Chapter 21
Underground Water of Deep Circulation in the National Park Guanahacabibes, Pinar del Rio Province, Cuba: Another Alternative with Water Supply Aims

R. Peláez García and N.A. González Cabrera

Abstract The National Park Guanahacabibes, located in the westernmost part of Pinar del Rio province, occupies an area of 1,200 km^2. It was recognized in 1987 in an official way and internationally as a town of biospheric transcendency. From the geologic point of view it is composed by Neogene – Quaternary rocks over other older Jurassic rocks with a great development of the karst of the plain that limits the existence of superficial fluvial flows. In those carbonated rocks, there is an aquifer open to the sea and strongly intrusive by marine waters, and the only possibility of finding sweet waters in the small lenses that float on the salted waters. As an alternative related to the different proposals carried out by the authors in different moments with the objective of solving the water supply to the peninsula, in this work there is an approach to the possibility of finding sweet waters of deep circulation in older rocks (Jurassic), outlining a Conceptual Model Geologic – Hydrogeologic Regional, using current interpretations.

Keywords Water supply • Karst • Aquifer • National Park Guanahacabibes • Cuba

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21.1 Introduction

To be able to develop a territory it is necessary to make works of diverse types that allow creating conditions for exploiting their resources. From the end of the 1960s and later on in the 1980s, when the development in tourism began in this country, the peninsula began to be studied with the objective of knowing its potentials for tourism, verifying the immense possibilities that it offers for the development of a nature tourism for the variety of flora and fauna resources in its emerged portion and submarine platform and the speleologic, archaeological and landscape values.

The peninsula of Guanahacabibes has been little studied due to the inaccessibility that offers its karst relief, the shortage of lands with agricultural potential, the absence of interests for mining activity and geographical accidents that allow the construction of important ports for marine sailing.

Another factor of first importance that breaks the socioeconomic development from the peninsula to a great scale is the enormous deficit of water with quality for its different uses (Vengrechanovich 1980). For its form and geologic constitution, with prevalence in the surface of carbonated karstified rocks, the hydric superficial resources of the peninsula are null and the shallow underground waters are generally affected by marine intrusion processes that convert them into not being capable for their social use, which constitutes the fundamental problem.

Due to the inconveniences of the analyzed variants in Peninsula Guanahacabibes with the intention of another variant starting from a detailed regional conceptual model of the geologic, geophysics, hydrological, hydrogeological and perforation information accumulated until the present in the region, the existence of a regional flow of waters of deep circulation of the Jurassic aquifer constituted by carbonated rocks (calcareous) of the Guasasa Formation of the age $J_3 - K_1$ is possible.

21.2 Geographical Characteristics of the Region

The implied area in the present investigation embraces the western south plain located to the southwest of Guane town as well as the hydrographic basin of Cuyaguateje. The interaction of the geologic, geomorphologic, climatic, hydrograghic and biotic factors have given the place a very specific landscape of lakes, lagoons, swamps, etc.

The peninsula of Guanahacabibes is geomorphologically an active karst plain, where several characteristic types of relief are appreciated, either emerged or submerged (ACC 1989).

To the north of the area occupied by Cuyaguateje Basin there are low mountains, which are very irregular. The average absolute mark of these elevations can be considered between 350 and 400 m; they are of the horst type and blocks of overthrust mantels, especially in the mogotes.

21.2.1 Regional Hydrogeologic Frame

The investigation that was carried out implies the analysis of the characteristics and the role played by three fundamental hydrogeologic units developed in the implied territory that extends from the eastern end of the basin of Cuyaguateje River to the Peninsula of Guanahacabibes. The search of a solution for the water supply in this last unit is not feasible without an integral and interrelated analysis of all the factors that can determine the possible election of variants (Castaño 2000).

