Estimation of the Effect of Climate Change on the Quantification of Water Resources in the Suaza River Basin, Tributary of the Magdalena River

The AILEG Project

Contract No.: EEM-I-00-07-00004-00 Task Order: AID-OAA-TO-11-00041

Suaza River, July 2013 (Photo credit: Suaza-Huila.gov.co)

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Estimating the Effects of Climate Change on Water Resources in the Suaza River Basin in Colombia

FINAL REPORT

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ACRONYMS

AILEG	Analysis and Investment for Low Emissions Growth
CAM	Corporation of the Alto Magdalena
CIDIAT	American Center for Land and Water Development
CO_2	Carbon dioxide
DEM	Digital Elevation Model
ETo	Evapotranspiration
FAO	U.N. Food and Agriculture Organization
GCM	Global Circulation Model
GIS	Geographic Information Systems
HIMAT	Colombian Institute of Hydrology, Meteorology, and Land Development
IDEAM	Institute of Hydrology, Meteorology, and Environmental Studies
IDF	Intensity-Duration-Frequency
IGAC	Geographical Institute Agustín Codazzi
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
lps	Liters per Second
MASL	Meters Above Sea Level
Msnm	Meters Above Sea Level (Spanish acronym)
m^3/s	Cubic Meters per Second
NASA	U.S. National Aeronautics and Space Administration
NGA	U.S. National Geospatial-Intelligence Agency)
PG	Puente Garcés
PPM	Parts per million
PRECIS	Providing Regional Climates for Impact Studies
SIHIM	Monthly Hydrological Simulation Model
SM	San Marcos
SRES	Special Report on Emissions Scenarios
STRM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
UNC	National University of Colombia

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1. INTRODUCTION

Colombia's abundant water resources have been significantly utilized for hydropower—providing approximately 70 percent of all energy in the country. For this reason, it is important to preserve the lifespan of hydropower infrastructure and to understand the effects of climate change and land use changes on water resources. Additionally, it is important for regions with high utilization of water resources to have decision support tools that enable local governments to assess scenarios of climate change, land use, and water demands for planning purposes. One of the regions of Colombia with a high potential for water resources, including hydropower, is the Alto Magdalena Watershed.

The Corporation of the Alto Magdalena (CAM) is preparing the "Huila 2050:;Preparing for Climate Change" with assistance from USAID. In September 2012, a knowledge and cooperation workshop was held at the CAM offices in Neiva. At this workshop, USAID's AILEG Project presented a proposal to conduct a study to estimate the effect of climate change on water resources in a pilot basin, located in the Upper Magdalena River.

This report provides the detailed assessment on the availability of water resources at the pilot basin, and its possible impact on these water resources due to climate changes, estimated by Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), for a planning horizon set at 2050. This study was conducted between January and September 2013. The main tasks of the study include the following:

- Acquisition and analysis of representative climate and hydrometric data for the basin under study.
- Instrumentation, calibration and application of rainfall-runoff hydrological models in order to assess the availability of water resources;
- Soil Water Assessment Tool (SWAT) model calibration, to evaluate the impact on water resources due to climate change;
- Analysis of climate change scenarios for the target basin developed by the IDEAM;
- Assess the effects of various climate change scenarios on the future availability of water resources at the pilot basin; and,
- Provide training on hydrological models for planning purposes at the local level.

The river flow estimates from this study will provide a basis to define adaptation and mitigation measures to reduce the potential negative impact of climate change.

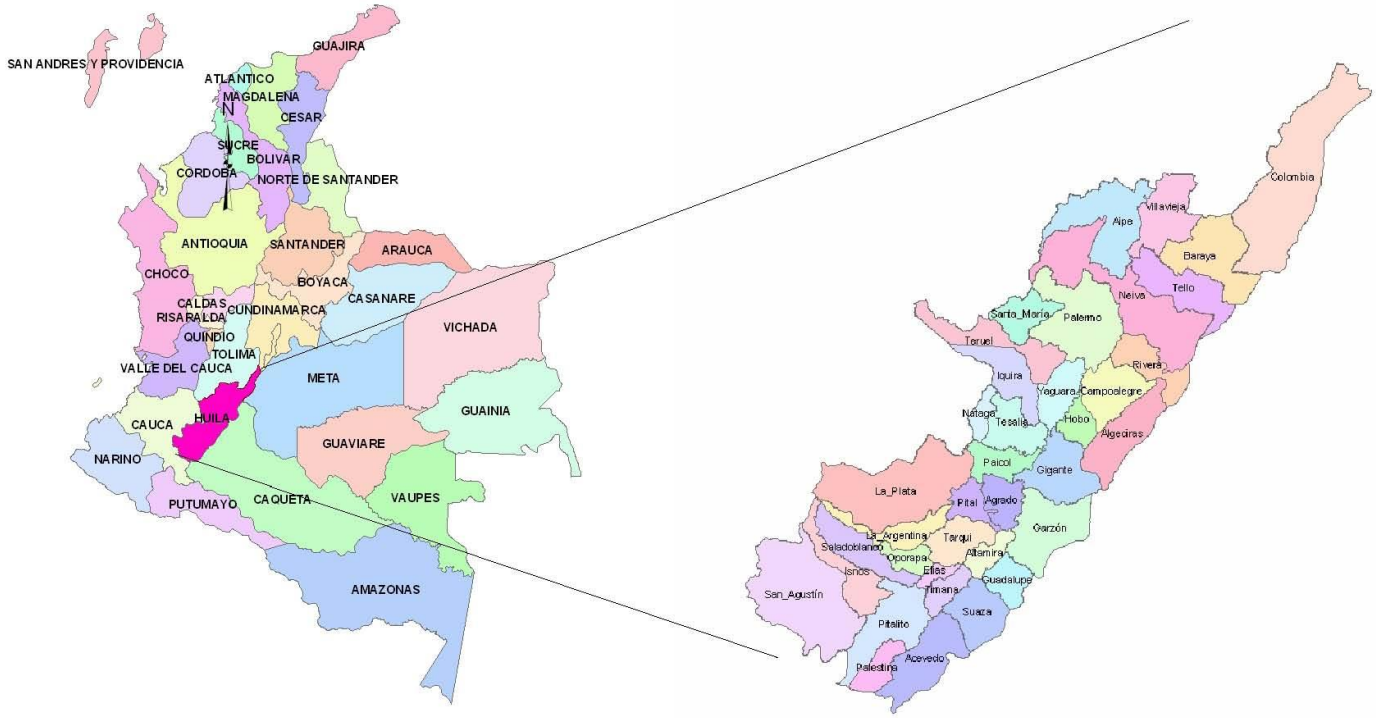
A pilot river basin was selected as part of the first activity of the study based on the following criteria:

- Basin size must be manageable; the SWAT model should be implemented during the period of performance of the AILEG project, considering all the basic data processing required by the model, which is very detailed.
- To properly test the methodology, it is necessary to have a level of hydro-climatic data with an adequate spatial coverage.
- Once the proposed methodology has been tested, it can be applied to all remaining basins that make up the entire Upper Magdalena Basin.

The selected river basin was the tributary to the Suaza River up to its confluence with the Magdalena River. Figure 1.1shows the location of the Suaza River Basin. The total basin area is 1,433 km^2 and the total river length is about 136 kilometers. The upper basin, upstream of San Adolfo, and the upper right boundary of the basin (Cordillera Oriental), are predominantly surrounded by forests, while the mid basin has perennial crops such as coffee and heterogeneous agricultural areas containing low vegetation, mixed with grasslands, shrub lands and some non-perennial crops. The vegetation at the low basin is predominantly comprised of forests, mixed with grasslands, riparian forest areas, and some heterogeneous agricultural areas.

The Suaza River's source is at Los Picos de La Fragua at the National Natural Park of Cueva de Los Guácharos (in the Municipality of Acevedo). Its right bank receives the water flows from the Cordillera Oriental (Eastern Mountain Ranges), and the left bank receives water flows from the Serranía de La Ceja. The Suaza River runs towards the northeast, receiving the flows from the Negra and Aguaclara streams and it meets the waters of the Riecito River, downstream from the town of San Adolfo, at La Esperanza. Later, it receives a series of small streams between the towns of San Marcos and Acevedo. Downstream from San Adolfo, it receives the flows of La Jacué, Tasajera, Agua Cabezas, and Emayá streams, before reaching the town of Suaza. Running northeast, near the town of Guadalupe, it receives the flows from La Viciosa creek. Downstream from Guadalupe, two important watercourses meet–Pescado and Aguas Calientes–before it flows into the Suaza River at the Magdalena River, near the town of La Jagua, upstream from Garzón. Figure 1.2 shows a photo of the Suaza River Basin.

Figure 1.1 Department of Huila and the Suaza River Basin



GOBERNACION DEL HUILA
SECRETARIA DE EDUCACION

Figure 1.2 Suaza River Valley

Source: Suaza-Huila.gov.co

2. ANALYSIS AND PROCESSING OF BASIC INFORMATION

2.1. Data Regarding Digital Elevation Models

To obtain the Suaza River Basin digital elevation model (DEM), downloads were performed from the U.S. National Aeronautics and Space Administration (NASA) Raster and the U.S. National Geospatial-Intelligence Agency (NGA), through the Shuttle Radar Topography Mission (STRM). This allowed NASA to obtain a topographic database covering the land strip that lies between latitudes from 56°S to 60°N, under the WGS84 projection system, with a resolution of 90m x 90m.

Twenty five files[1] were downloaded (to cover the entire Suaza River Basin):

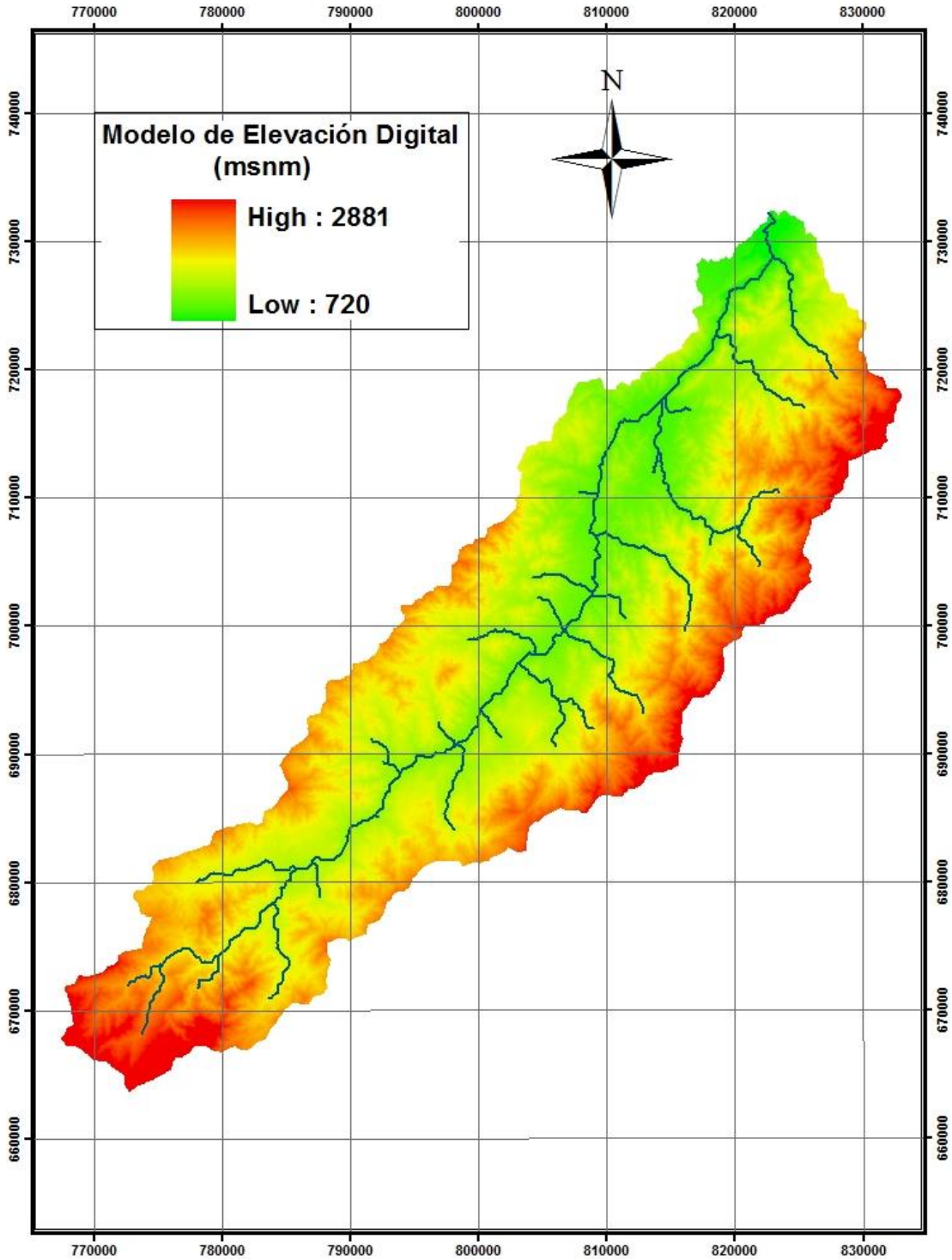
Data processing was carried out through the following activities:

- *. Hgt, is the original format for these files, which were processed to transform them into *. Tif. Subsequently, the files were integrated in a mosaic of the complete sampled area.
- After the mosaic was mounted on the ArcGIS program, the following process was performed:
  - A rectangular mask was created after analyzing the mosaic, to include the entire Suaza River Basin, until its outflow into the Magdalena River.
  - The DEM of the Suaza River Basin was created with this mask from the original mosaic; its projection was changed to the "Projected Coordinate System – National Grids – Colombia_Bogota_Zone".
  - Subsequently, the Basin was delineated through the application of the following ArcGis program commands:
    - "*FILL*" to fill and correct the DEM.
    - "*FLOW DIRECTION*" which defines flow direction at any point of the basin.
    - "*FLOW ACCUMULATION*" which determines flow accumulation trickling downhill to a determined cell. The basin drainage network is extracted from this analysis.
    - "*SNAP POUR POINT*", using the output from the FLOW ACCUMULATION step the point of discharge at the Magdalena River is defined as the basin outlet.
    - "*WATERSHED*", which displays the boundaries of the tributary basin of the Suaza River until it meets the Magdalena River.

FIGURE 2.1shows the digital terrain model of the Suaza River Basin up to its outflow into the Magdalena River.

[1] N01W073.hgt to N01W077.hgt, N02W073.hgt to N02W077.hgt, N03W073.hgt to N03W077.hgt, N04W073.hgt to N04W077.hgt, N05W073.hgt to N05W077.hgt

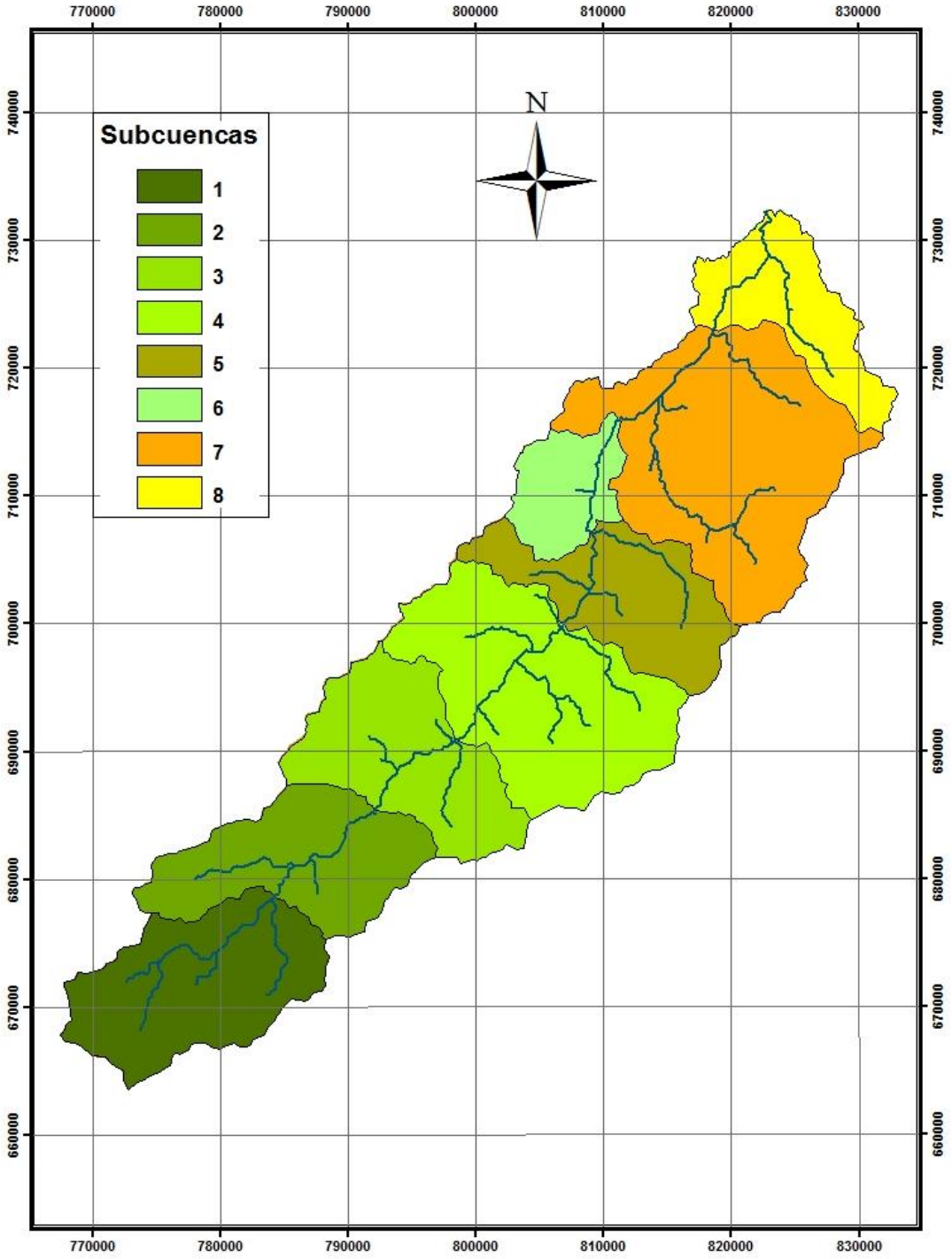
Figure 2.1 Digital Elevation Model of the Suaza River Basin



Source: Abt Associates

The most important sub-basins of the Suaza River Basin were later defined, taking into consideration the most predominant vegetation types, location of the hydrometric stations and tributaries, as well as the most important towns. FIGURE 2.2 shows the sub-basins.

Figure 2.2 Most Important Sub-Basins of the Suaza River Basin



Source: Abt Associates

Table 2.1 Sub-Basin Areas shows the sub-basin areas and the total basin area of the Suaza River up to the point of discharge into the Magdalena River.

Table 2.1 Sub-Basin Areas

Sub-basin	Area (km^2)
1	189.9
2	162.6
3	169.4
4	259.2
5	143.6
6	70.5
7	315.2
8	122.2
Total	1,432.5

2.2. Weather Information

Climate data were collected in two stages. Monthly data were collected in the first stage. The rain gages and weather stations for the calibration and application of models were selected, and variables defined for daily data collection. Table 2.2 shows the features of representative stations at the Suaza River Basin; PM stations are pluviometric stations and CO and CP are weather stations. Stations were identified by the letters in the column ID in Table 2.2.

Tables 2.3 to 2.9 depict the information available for the following variables: rainfall, pan evaporation, temperatures, relative humidity, wind, sunshine, and cloudiness, respectively. The period from 1972-2011 was analyzed. Gray cells reflect the existence of complete data, the orange cells have incomplete data, and the white cells represent an absolute lack of data.

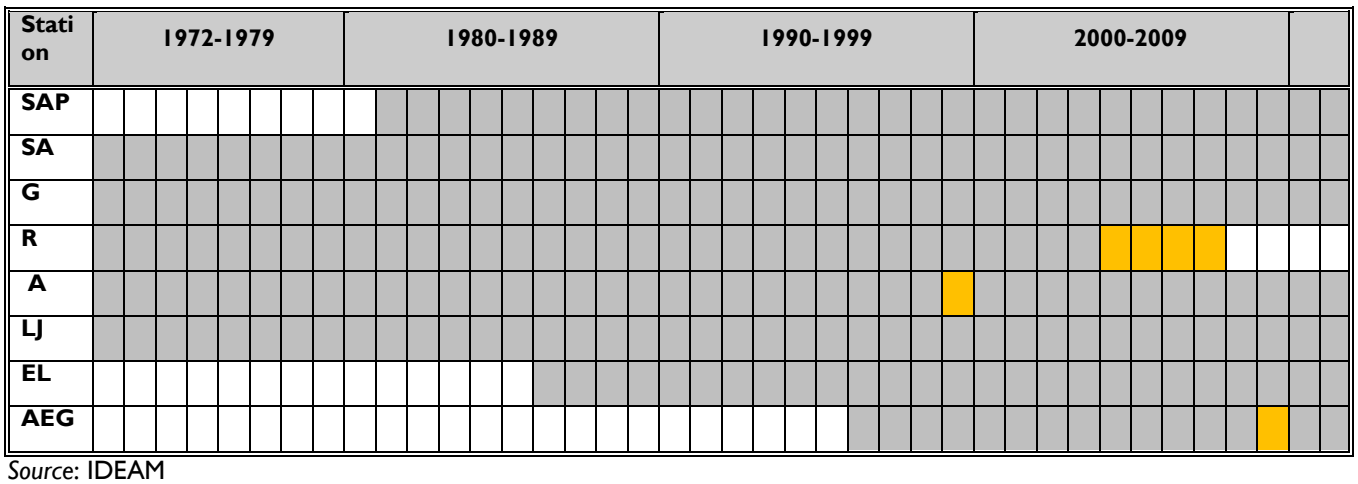
Figure 2.3 Rainfall Stationsshows the location of rainfall stations. The Resina, El Líbano and Altamira del Grifo Stations also collect data on other weather variables besides rainfall data. Figure 2.4 contains a photo of the El Líbano Station. Annex 2.1 includes the monthly data of all rainfall stations and the remaining climate variables observed at the Resina Station.

Table 2.2 Rainfall and Weather Stations, Suaza River Basin

ID	Code	Station	Altitude (msnm)	CT	Period
AEG	21025030	Altamira El Grifo	1,368	CO	1996-2011
G	21030050	Guadalupe	893	PM	1972-2011
SA	21030060	San Adolfo	1,345	PM	1972-2011
A	21030080	Acevedo	1,350	PM	1972-2011
LJ	21030090	La Jagua	755	PM	1972-2011
SAP	21030110	San Antonio del Pescador	1,190	PM	1981-2011
R	21035020	Resina	2,102	CO	1972-2007
EL	21035040	El Líbano	1,045	CO	1986-2011

Source: IDEAM

Table 2.3 Rainfall Data



Source: IDEAM

Table 2.4 PAN Evapotranspiration Data

Station	1972-1979								1980-1989										1990-1999										2000-2009											
R																																								
AEG																																								

Source: IDEAM

Table 2.5 Temperature data

Station	1972-1979								1980-1989										1990-1999										2000-2009											
Maximum Temperature																																								
R																																								
EL																																								
AEG																																								
Minimum Temperature																																								
R																																								
EL																																								
AEG																																								
Average Temperature																																								
R																																								
EL																																								
AEG																																								
Dew Point Temperature																																								
R																																								
EL																																								
AEG																																								

Source: IDEAM

Table 2.6 Relative Humidity Data

Station	1972-1979								1980-1989										1990-1999										2000-2009											
R																																								
EL																																								
AEG																																								

Source: IDEAM

Table 2.7 Wind Data

Station	1972-1979								1980-1989										1990-1999										2000-2009											
R																																								

Source: IDEAM

Table 2.8 Sunshine Data

Station	1972-1979								1980-1989										1990-1999										2000-2009											
R																																								
AEG																																								

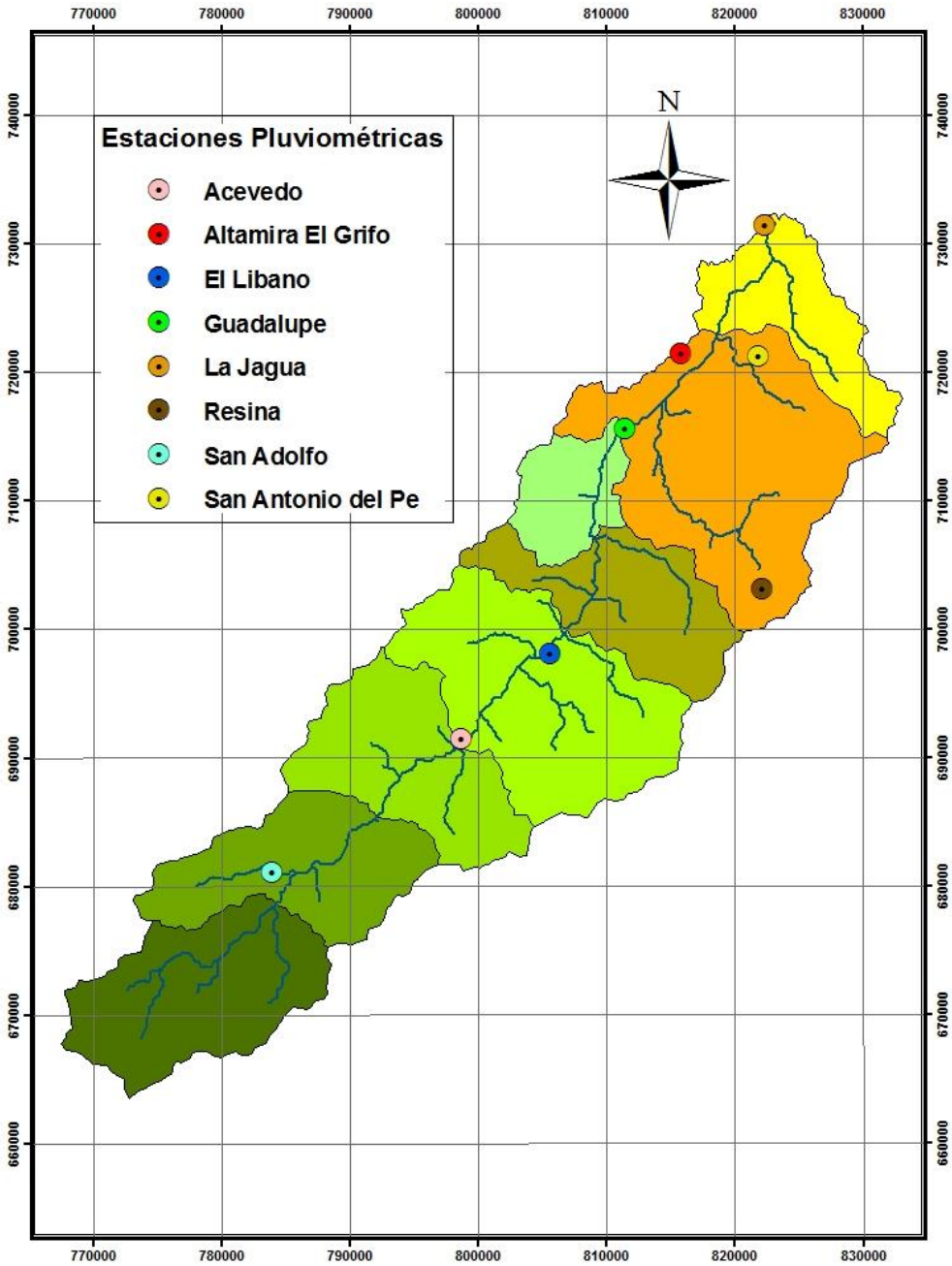
Source: IDEAM

Table 2.9 Cloudiness Data

Station	1972-1979								1980-1989										1990-1999										2000-2009											
R																																								
EL																																								
AEG																																								

Source: IDEAM

Figure 2.3 Rainfall Stations



Source: Abt Associates

Figure 2.4 El Líbano Station

Source: Rodolfo Camacho, Abt Associates

2.3. Hydrometric Data

There are two hydrometric stations on the Basin—the San Marcos Station located near San Marcos and the Suaza Station, known as Puente Garcés. TableTABLE 2.10 shows the main features of these two stations. Puente Garcés Station is the only one with data on suspended sediment transport. Annex 2.1 Weather and Hydrometric Data from IDEAM summarizes this information on a monthly basis.

Table 2.10 Hydrometric Stations, Suaza River Basin

ID	Code	Station	Current	CT	Period	Sediments
PG	21037010	PTE. GARCES	SUAZA	LG	1964-2011	S
SM	21037020	SAN MARCOS	SUAZA	LM	1964-2011	-

Source: IDEAM

Tables Table 2.11and TABLE 2.12 show the information available on average flows and sediment transportation respectively. Figure 2.5 includes a picture of the Puente Garcés Station, while Figure 2.6 shows the location of the hydrometric stations.

Table 2.11 Average Flow Data

Station	1972-1979	1980-1989	1990-1999	2000-2009
PG				
SM				

Source: IDEAM

Table 2.12 Sediment Transport Data

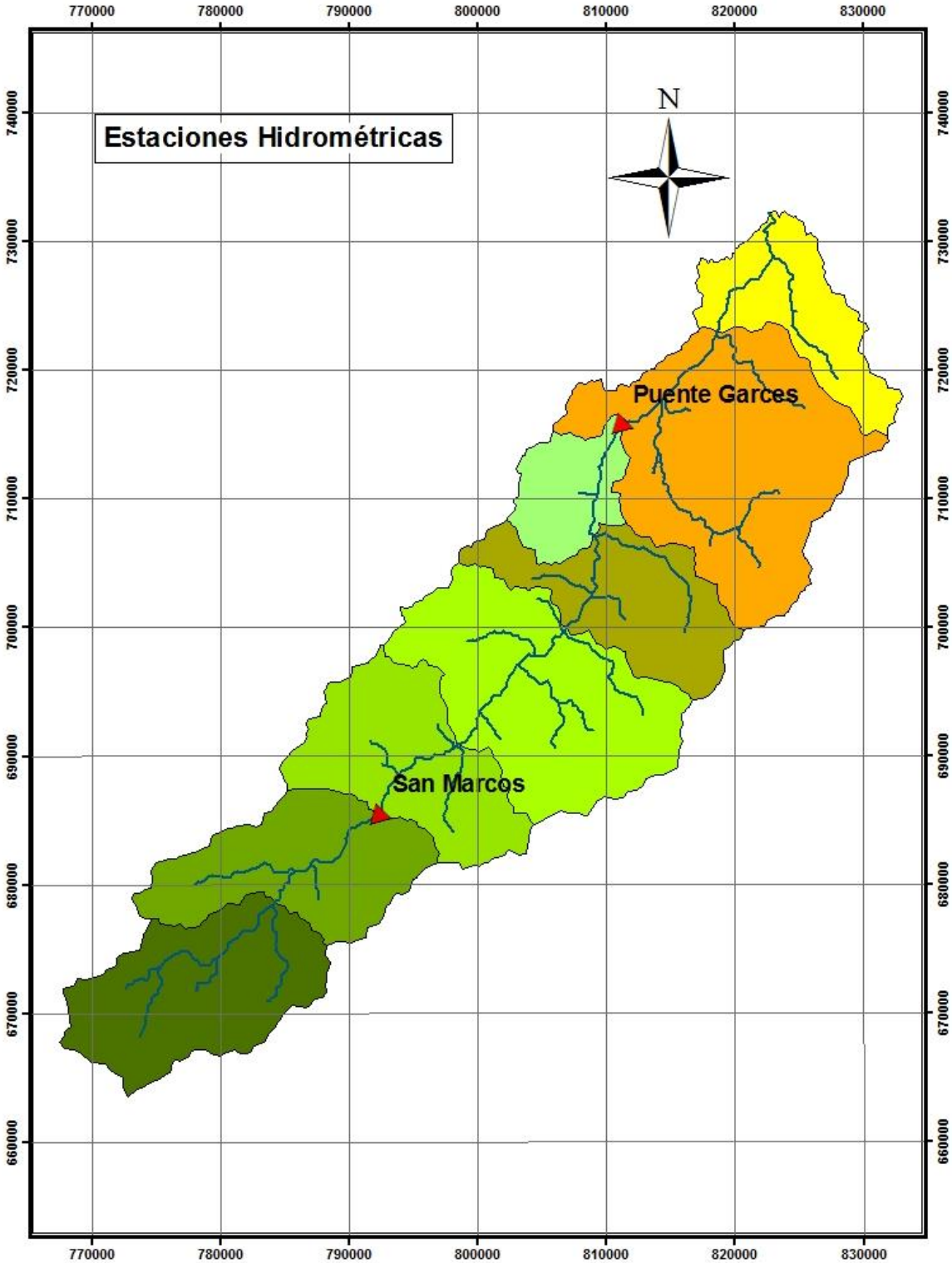
Station	1972-1979	1980-1989	1990-1999	2000-2009
PG				

Source: IDEAM

Figure 2.5 Puente Garcés Station

Source: Rodolfo Camacho. Abt Associates

Figure 2.6 Hydrometric Stations



Source: Abt Associates

2.4. Soil Data

Information was obtained from the Huila General Soil Survey (Volumes I and II), conducted by the "Division of Agrología" of Agustin Codazzi Geographic Institute, IGAC (1994).

