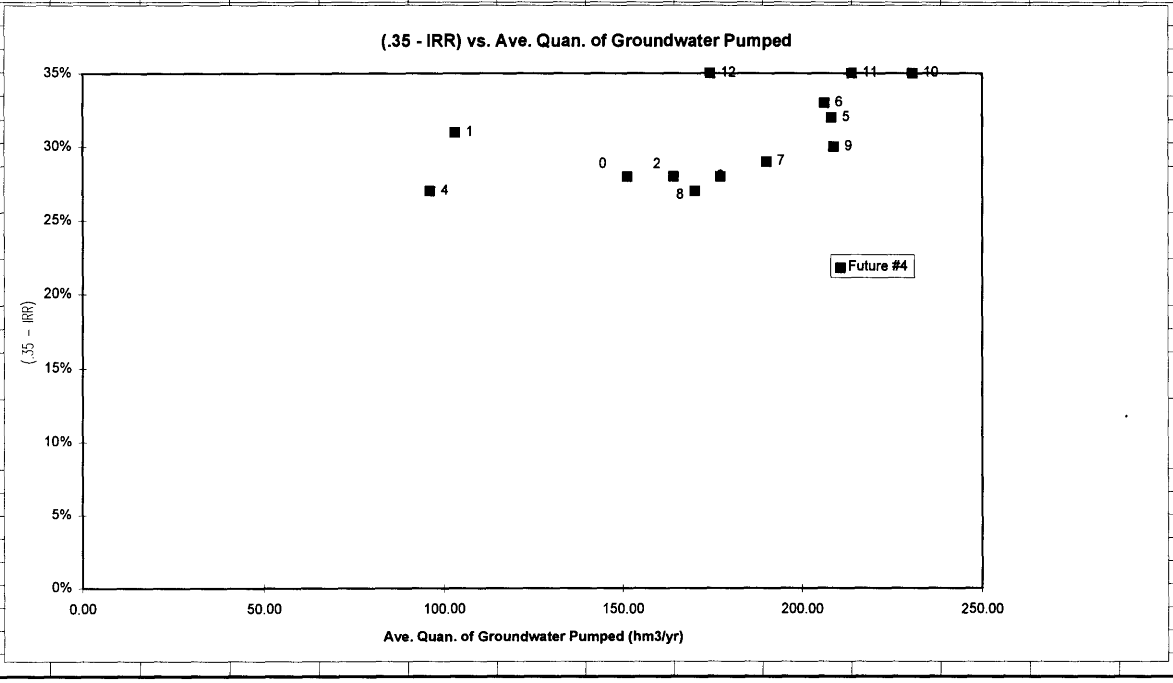

Present Value Costs Vs. Average Quantity of Ground Water Pumped
Present Value Costs ($000)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Ave. Quantity of Ground Water Pumped (hm3/yr)
◆ Future #3
1
4
0
2
3
12
11
6
8
9
5
9
10