- Neogene-Quaternary Complex (N1-Q III): This aquifer is broadly extended for the whole territory. The aquifer is related to the carbonated deposits of the Paso Real, Guane, Vedado and Jaimanitas Formations (Denis and Díaz Guanche 1993) with reef calcareous and organogene strongly karstified in the upper part of the geologic cut to approximately 300 m of depth. In the northern part of the area the rocks of Paso Real lie directly on the deposits of San Cayetano (Well Guane – 1). To the Paso Real Aquifer are attributed very high hydraulic properties with hydraulic conductivities elevated to 700–1,000 m/day, with specific expanses over 25–30 l/s/m and static levels very close to the surface – 1–4 m. The total thickness of the carbonated rocks of the units of the Neogene-Quaternary can range to 750m (ONRM 1970). The underground waters of this aquifer are fundamentally of the chloride-sodium type, due to the marine intrusion with a quantity of soluble salts that oscillates between 1 and 5 g/l, the chlorides vary from 500 to 800 mg/l, in general. In isolated points of the peninsula can be located lenses of fresh water "floating" on the salty waters of bicarbonate-calcic type with a total of dissolved salts of 0.6–0.8 g/l and chlorides between 90 and 290 mg/l (Alvares and Peláez 1970).
- Upper Jurassic – Inferior Cretácico Aquifer Complex (J_3-K_1gs) guasasa: This unit has its biggest development and blooming area in the intermountain hydrogeologic basin Sierra de los Organos coinciding with the hydrographic basin Cuyaguateje. This complex is related with the gray karstified and cracked limestones of the upper Jurassic that appear in the Sierra de los Organos conforming a relief of karst-denudative low mountains. When one advances toward the occident the complex of carbonated rocks submerges and is recovered by the terrestrial silts of the Paso Real Formation until arriving near to Isabel Rubio town where the carbonated complex does not appear for the geologic formation mentioned before. It is as though this whole structure goes toward the southwest of the Guanahacabibes Peninsula. To the north exists an alignment toward the southwest of big karst springs with flow with fresh water that oscillates between 80 and 350 l/s (Springs Los Acosta – 100 l/s, Teneria – 80 l/s and Los Portales 350 l/s) (Chetoni et al 1997). The presence of these springs and other discharges not mentioned attest to the existence of a component of the underground glide of considerable magnitude. A detailed valuation was made. The waters are bicarbonated-calcic type with a quantity of soluble salts between 0.3 and 0.6 g/l, stable in type and content of salts in the time, according to the monitoring of quality of the territory in more than 30 years in which substantial variations do not