Soil types are identified using five letters representing the following factors in order: 1) the landscape, 2) climate, 3) type of parent material, 4) slope range, and 5) erosion process.

- Types of landscapes:

  M: Mountain
  P: Piedmont
  L: Hills
  A: Dissected plateau
  V: Valleys

- Types of climate:

  E: Extremely cold, wet, and very wet
  H: Very cold and wet
  L: Cold wet
  Q: Average and wet
  R: Average and dry
  X: Warm dry and very dry

- Slope ranges:

  A: 0-3 percent
  B: 3-7 percent
  C: 7-12 percent
  D: 12-25 percent
  E: 25-50 percent
  F: 50-75 percent
  G: Over 75 percent (very steep)

- Erosion

  1: Slight
  2: Moderate
  3: Severe
  4: Very severe

For example, a soil defined as MLBd1 (IGAC, 1994):

M: Mountain landscape
L: Cold Humid weather
B: Pedological content
D: 12-25 percent slope, rugged relief
1: Slight erosion

The pedological content is characterized through a pit analysis that describes the soil profiles for each of its horizons. Annex 2.2 Profiles of Representative Soils at the Suaza River includes the most representative soil profiles of the Suaza River Basin.

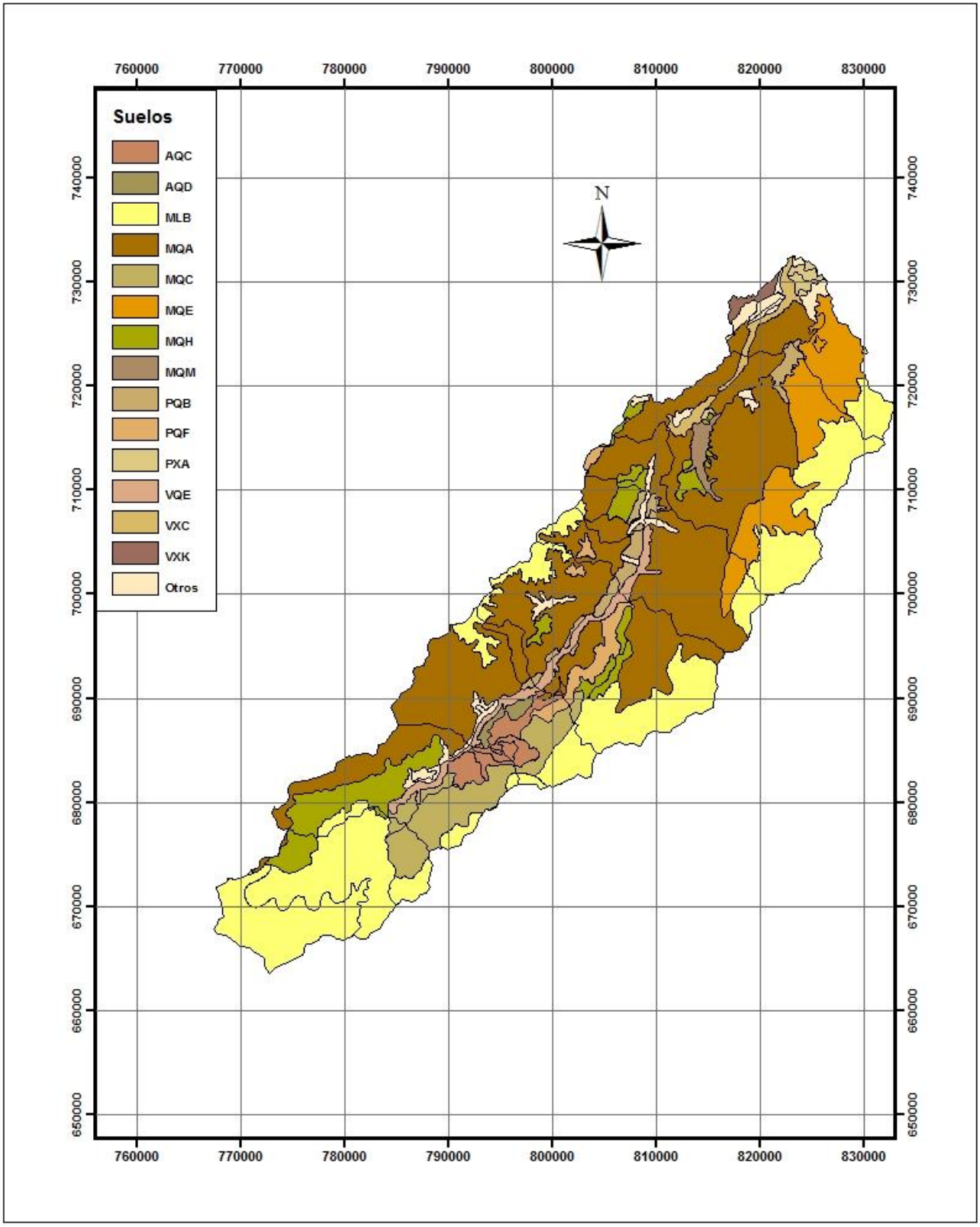
Figure 2.7 shows the most representative types of soils of the Suaza River Basin, considering only the first three letters of its definition – slope range and erosion are discussed in other figures. Table 2.13 Type of Soil Representative of Each Sub-Basin Area (percent) shows the percentages of each sub-basin area occupied by the soil types. The most important soil types were MQA, MLB, MQH, MQE, and MQC.

Table 2.13 Type of Soil Representative of Each Sub-Basin Area (percent)

Types of soil	Sub-basins								Total basins
	1	2	3	4	5	6	7	8	
MQA	0.6	23.4	49.1	47.8	69.2	66.0	44.4	19.8	39.0
MLB	84.4	8.3	18.5	30.5	11.8	1.3	22.8	14.0	27.4
MQH	6.6	25.9	0.0	6.4	0.0	17.1	3.0	0.0	6.5
MQE	0.0	0.0	0.0	0.0	6.1	0.0	20.0	34.1	7.7
MQC	8.3	26.1	9.9	0.9	0.0	0.0	0.0	0.0	5.5
PQF	0.0	0.0	2.2	6.5	1.6	3.0	0.0	0.0	1.8
AQC	0.0	8.4	10.5	0.0	0.0	0.0	0.0	0.0	2.2
MQM	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.7
VQE	0.0	4.0	3.3	3.6	4.5	0.0	0.0	0.0	2.0
VXC	0.0	0.0	0.0	0.0	0.0	0.1	2.4	7.6	1.1
PQB	0.0	0.0	0.5	2.7	4.9	6.8	2.1	0.7	1.9
VXK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.4
AQD	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.4
PXA	0.0	0.0	0.0	0.0	0.0	0.0	0.2	5.8	0.5
OTHER	0.1	3.8	2.4	1.5	1.9	5.8	1.6	12.9	2.9
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Abt Associates

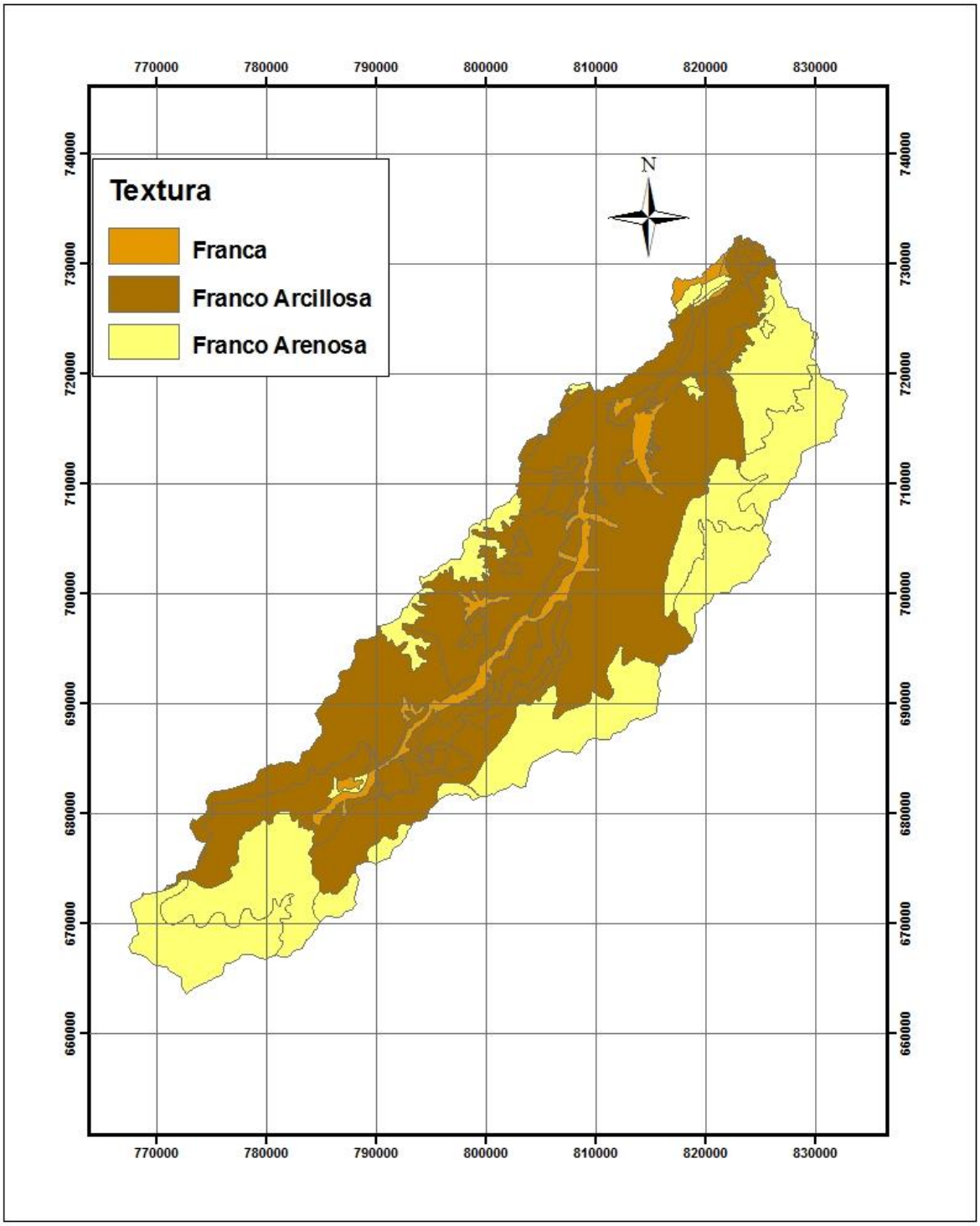
Figure 2.7 Soils of the Suaza River Basin



Source: CAM

Figure 2.8 shows major soil texture classes (Franca Loam; Franco Arcilloso: Silt Clay Loam; Franco Arenoso; Sandy Loam). Sandy loam is the main soil texture in the upper basin area of the Suaza River and high parts of the right drainage area. Silty clay loam and loam are the main textures in the middle and low basin areas and a very few valleys.

Figure 2.8 Texture of Soils Representative of the Suaza River Basin



Source: Abt Associates

Figure 2.8 shows that sandy loam is the main soil texture found in the upper basin area at the birth of the Suaza River and in the high parts of the right drainage area; while clay loam and loamy are the main textures found at the mid and low basin areas and in a very few valleys.

Table 2.14 Representative Soil Textures of the Sub-Basins (Percent)

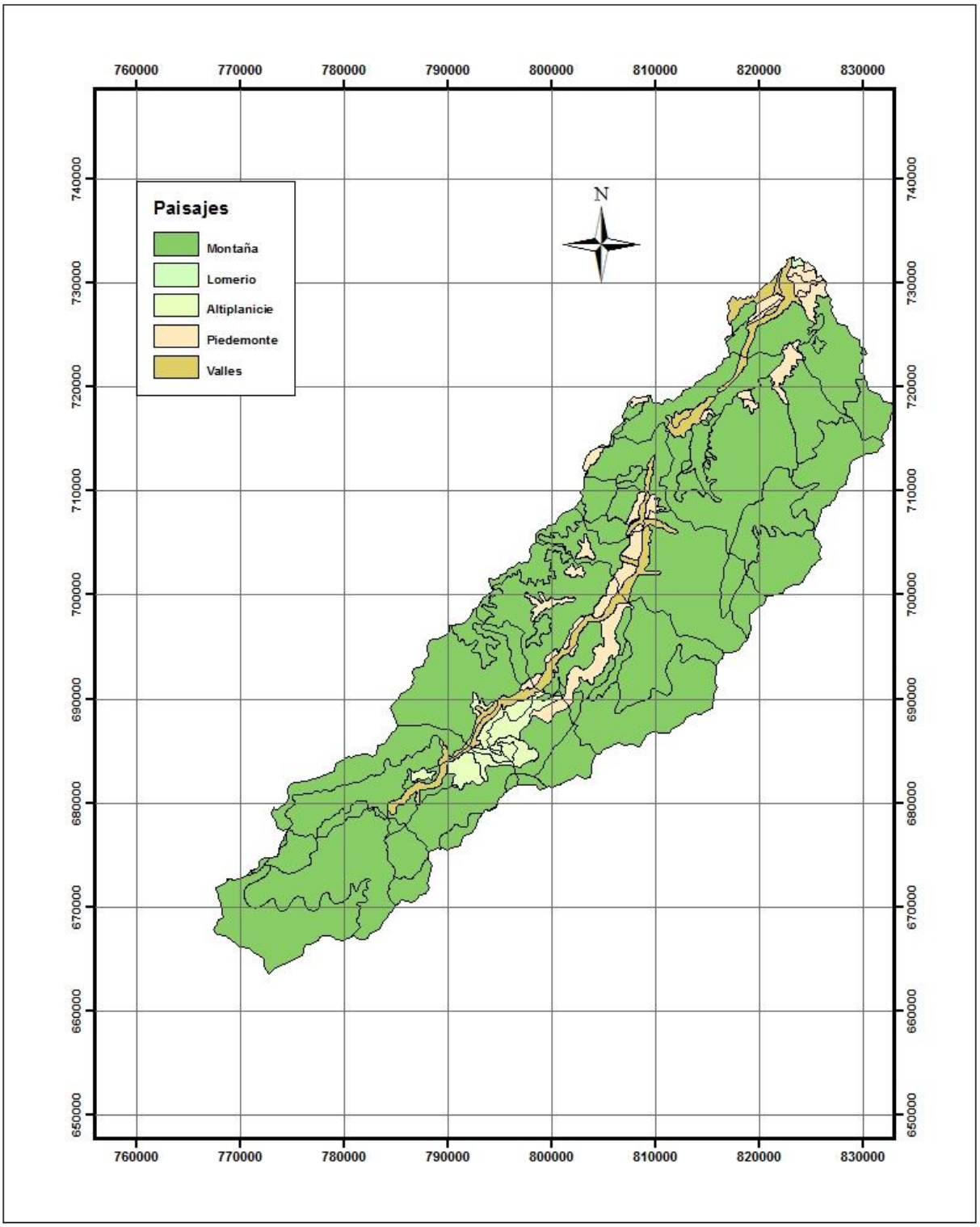
Texture	Sub-basins								Total basin
	1	2	3	4	5	6	7	8	
Sandy Loam	84.4	9.8	18.5	0.0	17.9	1.3	43.9	54.5	30.5
Loam	0.1	5.1	4.4	5.1	6.5	5.8	3.9	6.2	4.3
Clay Loam	15.5	85.0	77.1	94.9	75.7	92.9	52.3	39.3	65.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Abt Associates

Figure 2.9 shows typical Suaza River Basin landscapes[2], mainly mountainous with piedmonts and valleys. Figure 2.10 includes the erosion process at the basin level. Erosion is low in the upper basin and moderate in the mid and lower basin.

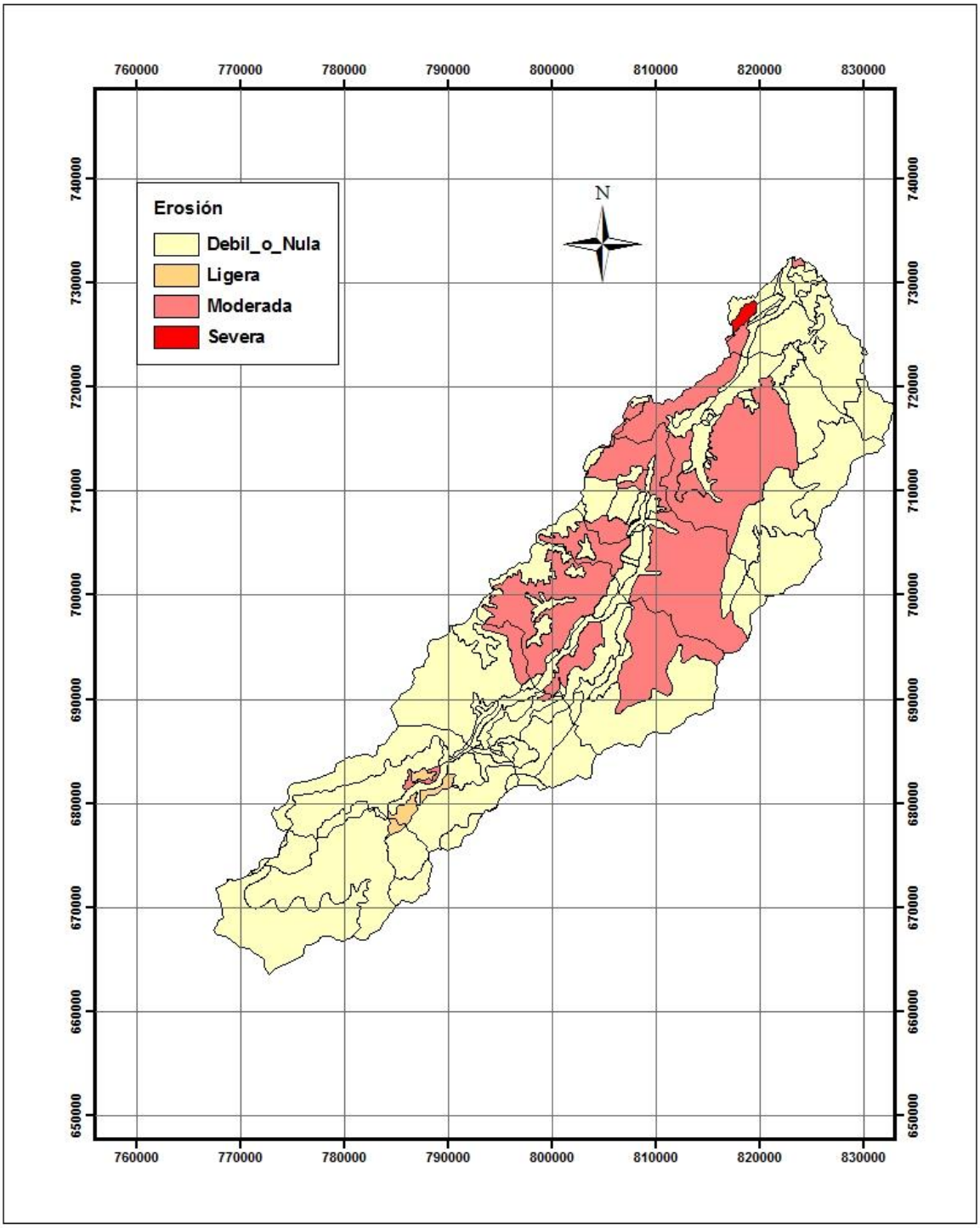
[2] Montaña: Mountain; Lomerio: Low Hills; Altiplanicie: High Plateau; Valles: Valleys

Figure 2.9 Landscape at the Suaza River Basin



Source: CAM

Figure 2.10 Extent of Erosion in the Suaza River Basin



Source: CAM

2.5. Vegetation and Land Use Data

The CAM provided data on the vegetation and land use of the department of Huila in Geographic Information Systems (GIS) shapes.

Table 2.15 Representative Vegetation and Land Use of Each Sub-Basin (Percent)shows the types of vegetation and land use prevalent in the Suaza River sub-basins. The sub-basin map was overlaid with the vegetation and land use map, to obtain these results.

Table 2.15 Representative Vegetation and Land Use of Each Sub-Basin (Percent)

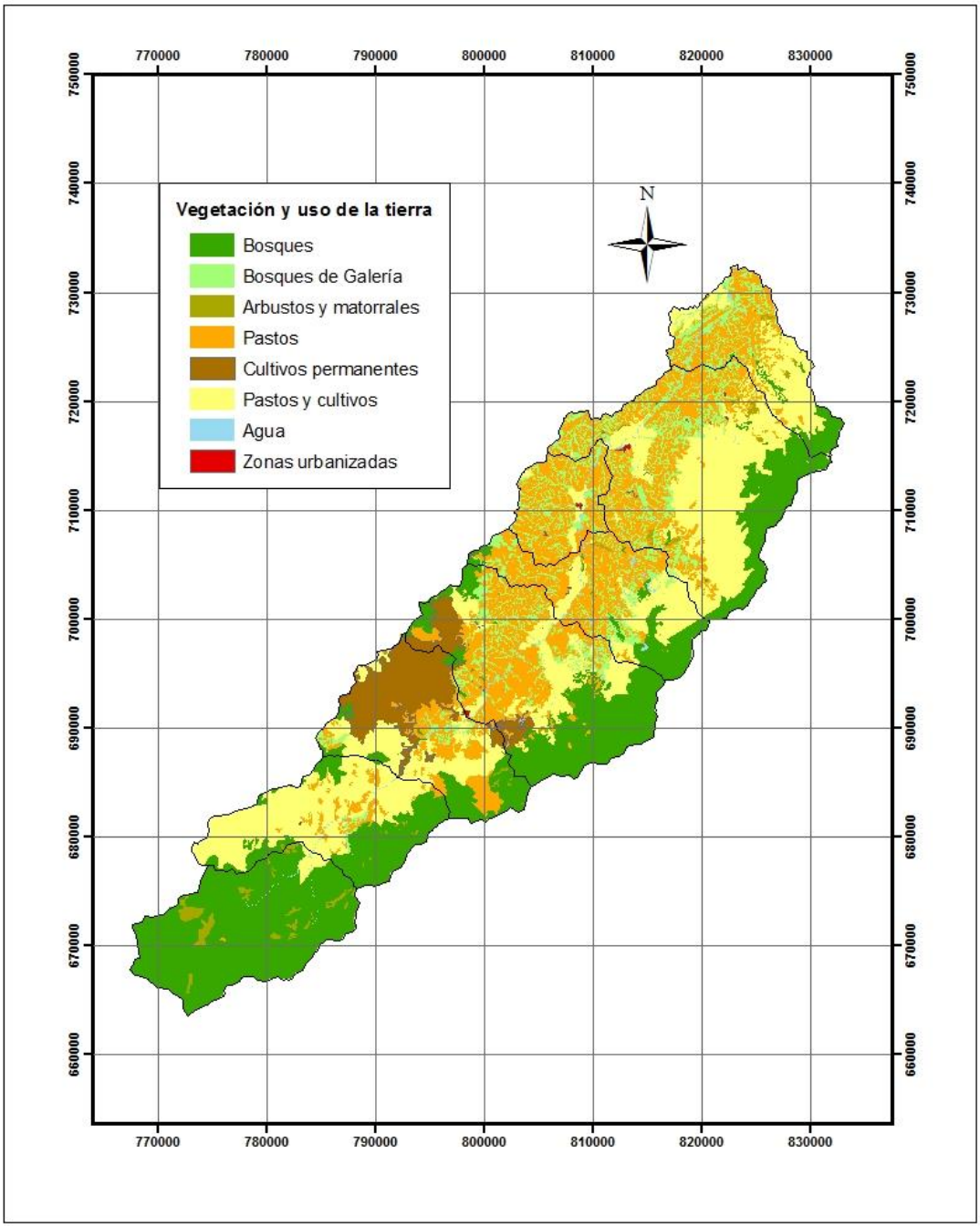
Vegetation and Land Use	Sub-basins								Whole Basin
	1	2	3	4	5	6	7	8	
Forest	91.8	34.8	17.0	34.0	17.5	0.0	18.7	10.3	31.0
Riparian Forest	0.0	0.9	3.5	10.3	15.6	26.9	14.4	17.5	9.9
Shrubs and bushes	5.6	0.4	0.5	0.4	0.3	0.0	0.8	1.2	1.2
Pastures	0.0	7.0	18.3	31.1	39.8	64.9	27.8	33.6	24.7
Perennial Crops	0.0	0.0	35.7	7.6	0.1	0.0	0.0	0.0	5.7
Pastures and crops	2.2	56.3	24.6	15.9	25.1	6.8	37.5	36.4	26.7
Water	0.3	0.5	0.3	0.5	1.5	0.9	0.5	1.0	0.6
Urbanized Areas	0.0	0.1	0.1	0.2	0.1	0.5	0.3	0.0	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Abt Associates

The major types of vegetation and land uses along the entire basin are forests, meadows, pastures, and crops; riparian forests are located along water courses. The most common vegetation and land uses in the upper basin are forests, pastures, and a combination of pastures and crops. Grasses, a combination of pasture and crops, and riparian forests dominate the lower basin.

Field visits made it clear that the perennial crops are mostly coffee. About 80 percent of the transitory crop mixed with grasslands is passion fruit (maracuyá). On a smaller proportion, small observed areas were planted with pumpkin (*Ccurbita maxima* known as squash), maize, banana, cassava, onion, vegetables, lulo (*solanum quitoense* also known as naranjilla), blackberries, and citrus.

Figure 2.11 Vegetation and Land Use[3], Suaza River Basin



Source: CAM

Figures 2.12 to 2.15 show the vegetation in selected areas of the Suaza River Basin.

[3] Bosques: Forest; Bosques de Galeria; Riparian Forest; Arbustos y Matorrales: Shrubs; Pastos: Paxture; Cultivos Permanentes: Perennial Crops; Agua: Water; Zonas Urbanizadas: Urban Areas

Figure 2.12 Suaza River Between the Municipalities of Guadalupe and Suaza

Source: Abt Associates

Figure 2.13 Pastures Near the Urban Limits of Suaza

Source: Abt Associates

Figure 2.14 Passionfruit Cultivation Upstream of Suaza

Source: Abt Associates

Figure 2.15 Suaza River Upstream from the Bridge over Road 45 in South Huila Department (Gallery Woods)

Source: Abt Associates

2.6. Water Use Concessions in the Suaza River Basin

Annex 2.3 Confessions for the Use of Water at the Suaza River Basin provides detailed information on water use concessions throughout the Suaza River Basin. The table provided lists using the following information:

- User name
- User type
- Municipality
- Location
- Watercourse used
- Concession in liters per second (lps)

Table 2.16 Water use concessions summarizes the water use concessions for each municipality and the total for the whole basin level, about one cubic meter per second (1 m^3/s).

Table 2.16 Water use concessions

Municipality	Concession (LPS)
Acevedo	72.83
Suaza	79.23
Guadalupe	103.42
Altamira	287.21
Garzón	495.25
Total	1,037.94

Source: Abt Associates

Table 2.17 summarizes water use concessions of major watercourses that discharge into the Suaza River—that amount reaches more than 90 percent of the total concession.

It is important to highlight that to date there is no concession for direct extraction of water from the Suaza River. However, the whole valley of the middle and lower basin can be irrigated with water from this river. Therefore, a major future irrigation project could be established in these valleys, in the municipalities of Suaza and Guadalupe.

Table 2.17 Water Use Concession at the Main Suaza Tributaries

Watercourses	Concession (LPS)	Municipality
Qda. Agua Caliente	466.42	Garzón
Qda. La Pescada	282.32	Altamira
Qda. El Emayá	45.39	Suaza
Qda. La Pintada	40.85	Guadalupe
Qda. La Viciosa	23.10	Guadalupe
Qda. La Correntosa	18.00	Acevedo
Qda. La Cuerva	18.00	Suaza
Qda. La Cristalina	15.05	Acevedo
Qda. La Perica	12.32	Guadalupe
Qda. Chontaduro	10.62	Garzón
Qda. La Callejona	8.16	Altamira
Qda. Las Perlas	5.30	Suaza

Source: Abt Associates

2.7. Prior Studies

This section lists previous hydrologic studies on the Suaza River Basin.

2.7.1. Studies from the Internet and Colombian institutions

- Álvarez, J.A. 2006. "*Análisis de la variación de caudales en la cuenca alta del Río Magdalena, Colombia, en fases extremas del ENSO1"*. School of Civil Engineering, La Salle University. Research Magazine, ISSN 16576772. Vol. 6 (1): 29-40. Bogotá, Colombia.
- Arango C., Dorado J., Guzmán D. and J.F. Ruiz. 2012. "*Cambio climático más probable para Colombia a lo largo del siglo XXI respecto al clima presente*. Grupo de Modelamiento de Tiempo, Clima y Escenarios de Cambio Climático Subdirección de Meteorología" – IDEAM. Bogotá, Colombia.
- Mayorga R., Hurtado G. and H. Benavides. 2011. "*Evidencias de cambio climático de Colombia con base en información estadística*." IDEAM-METEO/001-2011. IDEAM Technical Note. Bogotá, Colombia.
- Benavides H.O. and Rocha C.E. 2012. "Indicadores que manifiestan cambios en el sistema climático de Colombia (Años y décadas más calientes y las más y menos lluviosas)". IDEAM-METEO/001-2012. IDEAM Technical Note. Bogotá, Colombia.
- Caicedo, F. M. 2009. "Programa Piloto Nacional de Adaptación al Cambio Climático - INAP – (Integrate National Adaptation Program) Componente B – Alta Montaña." Ministry of the

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- CORMAGDALENA – Fluidis. 2007. Proyecto FFEM CORMAGDALENA. Plan de manejo de la cuenca del Río Magdalena – Cauca. - Segunda Fase. CORMAGDALENA, Bogotá, Colombia.
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- Restrepo J.C. y J.D. Restrepo. 2005. "*Efectos naturales y antrópicos en la producción de sedimentos en la cuenca del Río Magdalena"*. Rev. Acad. Colomb. Cienc. 29(111): 234-254. ISSN 0370-3908.
- Ruiz J.F. 2010. "Cambio climático en temperatura, precipitación y humedad relativa para Colombia usando modelos meteorológicos de alta resolución." Deputy Directorate of Meteorology. IDEAM. Bogotá, Colombia.
- Téllez-Guio P., Boshell-Villamarín J.F y J. A.Zea-Mazo. 2001. "*Proyecciones en los cambios del balance hídrico en Colombia bajo alteraciones en el contenido del dióxido de carbono"*. Colombian Meteorology, N° 4. Pp 87-102. ISSN-0124-6984. Bogotá, Colombia.
- USAID-FCMC. 2012. *Huila 2050: "Preparándose para el Cambio Climático. Propuesta para discusión"*. Neiva, City Hall CAM and the Department of Huila. Neiva, Colombia.