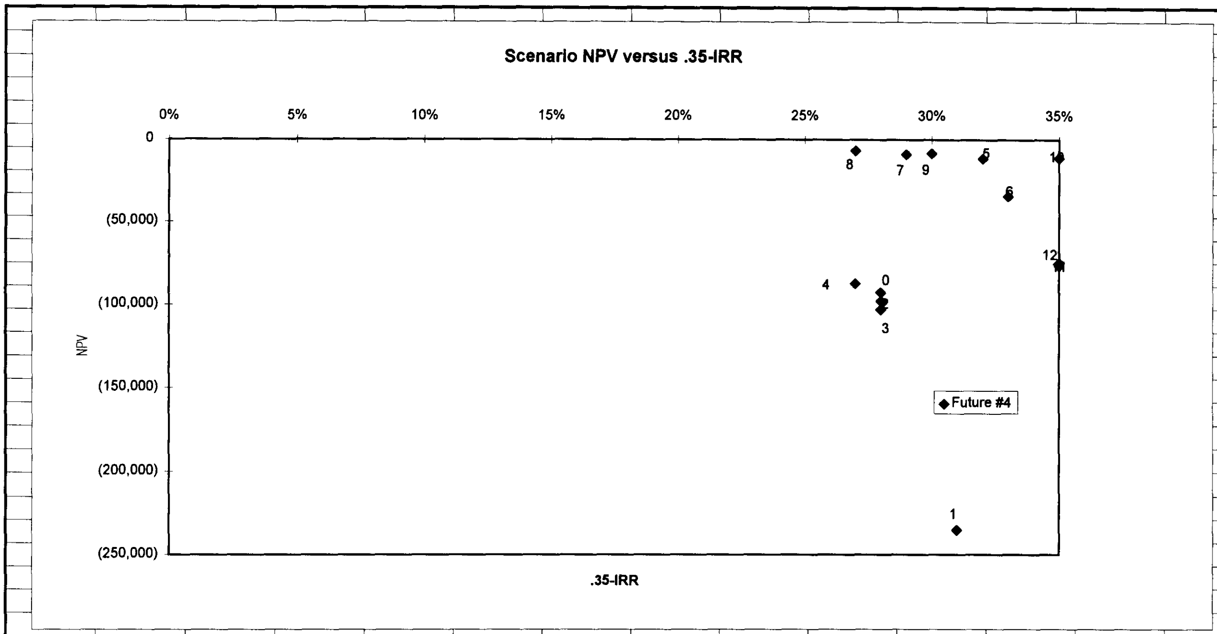

Present Value Costs vs. Ratio of GW Pumped and Infiltration Between Cach-Cip
Present Value Costs ($000)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Ground Water Pumped/Infiltration Cach-Cip
◆ Future #3
1
3
2
4
11
12
9
10
8
7
5
6

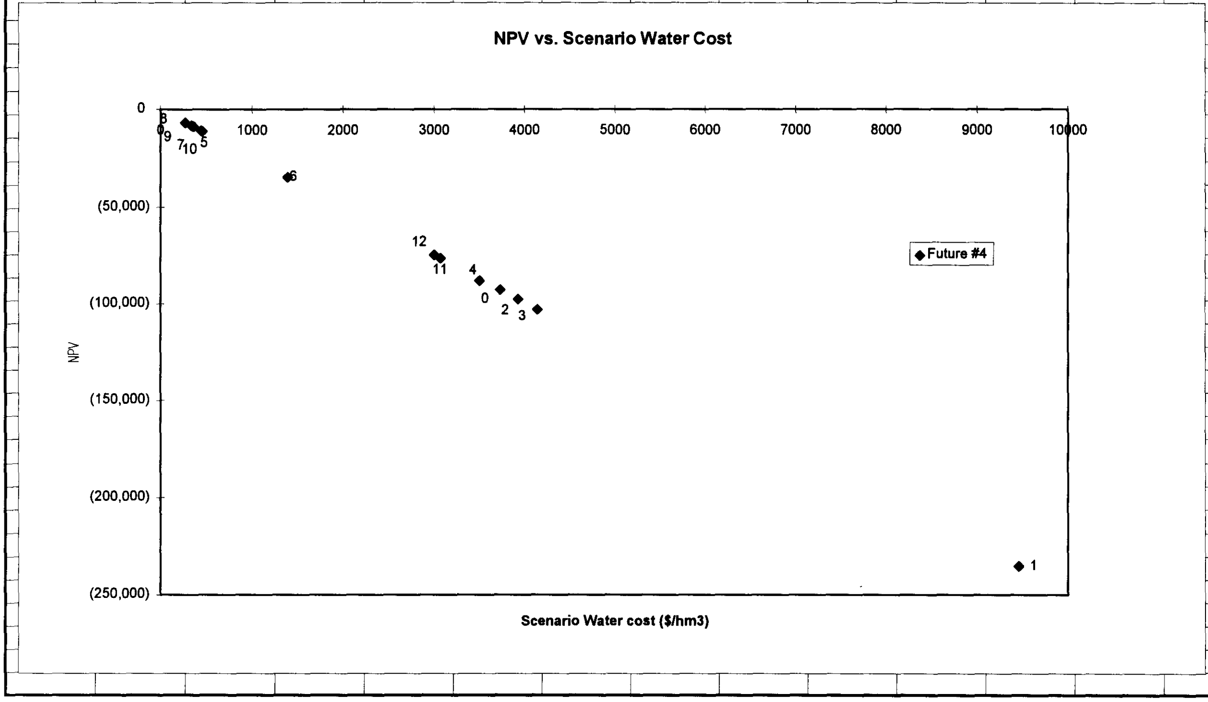
Scenario	FUTURE #4 Water Demand Variations			Water Loss Variations				
	Potable (OSM)	Industrial	Irrigation	Canal Marginal	Canal Lining	Aguas Claras (Clear Water)	Improved Usage	Total Quan. of GW Pmpd(hm3)
Existing Cach/Con Arrangement	6/95 Forecast	Constant	85,000 hectares	No	No	No	No	6267.3
0.) Potrerillos	6/95 Forecast	Constant	85,000 hectares	No	No	No	No	3780.1
1.) Potrerillos w/ 500hm3 Util.	6/95 Forecast	Constant	85,000 hectares	No	No	No	No	2577.8
2.) Potrerillos w/clear water (15%)	6/95 Forecast	Constant	85,000 hectares	No	Yes	Yes (15%)	No	4103.98
3.) Potrerillos w/clear water (30%)	6/95 Forecast	Constant	85,000 hectares	No	Yes	Yes (30%)	No	4431.23
4.) Potrerillos w/ Marginal Canal	6/95 Forecast	Constant	85,000 hectares	Yes	No	No	No	2405.74
5.) Marginal Canal	6/95 Forecast	Constant	85,000 hectares	Yes	No	No	No	5204.26
6.) Marginal Canal with Enlarged Condarco	6/95 Forecast	Constant	85,000 hectares	Yes	No	No	No	5155.66
7.) Marginal Canal plus 12% Reduction in Canal Losses	6/95 Forecast	Constant	85,000 hectares	Yes	Yes (12%)	No	No	4750.7
8.) Marginal Canal plus 24% Reduction in Canal Losses	6/95 Forecast	Constant	85,000 hectares	Yes	Yes (24%)	No	No	4254.45
9.) 24% Loss Reduction in Canals	6/95 Forecast	Constant	85,000 hectares	No	Yes (24%)	No	No	5219.91
10.) 12% Loss Reduction in Canals	6/95 Forecast	Constant	85,000 hectares	No	Yes (12%)	No	No	5767.92
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	6/95 Forecast	Constant	85,000 hectares	No	Yes (12%)	No	Yes (10%)	5346.33
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	6/95 Forecast	Constant	85,000 hectares	Yes	Yes (12%)	No	Yes (10%)	4358,25