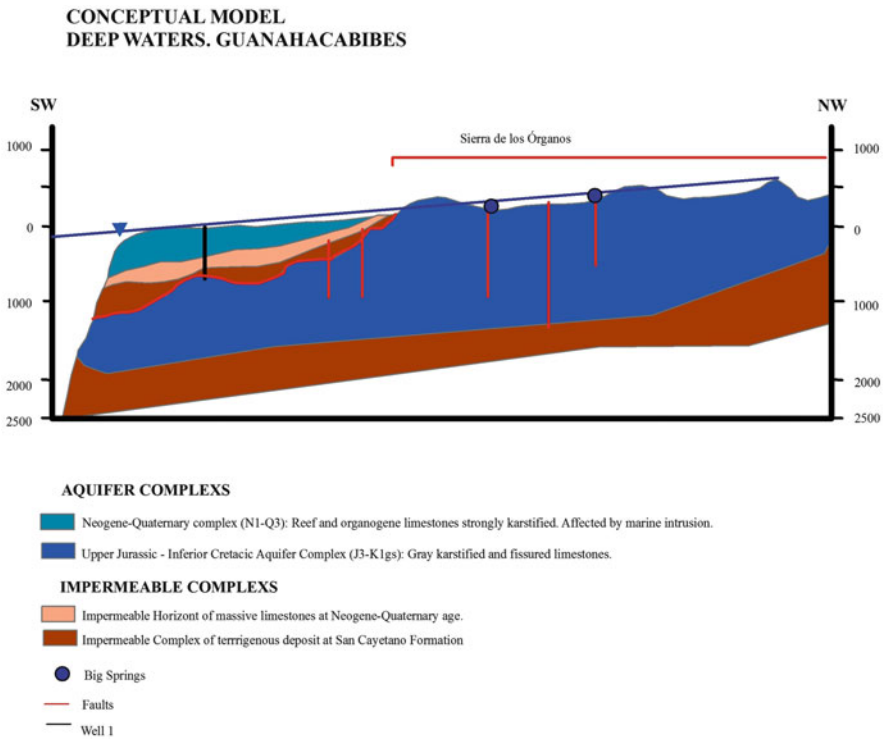

Fig. 21.1 Regional hydrogeologic model

exist in the chemical elements that characterize them. The hydraulic conductivities of this aquifer vary between 50 and 300 m/day. Through this aquifer the underground flow moves toward the southwest, that is, toward the peninsula (Díaz Hernández 2000).

- Upper Jurassic – Inferior Cretacic Aquifer Complex Esperanza (J_3-K_1es): It occupies the north of Cabo San Antonio from the plane of overthrust discovered for the Well Guanahacabibes-1 (Martínez 1994; Martínez et al 1988) that cut sericític carbonaceous schists of black color with andesite intercalations and gabros. The hydraulic conductivities of this aquifer have values up to 100 m/day. This aquifer unit is not considered as perspective (Fig. 21.1).

21.3 Methodology of the Investigation

The new variant is based on a Regional Conceptual Model of the occurrence of a deep aquifer in the Jurassic sediments of Guasasa Formation that underlie the carbonated rocks of the Neogene as well as the terrestrial sediments of San

Cayetano Formation like regional impermeable in the Guanahacabibes Peninsula. This idea is based on the fulfillment of several premises and general conditions that allow a base model of the underground runoff in the territory objective to study the argument of the possibility of capturing abundant flows of underground waters of good quality to depths over 800 m.

The premises that allow the verification of the outlined conceptual pattern are the following:

- Suitable geologic – hydrogeologic constitution.
- Positive hydric balance in the Cuyaguateje basin.
- Existence of submarine discharge areas.

21.3.1 Evaluation of the General Water Balance of Cuyaguateje Basin

The basin of Cuyaguateje River occupies a great part of the western portion of Sierra de los Organos extending from Cabezas town to the outlet of the river in the Ensenada de Cortés, which, in general has a surface of 723 km^2 (CITMA 2005).

Taking into account the environment of general karst development that has a great influence on the hydric balance of the basin, a special interest is dedicated to the valuation of the resources of underground runoff that have their origin inside the limits of the basin, and should go in a southwest direction toward the western is dedicated to part of the Peninsula of Guanacahabibes, taking advantage of the deep continuation of the geologic structure conformed by the carbonated rocks of Guasasa Formation.

The result of the hydric balance in Cuyaguateje Basin settles down for a component of underground runoff toward the south in about 548 million m^3/year (17.3 m^3/s) of water. Starting from the analysis of the structural geologic conditions of the region, this underground runoff should conform to the submarine discharges of the deep Jurassic aquifer in the marine channel along the beril edge to depths over 800 m.

The use of the underground resources that will be discharged to the sea constitutes a potential variant for water supply for the future investments foreseen in the Development Plan of Guanahacabibes that is insignificant of about 30 l/s according to the calculations of these enormous evaluated resources.

21.3.2 Existence of Areas of Submarine Discharges of Water

With the view to predict the places of more probability of submarine discharges a work of localization was carried out of these areas by means of the processing of available satellite images corresponding to the area of the marine platform.