2.7.2. Studies documented at CAM´s database

- *"Mapa Geológico del departamento del Huila2*. Escala 1:300.000. 2001. República de Colombia-Environment, Housing and Territorial Development, Ministry of Mining and Energy – Geoscientific, Mining, Environmental and Nuclear Research and Information Institute – INGEOMINAS.
- "*Plan de Ordenamiento y Manejo de la Cuenca Hidrográfica Quebrada Garzón. Fase Formulación*." 2008. Institute for the Sustainability of Development -ISD. Colombian Natural National Parks. Regional Autonomous Corporation of Alto Magdalena-CAM. Scientific Cooperatrion Agreement 158 of 2008.
- "Diseños de Obras de Control de Amenazas Naturales del Río Suaza y Las Quebradas Satia y La Viciosa en los Cascos Urbanos de los Municipios de Suaza y Guadalupe, Departamento del Huila." 2009. National University of Colombia – School of Engineering – Hydraulic Tests Laboratory. Regional Autonomous Corporation of Alto Magdalena - CAM. Admnistrative Contract LEHUN - CAM-450-2008.
- "Evaluación de las Amenazas Potenciales de Origen Geológico (actividad sísmica y volcánica), Geomorfológico (remociones en masa y erosión) e Hidrometeorológico (dinámica fluvial, inundaciones y sequías), y Caracterización Geotécnica Preliminar de las Cabeceras Municipales

del Departamento del Huila. Convenio no. 193 de 1998". 1999. National University of Colombia in Medellín. Environmental Studies Institute IDEA – UN. CAM. Regional Autonomous Corporation of Colombia.

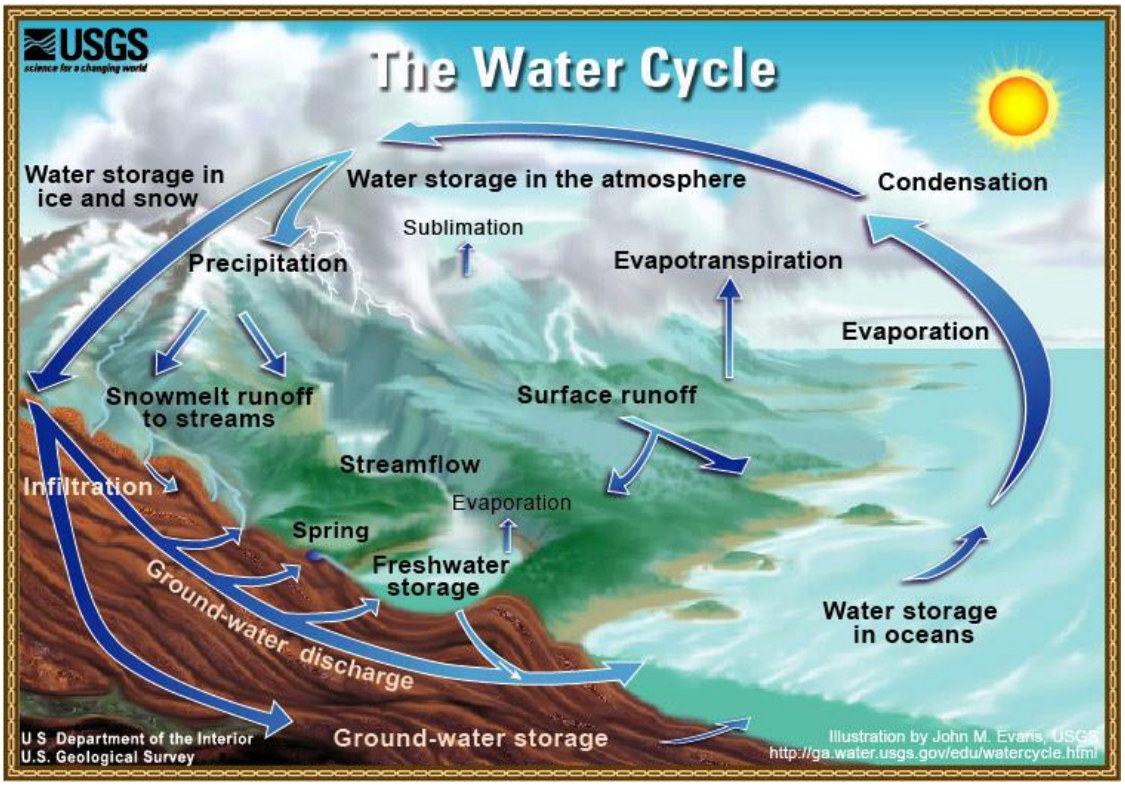
- "Determinación de la Pérdida de Suelo por Escorrentía (Real y Simulada) en la cuenca Alta del Río Magdalena, comparando diferentes arreglos productivos implementados por el Proyecto Corredor Biológico entre los Parques Nacionales Naturales Puracé y Cueva de Los Guácharos. 2007". Surcolombiana University. Astrid Lorena Dussan. Adriana Vargas Narváez. Armando Torrente Trujillo. Camilo Augusto. Agudelo Perdomo.
- "*Mapa de Cobertura de la Tierra 2010, Departamento del Huila"*. 2011. Protected Natural Areas Corporation ANP – Regional AutonomousCorporation of Alto Magdalena – CAM - Contract 013 of 2010.

3. IMPLEMENTATION, CALIBRATION AND APPLICATION OF THE RAINFALL-RUNOFF MODEL

3.1. Applying the Systems Concept to the Hydrologic Cycle Modeling

The quantification of the different components of the hydrologic cycle (Figure 3.1) and the interrelationships among them is complex and varies temporally and spatially. As a result, these components are grouped into subsystems that are often analyzed separately and then the results are combined.

Figure 3.1 Hydrological Cycle



Rainfall-runoff models use mathematical formulas to represent each of the processes that make up the water cycle and their interrelationships to estimate surface runoff from rainfall. Watershed features (soil, geomorphology, vegetation, and land use) are introduced into these models as parameters. The most important use of rainfall-runoff models is the estimation of surface runoff in hydraulic harvesting sites (reservoirs, diversions, etc.) that do not have any information recorded in the hydrometric measuring stations.

Various rainfall-runoff simulation models are available. The Monthly Hydrological Simulation Model (SIHIM) is widely used in the first phase of similar studies in Latin America. This model was developed at the American Center for Land and Water Development (CIDIAT) (Duque 1985).

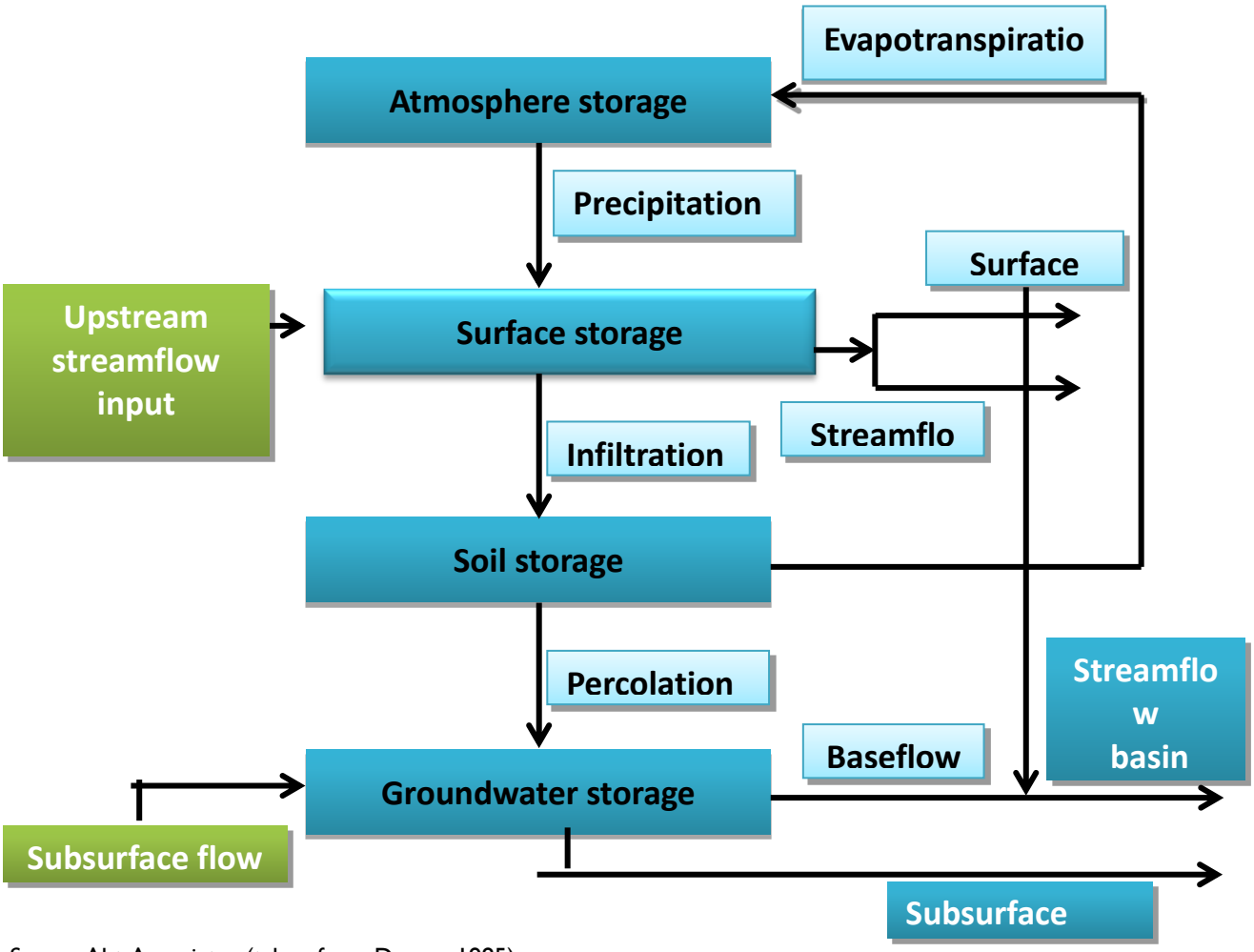
The SIHIM model uses data from representative rainfall stations and relative importance weights associated to each station in the sub-basin to calculate the average areal rainfall. After the SIHIM model was calibrated, the Soil Water Assessment Tool (SWAT) model was applied to obtain daily estimates of flows and sediment.

Figure 3.2 shows a schematic model of the SIHIM components using monthly rainfall and evapotranspiration in each of the sub-basins. Calibration of this model requires monthly average flows for the same periods used in the rainfall and evapotranspiration modeling. The SIHIM model considers the rainfall, evapotranspiration, infiltration, percolation, and baseflow from groundwater and surface storage; surface and groundwater flows coming from upper watersheds; and flows that leave the sub-basins.

The following activities were performed to calibrate the SIHIM model:

- Using map data and/or digital elevation models to delineate the basin and its main sub-basins.
- Select representative hydrometric or gauging stations that will be used in the model calibration process.
- Analyze the monthly mean flows for each of the hydrometric stations and choose a reporting period that matches the climate information from the sub-basins that make up the total basin.
- Analyze the characteristics of the sub-basins, regarding vegetation and land use, soil types, and calculate their morphometric characteristics.
- Select the model input values and calibrate, changing the parameter values until a better match between the series of historical and simulated flows is achieved for the selected period.
- Extend the model through the entire basin and the entire period with adequate climate information.
- After calibrating and applying the rainfall-runoff model on a monthly basis, calibrate the rainfall-runoff model on a daily basis (SWAT).
- Apply both models using the full range of weather data to generate a series of flows that is representative of current conditions; this will then be compared to those obtained in order to consider future climate conditions from climate change.

Figure 3.2 SIHIM Model



Source: Abt Associates (taken from Duque, 1985)

3.2. Temporary and Spatial Variation of Rainfall

According to the Climate Atlas (IDEAM 2010a), this basin is influenced by the Intertropical Convergence Zone (ITCZ), a strip of clouds and strong rainfall that changes position throughout the year (moving between 2° and 10° north latitude) due to the earth's orbit around the sun.

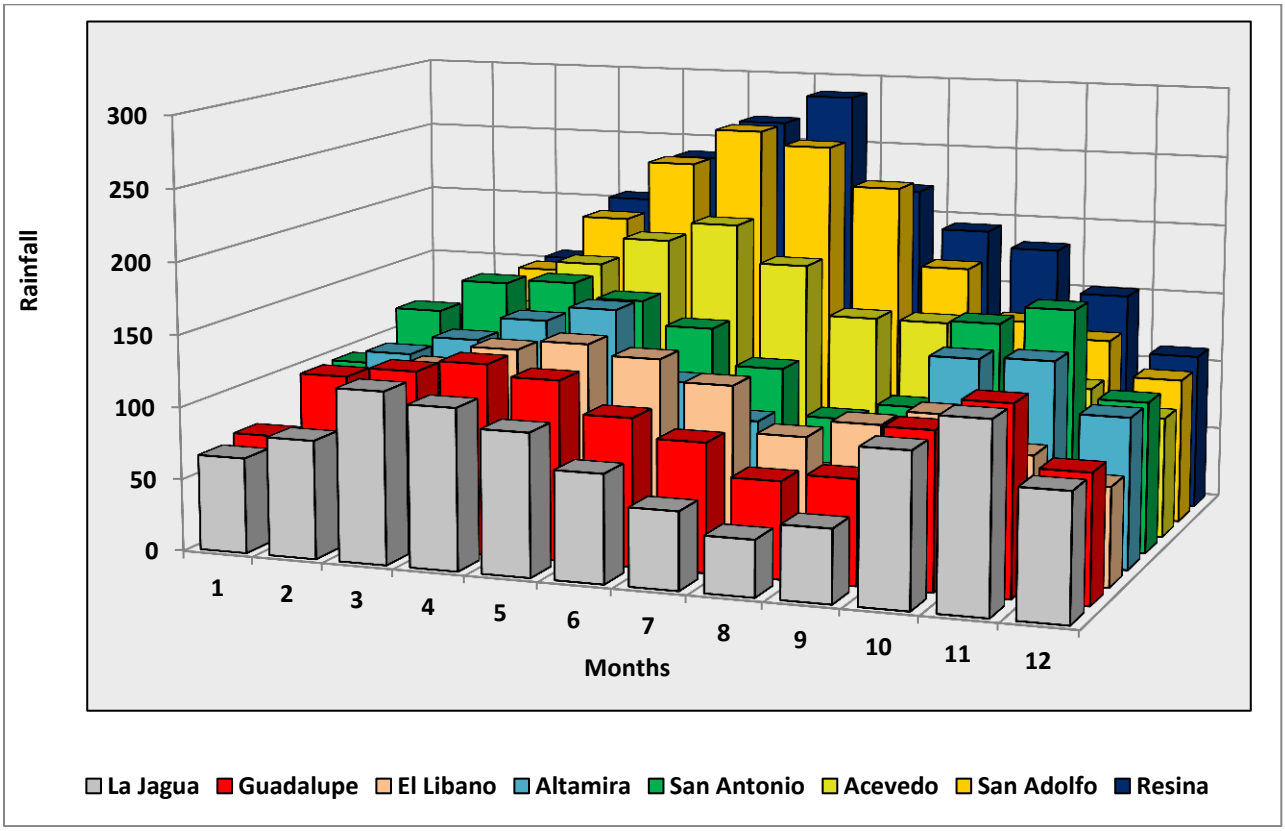
The effect of the ITCZ on the Magdalena River Basin generates a rainfall pattern characterized by two rainy and two dry periods. This bimodal pattern disappears along the North-South, until reaching a distribution with a rainy mid-year and a unimodal distribution due to local weather conditions.

> "The relief also serves important functions with regard to rainfall, since it intercepts the wind and erects barriers that contribute to more rainfall in the outer slopes of the mountain ranges—that is, on their windward side—that in the inner slopes, are downwind. The Magdalena-Cauca Basin, due to its Inter-Andean features, is downwind of major planetary atmospheric motions. These effects of the relief on the movement of air and rains are intensified locally with valley-mountain circulations and orographic rains that cause wet and dry

areas in various parts of the basin, such as in the erosion transverse valleys of several tributaries of the Magdalena and in the highlands of the Cordillera Oriental (Eastern Range)" (IDEAM 2010a).

Figure 3.3 Monthly Average Rainfall, Suaza River Basinshows both the spatial and temporary variation of the monthly average rainfall at the Suaza River Basin.

Figure 3.3 Monthly Average Rainfall, Suaza River Basin



Source: Abt Associates

The upper part of the basin (San Adolfo and Acevedo Stations) has a unimodal pattern of precipitation, with increased rainfall from May to July and minimal rainfall between December and January, with annual averages ranging from 1,600 to 2,000 millimeters. It is estimated that in the upper basin, precipitation must exceed 3,500 millimeters, since in Cueva Los Guácharos Station, which has a few years of records, there have been annual totals of around 3,000 millimeters.

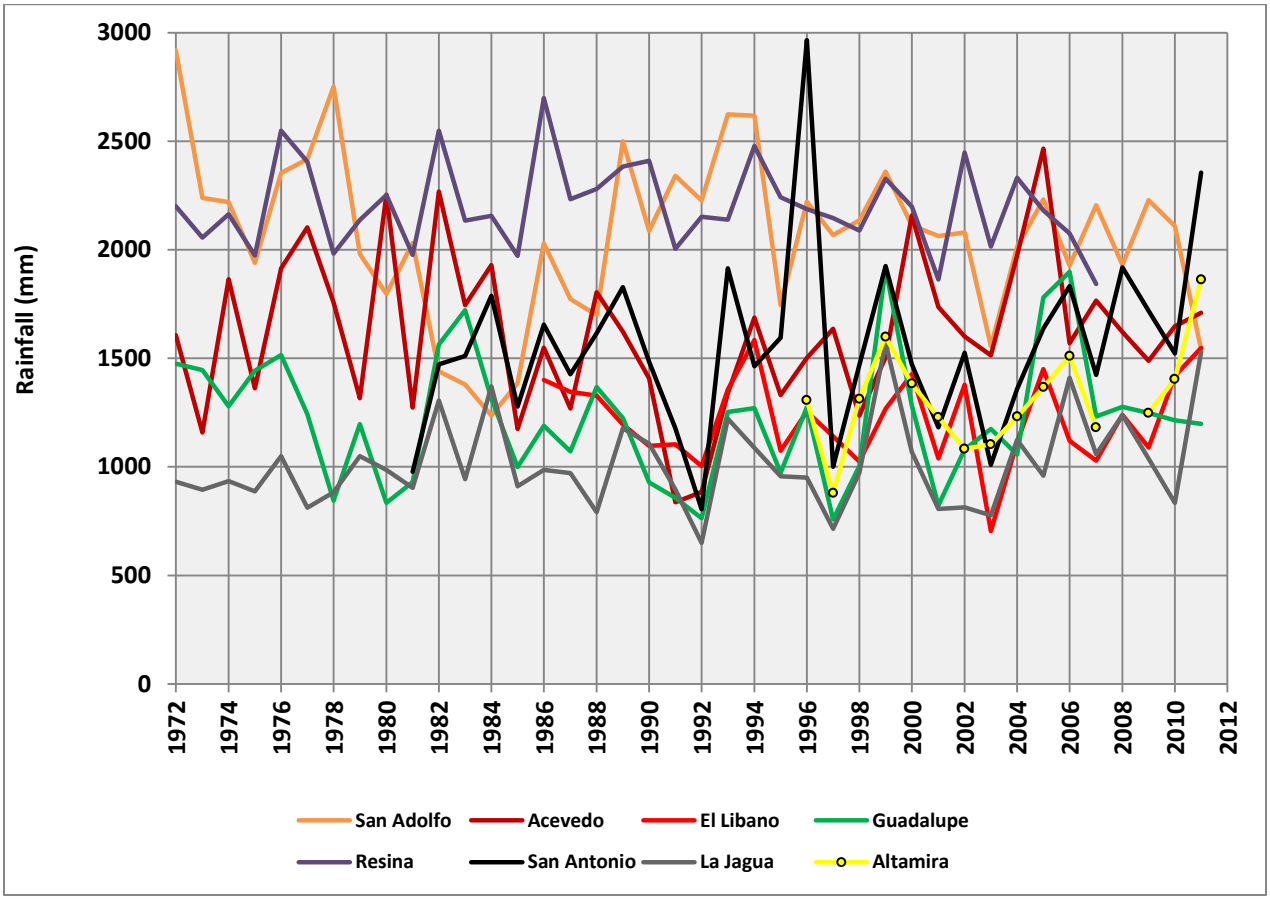
From El Líbano Station until the Suaza River discharges into the Magdalena River, there is a bimodal distribution of monthly average rainfall, with the bimodality enhanced in the south-north direction. At La Jagua Station (located at the northern end of the basin), this bimodality presents two rainy periods with maximum values in March and November and minimum values in January and August. At La Jagua, the average annual rainfall is reduced to a value around 1,000 millimeters. The highest annual average rainfall of 2,200 millimeters occurs at the Resina Station in the lower part of the basin, but at an altitude of around 2,100 meters above sea level along the Cordillera Oriental (Eastern Mountain

Range), and its distribution is unimodal, similar to the one observed at the upper Suaza Basin(figure 2.3).

These analyses reflect the importance of rainfall spatial variation in this basin, which requires a need for a large number of gauging stations to monitor this variability.

Figure 3.4 shows total annual rainfall for all representative rainfall stations in the Suaza River Basin. The high variability of rainfall in the San Adolfo, Acevedo and San Antonio del Pescador Stations stands out in comparison to the rainfall variability observed at Resina.

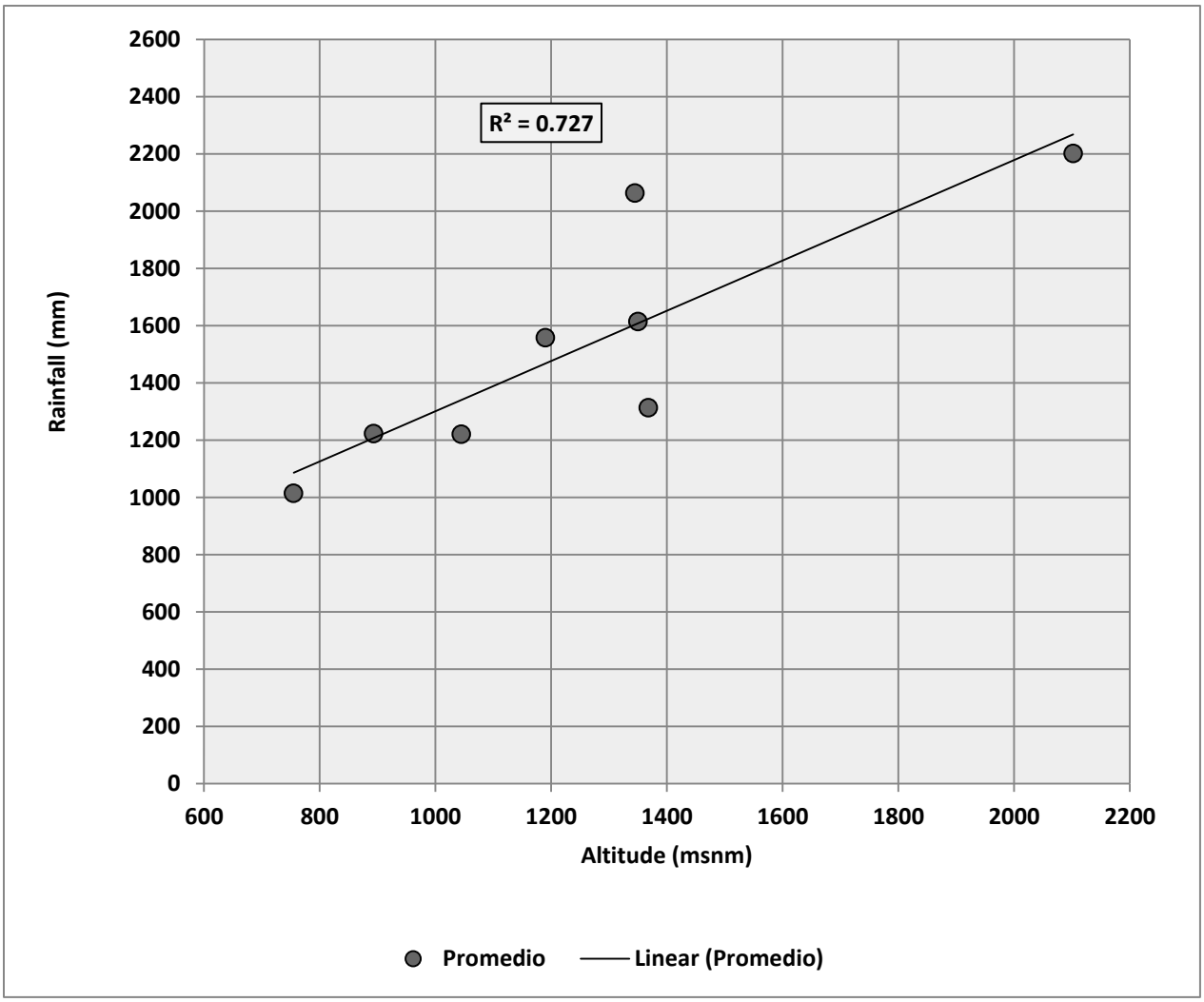
Figure 3.4 Total Annual Rainfall, Suaza River Basin



Source: Abt Associates

Figure 3.5 shows the relationship between altitude and annual average rainfall observed in each of the rainfall measuring stations. The altitude explains 73 percent of the annual average rainfall variability in the basin.

Figure 3.5 Annual Average Rainfall vs. Altitude



Source: Abt Associates

3.3. Estimation of Potential Evapotranspiration

3.3.1. Estimation method

The Penman-Monteith method, recommended by FAO (1998), is the standard method of using weather information to estimate the potential evapotranspiration of a reference crop (ETo), equivalent to grass with a five-inch height, an albedo of 0.23 and a surface resistance of 70 meters per second.

The Penman-Monteith equation is shown below:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (3.1)$$

In this equation ETo is expressed in mm per day $^{-1}$, where

$R_{n:}$ Net Radiation (MJ m^{-2} day^{-1})

G Heat flow towards the ground (MJ m^{-2} day^{-1})

γ Psychrometric Constant (kPa °C^{-1}).

This constant is estimated in accordance with the equation:

$$\gamma = \frac{C_p P}{\varepsilon \lambda_v} = 0.000665P \quad (3.2)$$

P : atmospheric pressure [kPa]

λ_v : vaporization latent heat, 2.45 [MJ kg^{-1}]

C_p : water specific heat, 1.013 10^{-3} [MJ kg^{-1} °C^{-1}]

ε : ratio between water vapor molecular weight / dry air = 0.622.

T : Mean temperature (°C)

$$T = \frac{T_{Máx} + T_{Mín}}{2} \quad (3.3)$$

e_s : Saturation vapor pressure at a T [kPa] temperature

Estimated according to equation:

$$e_s = 0.6108 \exp\left(\frac{17.27T}{T + 237.3}\right) \quad (3.4)$$

Given that the equation (3.4) is not linear, the best saturation vapor pressure estimator is the one obtained from averaging results of daily maximum and minimum temperature, according to the following equation:

$$e_s = \frac{e_s(T_{máx}) + e_s(T_{mín})}{2} \tag{3.5}$$

Δ : Slope of the saturation vapor pressure curve (kPa °C^{-1}).

$$\Delta = 4098\left[\frac{0.6108\exp\left(\frac{17.27T}{T+237.3}\right)}{(T+237.3)^2}\right] \tag{3.6}$$

e_a : Actual vapor pressure (kPa).

$$e_a = \frac{\frac{e_s(T_{mín})RH_{máx}}{100} + \frac{e_s(T_{máx})RH_{mín}}{100}}{2} \tag{3.7}$$

e_s (T_{min}) : Saturation vapor pressure at the minimum daily temperature [kPa]

e_s (T_{max}) : Saturation vapor pressure at the maximum daily temperature [kPa]

RH_{max} : Maximum daily relative humidity [%]

RH_{min} : Minimum daily relative humidity [%]

In the case that the RH_{max} and RH_{min} figures are available, the equation recommended is the one based on the mean relative humidity:

$$e_a = \frac{RH_{media}}{100}\left[\frac{e_s(T_{máx}) + e_s(T_{mín})}{2}\right] \tag{3.8}$$

RH_{med} : Daily mean relative humidity [%]

u_2 : wind speed at 2 meters height [m s^{-1}]

The CROPWAT program is recommended to calculate ETo, the evapotranspiration rate in millimeters /month (FAO 1998).

3.3.2. Applying the Penman-Monteith method using the weather data from the Resina Station

Resina is the weather station with the most information to allow the most precise application of the Penman-Monteith method in the Suaza River Basin. Table 3.1 shows monthly mean values for the maximum and minimum temperature variables, average relative humidity, wind speed, and sunshine at the station.

However, solar radiation data are absent. Therefore, the CROPWAT program was used to calculate potential evapotranspiration.

In addition to the data shown in Table 3.1, the altitude of the station (2102 m) and its geographical coordinates (longitude: -75.68°, latitude: 1.914°) are required for this model.

Table 3.1 Monthly Averages of Weather Variables at the Resina Station

Month	MinimumTemperature(°C)	MaximumTemperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)
1	13.4	21.1	85.0	144.0	3.4
2	13.5	21.1	85.0	153.0	3.3
3	13.6	21.0	86.0	151.0	2.8
4	13.7	20.8	87.0	184.0	2.7
5	13.6	20.3	87.0	186.0	3.0
6	13.0	19.8	87.0	218.0	3.3
7	12.3	19.2	87.0	212.0	3.1
8	12.5	19.5	86.0	225.0	3.4
9	13.0	20.5	85.0	205.0	3.5
10	13.4	20.8	87.0	112.0	3.0
11	13.6	20.7	88.0	79.0	2.8
12	13.6	20.8	87.0	133.0	3.1
Mean	13.3	20.5	86	167	3.1

Source: Abt Associates

Table 3.2 Estimation of Evotranspiration, Resina Station

Month	Minimum Temp. (°C)	Maximum Temp. (°C)	Relative Humidity (%)	Wind (km/ day)	Sun-shine (h/day)	Solar Radiation MJ/m²/ day	ETo	
							mm/ day	mm/ month
1	13.4	21.1	85.0	144.0	3.4	13.9	2.67	82.77
2	13.5	21.1	85.0	153.0	3.3	14.3	2.76	77.28
3	13.6	21.0	86.0	151.0	2.8	13.8	2.69	83.39
4	13.7	20.8	87.0	184.0	2.7	13.4	2.59	77.70
5	13.6	20.3	87.0	186.0	3.0	13.2	2.51	77.81
6	13.0	19.8	87.0	218.0	3.3	13.2	2.46	73.80
7	12.3	19.2	87.0	212.0	3.1	13.1	2.40	74.40
8	12.5	19.5	86.0	225.0	3.4	14.1	2.58	79.98
9	13.0	20.5	85.0	205.0	3.5	14.7	2.77	83.10
10	13.4	20.8	87.0	112.0	3.0	13.9	2.62	81.22
11	13.6	20.7	88.0	79.0	2.8	13.1	2.47	74.10
12	13.6	20.8	87.0	133.0	3.1	13.3	2.50	77.50
Mean	13.3	20.5	86	167	3.1	13.7	2.59	943.05

Source: Abt Associates

FAO has a global climate database, CLIMWAT. Some Colombian stations are included in this database and the one at Los Laureles[4] is the closest to the Suaza River Basin.

Table 3.3 shows the FAO's estimate of ETo at Los Laureles. Figure 3.6 indicates that these results at the Resina Station are similar in magnitude and temporal variation.

