



## **Bantayan Island water resources study**

P.M. Angus Jr, D.T. Jaque

*Water Resources Center, University of San Carlos, Cebu City,  
Philippines*

### **Abstract**

The increasing pressure for development in Bantayan Island led into the study of the water resources status. Two parameters were considered vital in the study, these are the quantity of useful groundwater reserve and the water quality.

Well surveys were conducted in two separate occasions to determine the groundwater level. The first survey was done in 1988-1989, and the second survey was conducted in 1995. In the second survey, assessment of the groundwater quality was also undertaken.

Results of the study showed that despite sufficient annual potential recharge in the island there is still an observable decrease in the groundwater table. Salinity concentration increases on water sources near the coasts which indicates movement of saline wedge towards the inland. Wells near the coasts have recorded chloride concentration of 250 ppm and above. This value exceeded the maximum limit set by the World Health Standard for drinking water.

It was recommended that monitoring of groundwater level and quality of water be conducted. A design of water recovery system will be made to optimise the withdrawal of water without any detrimental impact to the groundwater reserve.

### **1 Introduction**

Development of small islands must be done with great care to achieve a balance and sustainable use of the basic resources such as water. With a limited land area, development of water resources for domestic and agro-industrial consumption requires judicious land use planning and regulation of groundwater extraction.

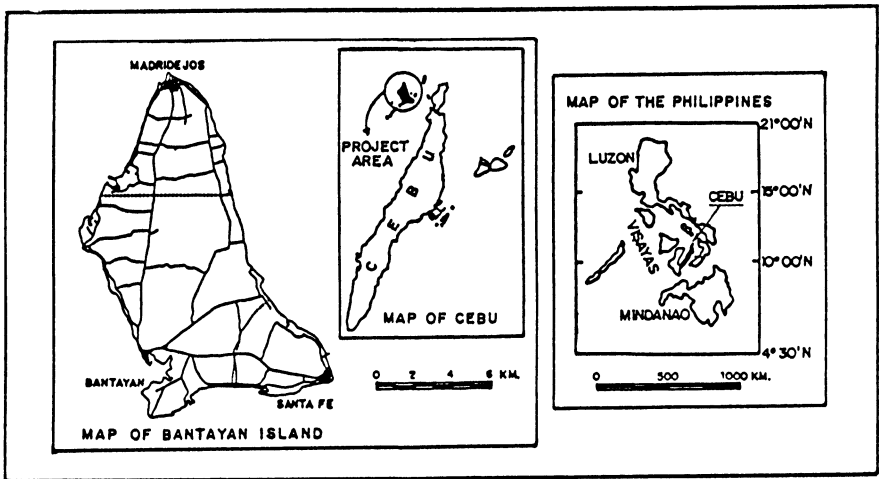


A special programme called Small Islands Agricultural Support Services (SMILES), under the Department of Agriculture and through the auspices of the European Union, identified Bantayan Island as a recipient of the program for an integrated and sustainable development. One of the project under this programme was an assessment of the groundwater resources and was recently implemented in the area.

Presented in this paper are the results on the investigation of the groundwater resources in Bantayan island, both for the water quantity and water quality.

## 2 Description of the area

Bantayan is a small island located west of the northern tip of Cebu province. The land area of the mainland is approximately 113 km<sup>2</sup> with a highest hill elevation of 75 m amsl. The population density is moderate with the 1990 census showed a population of 106,544 distributed over three municipalities; Bantayan, Santa Fe, and Madridejos (see Map 1). Since the farmlands are not quite promising, people resort to raising livestock and fishing as the main livelihood.



Map 1: Bantayan Island

### 2.1 Geology

Geologic investigation showed that the island is of limestone formation with a thin layer of top soil. There are several sink holes spotted in the island which possibly drains water easily to the sea. With this type of geology, permeability and infiltration capacity are high. Inherent property of limestone formation has two major unfavorable characteristics. Firstly, the possibility of seawater

intrusion along the nearshore when drawdown occurs due to high permeability, secondly, there is a high risk of bacterial and chemical contamination of wells especially in the urban areas. These two problems becomes apparent during the water resources investigation and is discussed later.