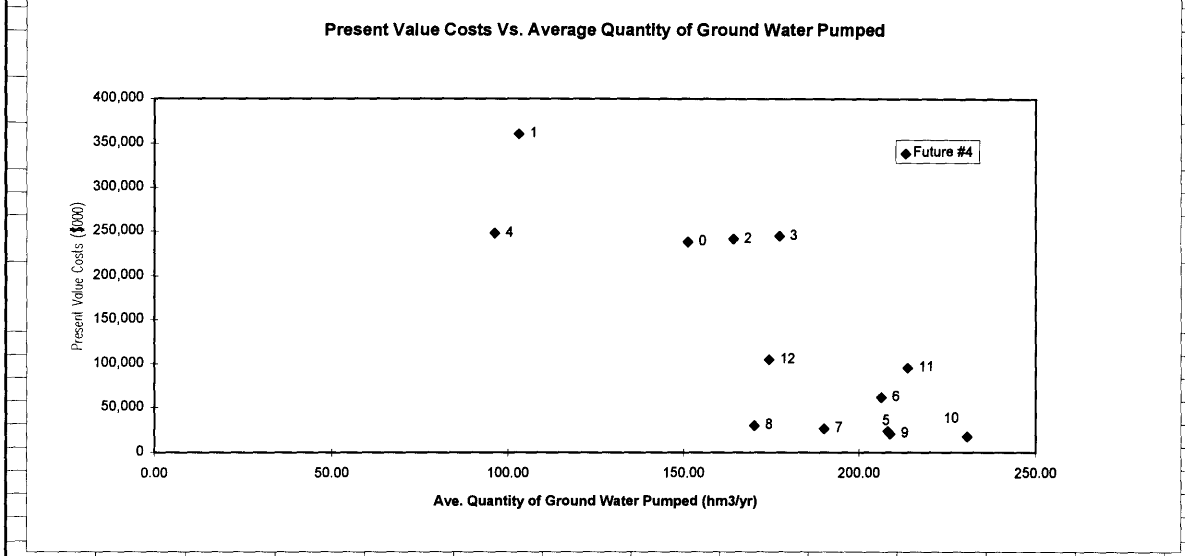
Scenario	Pertinent Results Compiled From Multiple Model Runs							
	Total Infiltration (hm3)		Ave.quan.of GW pumped (hm3/y	Ave. quan. of Elec. (Gwh/yr)	NPV Investor	NPV State Finan.	Total Cost NPV ($000)	IRR State Finan.
	Farms/Canals	Cach-Clp						
Existing Cach/Con Arrangement	7913.5	5170.75	250.70	245.84	N.A.	N.A.	N.A.	N.A.
0.) Potrerillos	7913.5	5257.47	151.21	882.15	(173,229)	(92,797)	238,862	7%
1.) Potrerillos w/ 500hm3 Util.	7913.5	5286.24	103.11	940.53	(364,187)	(235,206)	360,356	4%
2.) Potrerillos w/clear water (15%)	7913.5	6016.62	164.16	881.9	(177,988)	(97,676)	241,559	7%
3.) Potrerillos w/clear water (30%)	7913.5	6788.16	177.25	881.47	(183,193)	(103,031)	244,919	7%
4.) Potrerillos w/ Marginal Canal	7913.5	1720.36	96.23	874.33	(167,038)	(87,000)	247,711	8%
5.) Marginal Canal	7913.5	3142.72	208.17	245.84	(13,191)	(11,350)	24,370	3%
6.) Marginal Canal with Enlarged Condarco	7913.5	2531.68	206.23	304.52	(39,274)	(34,574)	62,227	2%
7.) Marginal Canal plus 12% Reduction in Canal Losses	7027.19	3142.72	190.03	245.84	(11,034)	(8,990)	27,067	6%
8.) Marginal Canal plus 24% Reduction in Canal Losses	6022.17	3142.72	170.18	245.84	(9,028)	(6,730)	30,427	8%
9.) 24% Loss Reduction in Canals	6022.17	5170.75	208.8	245.84	(9,993)	(8,377)	21,578	5%
10.) 12% Loss Reduction in Canals	7027.19	5170.75	230.72	245.84	(12,387)	(11,025)	18,218	n/a
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	6235.84	5170.75	213.85	245.84	(83,635)	(76,368)	96,393	n/a
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	6235.84	3142.72	174.33	245.84	(82,586)	(74,636)	105,242	n/a