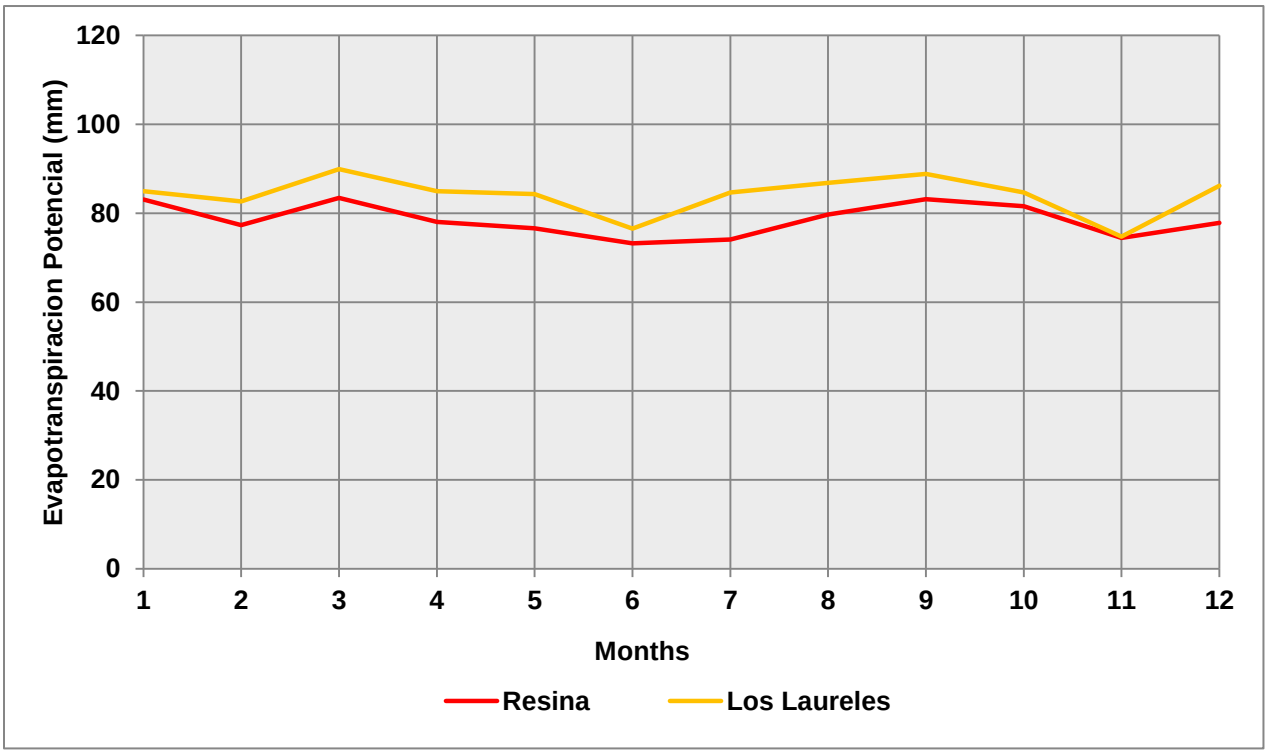
[4] Serial: 21115140, Current: Villa Vieja, Latitude: 3.094, Longitude: -74.921, Altitude: 2100 msnm

Table 3.3 Estimation of Evotranspiration, Los Laureles Station

Month	Minimum Temperature (°C)	Maximum Temperature °C)	Relative Humidity (%)	Wind (km/ day)	Sunshine/ day	Solar Radiation MJ/m²/ día	ETo	
							mm/day	mm/month
1	12.3	19	84	95	4.7	15.7	2.74	84.94
2	12.4	19.1	84	104	5.0	16.9	2.95	82.60
3	12.4	18.9	84	86	4.4	16.3	2.90	89.90
4	12.7	19.0	83	86	4.2	15.7	2.83	84.90
5	12.7	19.2	83	69	4.2	15.1	2.72	84.32
6	12.5	18.8	83	69	3.8	14.1	2.55	76.50
7	11.8	18.4	81	78	4.8	15.7	2.73	84.63
8	12.0	18.9	82	69	4.5	15.8	2.8	86.80
9	12.3	19.3	81	61	4.7	16.7	2.96	88.80
10	12.2	19.4	82	69	3.8	15.0	2.73	84.63
11	12.5	18.9	87	69	3.4	13.9	2.49	74.70
12	12.6	19.2	87	112	5.4	16.4	2.78	86.18
Mean	12.4	19	83	81	4.4	15.6	2.76	**1,008.90**

Source: Abt Associates

Figure 3.6 Evapostranspiration at the Resina and Los Laureles Stations



Source: Abt Associates

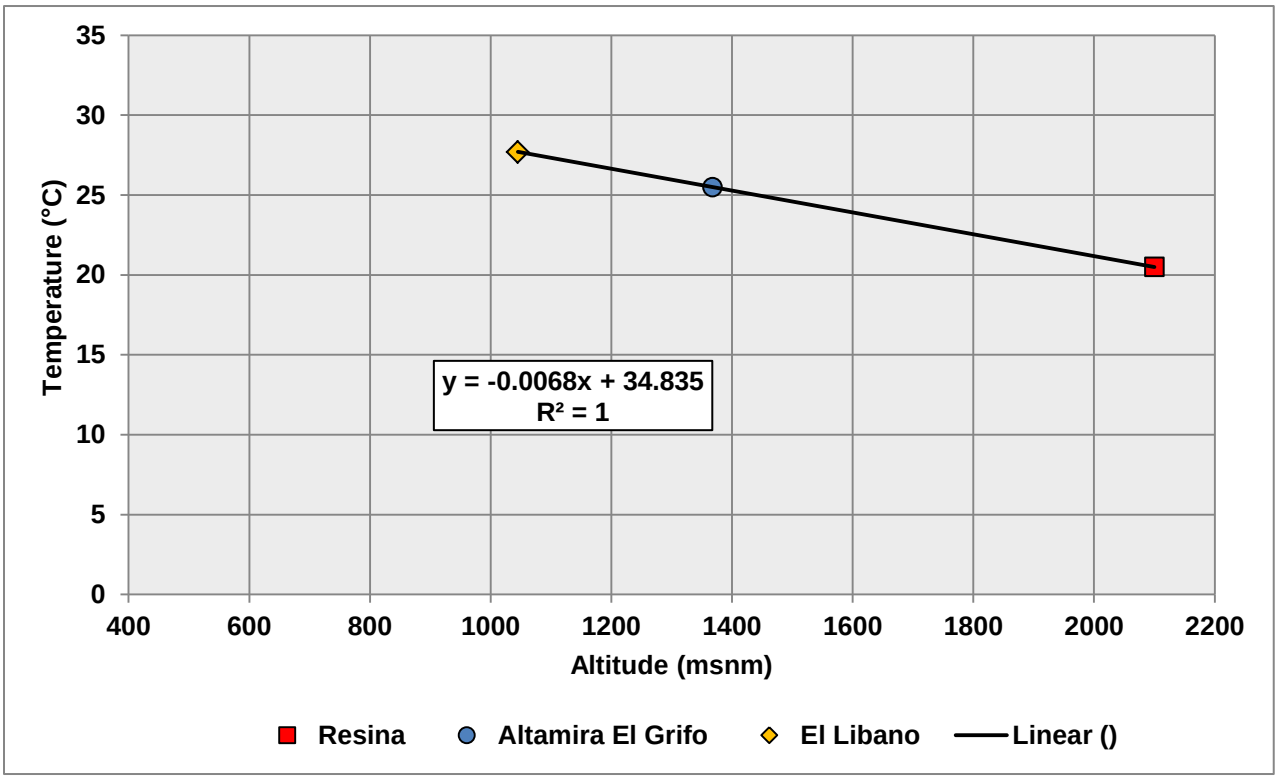
3.3.3 Estimation of evapotranspiration at the Suaza River sub-basins

Estimates of ETo in each sub-basin were made using the CROPWAT program and were based on the average altitude and geographic location for the center of each sub-basin.

The spatial variation of climatic variables was estimated using information from all weather stations within the basin. Figure 3.7 shows the spatial variation of the maximum mean annual temperature as a function of the altitude of each of the three stations located in the basin.

The maximum temperature gradient of 0.0068°C/m is similar to that shown in the Climate Atlas (IDEAM 2010a). With this temperature gradient and available data from the Resina Station on mean monthly maximum temperatures and altitude, the corresponding values for each sub-basin were estimated. A similar approach was used to estimate minimum temperatures, relative humidity, and sunshine. Wind speed was assumed constant for all the sub-basins since the information was only available for the Resina Station.

Figure 3.7 Maximum Annual Mean Temperature vs. Altitude



Source: Abt Associates

Annex 3.1 Estimate Potential Evapotranspiration shows the ETo results for each sub-basin on a monthly basis. Table 3.4 summarizes the results.

The Climate Atlas shows the potential evapotranspiration at the Suaza River Basin ranging from 1,000 to 1,200 millimeters in the upper basin, 1,200 millimeters in the mid-basin, and 1,400 millimeters in the lower basin. These published values are consistent with the results shown in Table 3.4.

Table 3.4 Estimation of Evapotranspiration at the Sub-Basin Level

Month	Resina Station	Sub-basin							
		1	2	3	4	5	6	7	8
1	83.1	85.6	94.2	93.9	93.9	95.8	112.8	104.2	108.2
2	77.3	79.2	87.4	87.4	87.1	88.8	105.0	96.9	100.8
3	83.4	85.3	93.6	93.6	93.6	95.5	111.9	103.5	107.9
4	78.0	79.8	88.5	88.5	88.2	90.0	107.1	98.4	102.6
5	76.6	79.7	88.0	88.0	87.7	89.9	106.6	98.3	102.3
6	73.2	75.9	84.3	84.6	84.3	86.4	103.5	94.8	99.3
7	74.1	76.6	84.9	84.9	84.9	86.8	103.5	94.9	99.5
8	79.7	82.5	91.8	91.8	91.5	93.9	111.9	102.9	107.3
9	83.1	86.1	95.4	95.4	95.4	97.2	116.4	106.5	111.3
10	81.5	83.4	91.1	91.1	91.1	92.7	107.6	99.8	103.9
11	74.4	75.9	82.2	82.2	81.9	83.4	96.0	89.4	92.7
12	77.8	79.7	87.7	87.7	87.4	89.3	103.9	96.4	100.1
Total	**942.1**	**969.5**	**1,069.2**	**1,069.2**	**1,067.1**	**1,089.6**	**1,286.3**	**1,186.0**	**1,235.8**

Source: Abt Associates

Table 3.5 contains the factors used to estimate evapotranspiration throughout the basin compared to the actual values at Resina.

Figure 3.8 shows the large influence of average altitude on the potential annual average evapotranspiration

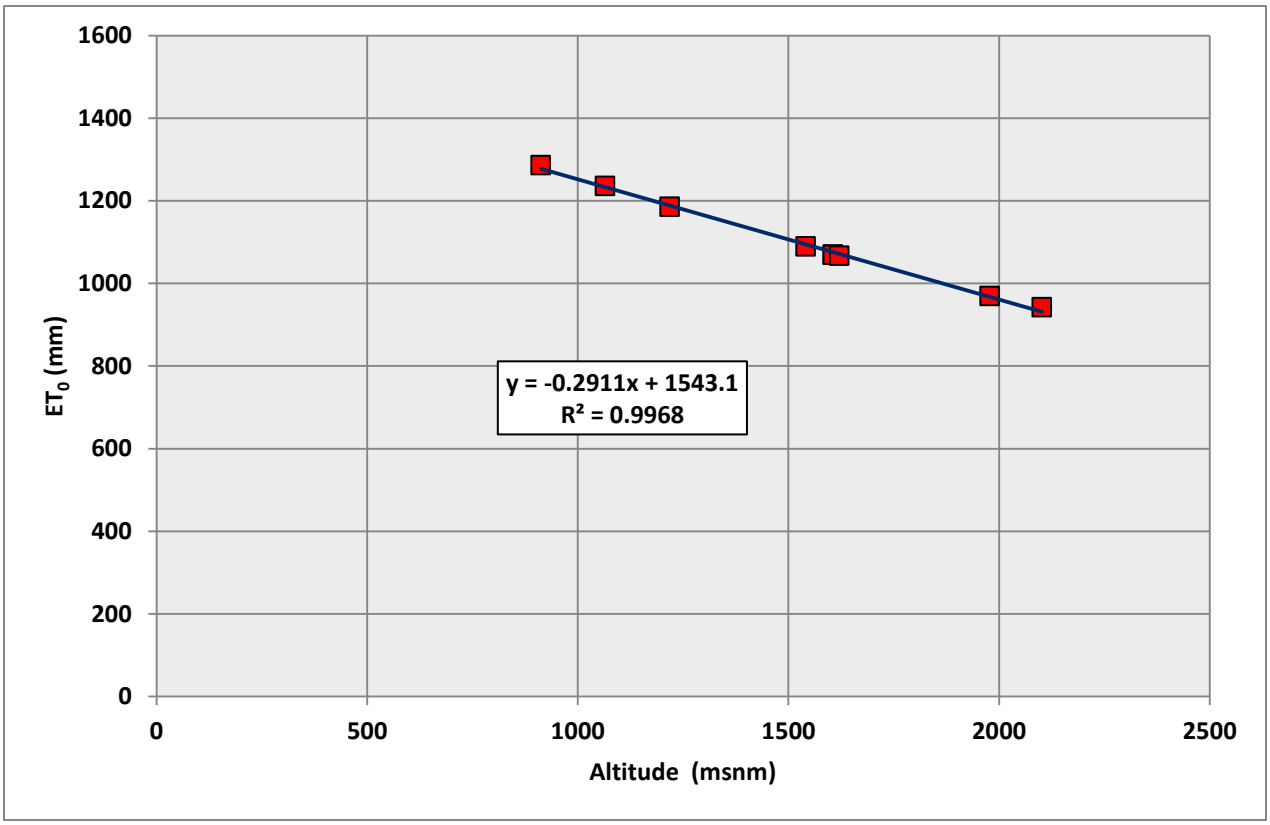
Note that the ETo values are multiplied by a Kc factor, which depends on the type of vegetation to determine potential evapotranspiration associated with the different types of vegetation. FAO (1998) contains typical values for the Kc factor.

Table 3.5 Factors to Estimate Evapotranspiration from Resina Data

Month	Resina Station	Sub-basins							
		1	2	3	4	5	6	7	8
1	1.00	1.03	1.13	1.13	1.13	1.15	1.36	1.25	1.30
2	1.00	1.03	1.13	1.13	1.13	1.15	1.36	1.25	1.30
3	1.00	1.02	1.12	1.12	1.12	1.14	1.34	1.24	1.29
4	1.00	1.02	1.13	1.13	1.13	1.15	1.37	1.26	1.32
5	1.00	1.04	1.15	1.15	1.15	1.17	1.39	1.28	1.34
6	1.00	1.04	1.15	1.16	1.15	1.18	1.41	1.30	1.36
7	1.00	1.03	1.15	1.15	1.15	1.17	1.40	1.28	1.34
8	1.00	1.04	1.15	1.15	1.15	1.18	1.40	1.29	1.35
9	1.00	1.04	1.15	1.15	1.15	1.17	1.40	1.28	1.34
10	1.00	1.02	1.12	1.12	1.12	1.14	1.32	1.22	1.27
11	1.00	1.02	1.10	1.10	1.10	1.12	1.29	1.20	1.25
12	1.00	1.02	1.13	1.13	1.12	1.15	1.33	1.24	1.29
Mean	**1.00**	**1.03**	**1.13**	**1.13**	**1.13**	**1.16**	**1.37**	**1.26**	**1.31**

Source: Abt Associates

Figure 3.8 Ratio Between Altitude and Evapotranspiration, Suaza River Basin



Source: Abt Associates

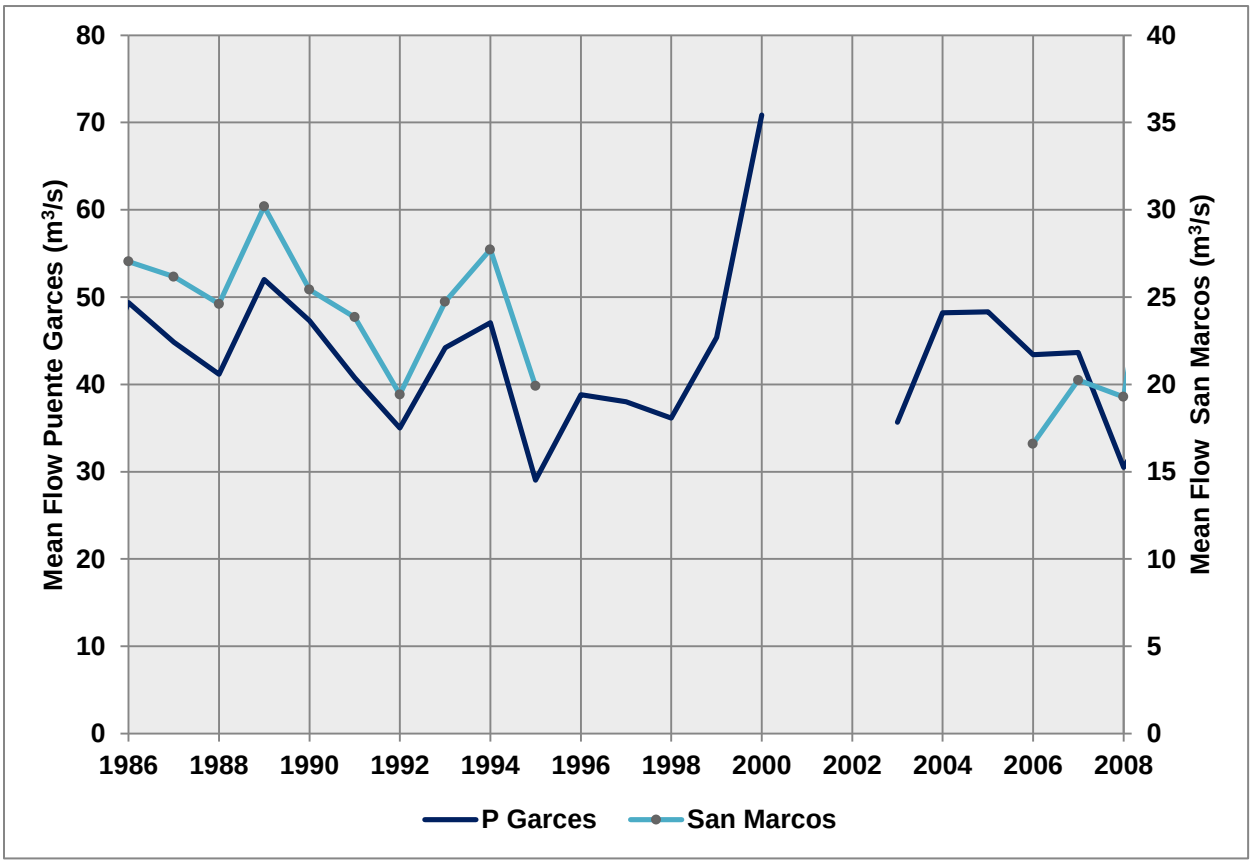
3.4. Hydrometric Data

The 1986-2007 period was selected for calibration and application of the rainfall-runoff model based on the availability of rainfall and temperature data.

Figure 3.9 compares the mean annual flows at two stations. Although the scale varied for the two stations, the annual patterns were similar in most years with available information.

Data are missing for both stations, between 1996 and 2005 for San Marcos Sstation, and in 2001 and 2002 for the Puente Garcés Station.

Figure 3.9 Annual Mean Flows in Puente Garcés and San Marcos



Source: Abt Associates

3.5. Calibration of the SIHIM Rainfall-Runoff Model

3.5.1. San Marcos Station

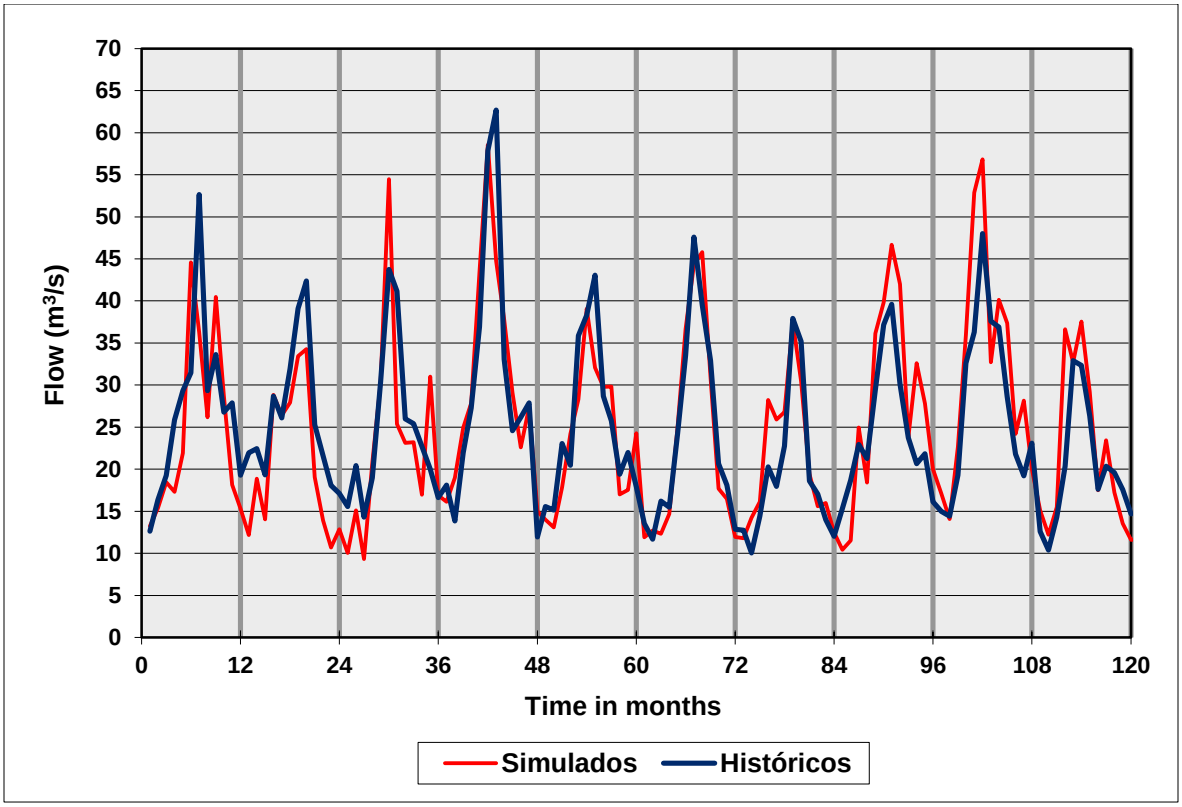
The rainfall data from the San Adolfo and Acevedo Stations and the sub-basins 1 and 2 were used to calibrate the rainfall-runoff model for San Marcos. Sub-basins 1 and 2 have tributary areas of 189.9 km^2 and 162.6 km^2, respectively.

Soils in sub-basin 1 are predominantly sandy loam in texture while they are mainly clay loam in sub-basin 2.

A calibration period from 1986 to1995 was adopted, based on Figure 3.9. Figure 3.10 shows the in monthly average flow results

Table 3.6 compares the average flows of the series, both simulated and historical, as well as the maximum and minimum values and the correlation coefficient between the series.

Figure 3.10 Calibration of the Rainfall-Runoff Model to the San Marcos Hydrometric Station, 1986-1995



Source: Abt Associates

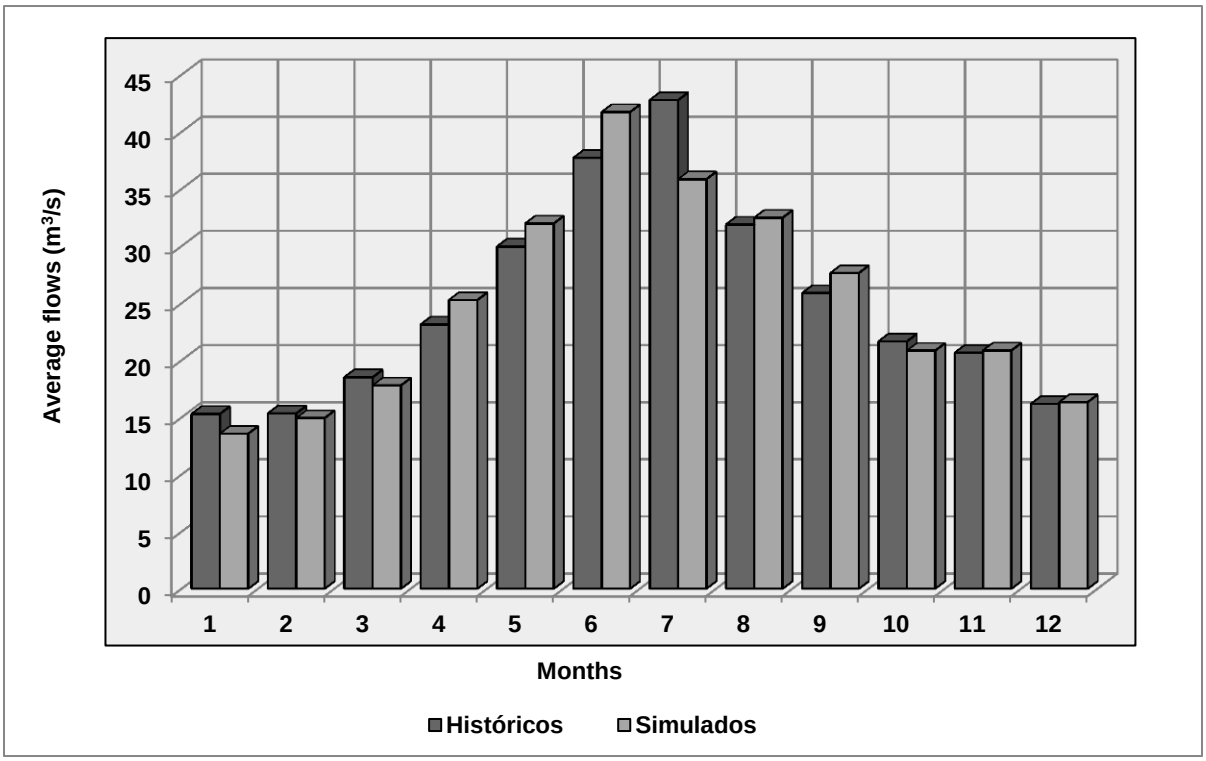
Table 3.6 Statistics of Simulated and Historical Flow Series, San Marcos Station, 1986-1995

Statistics	Flow series (m^3/s)	
	Simulated	Historical
Mean	24.931	24.909
Minimum value	9.335	10.050
Maximum value	58.527	62.700
Correlation Coefficient	0.848	

Source: Abt Associates

Figure 3.11 compares monthly average flows, simulated and historical.

Figure 3.11 Comparison of Monthly Averages in San Marcos



Source: Abt Associates

3.5.2. Puente Garcés Station

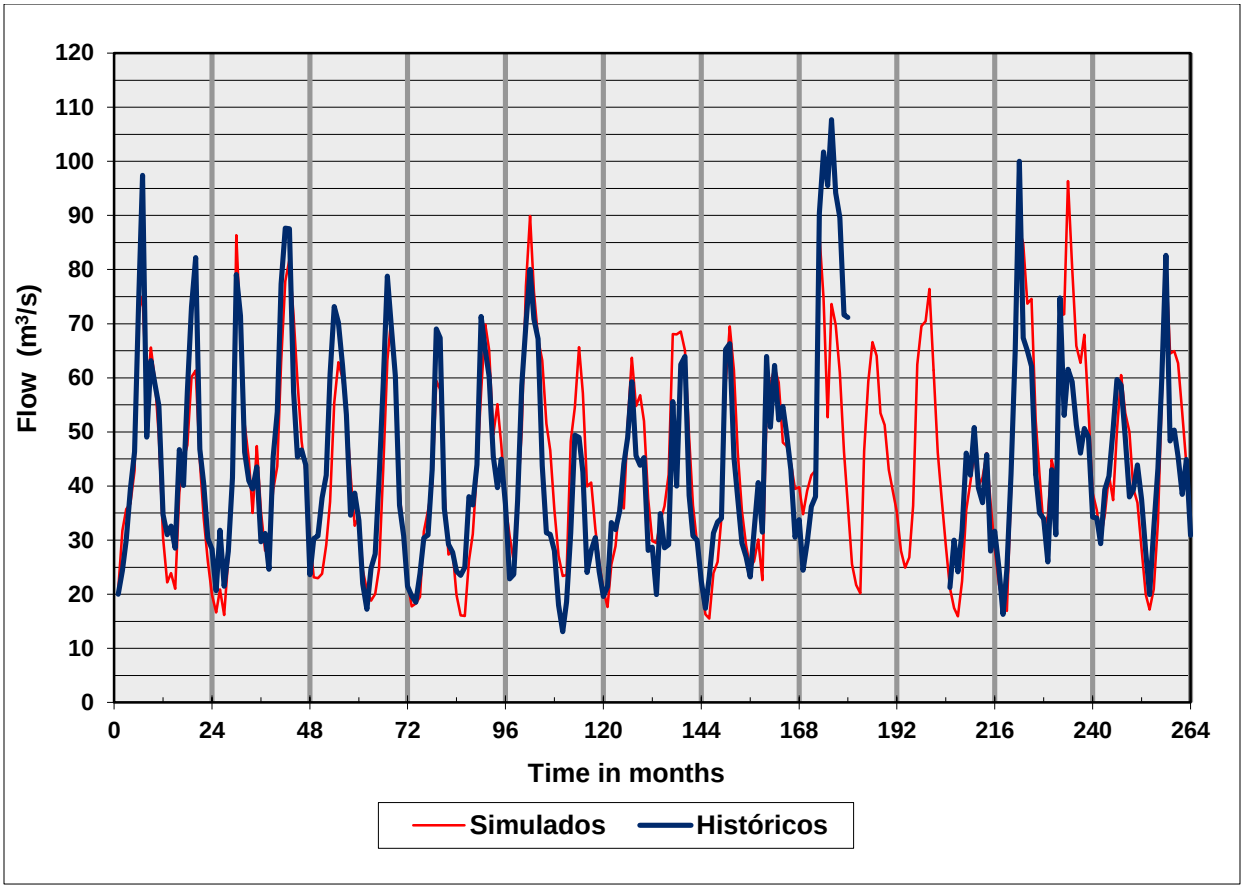
To calibrate the rainfall-runoff model up to the Puente Garcés Station, the rainfall observed in the San Adolfo, Acevedo, El Líbano, Guadalupe, and Resina Stations, and sub-basins 1, 2, 3, 4, 5, and 6, with tributary areas of 189.9 km^2, 162.6 km^2, 169.4 km^2, 259.2 km^2, 143.6 km^2, and 70.5 km^2, respectively, were used as input data.

To define the parameters of the model, it was necessary to consider the types of soils and vegetation and prevailing usage. Most sub-basins have predominant clay loam soils except for sub-basin 1, which is sandy loam.

Although data were available for 1986-2007; data on the 1986-1999 period was also used since it resulted in a better calibration.

Figure 3.12 contains the average monthly flow results for 1986-2007 compared to the data observed at the gauging station. Table 3.7 compares the simulated and historical mean flows of the series, as well as maximum and minimum values, and the correlation coefficient of the series.