## 2.2 Climatic condition

Based on Thornthwaite's moisture index, the climatic condition of Bantayan Island is classified as dry sub-humid. The average annual precipitation amounts to 1580 mm. There are two pronounced season observed in the area; i.e. dry and rainy season. The rainy season last for about 8 months which runs from May to December.

## 3 Water resources assessment

Evaluation of the water resources status of the island, both for water quality and volume of groundwater reserve, can be done using a systematic well survey. Well survey was conducted to determine the actual water consumption, the location of groundwater level, and the status of water quality. In addition, observation of hydrologic data such as rainfall and evaporation was undertaken. Details of the survey are presented in the succeeding section.

### 3.1 Well survey

Well survey was conducted in two separate occasions to determine the groundwater extraction, location of the groundwater table and water quality. The first was conducted in 1988-89, and the second survey was done in 1995. Since the location of the groundwater table fluctuates with hydrologic parameters such as rainfall, the survey was undertaken on the same season. The time of observation during the year as well as pertinent hydrologic data was obtained in order to correlate any variation of the measured data.

#### 3.1.1 Water level

Control wells were selected at random forming a grid in the area of interest. The location of groundwater table was then measured with respect to the mean sea level(msl). The actual groundwater level of control wells were calculated accounting for the influence of tidal fluctuation.

Figure 1 and 2 show the isoline of the groundwater table above the mean sea level obtained in 1989 and 1995, respectively. In the 1995 survey, it is observed that the isoline moved toward the inland which indicate the lowering of the groundwater table and reduction of the freshwater lens. It was observed that a maximum decrease of 1.29 m located at Tangkong area. The decrease of the water level generally observed near the shoreline resulted in the seawater intrusion. This is discussed at length in the next section.

### 3.1.2 Salinity intrusion

During the well survey, electrical conductivity of the water samples was measured. Conductivity is one of the indicators of water quality in relation to the chloride content of water. Although chloride is present in all natural waters at a concentration up to about 40 mg/L, high concentration of chloride in wells will indicate intrusion of saltwater from the sea; the sea having chloride content of about 19000 mg/L. This is true if there is no other source of chloride which can be traced in the area.

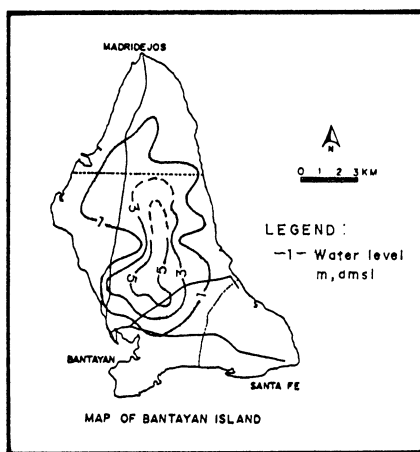
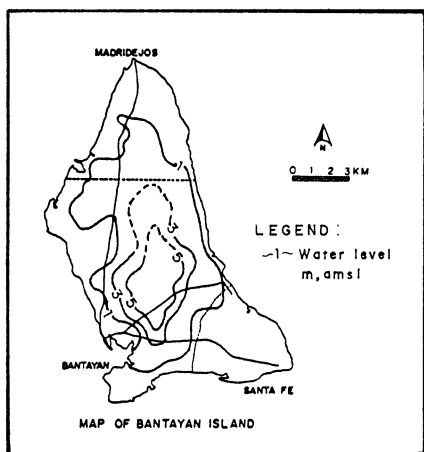


Figure 1: Groundwater isoline, 1989

Figure 2: Groundwater isoline, 1995

Water conductivity of control wells was measured directly in the field. Results for the 1989 and the 1995 survey are presented in terms of the iso-conductivity line shown in Figure 3 and 4.