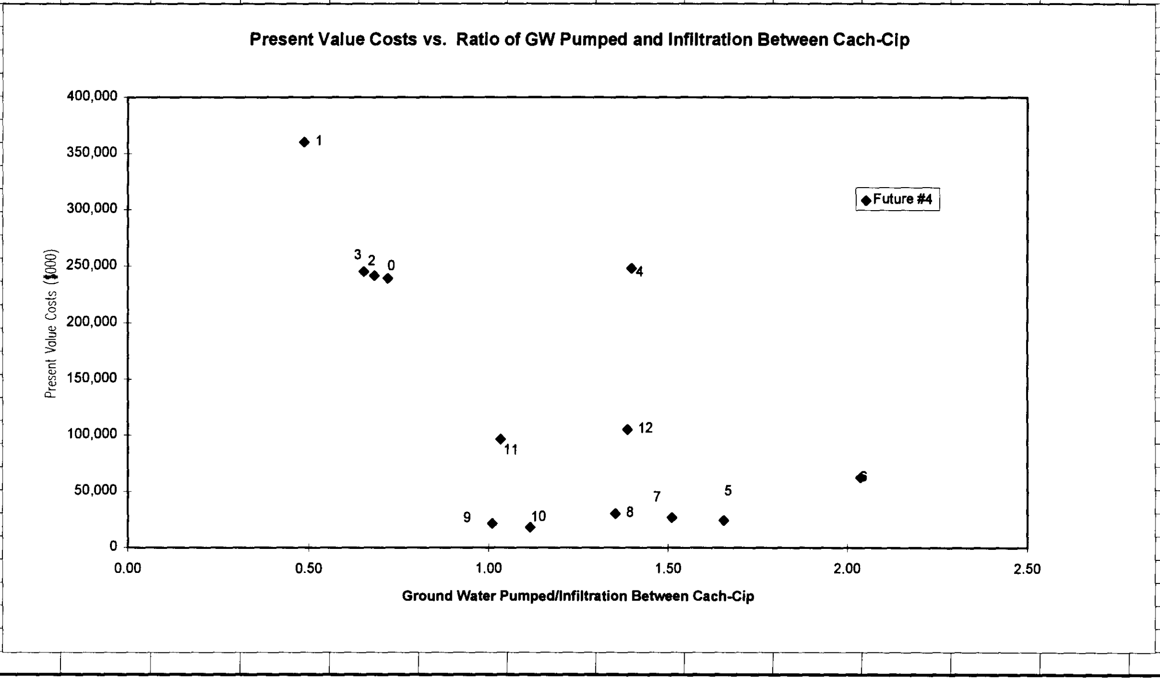

(1-Capacity Factor) Vs. Ave. Quan. Groundwater Pumped
1-Capacity Factor
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
50.00
100.00
150.00
200.00
250.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
4
1
0
2
3
6
8
12
7
9
5
1
10
now
Future #4


(.35 - IRR) vs. Ave. Quan. of Groundwater Pumped
(.35 - IRR)
35%
30%
25%
20%
15%
10%
5%
0%
0.00
50.00
100.00
150.00
200.00
250.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
12
11
10
6
5
1
9
0
2
7
4
8
Future #4