Figure 3.12 Gauging of the Rainfall-Runoff Model to the Puente Garcés Hydrometric Station, 1986-2007



Source: Abt Associates

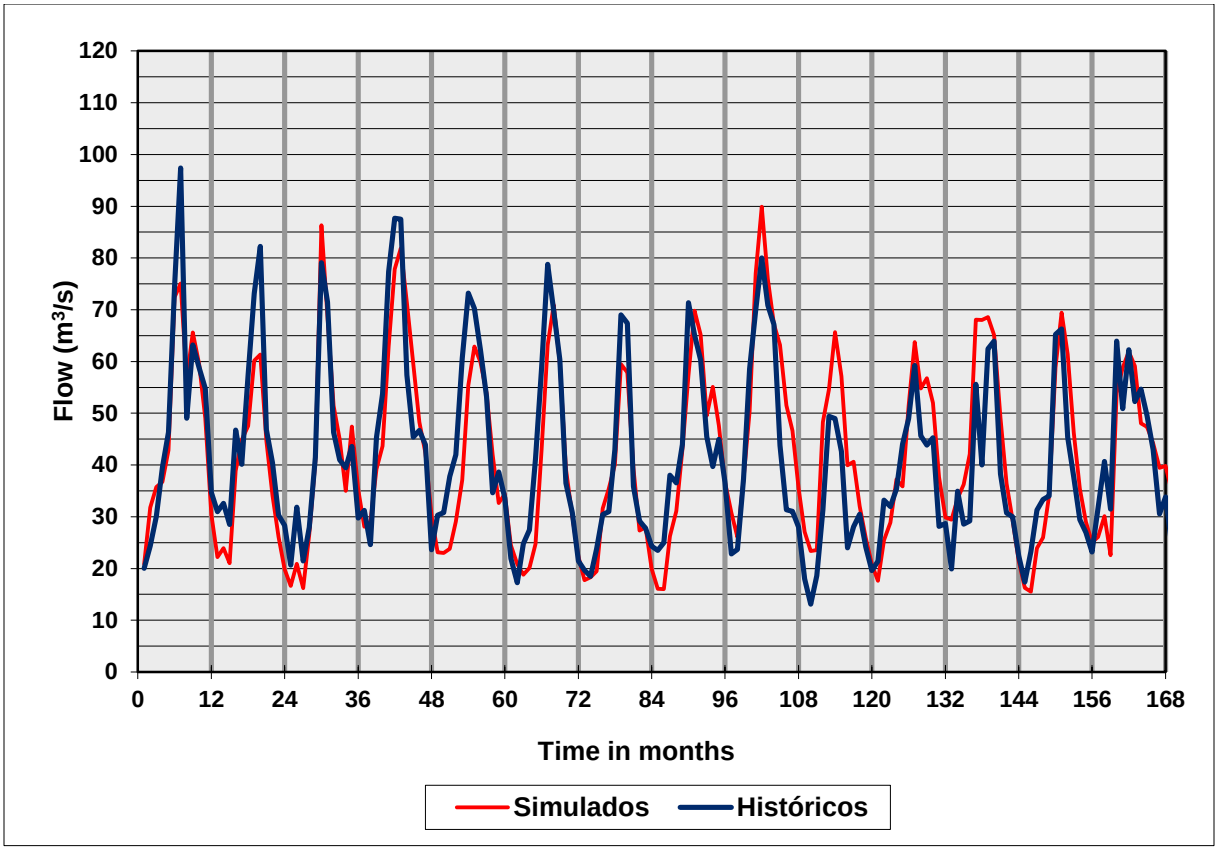
Table 3.7 Statistics of the Series of Simulated and Historical Flows at the Puente Garcés Station, 1986-2007

Statistics	Flow Series (m^3/s)	
	Simulated	Historical
Mean	43.97	43.96
Minimum value	15.51	13.10
Maximum value	96.33	107.70
Correlation Cefficient	0.842	

Source: Abt Associates

Figure 3.13 and Table 3.8 show the outcomes for the 1986-1999 period; while Figure 3.14 shows a comparison between monthly average flows of both series.

Figure 3.13 Gauging of the Rainfall-Runoff Model to the Puente Garcés Hydrometric Station, 1986-1999



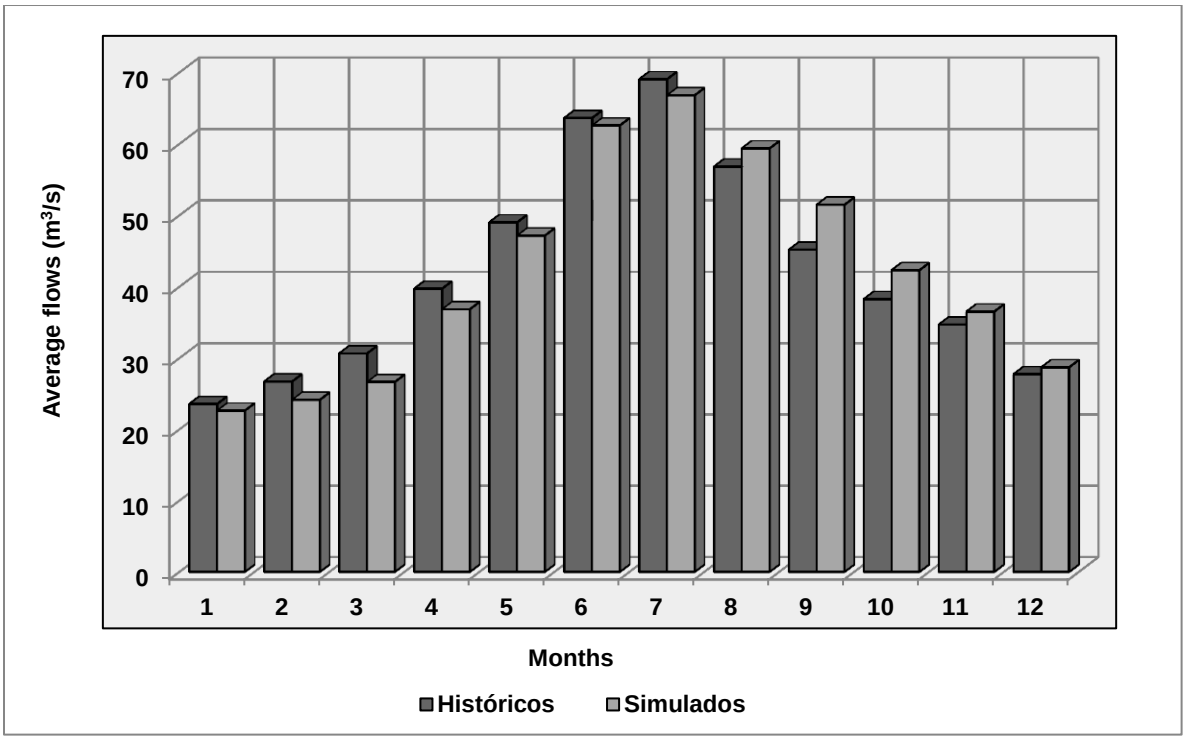
Source: Abt Associates

Table 3.8 Statistics of the Series of Simulated and Historical Flows, Puente Garcés Station, 1986-1999

Statistics	Flow Series (m^3/s)	
	Simulated	Historical
Mean	42.09	42.08
Minimum value	15.51	13.10
Maximum value	89.90	97.40
Correlation Coefficient	0.88	

Source: Abt Associates

Figure 3.14 Comparison of Monthly Averages at Puente Garcés, 1986-1999



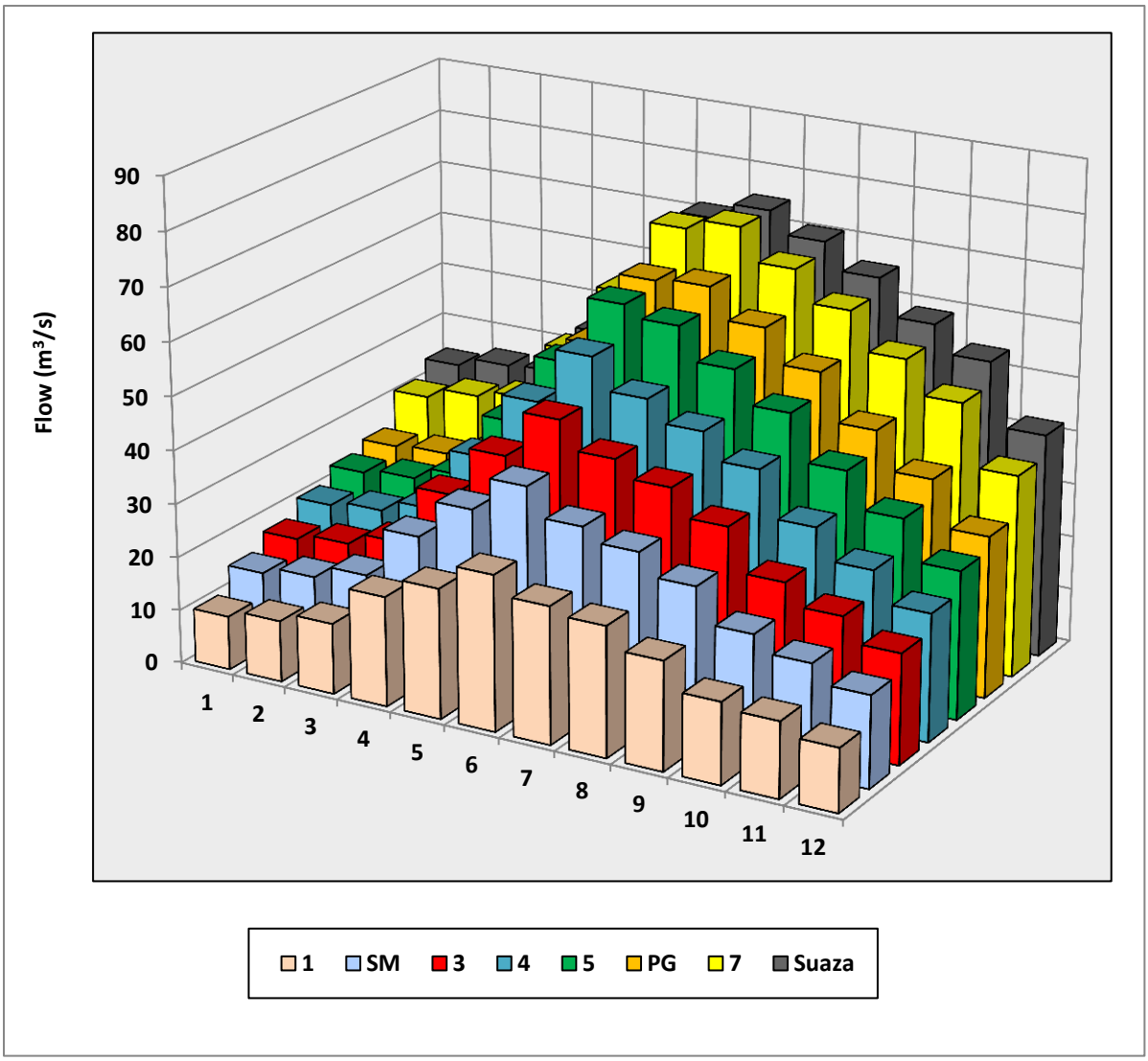
Source: Abt Associates

3.6 Series of Monthly Simulated Flows in Each Sub-Basin

After calibrating the rainfall-runoff model at Puente Garcés Station, the model was applied to all eight Suaza River sub-basins up to their discharge into the Magdalena River. Figure 3.15 summarizes the estimated monthly mean flows for each sub-basin. Sub-basin 2 was identified as San Marcos (SM), number 6 as Puente Garcés (PG) and number 8 as Discharge of the Suaza River into the Magdalena River (Suaza). Figure 3.16 contains monthly mean flows in SM, PG and the whole Suaza River Basin (Suaza).

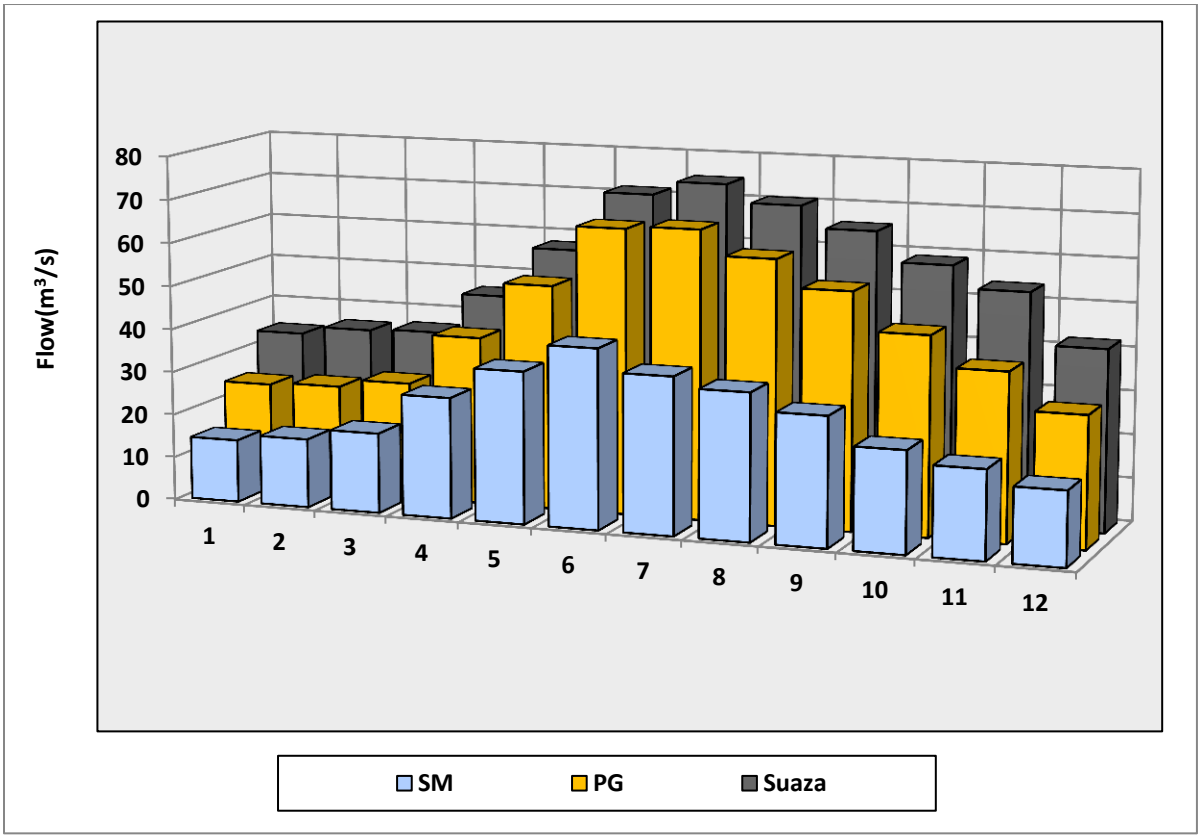
Table 3.9 and Figure 3.17 show the ratio of the average flows and the unit runoff, dependent on the tributary area for each sub-basin. Note the high flows in some parts of the upper basin are over 70 lps/km^2/year. The total basin has a water yield per unit area of approximately 37 lps/km^2/year.

Figure 3.15 Monthly Average Flows at the Suaza River Sub-Basins, 1986-2007



Source: Abt Associates

Figure 3.16 Monthly Average Flows in San Marcos, Puente Garcés and at the Discharge Point of the Suaza River into the Magdalena River, 1986-2007



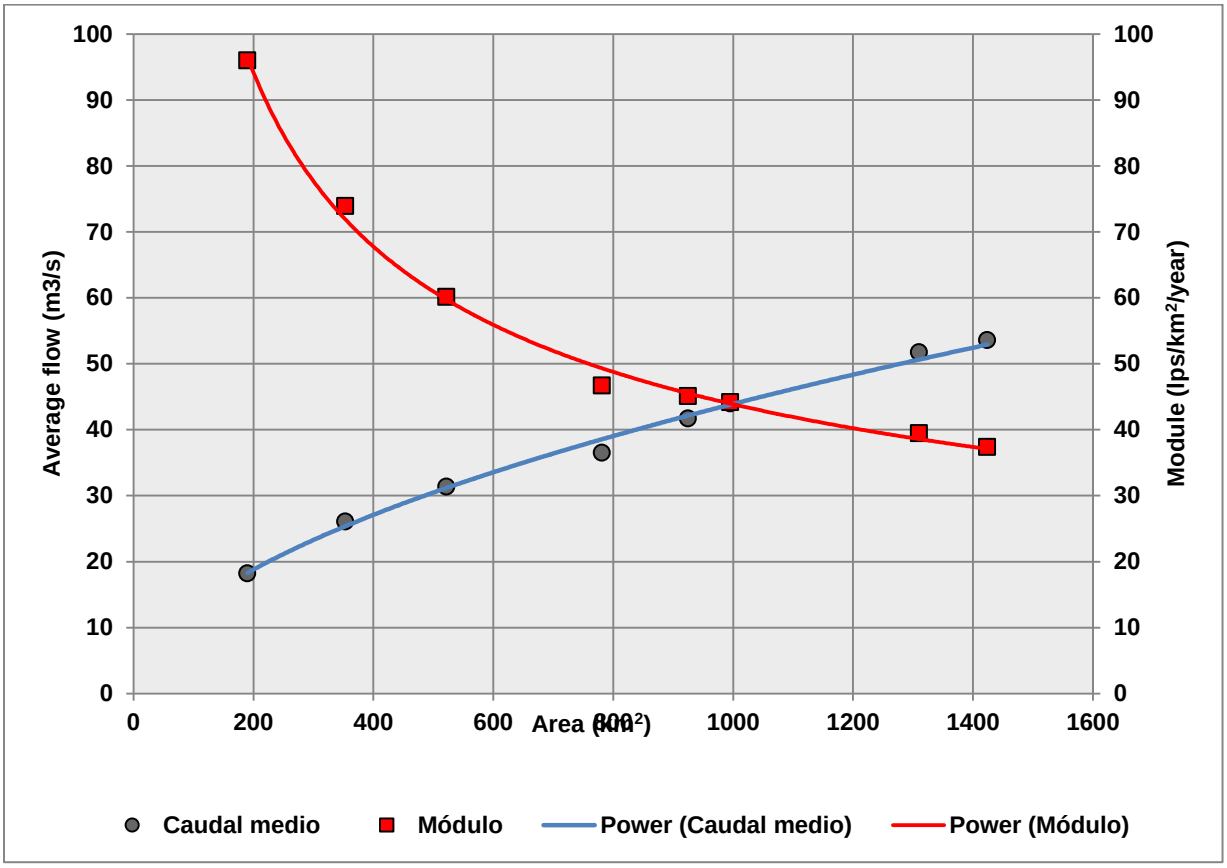
Source: Abt Associates

Table 3.9 Ratio Between the Tributary Area to Sub-Basin Outflows, Flows and the Runoff Unit Module, 1986-2007

Sub-basins	Tributary area (km^2)	Average flow (m^3/s)	Module (lps/km^2)
1	189.9	18.2	95.96
2	352.5	26.0	73.90
3	521.8	31.4	60.13
4	781.0	36.5	46.70
5	924.6	41.7	45.09
6	995.2	44.0	44.18
7	1310.3	51.7	39.48
8	1432.5	53.6	37.39

Source: Abt Associates

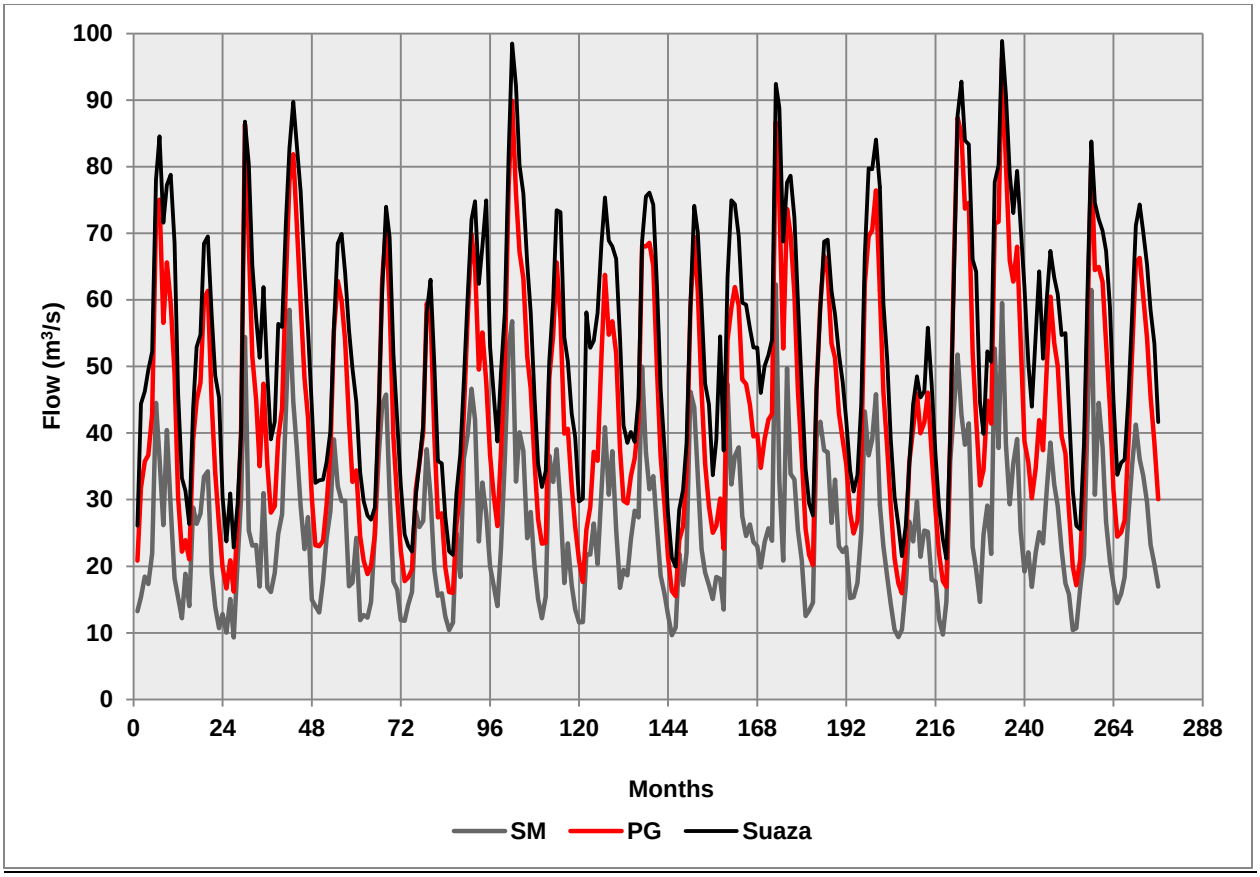
Figure 3.17 Ratio Between the Tributary Area at Each Sub-Basin Output, Average Flow and Runoff Unit Module, 1986-2007



Source: Abt Associates

Figure 3.18 details the series of monthly flows in San Marcos (SM), Puente Garcés (PG) and the whole Suaza River Basin (Suaza), for the 1986-2007 period.

Figure 3.18 Series of Monthly Flows in San Marcos, Puente Garcés and the Site Where the Suaza River Flows Into the Magdalena River, 1986-2007



Source: Abt Associates

4. SWAT MODEL CALIBRATION, IMPLEMENTATION, AND APPLICATION

4.1. Introduction

The Soil and Water Assessment Tool (SWAT) was applied to the Suaza River Basin to estimate the effects of climate change through the year 2050. The SWAT model can be applied to predict the impact of water and soil management practices on watershed runoff and sediment yield from sheet erosion and scour of the river bottom and banks in river basins and sub-basins. This model can handle large, complex watersheds with different soil types, vegetation and land uses, and management conditions over long periods of time.

The SWAT model has some useful features:

- A physical basis. Rather than using regression models that relate input with output data, this model requires specific information on climate, soils, topography, vegetation, land use, and management practices applied to basin sectors. SWAT can model all physical processes associated with the movement of water and sediment directly.
- The required input data are available for most basins.
- Simulates the behavior of large, complex watersheds with a wide variety of soils, land uses, climates and management practices.
- It can be used to evaluate the effect of climate change on water resources, since the model ability to predict the development of vegetation units, whether natural or agricultural crops, taking into consideration the concentration of CO_2 in the atmosphere and its impact on the growth of the vegetative cover.
- It allows the study of long-term impacts, such as siltation of reservoirs.

The model allows the division of the basin into several sub-basins taking into account the variability of land use, soils, topography, climate, and the existence of flow solid and hydrometric gauging stations.

Each sub-basin requires the following input data sets:

- Climate data
- Vegetation cover and land use
- Soil features
- Geomorphological data, lengths, areas, slopes, ridges, etc.
- Management practices
- Characteristics of groundwater flow
- Characteristics of lagoons and/or reservoirs in the basin

The most important component of the model is the simulation of all the processes that comprise the hydrological cycle, which allows a water balance throughout the basin. This water cycle controls the

amount of water and sediment flowing through the basin toward the drainage network, once the water reaches the network transit of both water and sediment starts along this network.

Each sub-basin is divided into hydrological response units (HRU) that combine soil types, vegetation, land use and slopes, as defined by the user. Hydrologic simulation is performed in two stages. In the first stage, the model estimates the amount of water and sediment that reaches the drainage system or main channel in each sub-basin (Figure 4.1). In the second stage, the model carries out the routing process of water and sediment, through the basin drainage network, up to the outlet or basin closure point.

4.2 SWAT Model Implementation

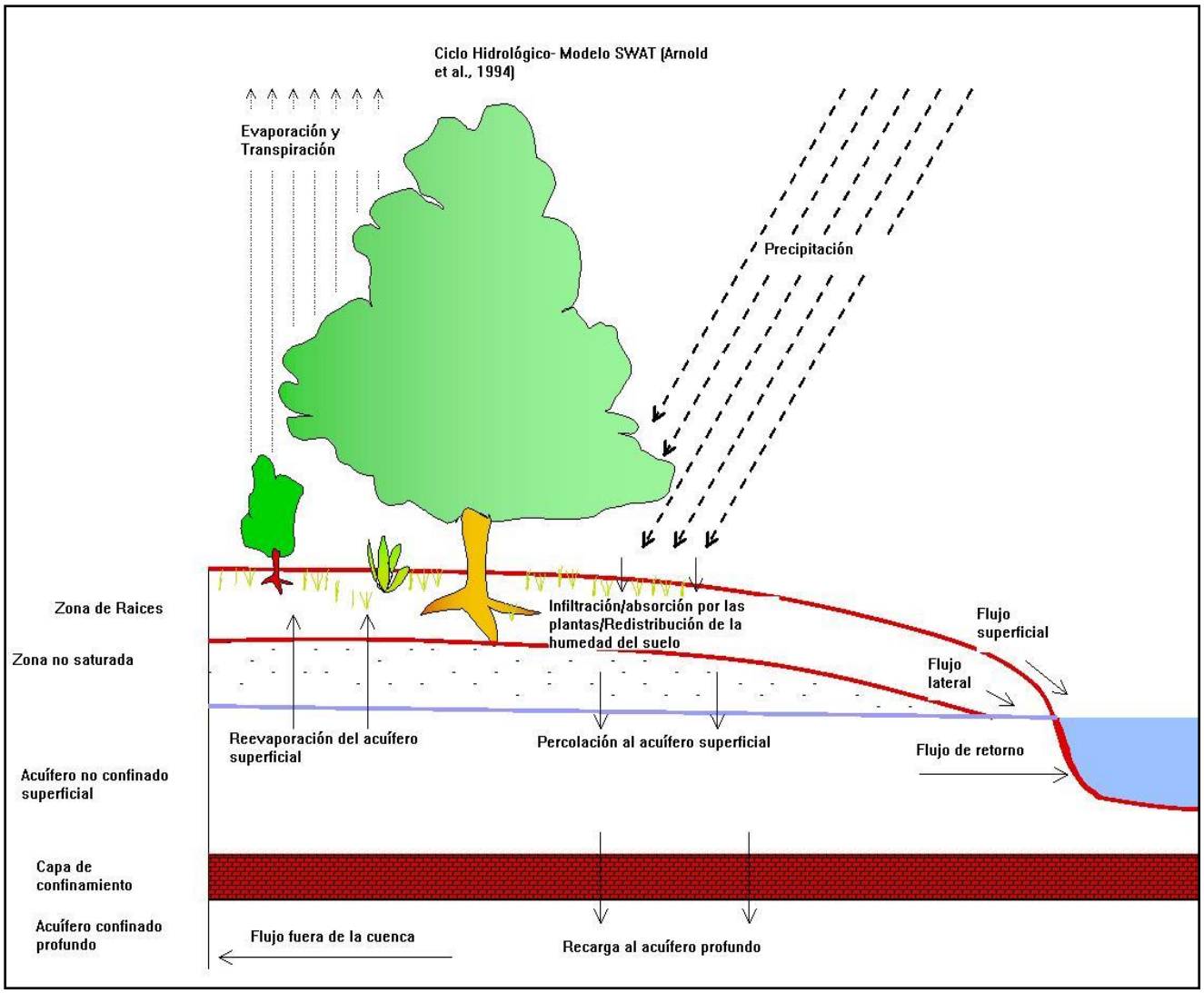
This study used the 2009 ArcSWAT interface, an extension to the ArcGIS 2009 program. The following description explains how the data were processed.

4.2.1 Processing the digital terrain model

The delineation of the Suaza River Basin up to its discharge point into the Magdalena River and the main sub-basins was achieved using the Automatic Watershed Delineator of the ArcSWAT model. Figure 4.2 shows this process where the total basin and the eight sub-basins that comprise it can be observed. It is important to note that in this definition of sub-basins, the SWAT model numbered them from their mouth (sub-basin 1) to the highest basin (sub-basin 8). In other words, the San Marcos hydrometric station is located at the outlet of sub-basin 7 and the Puente Garcés hydrometric station at the outlet of sub-basin 3.

Table 4.1 shows the areas associated to each sub-basin from the upper watershed (sub-basin 8 SWAT) to the most downstream part of the watershed (sub-basin 1).