Based on WHO standard for drinking water, the chloride content of fresh water used for drinking must not be greater than 200 mg/L, or approximately equivalent to a calibrated conductivity value of 1350  $\mu\text{S}/\text{cm}$ .

It was observed also that saltwater has intruded inland in many areas of the Island especially in highly populated areas. Wells along the shoreline registered conductivity values of more than 1500  $\mu\text{S}/\text{cm}$  which is over 250 mg/L or more. Based on the 1989 and the 1995 survey, a progression of seawater intrusion in some of the areas was observed. In Madridejos, the 1500  $\mu\text{S}/\text{cm}$  isoline also moved 1 km inland. In areas where the water level elevation is constricted, a high conductivity was observed. This is probably due to the karstic characteristic of limestone formation and the effect of cave system.

Saltwater intrusion was attributed to increase in groundwater extraction due to increasing number of wells in the area. These are the areas with high number of clustered wells. This is aggravated by the type of geologic formation in the area which is limestone.

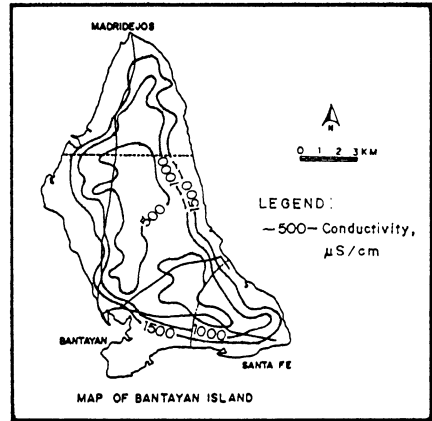
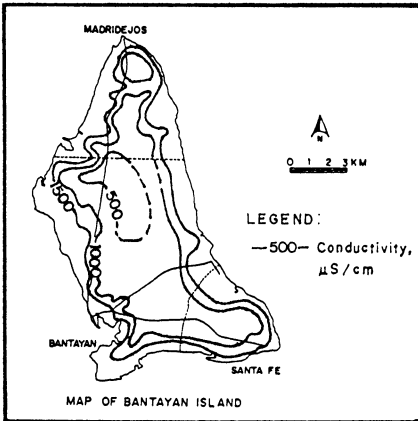


Figure 3: Iso-conductivity line, 1989

Figure 4: Iso-conductivity line, 1995

### 3.1.3 Biological contaminants

The method of collecting water samples for bacteriological and chemical analyses was done according to the procedures recommended by the Philippine National Standards for Drinking Water and the Standard Methods for the Examination of Water and Wastewater. Results of the water quality tests are presented in Table 1.

Table 1: Observed level of contaminants and the WHO standard

Parameters (Month observed)	Observed	WHO standard	Remarks
<b>Escherichia Coli</b> (July sampling) (November sampling)	Contaminated Contaminated	0	39 exceed 29 exceed
<b>Fecal Coliform</b> (July sampling) (November sampling)	Contaminated Contaminated	0	36 exceed 35 exceed
<b>Phosphate</b> (July sampling) (November sampling)	0.01-0.36 mg/L 0.05-0.43 mg/L	*0.17 mg/L	1 exceed 5 exceed
<b>Nitrate</b> (July sampling) (November sampling)	2.4 - 118 mg/L 3.7 - 59 mg/L	10 mg/L	26 exceed 34 exceed
<b>pH</b>	7.5	6.5 - 8.5	OK

\*EEC Guideline

Table 1 shows the water quality parameters, observed level of concentration and the WHO guideline values. The last column indicates the number of wells (of the 41 wells sampled) that exceed the standard limit.



Two indicator bacteria were used for the bacteriological analysis of water samples, one was *Escherichia coli*; an indicator bacteria for human waste contamination, and Fecal coliform; an indicator bacteria for both human and animal waste contamination.

Of the 41 samples collected for microbiological analysis last July 1995, 39 samples showed *E. coli* growth and 36 samples showed Fecal coliform growth. During the November 1995 sampling, 29 samples showed *E. coli* growth and 35 samples showed Fecal coliform growth as shown in Table 1. The result indicates that most of the water sources are bacteriologically unsafe for drinking.