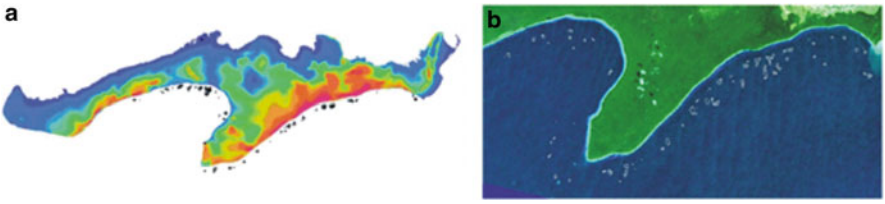

Fig. 21.2 Submarine discharge associated to the aquifer N-Q (*left*). Submarine discharges associated to the deep aquifer of Guasasa Formation (*right*)

In the area to investigate only the information exists related to satellite images (Multispectral reflectance) and bathometry data. The satellite information is limited to a set of images of the Thematic Map (TM) of year 2000 that includes the bands 1, 2, 3, 4, 5, 7, 61 and 62.

The bathometry was extracted from cartographic maps 1:250,000 with an implicit precision.

21.4 Results and Discussions

As a result of the analysis of the regional geologic-hydrogeologic structure the continuity in depth of the sequences of Sierra de los Organos toward the west-southwest in Guanahacabibes region were considered, and can also wait the existence of "valleys and windows" of tectonic-erosive origin under neogene – quaternary carbonated sediments.

The water balance in Cuyaguateje basin throws a component of underground runoff in about 548 million m^3/year (17.3 m^3/s) of water directed toward the south. Starting from the analysis of the structural geologic conditions of the region this underground runoff should conform the submarine discharges of the aquifer detected by the analysis of satellite images in the blooming areas along the insular talus to depths over 1,000 m.

In the Fig. 21.2 (left) the discharges, of the neogene-quaternary aquifer on the isobate of 200–500 m and in the Fig. 21.2 (right) Jurassic aquifer on the isobata of 1,000 m usually model the coast of the peninsula and present exit areas of 500 × 500 m and larger.

The use of the underground resources that in a certain way will be discharged to the sea constitutes a potential variant for water supply for the future investments foreseen in the Development Plan of Guanahacabibes that is insignificant according to the calculations (30 l/s) in front of these enormous resources.

The Jurassic discharges associated with the Guasasa Formation, according to the Regional Conceptual Hydrogeologic Model, are disseminated between 1,000 and 1,500 m deep. In this interval of depths certain groups appear with a symmetrical correct alignment to the coast. The main direction of calcareous structure toward the peninsula was established by data of the complex analysis with a quite high