Figure 4.1 Components of the Hydrologic Cycle, SWAT Model



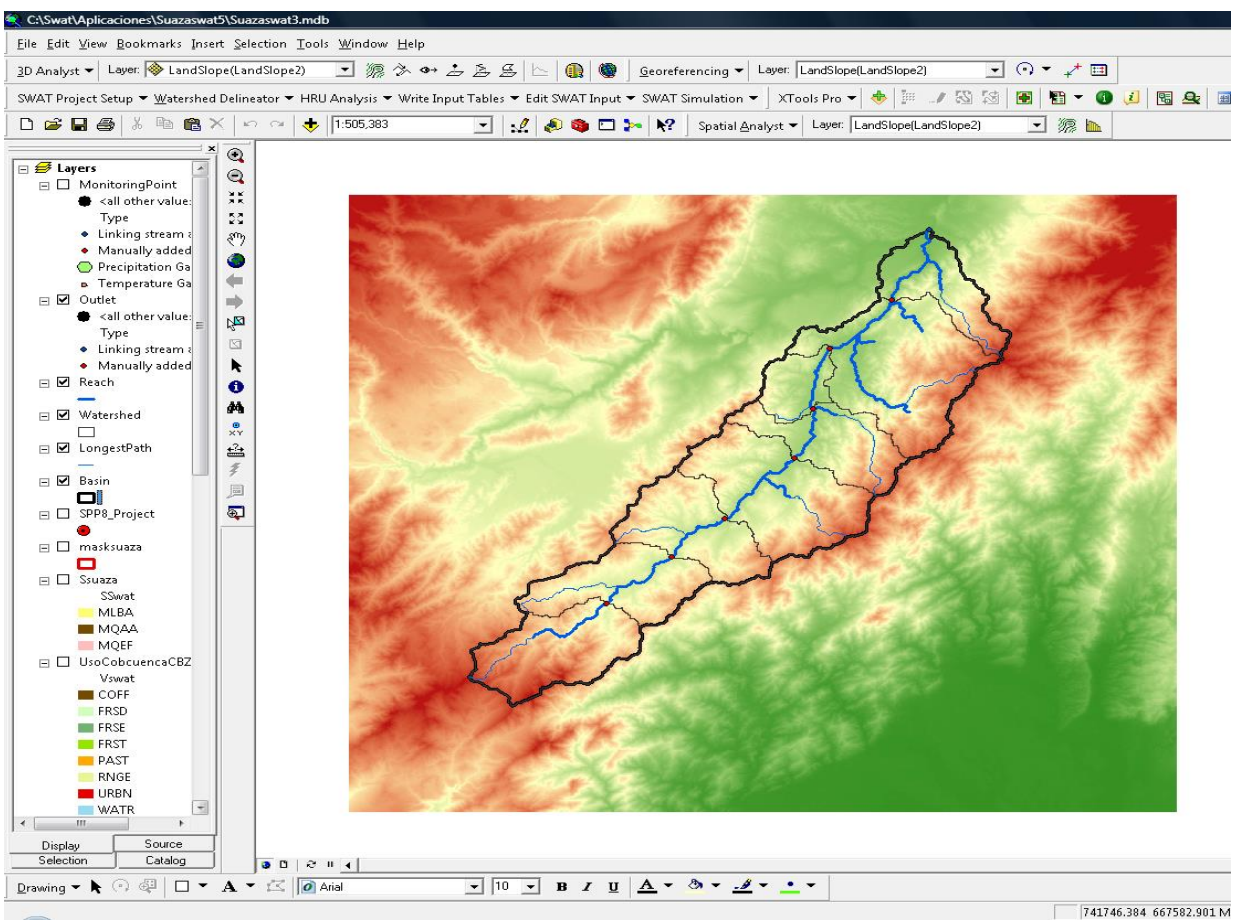
Source: Neitsch S., et al, (2009)

Table 4.1 Sub-Basin Areas, SWAT Model

Original numbering	SWAT numbering	Area (km^2) SWAT	Area (km^2) Accumulated
1	8	189.9	189.9
2	7	162.6	352.5
3	6	169.4	521.8
4	5	259.2	781.0
5	4	143.6	924.6
6	3	70.5	995.2
7	2	315.2	1,310.3
8	1	122.2	1,432.5
Total		1432.5	

Source: Abt Associates

Figure 4.2 Suaza River Basin and Its Main Sub-Basins



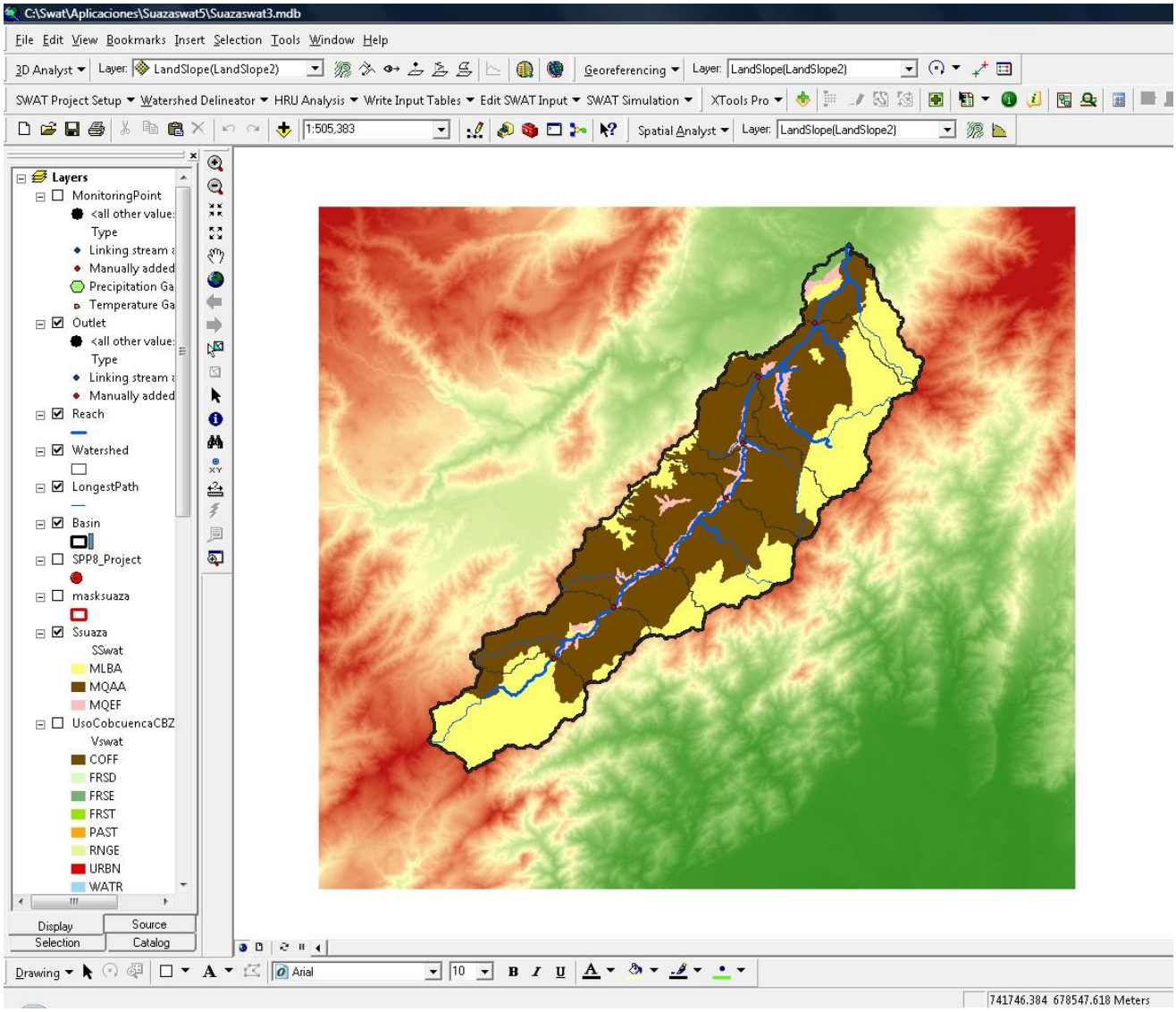
Source: Abt Associates

4.2.2. Soil features

Soil information was taken from the description in Annex 2.2 Profiles of Representative Soils at the Suaza River and the General Land Survey of the Department of Huila (Volumes I and II) prepared (IGAC 1994). Only three types of soil were considered. Soil types shown in Figure 2.7 were aggregated to the most representative soils of the basin. Three soil types (MQA, MLB, and MQE) accounted for nearly 75 percent of the basin area. Areas with other similar soil types were combined with these three types.

These soil types were added to the SWAT database, defined as "User Soils," identified by four letters. Figure 4.3 shows the Suaza Basin soils, identified as MQAA, MLBA, and MQEF.

Figure 4.3 Main Soil Types at the Suaza River Basin



Source: Abt Associates

4.2.3. Characterization of vegetation and land use in the watershed

CAM provided the information on vegetation and land use shown in Figure 2.11. Table 4.2 lists the land cover and plant growth characteristics that were incorporated in the SWAT program and the corresponding areas are mapped in Figure 4.4.

Table 4.2 Vegetation Types and Land Use, Suaza River Basin

Vegetation and land use	Type	OV_N	USLE_C	CN	
				B	C
Forests	BOSV	0.40	0.001	55	65
Gallery forests	BOGA	0.40	0.003	55	65
Shrubs and bushes	ARMA	0.25	0.003	60	70
Pastures	PRAD	0.15	0.006	60	70
Perennial crops	CAFE	0.25	0.003	58	68
Pastures and crops	SAGR	0.20	0.004	60	70
Water	WATR	Same as the original SWAT base factors			
Developed areas	URBN				

Source: Abt Associates
Note:

OV_N	"n" Surface runoff Manning coefficient.
USLE_C	Minimum value of the C coverage factor for Soil Loss.
CN	Number of the curve of the SCS method, according to soil type
B	Soil types: MLBA y MQEF
C	Soil type: MQAA

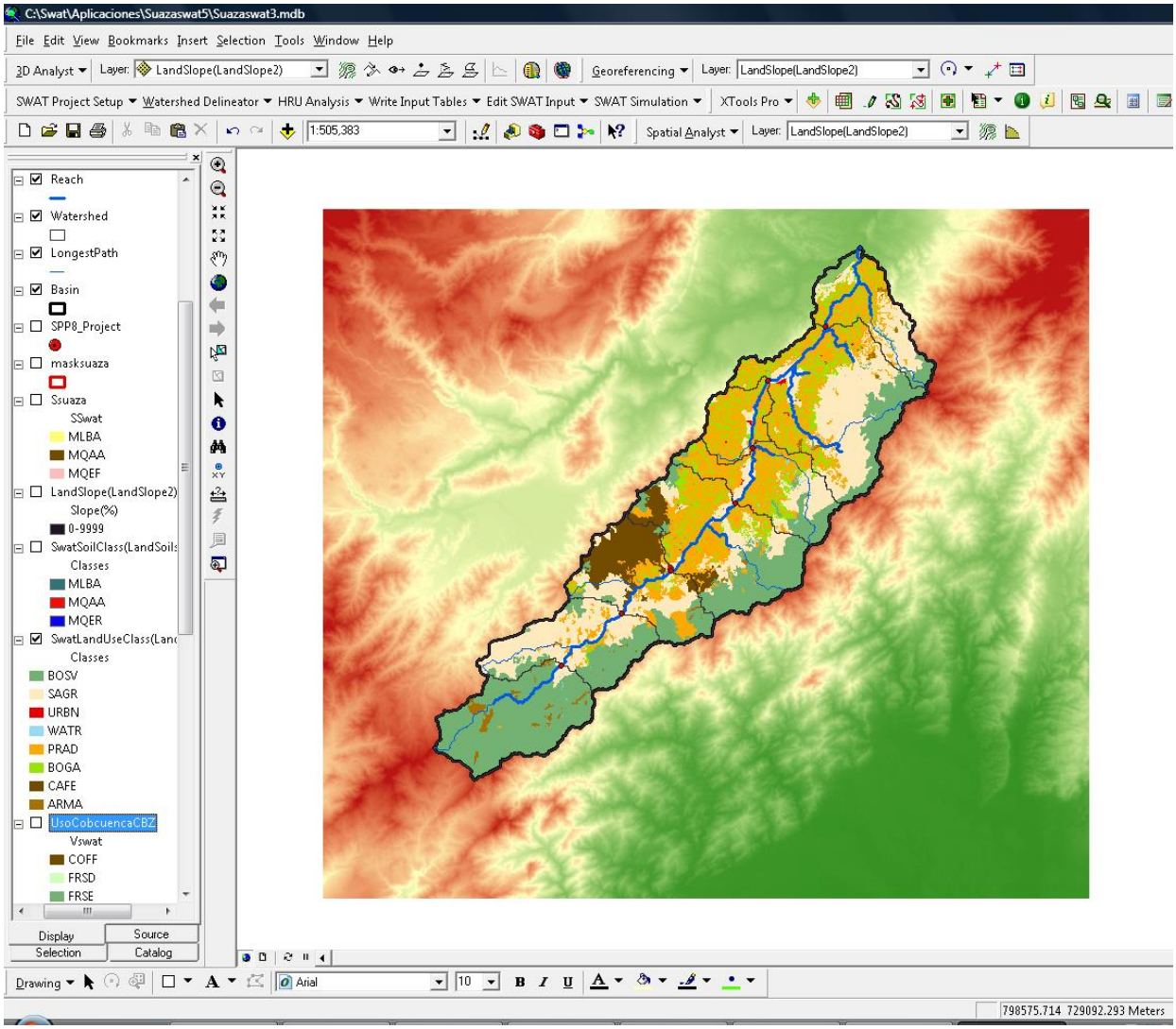
4.2.4. Climate characterization

Rainfall is the most important factor affecting the spatial and temporal variability of climate. The SWAT model accepts the definition of a station for each sub-basin in particular. It does not weigh timely rainfall to estimate areal average rainfall; therefore, rainfall data associated with each sub-basin should represent area averages.

For this reason, the rainfall runoff model described in chapter 3 was previously instrumented and calibrated to estimate daily rainfall averages for each sub-basin. Calibration of the continuous rainfall-runoff type simulation model was achieved up to the hydrometric stations of Puente Garcés and San Marcos. A database of daily rainfall for each sub-basin was created with areal averages.

Moreover, the climate data used in estimating potential evapotranspiration in each sub-basin was used, as described in section 3.4. Hydrometric (see Annex 3.1 Estimate Potential Evapotranspiration). Additionally, the series of daily maximum and minimum temperatures for each sub-basin were estimated.

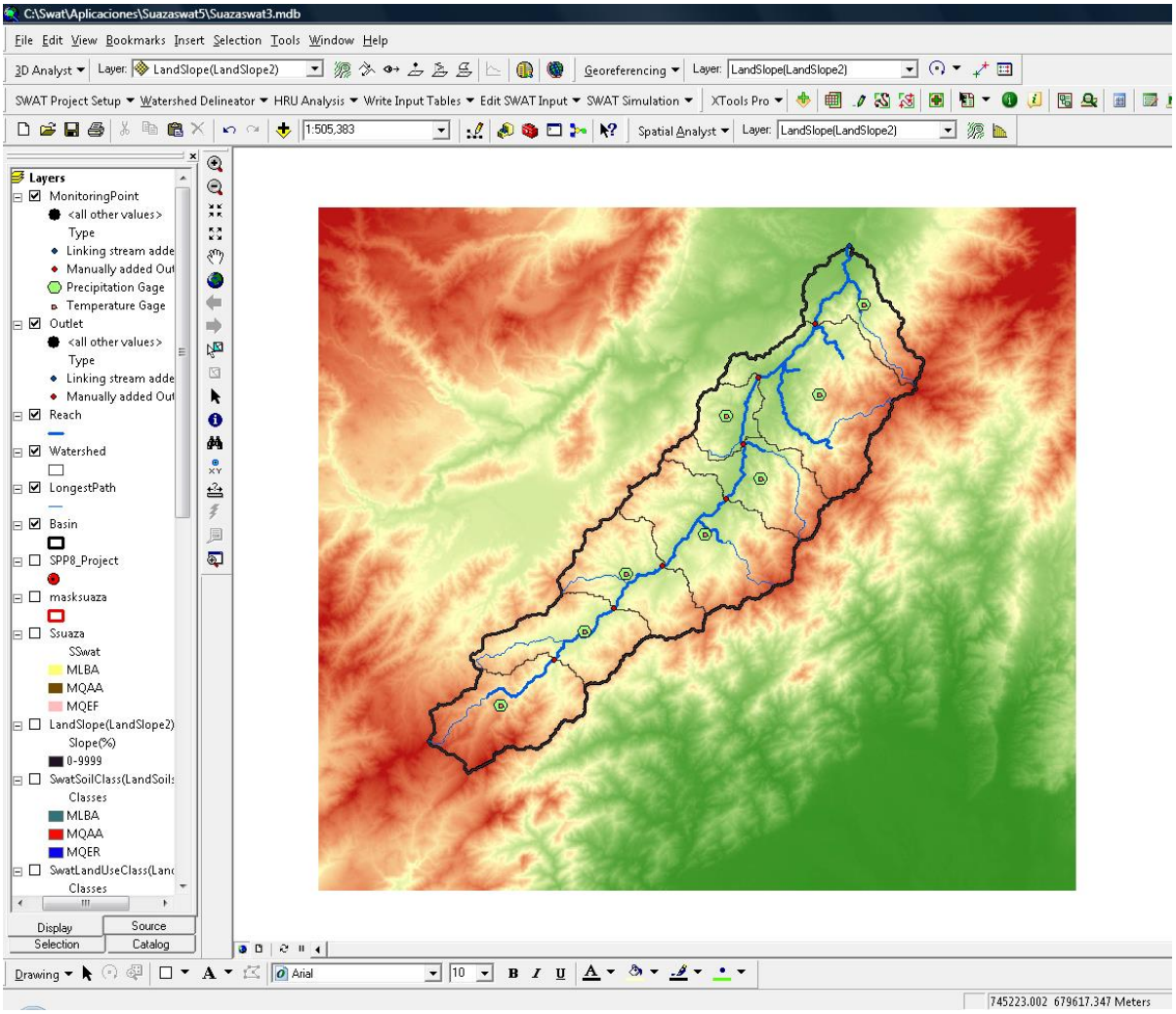
Figure 4.4 Main Vegetation Types and Land Use at the Suaza River Basin



Source: Abt Associates

Figure 4.5 shows the location of the weather and rainfall stations in each sub-basin.

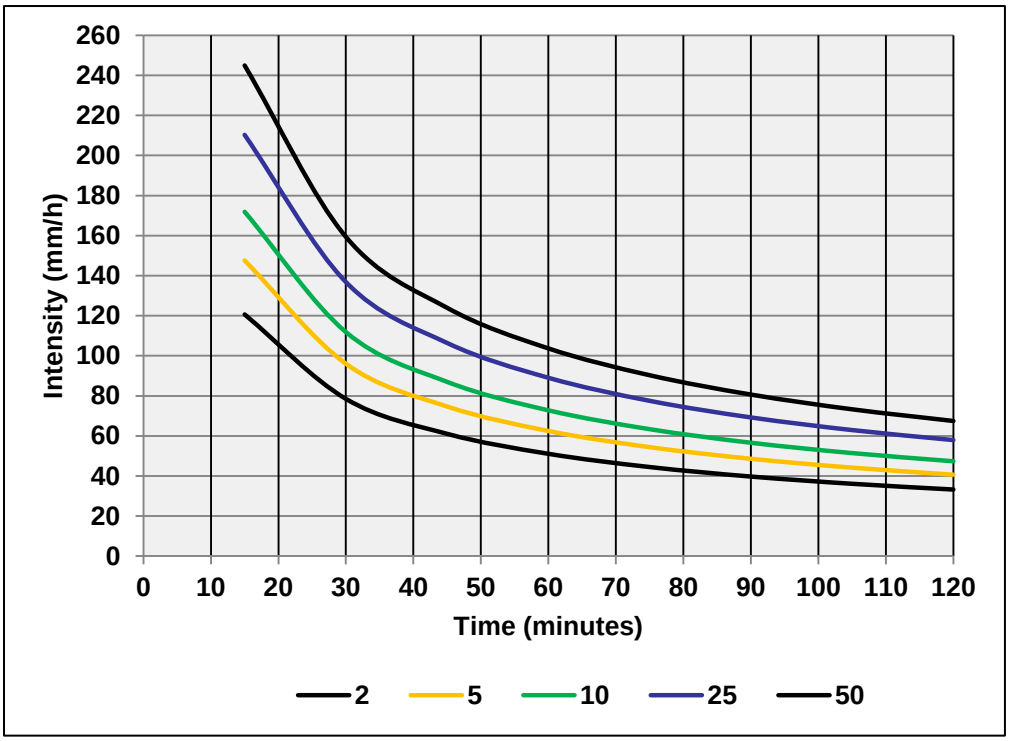
Figure 4.5 Location of the Rainfall and Weather Stations



Source: Abt Associates

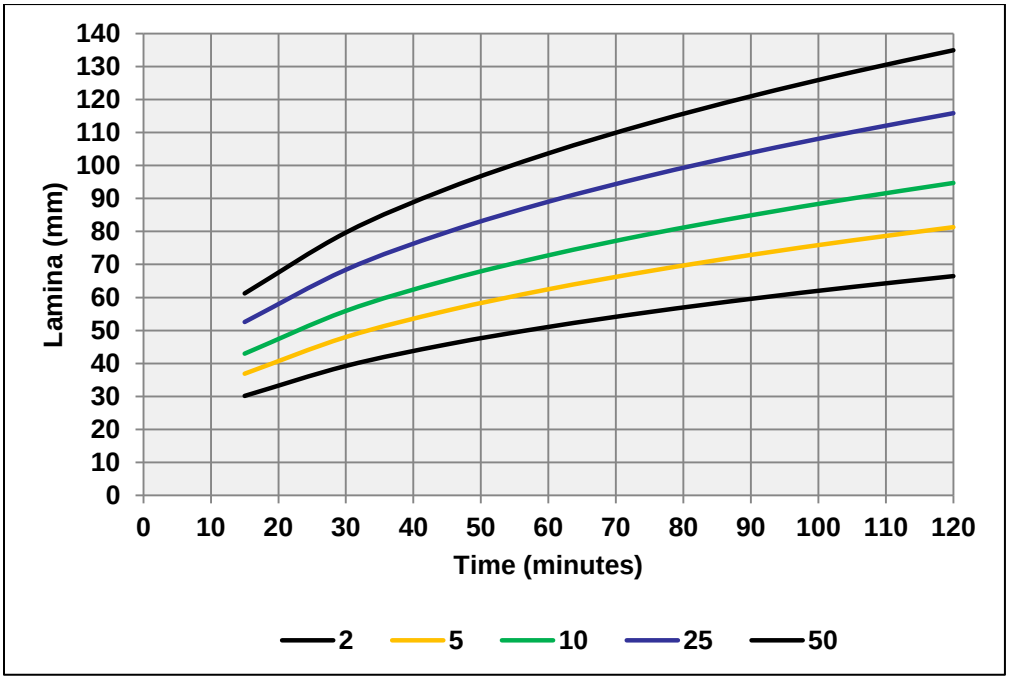
The AILEG team obtained storm information from National University of Colombia (UNC) (2009), including Intensity-Duration-Frequency curves (IDF), for the Guadalupe Station. Figure 4.6 and Figure 4.7 show the Intensity-Duration-Frequency and Depth-Duration-Frequency curves for the Guadalupe Station. Annex 4.1 Intensity-Duration-Frequency Curves and Depth-Duration-Frequency Curves at the Guadalupe, El Líbano, and Resina Stations contains similar curves for El Líbano and Resina Stations.

Figure 4.6 Intensity-Duration-Frequency Curves, Guadalupe Station



Source: UNC (2009)

Figure 4.7 Depth-Duration-Frequency Curves, Guadalupe Station



Source: UNC (2009)

4.3 Calibration of the SWAT Model

The SWAT model calibration was performed in sections with water production first and sediment yield second.

4.3.1 Calibration of water production

The SWAT model calibrates water production through the rainfall-runoff model discussed in chapter 3. Historical records from gauging stations were also used.

The values of the runoff Curve Number (USDA 1999) were changed for calibration purposes; they were estimated using vegetation types and land uses associated with the soil types in the sub-basins.

To calibrate the baseflows of the sub-basins, the soil storage capacity values as well as the saturated hydraulic conductivity and parameter values that define the groundwater flow were varied to simulate the low flow dynamics.

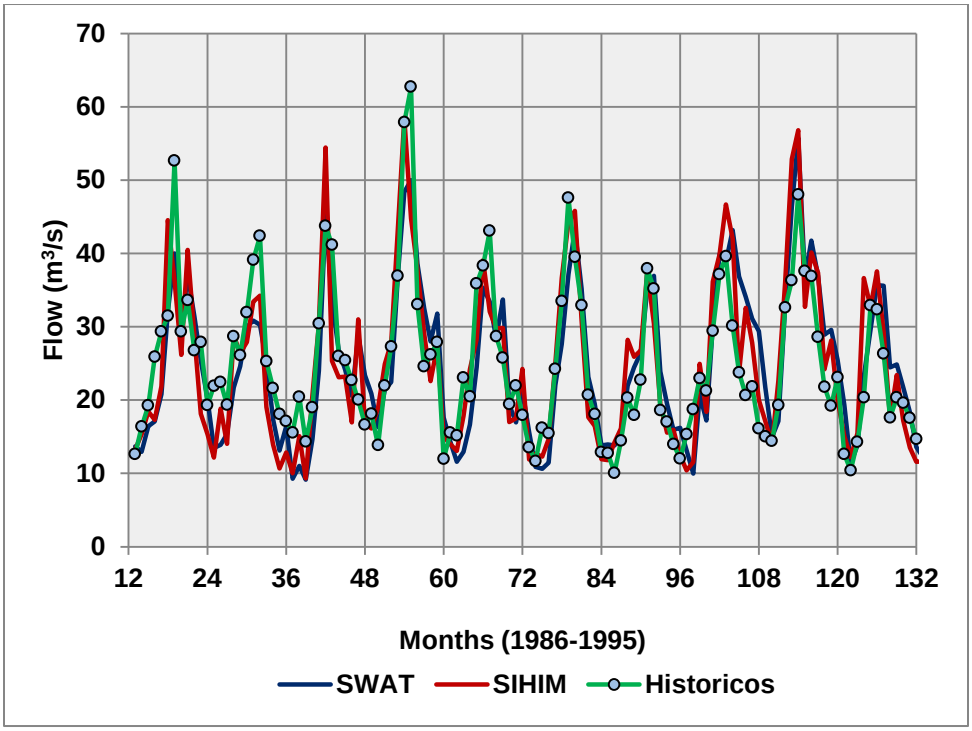
To obtain suitable initial surface water storage conditions of ground and groundwater, a fictitious year was added to the climate database at the beginning of the model´s implementation period (1986-2007), by including the year 1985 and assigning it a climatic basis equal to that of 1986. After obtaining the results, those associated to year 1985 were rejected and only those corresponding to the 1986-2007 period were used.

4.3.1.1. Calibration up to the San Marcos gauging station

Figure 4.8 and Figure 4.9 show the hydrometric results up to the San Marcos Station. Figure 4.8 shows the historical data series and the results from the SIHIM and SWAT models.

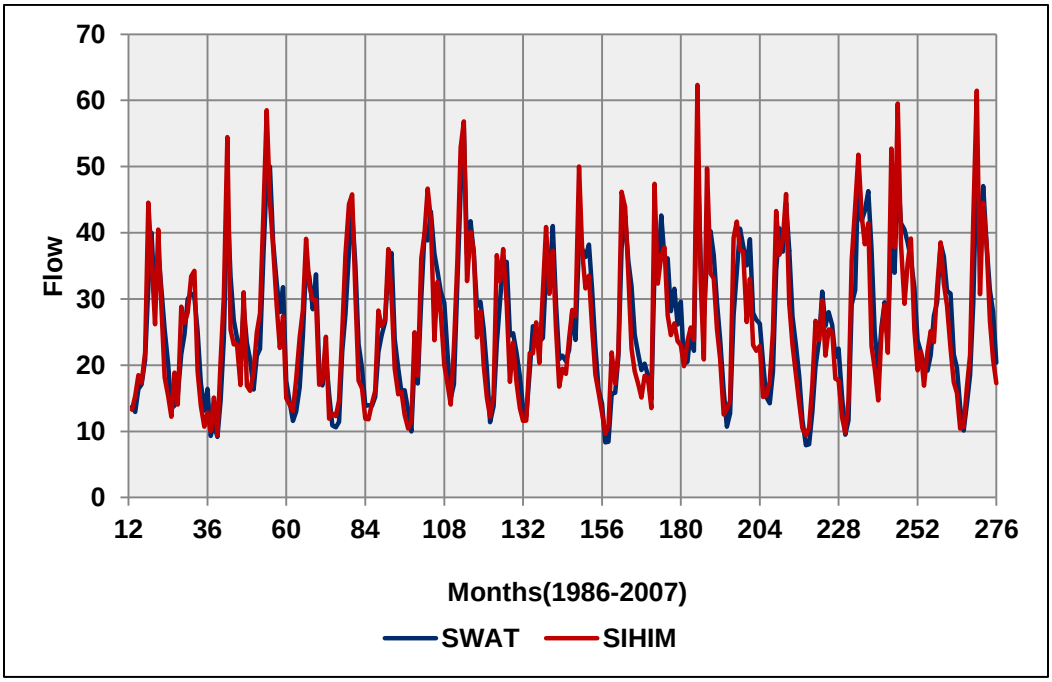
Table 4.3 presents the main results, estimated average, maximum, and minimum flows with the SWAT and SIHIM models and the correlation coefficients of these series with the recorded flows.

Figure 4.8 Comparison between the series of historic values and those created by the SIHIM and SWAT models, Suaza River in San Marcos, 1986-1995



Source: Abt Associates

Figure 4.9 Comparison Between the Monthly Series of the SIHIM and SWAT Models, Suaza River in San Marcos, 1986-2007



Source: Abt Associates

Table 4.3 Comparison of the Statistical Data of the Flow Series of the Suaza River in San Marcos, 1986-1995, SIHIM and SWAT Models

Statistics	Flow series (m^3/s)		
	Simulated		Historic
	SWAT	SIHIM	
Mean	24.93	24.93	24.91
Max value	55.78	58.53	62.70
Min value	9.16	9.33	10.05
Correlation Coefficient with historic data	0.835	0.848	-
Correlation Coefficient for SWAT-SIHIM	0.911		-

Source: Abt Associates

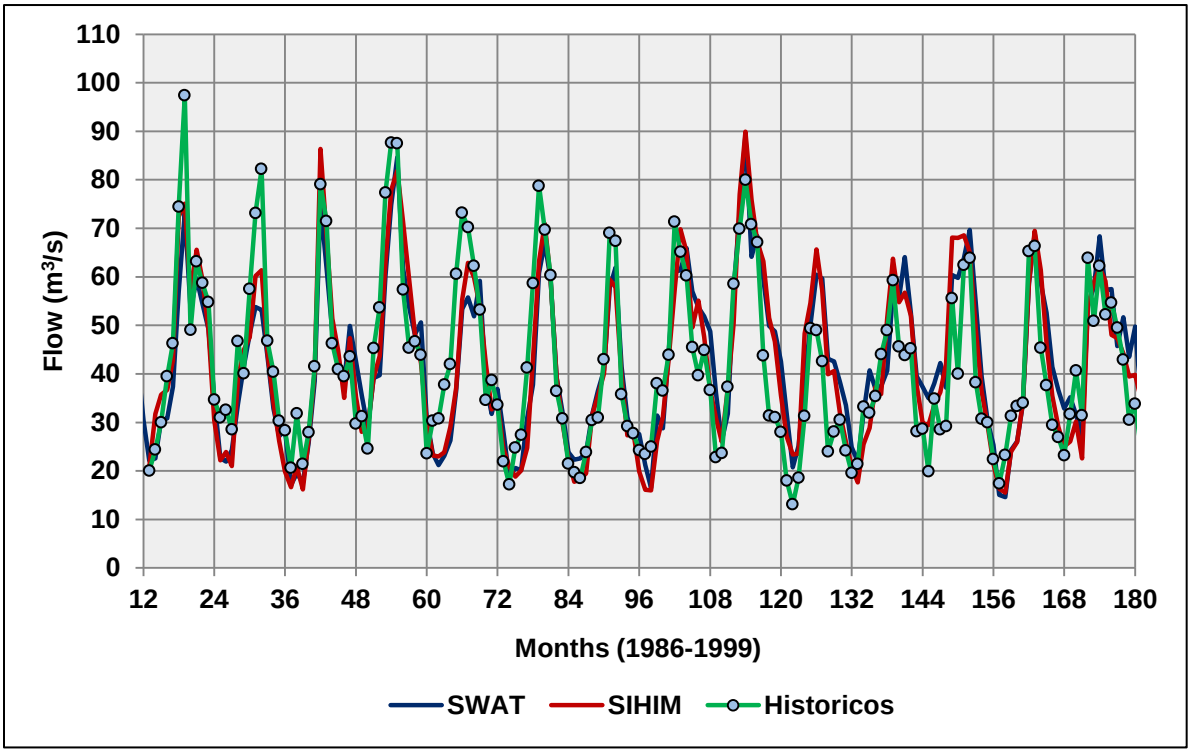
4.3.1.2. Calibration up to the Puente Garcés Station

Figure 4.10 and 4.11 show the results up to the Puente Garcés station. Figure 4.10 presents the historical data and the results of the SIHIM and SWAT models for 1986-1999.

Table 4.4 presents the average, maximum, and minimum flows of the simulated series with the SWAT and SIHIM models as well as the correlation coefficients between the simulated series, and between these series and the historical data.

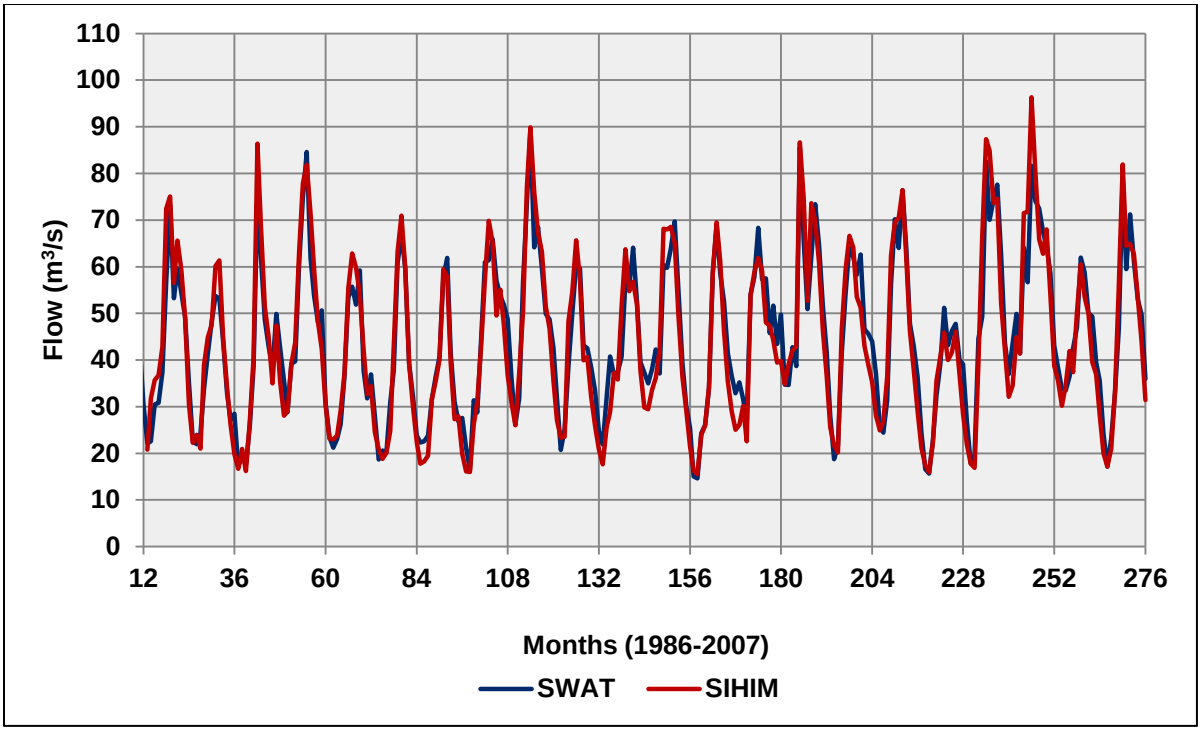
The average, maximum and minimum flows for 1986-1999 were similar and the correlation coefficients of both models with the historical series were of the same order. The correlation coefficient of the monthly series generated by both models was 0.96.