Inorganic phosphorus compounds are not toxic, but they are undesirable component of surface waters used for drinking. Also, there is danger of eutrophication or algal blooming at concentration even as low as 0.05 mg/L. Phosphate concentration of water samples collected last July 1995 ranged between 0.01 and 0.36 mg/L with one sample exceeding the EEC guideline. The samples collected last November 1995 had concentrations between 0.05 and 0.43 mg/L with 5 samples exceeding the EEC guideline.

Nitrate ( $\text{NO}_3^-$ ), in itself is not particularly dangerous. However, certain bacteria commonly found in intestinal tract of infants can convert nitrates to highly toxic nitrites which have greater affinity for hemoglobin in the bloodstream, than does oxygen. When nitrite replaces oxygen, methaemoglobinaemia or oxygen starvation result which causes a bluish discoloration of the infant. This is also called the "blue baby" syndrome. Nitrate concentration of the water samples are given in Table 1.

The pH of water has no direct health effect but may have aesthetic effects on drinking water quality. pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, pH should preferably be less than 8. Low pH values could cause corrosion of pipes in water systems resulting in adverse effects on the physical characteristic of water such as taste, odour and appearance.

From the results, it can be seen that the majority of the water source in the island are contaminated. It was observed that contaminated wells are those shallow water sources and are relatively close to agro-farms and in densely populated areas. Deep wells which are covered, well maintained with clean surroundings were not contaminated.

High concentrations of nitrate indicate that the water source is contaminated with nitrogenous substances either from inorganic nitrate-containing fertilizers, or from organic sources like animal manure. In the case of the Bantayan Island, most of the nitrate contaminated sources were located near poultry farms which is the source of nitrates as a final oxidation product.

### 3.2 Depletion of groundwater

Groundwater level data obtained for the years 1989 and 1995 indicate that the fresh water lens has reduced, consequently, saltwater intrudes into the mainland.

It was shown that the area of the freshwater lens is confined at the center of the island (see Figure 2 and 3). Comparison of observed groundwater level for the year 1989 and 1995 revealed that there is a general decrease or lowering of the groundwater table.

An approximate volume of groundwater depletion can be calculated using the previous and present groundwater level. Based from the groundwater level data for 1989 and 1995, and taking 30% porosity for limestone formation, the volume of fresh groundwater depletion is approximately 4.06 M m<sup>3</sup>/year. The significance of this value may be apparent by using the water balance concept discussed in the next section.

### 3.3 Water balance analysis

In the water balance analysis, several components are considered; these are the total recharge area, annual rainfall, evapotranspiration, aquifer transmissivity and actual consumption of the community. A control system concept is used in the analysis which accounts all components.

#### 3.3.1 Annual potential recharge

The effective recharge area was known by outlining an imaginary line on the map. The line corresponds to the freshwater and seawater interface. This is also the boundary when the tidal fluctuation is fading out or has no influence on the wells. The effective recharge area was determined by a planimeter and is equal to 83 sqkm. The annual potential recharge of the aquifer can then be calculated as

$$APR = RA \times INF \quad (1)$$

where APR is the annual potential recharge, RA is the effective recharge area, and INF is the depth annual infiltration which is equal to the annual rainfall less runoff and evapotranspiration. With a mean annual rainfall of 1580 mm/year and evapotranspiration equal to 1165mm/year, estimated using Turc-Langbein, the APR is calculated to be 35.1 M m<sup>3</sup> per year.

#### 3.3.2 Natural outflow

Determination of the total outflow (Q) to the sea can be done using the recent water level map and the aquifer characteristics. This outflow can be estimated using Darcy's equation expressed as

$$Q = ibT \quad (2)$$

where Q = total discharge, i is the hydraulic gradient, b is the length of the aquifer perpendicular to the flow, and T is the transmissivity. Using all available data, the outflow was calculated to be 19.51 m<sup>3</sup>/year.