Scenario NPV versus .35-IRR

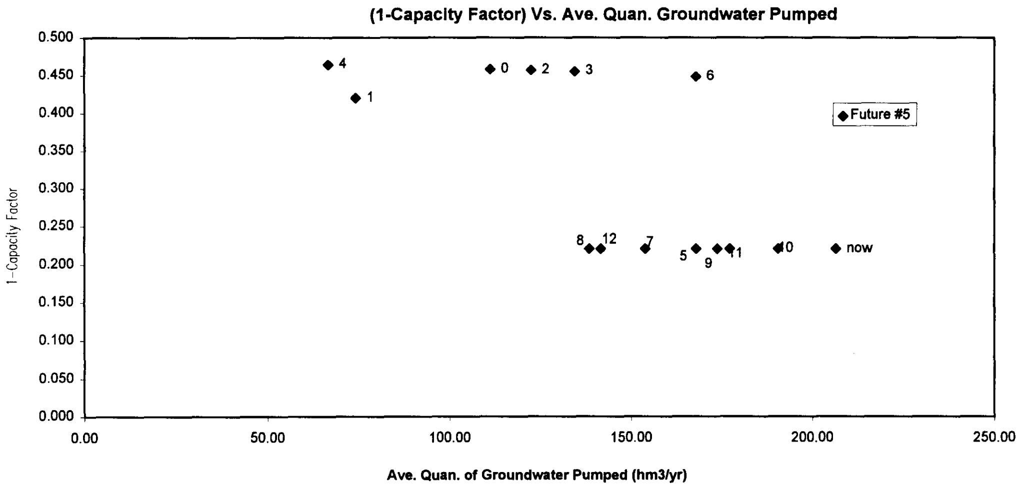

NPV vs. Scenario Water Cost

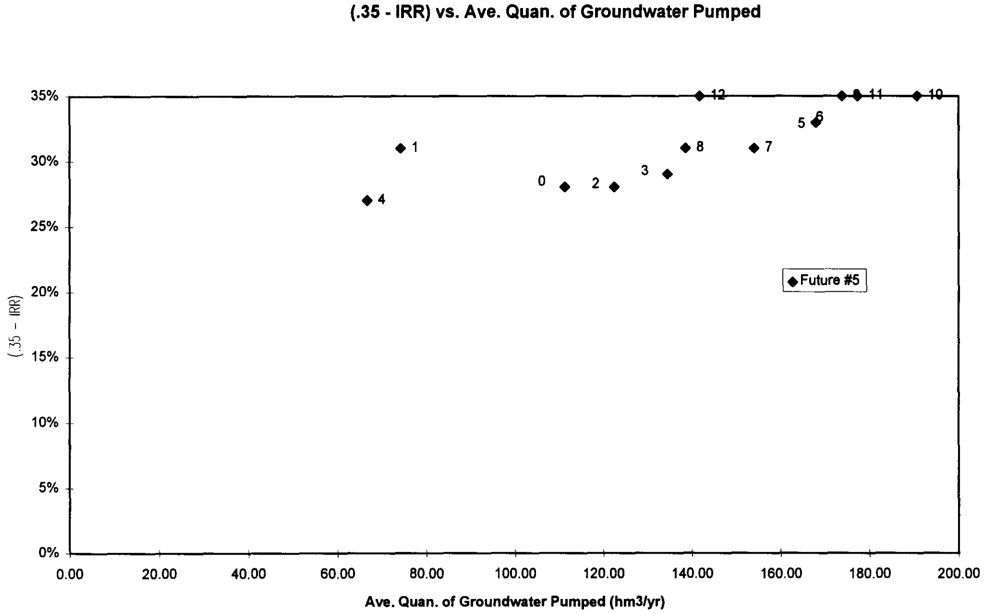

Present Value Costs Vs. Average Quantity of Ground Water Pumped

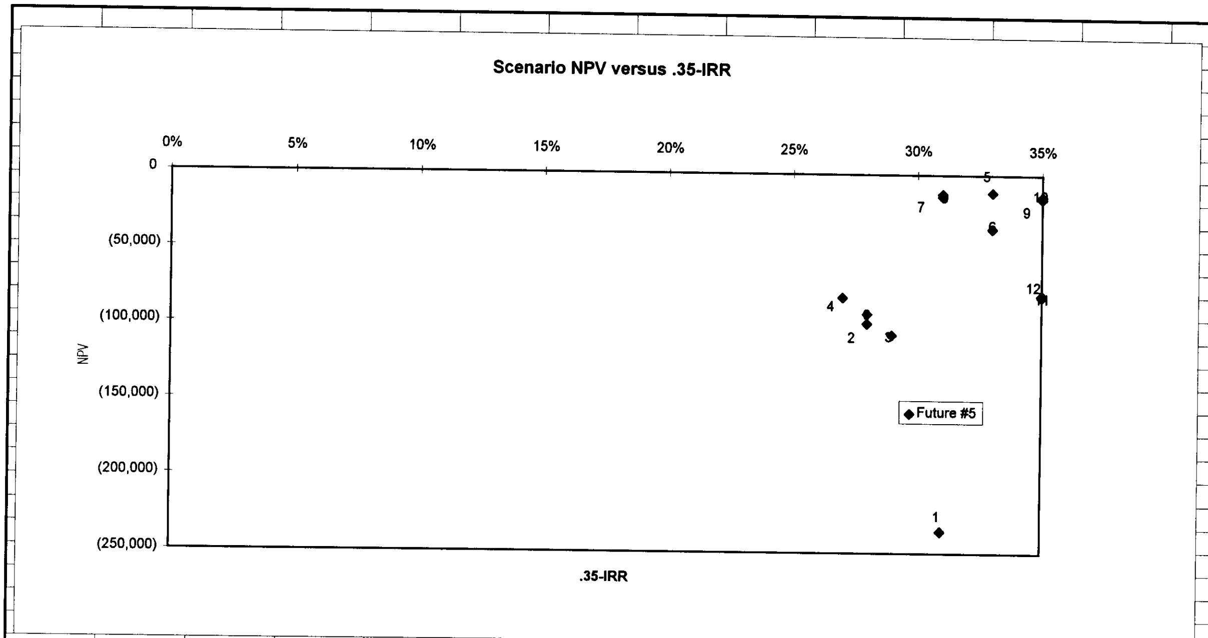

Present Value Costs vs. Ratio of GW Pumped and Infiltration Between Cach-Cip

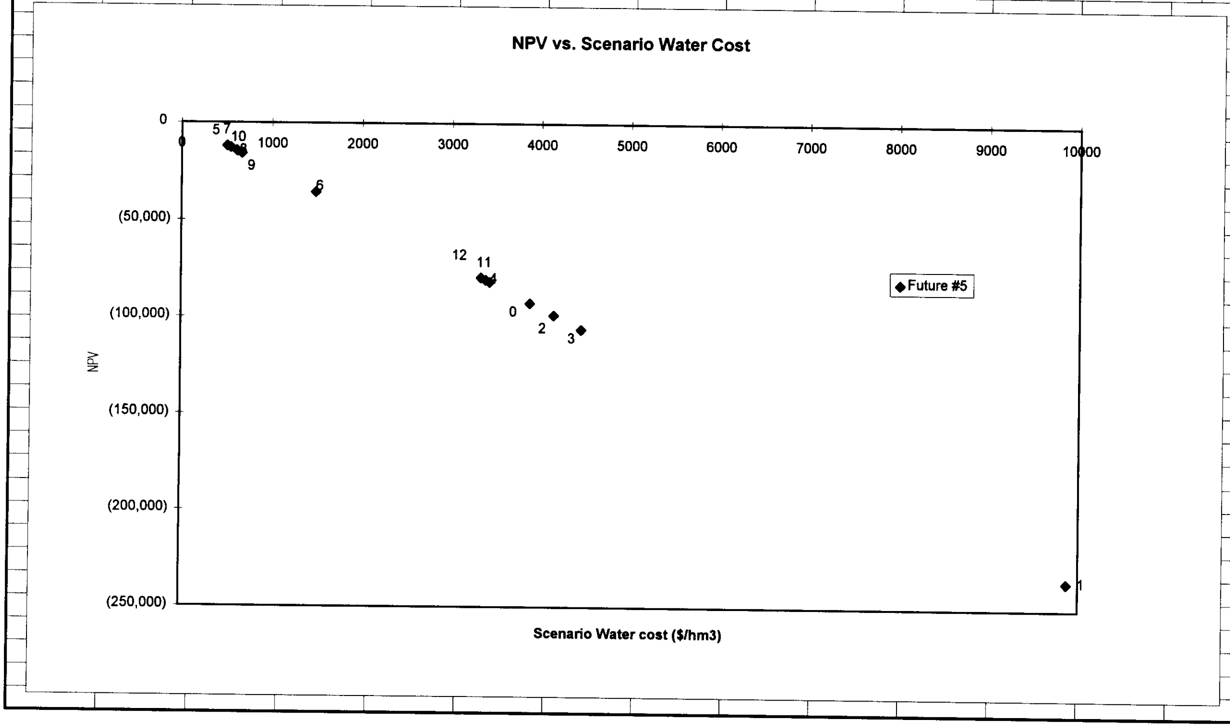
Scenario	FUTURE #5 Water Demand Variations			Water Loss Variations				
	Potable (OSM)	Industrial	Irrigation	Canal Marginal	Canal Lining	Aguas Claras (Clear Water)	Improved Usage	Total Quan. of GW Pmpd(hm3)
Existing Cach/Con Arrangement	% Yearly Growt	Constant	74,500 hectares	No	No	No	No	5164.64
0.) Potrerillos	% Yearly Growt	Constant	74,500 hectares	No	No	No	No	2780.46
1.) Potrerillos w/ 500hm3 Util.	% Yearly Growt	Constant	74,500 hectares	No	No	No	No	1854.01
2.) Potrerillos w/clear water (15%)	% Yearly Growt	Constant	74,500 hectares	No	Yes	Yes (15%)	No	3061.6
3.) Potrerillos w/clear water (30%)	% Yearly Growt	Constant	74,500 hectares	No	Yes	Yes (30%)	No	3362.83