Figure 4.10 Comparison Between the Series of Historic Values From the SIHIM and SWAT Models, Suaza River at Puente Garcés, 1986-1999



Source: Abt Associates

Figure 4.11 Comparison Between the Monthly Series of the SIHIM and SWAT Models, Suaza River at Puente Garcés, 1986-2007



Source: Abt Associates

Table 4.4 Statistical Comparison of the Flow Series for the Suaza River at Puente Garces, 1986-1999, SIHIM and SWAT models

Statistics	Flow series (m^3/s)		
	Simulated		Historic
	SWAT	SIHIM	
Mean	42.47	42.09	42.08
Max value	89.24	89.90	97.40
Min value	14.59	15.51	13.10
Correlation Cefficient with historic data	0.838	0.877	-
Correlation Coefficient of the SWAT-SIHIM	0.960		-

Source: Abt Associates

4.3.1.3. Calibration up to the site where the Suaza River discharges into the Magdalena River

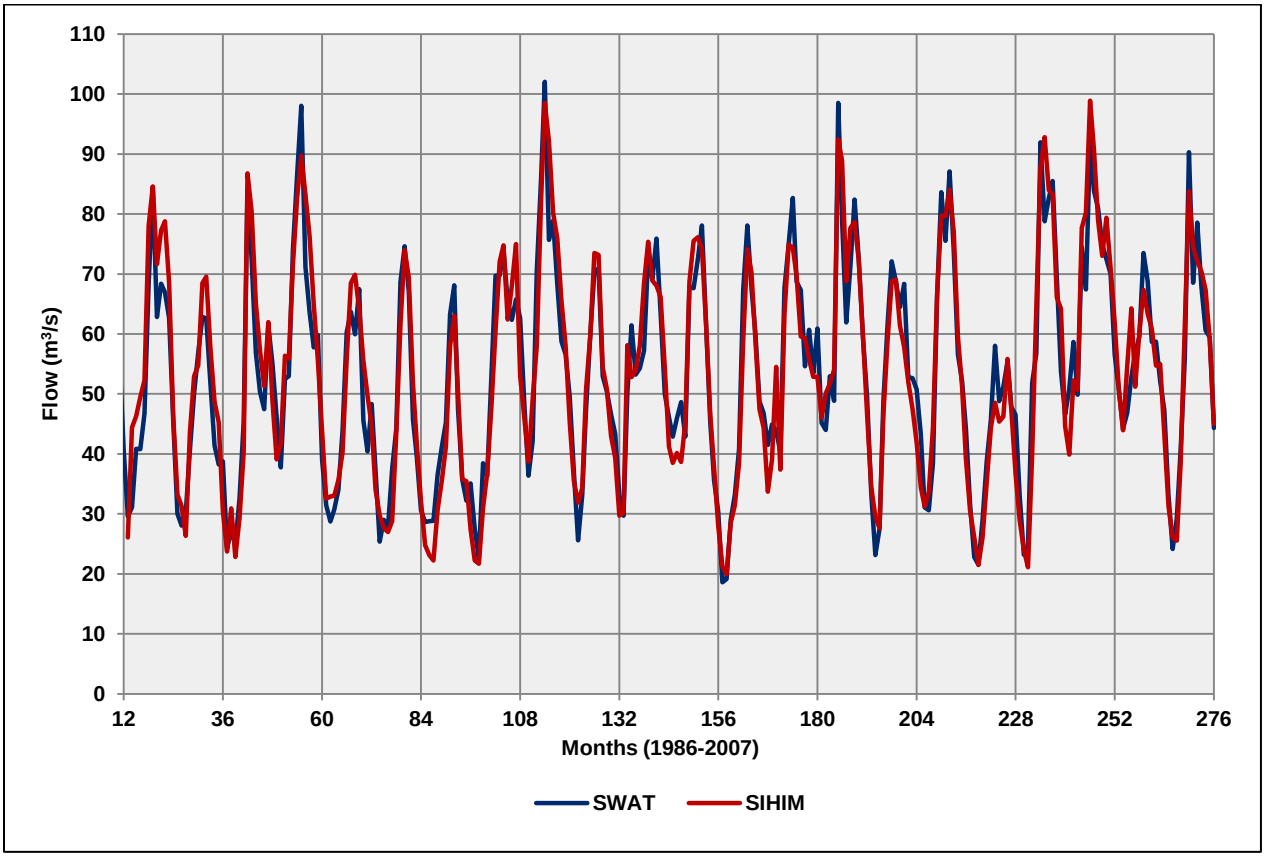
Since historic hydrometric data and records on the outflow level (confluence with the Magdalena River) is lacking, it was necessary to compare the monthly and annual discharges generated by the SWAT and SIHIM models (Figure 4.12 and Figure 4.13).

Table 4.5 summarizes the main results of the comparisons. The correlation coefficient of the monthly series generated by both models was 0.954.

Figure 4.14 compares the monthly average flow series for the SWAT and SIHIM models. Figure 4.15 shows the distribution of the monthly average flows in time and space from the SWAT model for the eight sub-basins.

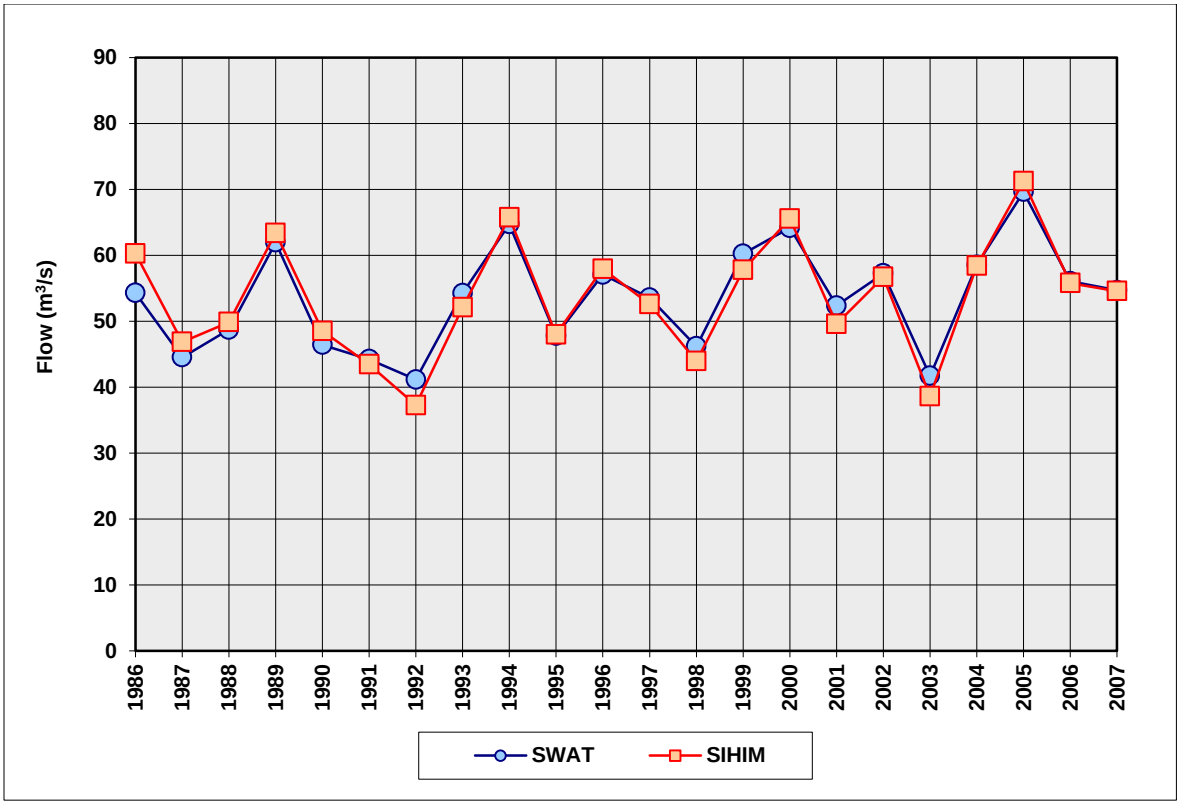
Annex 4.2 Monthly Flows Estimated with the SWAT Model in Each Sub-Basin of the Suaza River contains the estimated annual and monthly flow tables in the eight sub-basins for 1986-2007.

Figure 4.12 Comparison Between the Monthly Series of the SIHIM and SWAT Models, Suaza River Confluence, 1986-2007



Source: Abt Associates

Figure 4.13 Comparison Between the Annual Series of the SIHIM and SWAT Methods, Suaza River Confluence, 1986-2007



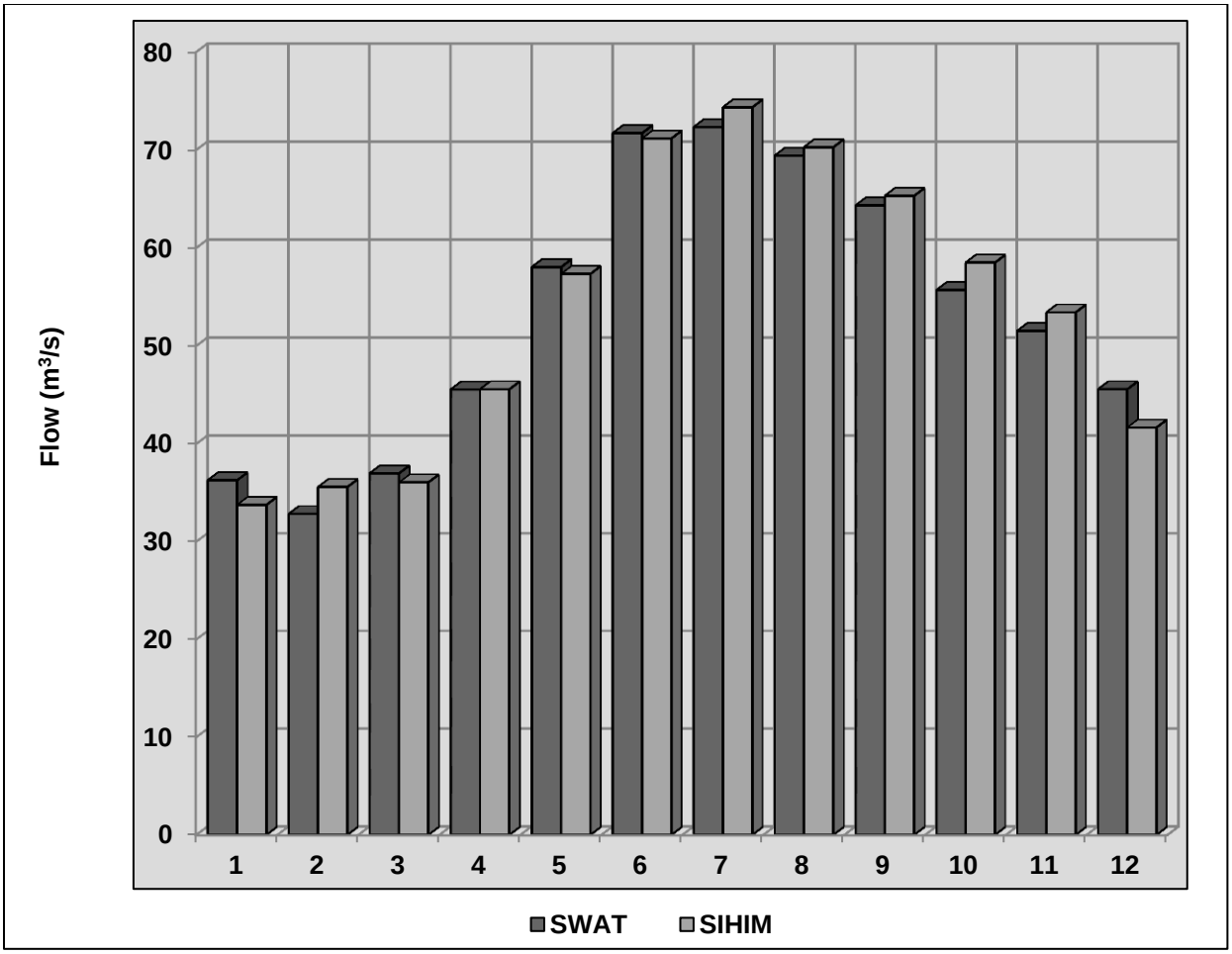
Source: Abt Associates

Table 4.5 Comparison Between the Statistics of the Flow Series of the Suaza River Confluence, 1986-2007, SIHIM and SWAT Models

Statistics	Flow Series (m^3/s)	
	SWAT	SIHIM
Mean	53.34	53.56
Max value	102.02	98.90
Min value	18.59	19.92
SWAT-SIHIM Correlation Coefficient	0.954	

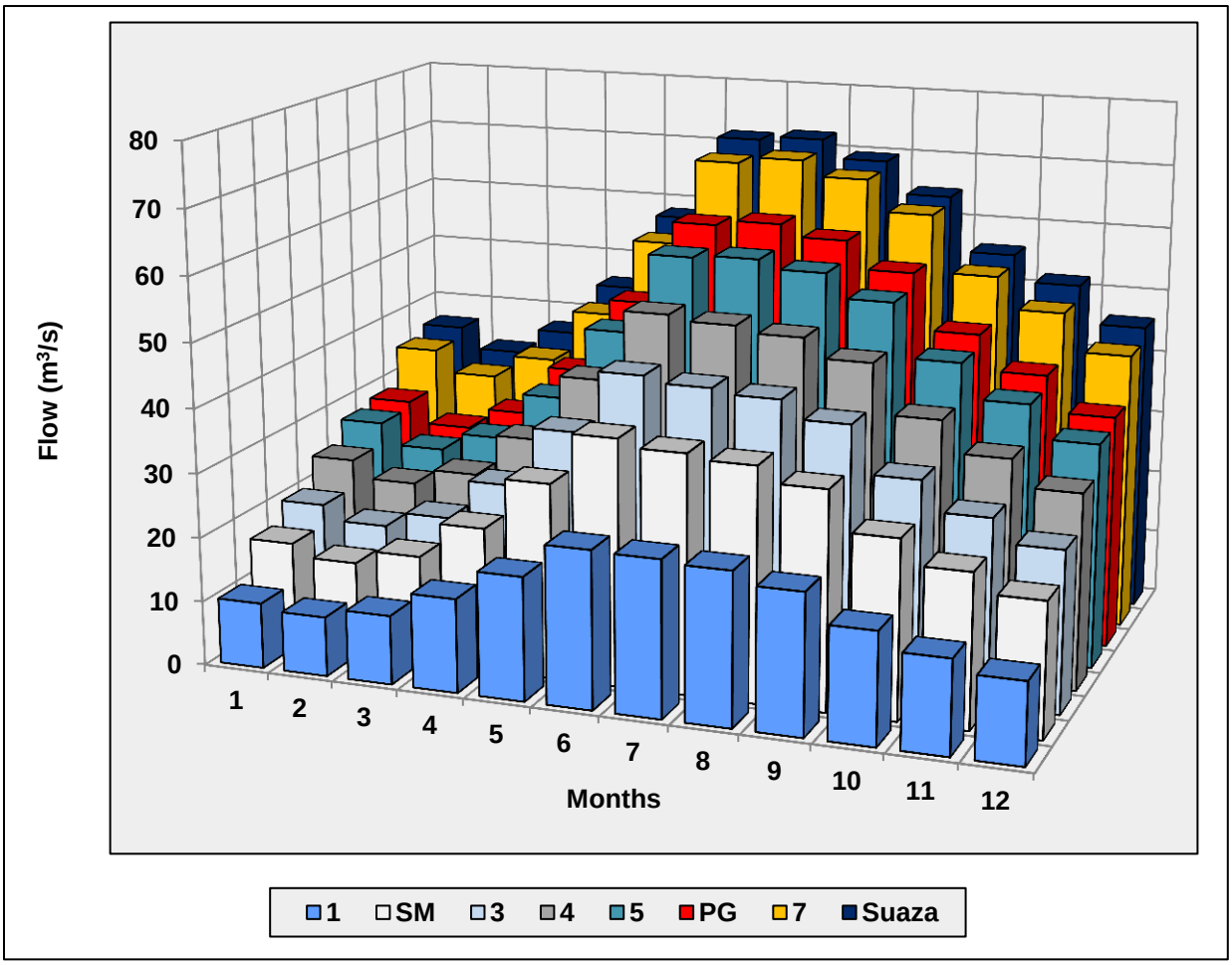
Source: Abt Associates

Figure 4.14 Monthly Average Flows of the Suaza River Confluence with the Magdalena River, 1986-2007



Source: Abt Associates

Figure 4.15 Monthly Average Flows at the Sub-Basins of the Suaza River, SWAT Model, 1986-2007



Source: Abt Associates

4.3.2 Estimating sediment yield

Sedimentation is a critical factor in the expected lifetime and operating costs of dams and reservoirs and impacts on aquatic ecosystems. The sediment yield model is calibrated with data from hydrometric stations and/or reservoir bottom depth measurement (bathymetry) to increase the reliability of the estimates. Suspended sediment estimates were generated by IDEAM using sedimentation curves from data on liquid flows and suspended solids at the Puente Garcés Station, which is analyzed in the next section.

4.3.2.1. Analysis of the suspended sediment transport estimation available in the Suaza River station at Puente Garcés

Table 4.6 presents the estimated annual values of suspended sediments transported in the Suaza River at the Puente Garcés gauging station. The average yield of suspended sediments was about 460,000 tons per year. Since the area of the Suaza River Basin at the Puente Garcés Station is 995 km^2, sediment transport amounts to about 460 t/km^2/year.

Table 4.6 Sediment Transport from the Suaza River to the Puente Garcés Station

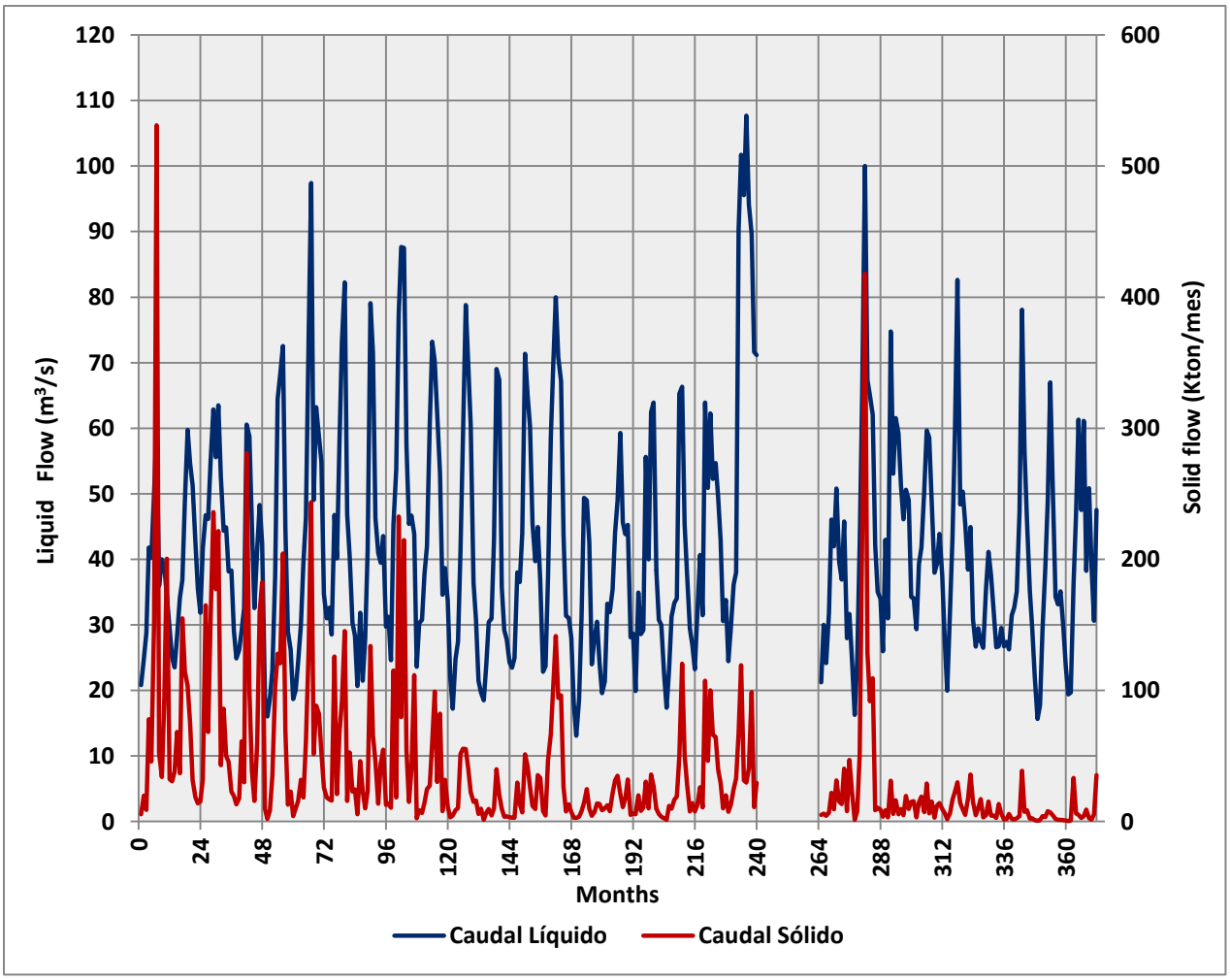
Year	Annual transport in millions of tons	Year	Annual transport in millions of tons
1981	1.26	1997	0.17
1982	0.70	1998	0.34
1983	1.30	1999	0.53
1984	0.98	2000	0.51
1985	0.72	2001	
1986	0.81	2002	
1987	0.62	2003	0.21
1988	0.48	2004	1.08
1989	0.91	2005	0.13
1990	0.41	2006	0.15
1991	0.29	2007	0.18
1992	0.12	2008	0.09
1993	0.27	2009	0.08
1994	0.62	2010	0.04
1995	0.11	2011	0.11
1996	0.21	**Mean**	0.46

Source: IDEAM

After the monthly sediment flows were compared to the monthly average liquid flow rate, it became evident that sediment yields tended to decrease with time, while the liquid flow trend remained constant.

Figure 4.16 compares the liquid and solid series of flows observed in the gauging station of the Suaza River at Puente Garcés.

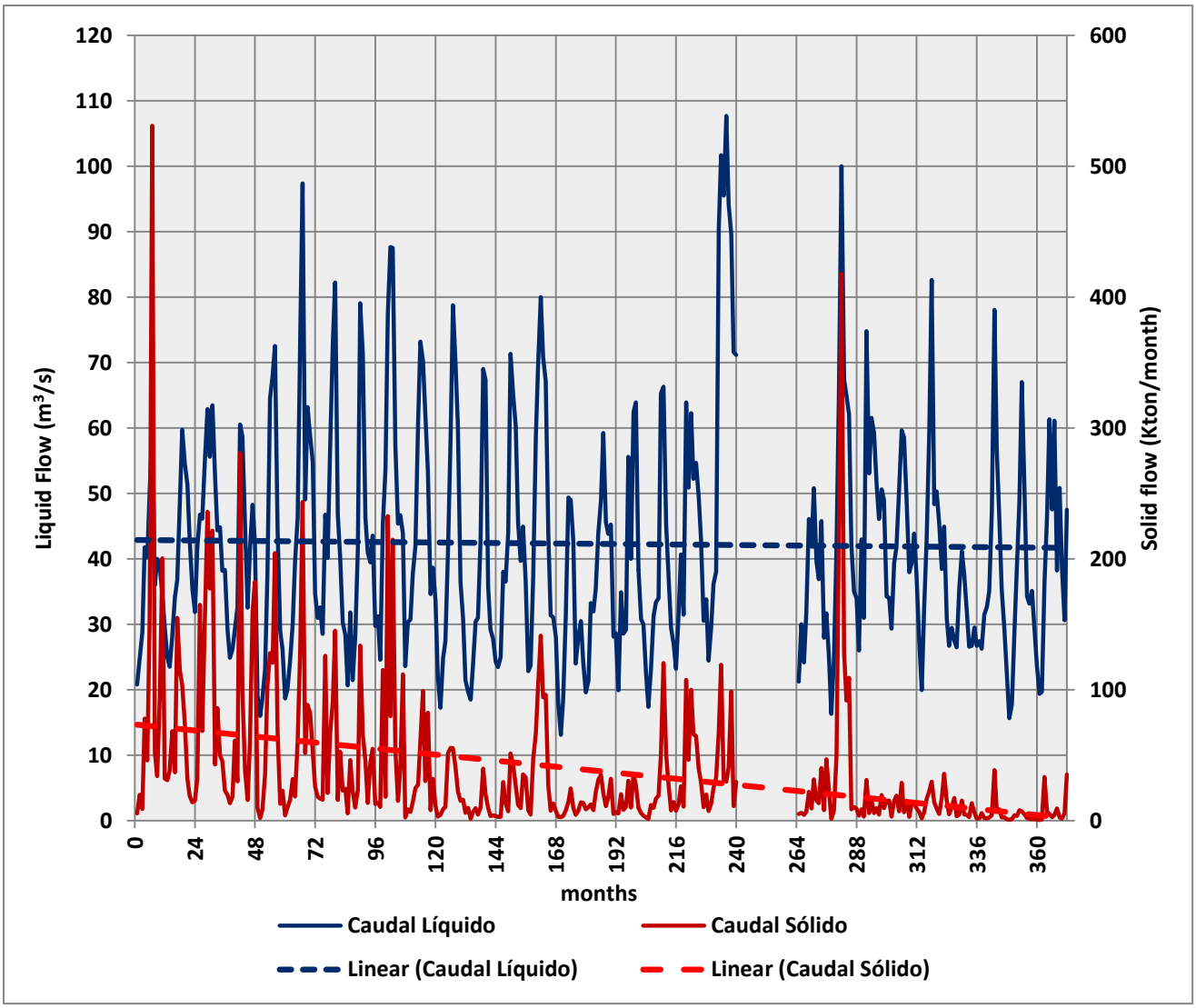
Figure 4.16 Comparison of Liquid and Solid Flow Series, Puente Garcés Station, 1981-2011



Source: Abt Associates

Figure 4.17 presents the analysis of the liquid and solid flow data trends. Unlike liquid flows, the sediment flows trended down. The annual average sediment transported in 1981-1994 was around 680,000 tons per year, whereas during 1995-2011, this average dropped down to 260,000 tons per year, or nearly three times less. Figure 4.18 shows the relationship between the liquid and solid flow series observed at Puente Garcés station from 1981 to 2011. The annual ratios have been changing over time. Although the liquid flow rates were similar to the beginning of the period (1981-1983) the associated solids flow was almost an order of magnitude lower in recent years (2009-2011).

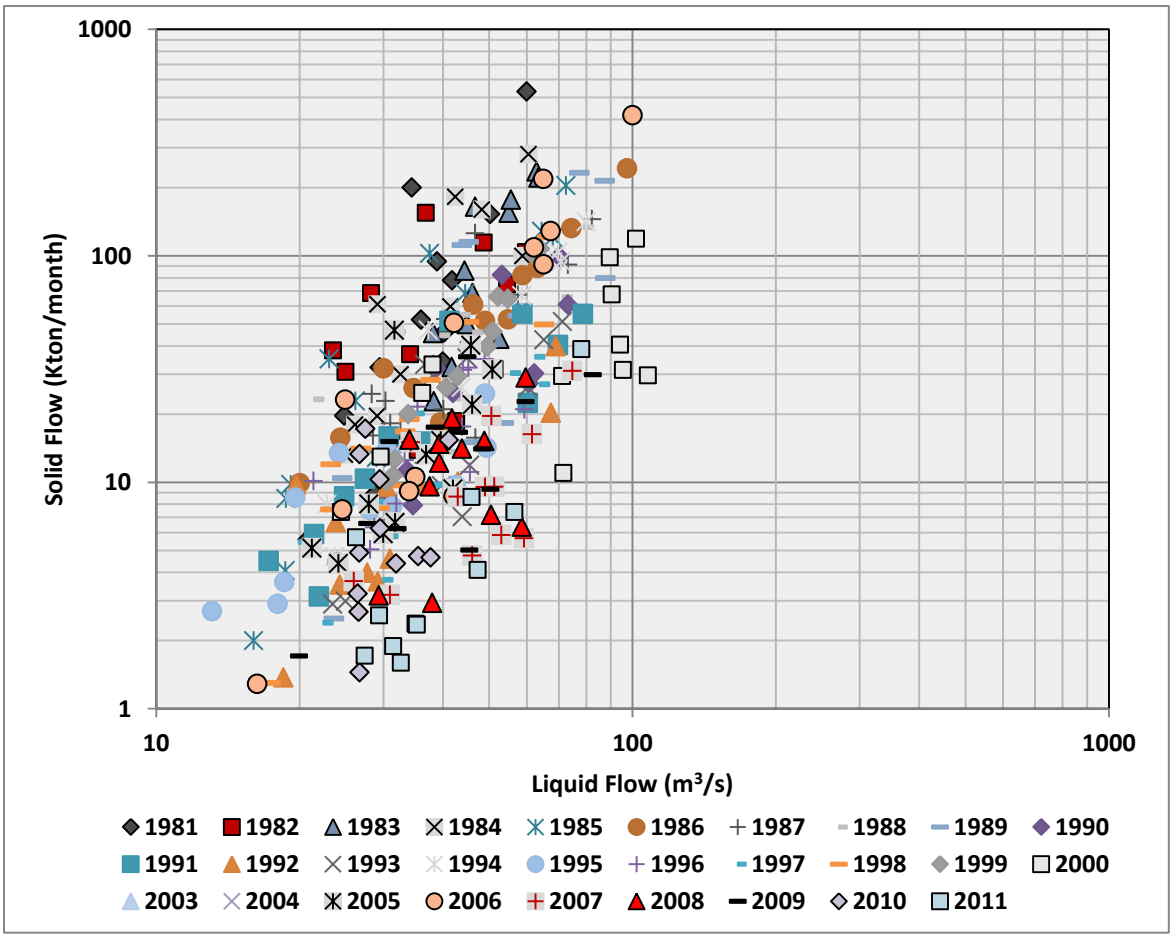
Figure 4.17 Analysis of the Liquid and Solid Flow Series Trend, Puente Garcés Station, 1981-2011



Source: Abt Associates

To learn more about these differences, the team visited the IDEAM offices in Bogotá and found that the HIMAT performed the measurements in the earlier years, while IDEAM performed the measurements in the later years. HIMAT's measurements were numerous, but with little quality control. IDEAM took fewer, but better quality measurements. As a result, the time series data are only indicative.

Figure 4.18 Ratio Between Liquid and Solid Flow Series, Puente Garcés Station, 1981-2011



Source: Abt Associates

4.3.2.2. Implementation of the SWAT model to estimate sediment yield at the Suaza River Basin up to the confluence with the Magdalena River

After calibrating the runoff volumes, the team used the SWAT model to estimate sediment yields.