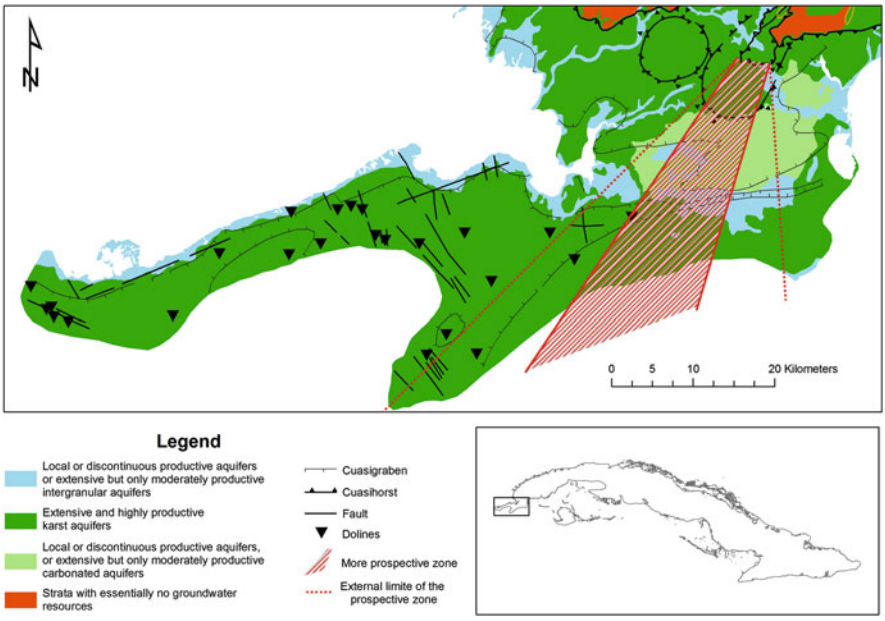

Fig. 21.3 Direction of the prolongation of the deep aquifer structure

security as to have the continuity of the future investigation that allows thinking of a deep perforation of about 1,000–1,200 m of depth in the central area shown in Fig. 21.3.

21.5 Conclusions

According to the analysis of the available information on the geologic structure of the territory, it is possible to assure the occurrence of a deep aquifer container of capable waters for the human consumption, associated with carbonated rocks of Guasasa Formation.

The results of the calculation of the hydric balance in Cuyaguateje River attest for the existence of an underground runoff of large proportions that should circulate for the deep aquifer horizon of Guasasa Formation in the direction of The National Park Guanahacabibes.

Although the available satellite information was not optimum, the investigation showed as a result the existence of submarine discharges of underground waters, located in the area of the blooming of the Guasasa Formation in the marine bottom, between Cabo Frances and Cabo Corrientes to 1,000–1,500 m of depth.

A preliminary evaluation of the economic feasibility of the different variants for water supply in the Peninsula Guanahacabibes allows acceptance of the option of

the employment of underground water of deep circulation of the aquifer Guasasa. This will be possible due to its low operation cost and environmental impacts.

In the future geophysical works of electric sounding, gravimetric and seismic to locate fossil valleys covered by Paso Real Formation will be needed to locate a deep exploratory well of 800–1,000 m in depth to carry out hydrogeologic works for the evaluation of the aquifer Guasasa.

References

ACC (1989) Nuevo Atlas Nacional de Cuba. Ed. Instituto de Geografía de la Academia de Ciencias de Cuba

Álvarez Sánchez H, Peláez García R (1970) Informe sobre las investigaciones hidrogeológicas en la Península de Guanahacabibes. Archivo INRH, Inédito

Castaño S (2000) Land and water management in mediterranean islands using earth observation data. Instituto de Técnicas Aeroespaciales de España. http://www.uclm.es

Chetoni R, Reyes R, Martinez D, Sobrino E (1997) Reporte de las investigaciones Geológicas e Hidrogeológicas realizada en los Manantiales "Los Portales", Guane. Pinar del Río (Archivo ONRM), La Habana, Cuba

CITMA (2005) Plan Gestor de Ordenamiento Territorial de la Península de Guanahacabibes (Archivo Delg. Prov. CITMA). Pinar del Río, Cuba

Denis R, Díaz Guanche C (1993) Características geológicas y geomorfológicas de la Península Guanahacabibes. Dirección Provincial de Planificación Física, Pinar del Río

Díaz Hernández D (2000) Informe sobre los pozos de monitoreo del Centro Internacional de Buceo María La Gorda. Archivo Instituto Nacional de Recursos Hidráulicos (INRH), Inédito

Martínez D (1994) Informe sobre la Generalización del Mapa Geológico del Occidente de Cuba a Escala 1:100000. (Archivo ONRM). La Habana, Cuba

Martínez D, Fernández de Lara R, Peláez R et al (1988) Informe Sobre los Trabajos de Levantamiento Geológico 1:50 000 y Búsquedas Acompañantes. Pinar Central (CAME II), ONRM

ONRM (1970) Reporte sobre el Pozo Guanahacabibes. (Archivo ONRM) La Habana, Cuba

Vengrechanovich R (1980) Informe sobre las investigaciones hidrogeológicas en la Península de Guanahacabibes. Archivo INRH, Inédito