4.) Potrerillos w/ Marginal Canal	% Yearly Growt	Constant	74,500 hectares	Yes	No	No	No	1665.51
5.) Marginal Canal	% Yearly Growt	Constant	74,500 hectares	Yes	No	No	No	4201.7
6.) Marginal Canal with Enlarged Condarco	% Yearly Growt	Constant	74,500 hectares	Yes	No	No	No	4199.04
7.) Marginal Canal plus 12% Reduction in Canal Losses	% Yearly Growt	Constant	74,500 hectares	Yes	Yes (12%)	No	No	3849.9
8.) Marginal Canal plus 24% Reduction in Canal Losses	% Yearly Growt	Constant	74,500 hectares	Yes	Yes (24%)	No	No	3464.25
9.) 24% Loss Reduction in Canals	% Yearly Growt	Constant	74,500 hectares	No	Yes (24%)	No	No	4346.25
10.) 12% Loss Reduction in Canals	% Yearly Growt	Constant	74,500 hectares	No	Yes (12%)	No	No	4765.93
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	% Yearly Growt	Constant	74,500 hectares	No	Yes (12%)	No	Yes (10%)	4433.62
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	% Yearly Growt	Constant	74,500 hectares	Yes	Yes (12%)	No	Yes (10%)	3543.95