### 3.3.3 Water demand

The rate of groundwater withdrawal is an important parameter to assess the water availability in the area. For this reason, a survey was conducted to determine the actual groundwater extraction in the area. Result of the survey indicates that the total fresh water demand (extraction within the fresh water lens) is 1.25 M m<sup>3</sup>/year.

### 3.3.4 Groundwater balance

Following the systems concept, a simple groundwater balance can be made. Mathematically, this is expressed as

$$\text{APR} = \text{WD} + \text{Q} + \text{LN} + \text{DEF} \quad (3)$$

where WD is the water demand of the community which include domestic and agricultural consumption, Q is the outflow to the sea, LN is the unaccounted losses, and DEF is the observed groundwater deficit. Hence, using the estimated values for each component, the natural losses are calculated as 10.29 M m<sup>3</sup> per year. The natural losses are probably caused by the karst characteristics of the limestone formation as well as the underground cave system.

It can be seen that the annual potential recharge are much bigger compared to the fresh water demand which is 1.25 M m<sup>3</sup>/year. However, due to geologic formation, the apparent surplus of water is consumed into natural losses which results into depletion of groundwater reserved.

## 4 Hydrogeologic problem

As seen in the water balance analysis, there is high annual potential recharge. On the contrary, water level data as well as the conductivity records showed that there is depletion of the groundwater resources. This leads to several theory, one is that the aquifer cannot store water, i.e. water flows directly to the ocean through solution channels, and secondly, the water did not reach the groundwater table and it is lost through evapotranspiration.

The first hypothesis is preferred due to the geology of the area which is karstic limestone. This layer is located at a short distance or depth from the top soil. The presence of the karstic limestone has pros and cons in relation to recharging the aquifer. The advantage is obvious in that the formation is highly porous and has high permeability and/or infiltration capacity. However, because of its inherent property which dissolves in transient water, it may result to solution channels. Thus, water is transported easily to the ocean through solution channels without it being stored in the water bearing formation.



## 5 Conclusion

The study was conducted to investigate the water resources status of Bantayan Island. Two main components of the study were considered vital; these are the assessment of the quantity and quality of groundwater. Results from the investigation indicate that groundwater level decreases despite sufficient annual potential recharge. This is mainly due to the geologic formation of the area, which is karstic limestone formation. Solution channels are present in the area which discharged groundwater directly into the sea.

Salinity intrusion is significant especially in the suburbs. Several wells are bacteriologically contaminated by wastes from human and from poultry farms. Result indicates that most shallow wells are contaminated, and hence, they are not suitable for drinking.

## 6 Recommendations

Results on the water resources status investigation of the island leads to the following recommendations:

1. In critical areas, characterized by a progressive seawater intrusion, regulation of groundwater extraction is essential to prevent further movement of the seawater inland.
2. An alternative source of water supply must be introduced in the affected areas nearshore. This implies that a water system will be designed with its water source located at the fresh water lens.
3. Open dug wells must be rehabilitated to prevent from possible entry of contaminants.
4. Considering the extent of bacterial contamination of the water sources in the island it is important that a water laboratory be set-up in conjunction with the sanitation program and water treatment scheme in the island.
5. It is essential that a water recovery system be designed. This system enables collection of water efficiently before it flows to the seawater zone.

## References

1. Bouwer, H. *Groundwater Hydrology*, McGraw Hill, 1978.1.
2. Metcalf and Eddy, Inc., *Wastewater Engineering. Treatment, Disposal and Reuse*. 3rd ed., McGraw Hill, 1991.



## 120 Hydraulic Engineering Software

3. Chow, V.T. (ed). *Handbook of Applied Hydrology*, McGraw Hill, New York, 1964.
4. Well Survey of Bantayan Island. Water Resources Center, University of San Carlos, 1990.
5. Bantayan Island Production Wells. Water Resources Center, University of San Carlos, 1989.
6. Water Resources Survey of the Bantayan Island, An Update, Water Resources Center, University of San Carlos, March 1996.