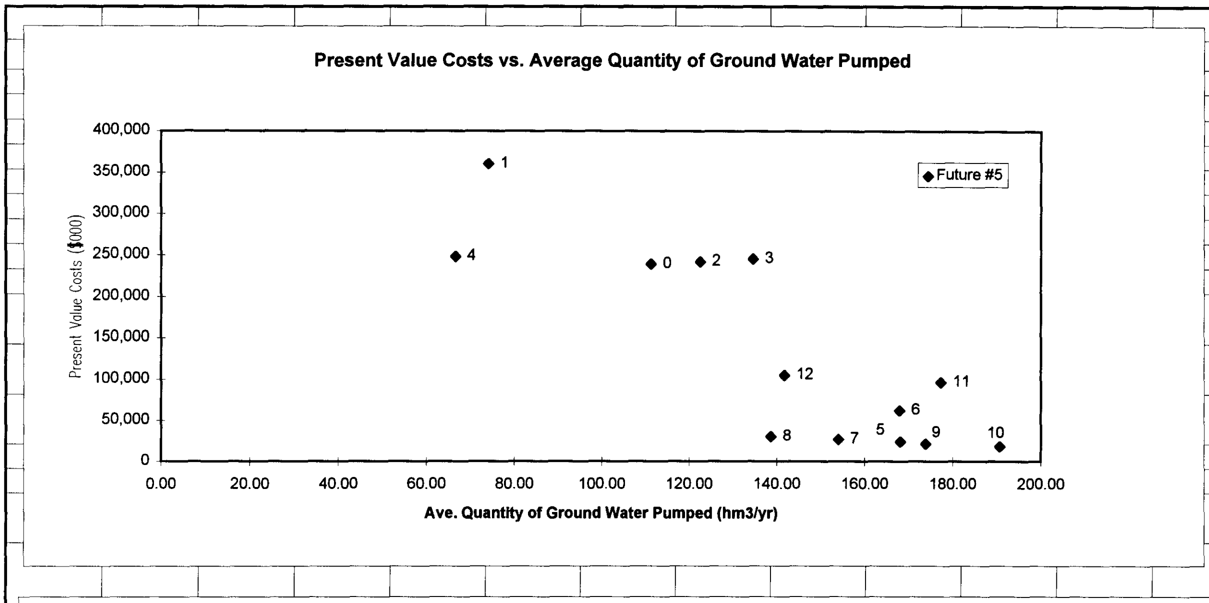
Scenario	Pertinent Results Compiled From Multiple Model Runs							
	Total Infiltration (hm3)		Ave.quan.of G pumped (hm3/y	Ave. quan. of Elec. (Gwh/yr)	NPV Investor	NPV State Finan.	Total Cost NPV ($000)	IRR State Finan.
	Farms/Canals	Cach-Cip						
Existing Cach/Con Arrangement	6935.95	5170.8	206.59	245.84	N.A.	N.A.	N.A.	N.A.
0.) Potrerillos	6935.95	5266.26	111.22	877.99	(172,890)	(92,458)	238,862	7%
1.) Potrerillos w/ 500hm3 Util.	6935.95	5289.79	74.16	940.4	(364,644)	(235,663)	360,356	4%
2.) Potrerillos w/clear water (15%)	6935.95	6038.07	122.46	880.14	(178,987)	(98,795)	241,559	7%
3.) Potrerillos w/clear water (30%)	6935.95	6805.3	134.51	882.09	(186,066)	(106,174)	244,919	6%
4.) Potrerillos w/ Marginal Canal	6935.95	1782.83	66.62	867.64	(162,116)	(81,684)	247,711	8%
5.) Marginal Canal	6935.95	3204.03	168.07	245.84	(13,774)	(11,933)	24,370	2%
6.) Marginal Canal with Enlarged Condarco	6935.95	2593.9	167.96	304.52	(40,194)	(35,494)	62,227	2%
7.) Marginal Canal plus 12% Reduction in Canal Losses	6159.1	3204.03	154	245.84	(15,156)	(12,908)	27,067	4%
8.) Marginal Canal plus 24% Reduction in Canal Losses	5278.26	3204.03	138.57	245.84	(17,446)	(14,690)	30,427	4%
9.) 24% Loss Reduction in Canals	5278.26	5170.8	173.85	245.84	(17,980)	(15,893)	21,578	0%
10.) 12% Loss Reduction in Canals	6159.1	5170.8	190.64	245.84	(16,011)	(14,431)	18,218	-
11.) Existing w /12% + 10% Loss Reduction vs. existing Cach/Con	5465.53	5170.8	177.34	245.84	(88,125)	(80,640)	96,393	-
12.) Existing w/MC+ 12% + 10% Loss Reduction vs. Existing Cach/Con	5465.53	3204.03	141.76	245.84	(87,525)	(79,371)	105,242	-

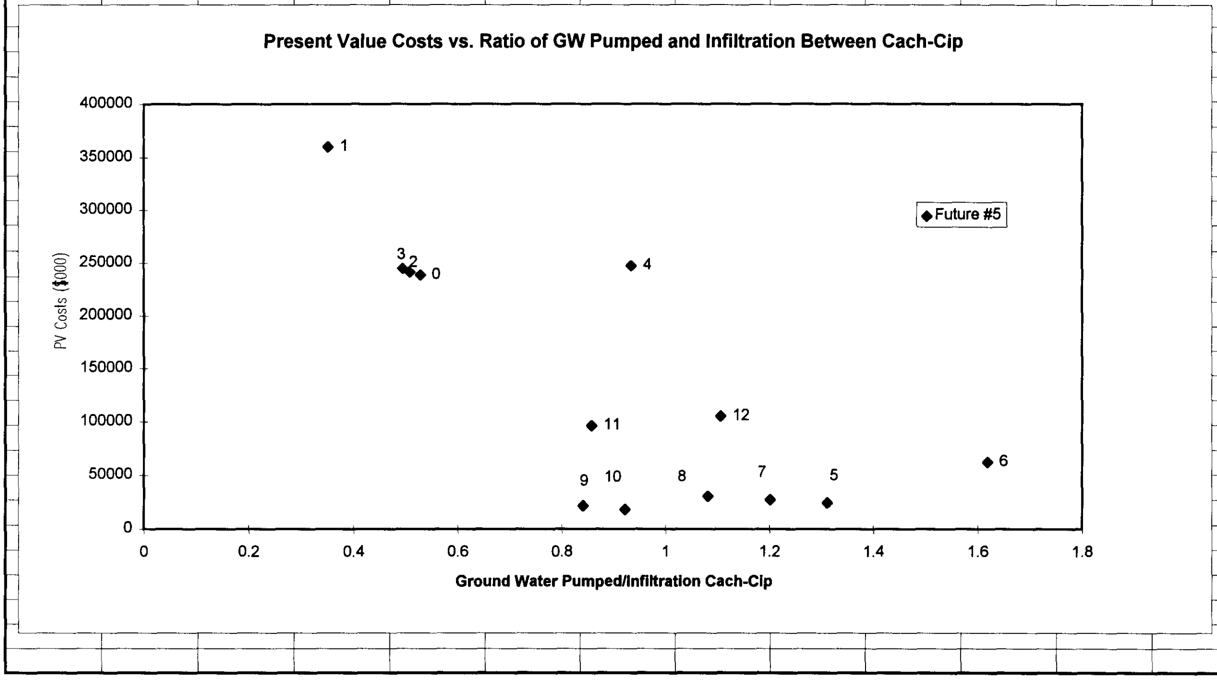

(1-Capacity Factor) Vs. Ave. Quan. Groundwater Pumped
1-Capacity Factor
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
50.00
100.00
150.00
200.00
250.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
4
1
0
2
3
6
8
12
7
5
9
11
10
now
◆Future #5


(.35 - IRR) vs. Ave. Quan. of Groundwater Pumped
(.35 - IRR)
35%
30%
25%
20%
15%
10%
5%
0%
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Ave. Quan. of Groundwater Pumped (hm3/yr)
12
11
10
5
6
1
8
7
0
2
3
4
◆Future #5


Scenario NPV versus .35-IRR
0%
5%
10%
15%
20%
25%
30%
35%
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
NPV
.35-IRR
◆ Future #5
1
2
3
4
5
6
7
9
10
11
12


NPV vs. Scenario Water Cost
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
(50,000)
(100,000)
(150,000)
(200,000)
(250,000)
NPV
Scenario Water cost ($/hm3)
◆ Future #5
0
1
2
3
5
6
7
9
10
11
12


Present Value Costs vs. Average Quantity of Ground Water Pumped
Present Value Costs ($000)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
Ave. Quantity of Ground Water Pumped (hm3/yr)
◆ Future #5
1
4
0
2
3
12
11
6
8
7
5
9
10


Present Value Costs vs. Ratio of GW Pumped and Infiltration Between Cach-Cip
PV Costs ($000)
400000
350000
300000
250000
200000
150000
100000
50000
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Ground Water Pumped/Infiltration Cach-Cip
◆ Future #5
1
3
2
0
4
11
12
6
9
10
8
7
5