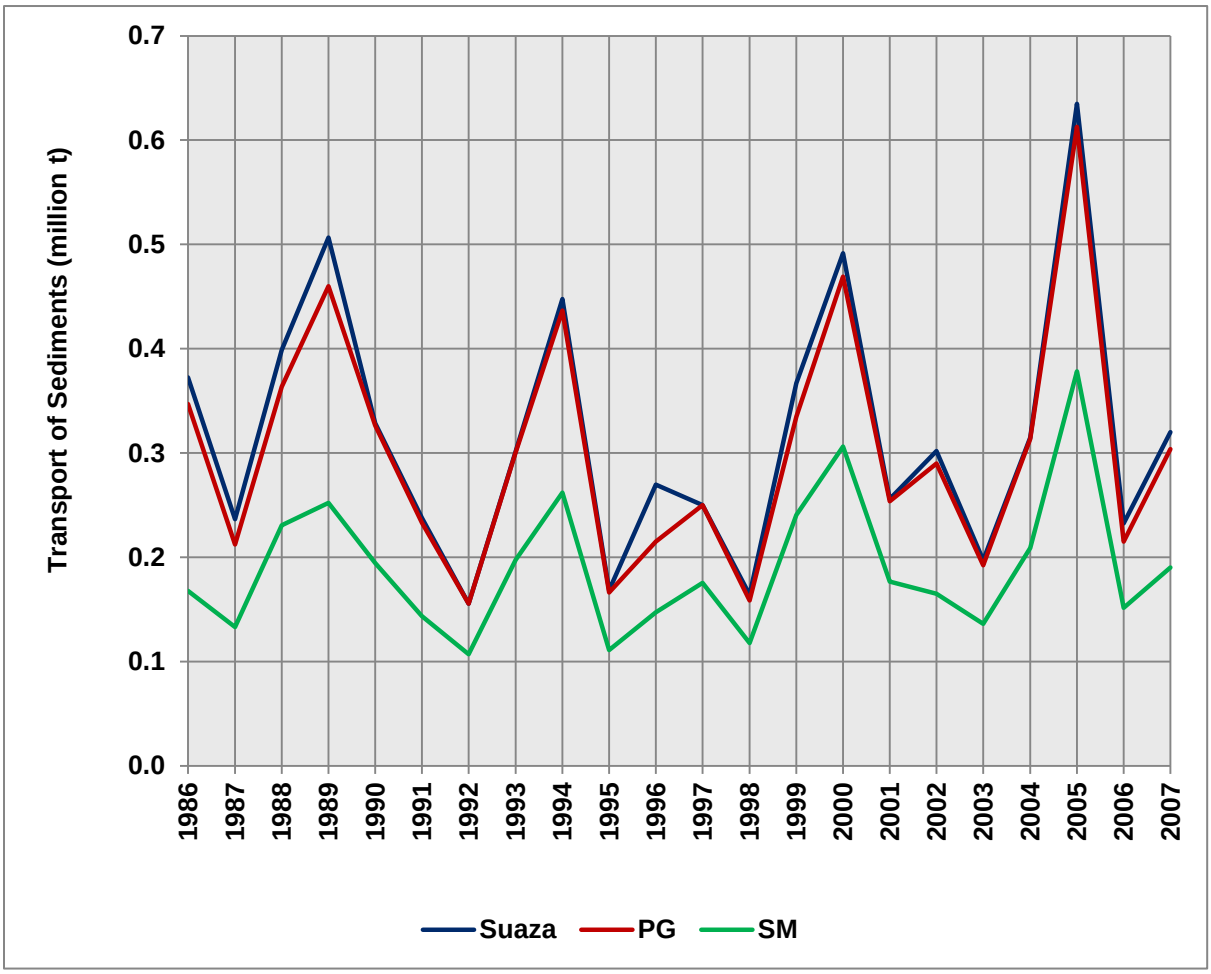
The SWAT model applies the Modified Soil Loss Equation (MUSLE) (Williams 1975) to compute the erosion caused by rainfall and runoff. This equation is a modified version of the Universal Soil Loss equation (USLE), which uses the same USLE's parameters C, K, P, and LS (Wischmeier and Smith 1978). USLE is used to predict average annual gross erosion, per unit area, as a function of topographic data (LS parameter), soil characteristics (K), current vegetative cover (C), and watershed management practices and conservation (P). The MUSLE equation replaces the rainfall energy factor (in USLE) by a runoff factor, which allows it to estimate sediment yields associated with individual storms events (Neitsch et al, 2009); therefore, using this methodology it is possible to estimate daily sediment yield at the basin outlet (and at any sub-basin outlet). Williams and Berndt (1977) describe the procedure to estimate daily sediment yield using MUSLE.

The parameters of sediment routing through the stream network were based on the characteristics of the drainage system—lengths, slopes, and channel widths. Table 4.7 and Figure 4.19 contain the results of the SWAT model.

Table 4.7 Sediment Yield Up to the Suaza River Basin to the San Marcos and Puente Garcés Stations and the Confluence With the Magdalena River (Suaza)

Year	Suaza	PG	SM
1986	0.37	0.35	0.17
1987	0.24	0.21	0.13
1988	0.40	0.36	0.23
1989	0.51	0.46	0.25
1990	0.33	0.33	0.19
1991	0.24	0.23	0.14
1992	0.16	0.16	0.11
1993	0.30	0.30	0.20
1994	0.45	0.44	0.26
1995	0.17	0.17	0.11
1996	0.27	0.22	0.15
1997	0.25	0.25	0.18
1998	0.16	0.16	0.12
1999	0.37	0.33	0.24
2000	0.49	0.47	0.31
2001	0.26	0.25	0.18
2002	0.30	0.29	0.16
2003	0.20	0.19	0.14
2004	0.31	0.31	0.21
2005	0.63	0.61	0.38
2006	0.23	0.22	0.15
2007	0.32	0.30	0.19
Average	0.32	0.30	0.19
Area (km^2)	1432.5	995.2	352.5
Module t/km^2 year	221	302	541

Figure 4.19 Annual Sediment Production Series Estimated by the SWAT Model



Source: Abt Associates

The measured suspended sediments at the Puente Garcés gauging station was 460 t/km^2/year, which exceeded the SWAT model estimate of 302 t/km^2/year. However, the accuracy of the data from this hydrometric station was uncertain. The sediment yield per unit area for the 1995-2011 period based on IDEAM's data was 261 t/km^2/year.

5. ANALYSIS OF IDEAM CLIMATE CHANGE SCENARIOS FOR THE SUAZA RIVER BASIN

For the purpose of achieving one of the main objectives of the study, the Alto Magdalena Corporation (CAM) asked the IDEAM to provide information related to possible climate change expected to occur in the future on the Suaza River Basin that was selected as the pilot basin.

In response to this request, IDEAM's Global Climate Change Group delivered a series of files containing potential monthly rainfall series and average temperatures for the 2011-2100 period corresponding to four emission scenarios. This information is based on five rainfall stations and one weather station representative of the Suaza River Basin.

All of the data were processed and analyzed together with the professional subject matter experts of IDEAM, which allowed the definition of three climate change scenarios, which can be applied to the Suaza River Basin, in order to evaluate the possible availability of water resources in the basin.

5.1 Methods Used by the IDEAM to Estimate the Effect of Climate Change in Colombia

The methods to estimate climate change in Colombia have been described in Arango C., Dorado J., Guzmán D. y Ruiz J.F. (2012), Ruiz J.F. (2010), IDEAM (2010a), and IDEAM (2010b).

Arango, et al. (2011) analyzed monthly precipitation and temperature data for e 1971 to 2010 (40 years). To validate the historic data, quality control checks were applied to the time series, including the identification of data due to events of extreme climate variability, and statistical homogenization and grouping by principal components. In addition, statistical methods were applied to complete the time series and validate data consistency. Then, climate change was projected through a multi-scenario ensemble, using a hybrid method (dynamic statistics) and interpolating precipitation and mean temperature, using IDW (Inverse Distance Weighting) method and Cokriging method, respectively (http://resources.arcgis.com/es/help/main/10.1/). The current climate regime maintains the rainfall distribution that follows a unimodal pattern in the upper basin, and its bimodal distribution in the lower basin; while the temperature maintained its historical behavior.

Climate change projections were made using three greenhouse gas emission scenarios, and information generated by the global circulation models (GCMs) HadCM3 and ECHAM5 from the Hadley Centre in the UK. These models represented the reference climate of Colombia quite accurately (Rodríguez 2010). The global model data were used as initial boundary conditions to get high resolution results using the PRECIS (Providing Regional Climates for Impact Studies). This model allowed "dynamic downscaling", with a spatial resolution of 25 km x 25 km (Ruiz 2010). The adjustment at each station was performed with the "Change Factor" technique (Anandhi, et al. 2011), which allowed the determination of adjustment factors that are applied to obtain the projected climate change scenarios. These factors were applied to the reference climate in a multiplicative form for rainfall and an additive form for average temperature.

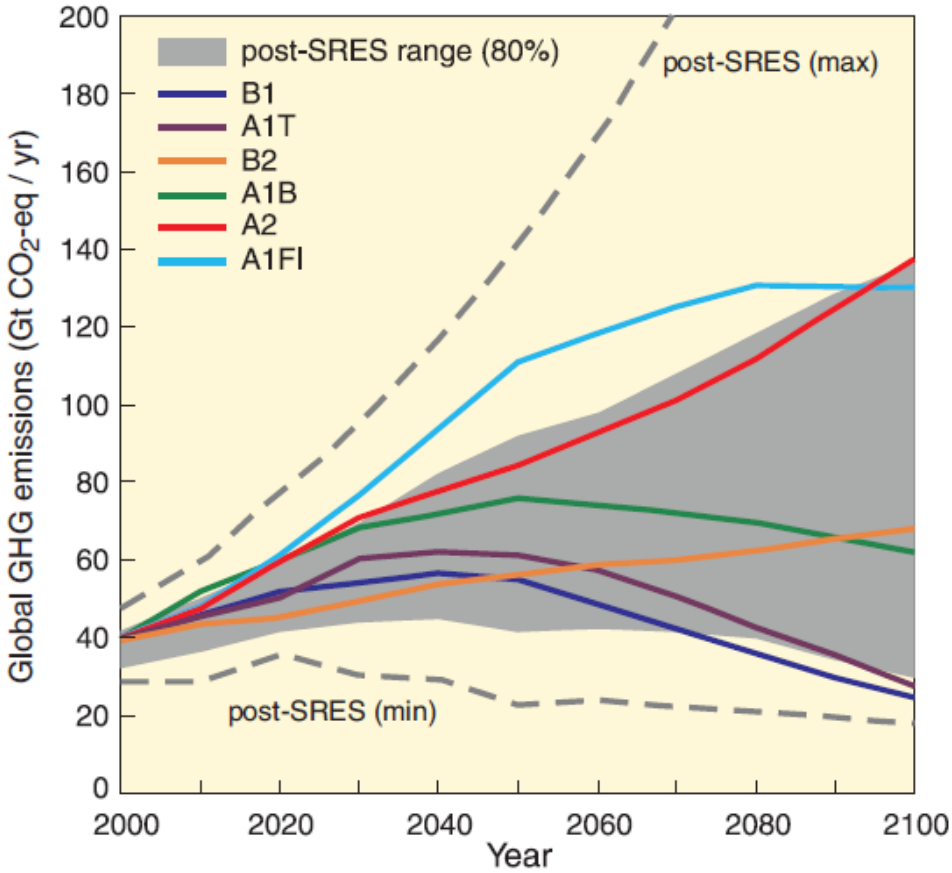
The initial conditions of GCMs MPIECH5 (ECHAM5) and HadCM3 were used for climate change projection in scenarios A2, B2 and A1B during the 2011-2100 period. The current reference climate was taken from ERA 40 for 1971-2010.

Arango, et al. (2011) noted that a "climate change scenario is a representation of a climate under a greenhouse gas condition based on a set of assumptions about external social-economic and technological factors." The assumptions for each scenario follow:

- A2: Driven towards regional development with a population under constant growth, and with a slower economic and technological growth than in other scenarios.
- A1B: Rapid economic growth, with a global population at its peak boom by mid-century, outstanding for the balanced use of all sources of energy.
- B2: Predominating economic, social, and environmental sustainability, population increases at a lower rate than A2, with an intermediate level of economic development.

Figure 5.1 shows the future, projected changes in CO_2 emissions associated with the scenarios A2, B2 and A1B.

Figure 5.1 CO2 Emission Change Scenarios



Source: IPCC (2007)

5.2. Results Obtained by IDEAM

5.2.1. Rainfall

5.2.1.1. Stations analyzed

Table 5.1 shows the stations by climate change information, where the code, station name and file name are included. As shown in Figure 2.3 (station location), the available information covers the Suaza River Basin in full.

Table 5.1 Rainfall Stations With Climate Change Scenario Data

Code	Station	File name
21030050	Guadalupe	2103005-Indices.xls
21030060	San Adolfo	2103006-Indices.xls
21030080	Acevedo	2103008-Indices.xls
21030090	La Jagua	2103009-Indices.xls
21030110	San Antonio del Pescador	2103011-Indices.xls

Source: IDEAM

5.2.1.2. Information used in the analysis

Annex 5.1 Climate Change Scenarios at Representative Rainfall Stations of the Suaza River Basin shows the series of total annual precipitation of all rainfall stations described in Table 5.1. It also includes the historical series (1971-2010) for each rainfall station and the series affected by climate change (2011-2100) for the three scenarios and trends analyzed.

5.2.2. Average temperature

5.2.2.1. Analyzed station

The only weather station representative of the Suaza River Basin that has information related to the climate change scenarios is the Resina Station. Table 5.2 lists the station code and the file sent by IDEAM containing the above scenarios.

Table 5.2 Weather Station With Climate Change Scenario Data

Code	Station	File name
21035020	Resina	2103502-Indices.xls

Source: IDEAM

5.2.2.2. Data used in the analysis

The set of monthly daily temperature averages corresponds to 1971-2010 (historical data) in the station analyzed. The 2011-2100 period represents the potential average temperatures associated with different climate change scenarios.

Annex 5.2 Climate change scenarios at the Resina station for average Annual temperatures includes the daily average temperature series and the annual average for the Resina Station, where the 1971-2010 period corresponds to the historic series and the 2011-2100 period corresponds to the series affected by climate change, associated with the three scenarios and trends analyzed.

5.2.3. CO_2 concentration in the atmosphere

Table 5.3 and Figure 5.2 show the future scenarios of atmospheric CO_2 concentrations estimated by the IDEAM.

Table 5.3 CO_2 Concentration in the Atmosphere (ppm)

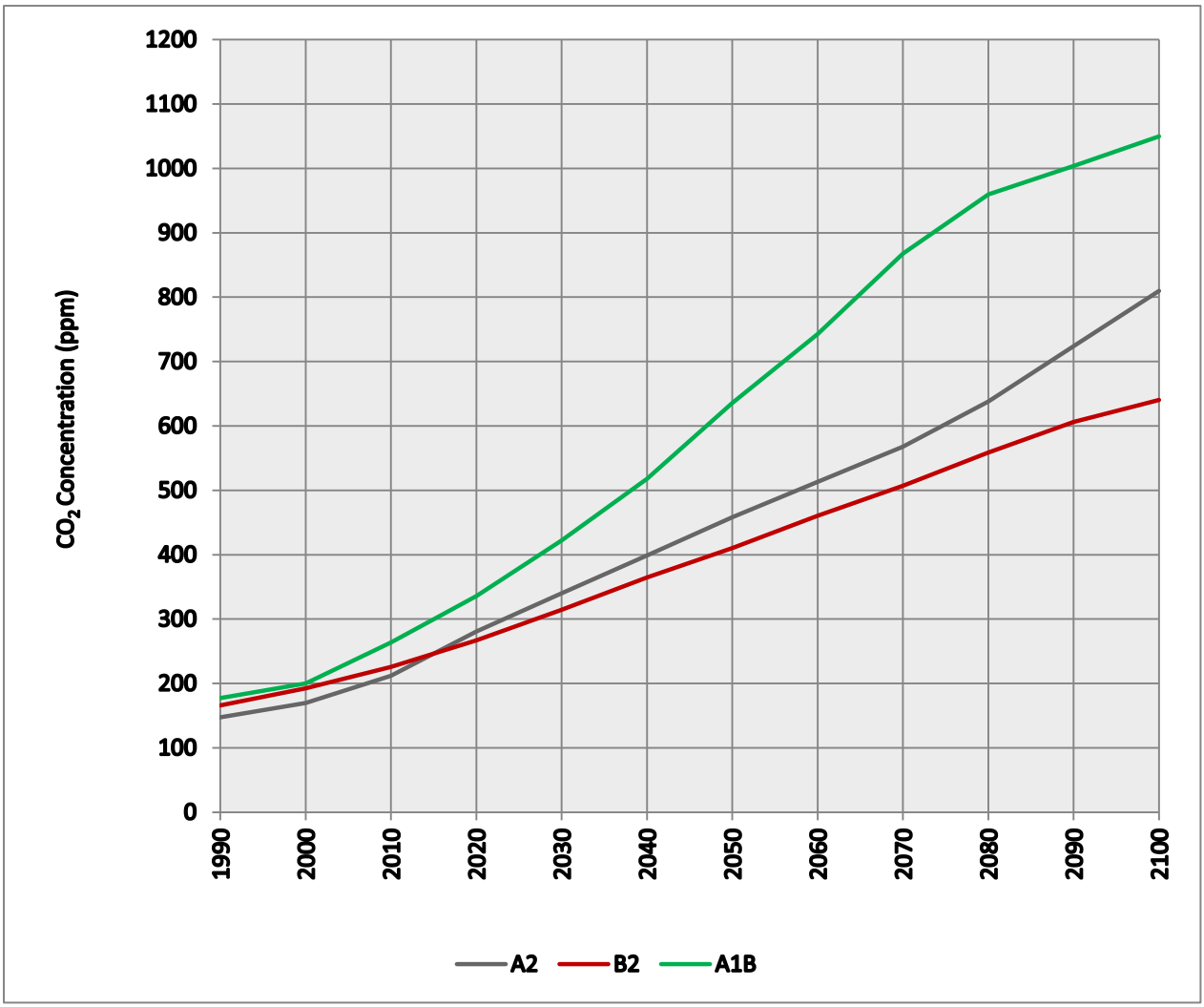
Year	Scenarios		
	A2	B2	A1B
1990	147.6	165.8	177.2
2000	169.8	192.5	200.0
2010	212.1	225.8	263.7
2020	280.6	266.7	335.6
2030	339.8	314.5	422.3
2040	399.0	364.7	518.0
2050	458.2	410.0	635.5
2060	513.0	460.3	742.6
2070	567.8	506.8	867.8
2080	638.2	558.6	959.4
2090	724.1	606.0	1,003.6
2100	809.9	640.2	1,049.8

Source: IDEAM

5.3. Scenario Development

After analyzing the IDEAM's data on rainfall and temperature associated with climate change scenarios in the representative stations of the Suaza River Basin, the team decided to use scenarios A2, B2, and A1B-ECHAM5 for the rainfall-runoff models. These hydrological models were calibrated up to the locations of the hydrometric stations of the Suaza River Basin (San Marcos and Puente Garcés) for 22 years (1986-2007). To estimate the rainfall and temperature variability in 2050 (the planning horizon established by CAM), the team compared the mean of each analyzed variable for each emission scenario during 2040-2060 (21 years) to the historical averages for 1971-2010 and 1986-2007 (calibration period for the hydrological model).

Figure 5.2 CO_2 Concentration in the Atmosphere



Source: IDEAM

5.3.1. Rainfall

Annex 5.2 Climate change scenarios at the Resina station for average Annual temperaturescontains the data used to calculate the annual average rainfall for 2040 to 2060 for each of the rainfall stations and for each one of the emission scenarios analyzed. Table 5.4 summarizes the results obtained.

Table 5.4 Annual Average Rainfall Projected, 2040-2060 (mm)

Station	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
San Adolfo	1916.6	1771.1	1957.7	2097.3
Acevedo	1561.0	1447.9	1594.7	1569.7
Guadalupe	1136.5	1054.0	1124.6	1204.8
San Antonio	1541.7	1475.7	1212.1	1649.3
La Jagua	879.1	837.6	730.0	1008.1
Maximum	1916.6	1771.1	1957.7	2097.3
Average	**1407.0**	**1317.3**	**1323.8**	**1505.9**
Minimum	879.1	837.6	730.0	1008.1

Source: Abt Associates

Table 5.5 shows average annual rainfall at each of the rainfall stations for 1971 to 2010 (used by the IDEAM to generate the climate change scenarios) and from 1986 to 2007 (used to calibrate the rainfall runoff hydrological models).

Table 5.5 Annual Average Rainfall During Historic Periods (mm)

Station	Average 1971-2010	Average 1986-2007
San Adolfo	2085	2119
Acevedo	1620	1577
Guadalupe	1234	1190
San Antonio	1633	1547
La Jagua	1003	1003

Source: IDEAM

Table 5.6 shows the ratio between projected mean annual rainfall for 2040-2060 and 1971-2010. Table 5.7 compares the projected rainfall to the period from 1986 to 2007, respectively. These ratios were similar for both periods. In general, rainfall was projected to decrease in 2050 between 6 and 14 percent under the climate change scenarios compared to the baseline scenario.

Table 5.6 Ratio Between the 2040-2060 Average and the Historic Average (1971-2010)

Station	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
San Adolfo	0.92	0.85	0.94	1.01
Acevedo	0.96	0.89	0.98	0.97
Guadalupe	0.92	0.85	0.91	0.98
San Antonio	0.94	0.90	0.74	1.01
La Jagua	0.88	0.83	0.73	1.00
Maximum	0.96	0.90	0.98	1.01
Average	**0.92**	**0.87**	**0.86**	**0.99**
Minimum	0.88	0.83	0.73	0.97

Source: Abt Associates

Table 5.7 Ratio Between the 2040-2060 Average and the Historic Average (1986-2007)

Station	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
San Adolfo	0.90	0.84	0.92	0.99
Acevedo	0.99	0.92	1.01	1.00
Guadalupe	0.96	0.89	0.95	1.01
San Antonio	1.00	0.95	0.78	1.07
La Jagua	0.88	0.84	0.73	1.01
Max	1.00	0.95	1.01	1.07
Average	**0.94**	**0.89**	**0.88**	**1.01**
Min	0.88	0.84	0.73	0.99

Source: Abt Associates

5.3.2. Mean temperature

Annex 5.2 Climate change scenarios at the Resina station for average Annual temperaturescontains the average temperature data at the Resina station under each of the emission scenarios analyzed. Table 5.8 summarizes the results.

Table 5.8 Annual Average Temperature Projected, 2040-2060 (°C)

Station	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
Resina	19.36	19.17	17.83	15.88

Source: Abt Associates

Table 5.9 shows the annual average mean temperature for 1971-2010 and 1986-2007.

Table 5.9 Annual Average Temperatur, 1971-2010 and 1986-2007(°C)

Station	Average 1971-2010	Average 1986-2007
Resina	15.89	15.94

Source: Abt Associates

Table 5.10 and Table 5.11 show the difference between the projected annual mean temperature for 2040-2060, 1971-2010 and 1986-2007. As was the case with rainfall, the temperatures' differences were similar for both periods. The average annual temperature in 2050 was projected to increase between 12 percent and 22 percent under the climate change scenarios.

Table 5.10 Difference Between the Averages for 2040-2060 and 1971-2010 (°C)

Station	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
Resina	3.47	3.28	1.94	0

Source: Abt Associates

Table 5.11 Difference Between the Averages for 2040-2060 and the Historic Series Average (1986-2007) (°C)

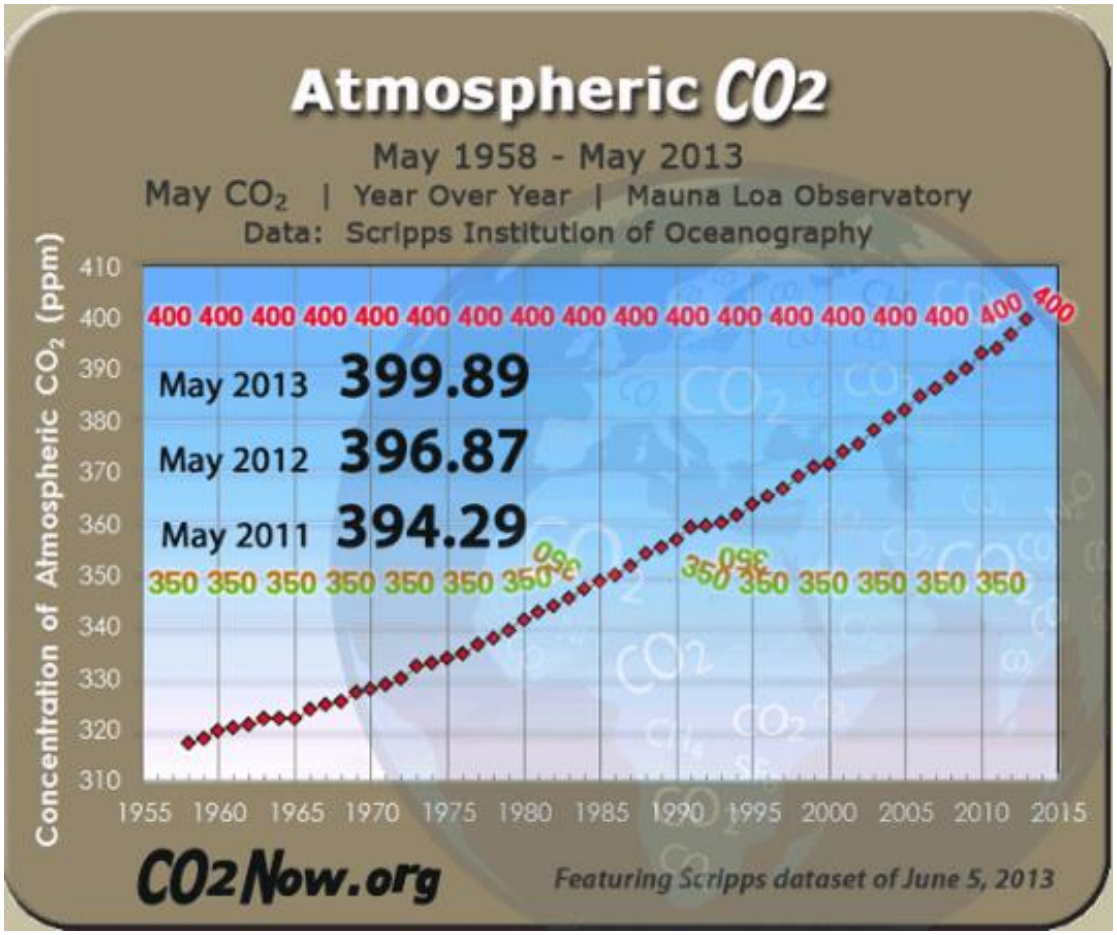
Station	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
Resina	3.42	3.23	1.89	0

Source: Abt Associates

5.3.3. Atmospheric CO_2 concentration

Figure 5.3 shows CO_2 concentration in the atmosphere was around 392 ppm in 2010 and 399.89 ppm in May 2013 (http://co2now.org/). Table 5.12 uses this figure to re-scale the data from IDEAM (Table 5.3) to reflect the 2010 concentration. The future values were extrapolated by adding the difference between the IDEAM values and the 2010 level. In general, the re-scaling process increased the preliminary IDEAM estimates and also followed CO_2 increasing historic tendency.

Figure 5.3 Atmospheric CO_2 Concentration



Source: http://co2now.org/

Table 5.12 Atmospheric CO_2 Concentration, Updated (ppm)

Year	Scenarios		
	A2	B2	A1B
2010	392.0	392.0	392.0
2020	460.5	432.9	463.8
2030	519.7	480.7	550.6
2040	578.9	530.9	646.3
2050	638.1	576.2	763.8

Source: Abt Associates

5.4. Selected Scenarios for the Year 2050

Three scenarios were developed using all the information processed in the previous sections, which were analyzed with the rainfall-runoff models:

- **A2**: A 5 percent rainfall reduction, 3.4°C temperature rise, and an increase in CO_2 concentration to 638 ppm.
- **B2**: A 10 percent rainfall reduction, 3.4°C temperature rise, and an increase in CO_2 concentration to 576 ppm.
- **AIB**: A 15 percent rainfall reduction, 1.9°C temperature increase, and CO_2 concentration increase to 764 ppm.

Ruiz (2010) obtained similar results by applying a multi-model ensemble for the Department of Huila over the years 2041-2070 (which includes year 2050):

- Average temperature increase of 2.6°C.
- Average rainfall decrease of 13 percent.
- Average relative humidity decrease of 2.9 percent.

These results fall within the values estimated for the scenarios used in the AILEG analysis.

6. EVALUATION OF THE EFFECT OF THESE CLIMATE CHANGE SCENARIOS IN THE FUTURE AVAILABILITY OF WATER RESOURCES AT THE SUAZA RIVER BASIN

The following climate change scenarios used to project the availability of water resources in the Suaza River Basin:

- Esc-I
- Esc-II
- Esc-III
- Baseline

The impact on the availability of water resources was analyzed using SIHIM and SWAT models.

6.1 The Effects of Climate Change Scenarios using the SIHIM Model

6.1.1 Evapotranspiration changes due to temperature changes

The potential rate of evapotranspiration was estimated using the Penman-Monteith equation (Equation 3.1), recommended by FAO (1998). ETo was estimated at each sub-basin using the CROPWAT program (FAO 1998) and the average altitude and geographic location of the center of gravity of each sub-basin. The spatial variation of climatic variables was estimated using the records from all weather stations located within the basin.

The ETo of the Resina Weather Station was multiplied it by factors to estimate the ETo of each sub-basin (Table 3.5).

The increased ETo due to temperature changes were estimated using information from the Resina Weather Station. The estimated changes were:

- Esc-I and Esc-II: increased the temperature by 3.4°C.
- Esc-III: increasing the temperature by 1.9°C.

The results obtained by applying the CROPWAT model are shown in Table 6.1 and Figure 6.1. A 1.9° C increase in temperature resulted in a 5 percent ETo increase while a 3.4°C temperature increase produced a 9 percent ETo increase.

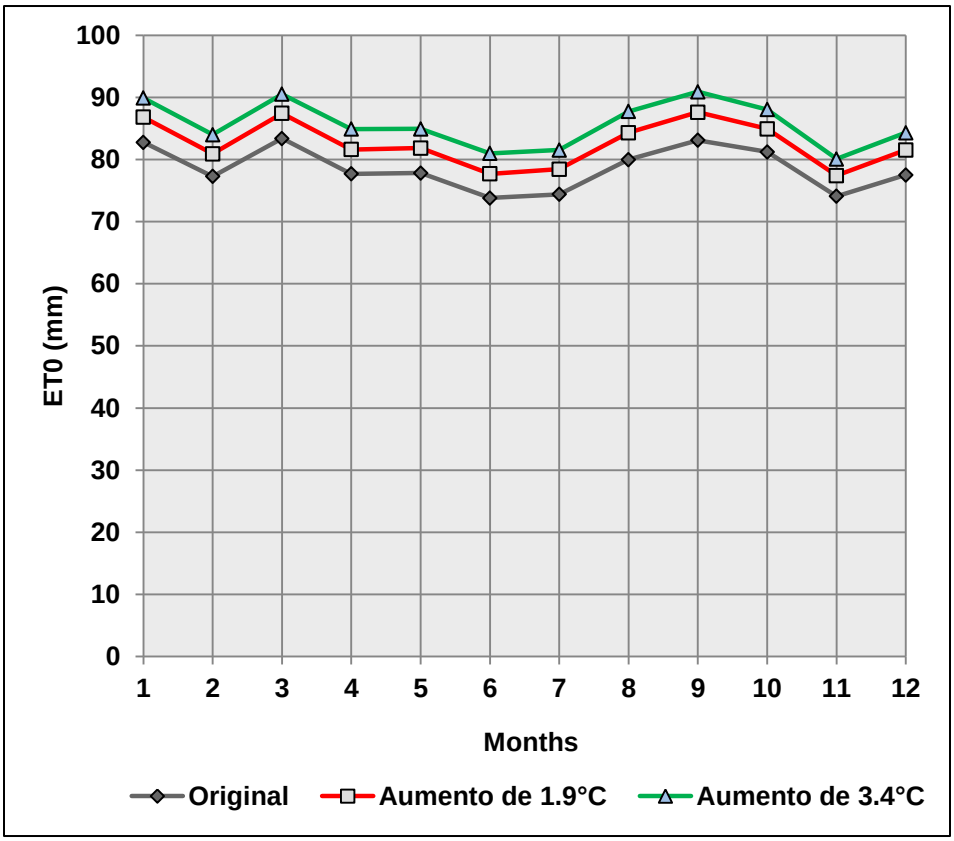
Table 6.1 Changes in Evapotranspiration (mm) Due to Temperature Changes at the Resina Station

Month	Baseline	1.9° C increase	3.4° C increase
1	82.77	86.80	89.90
2	77.28	80.92	84.00
3	83.39	87.42	90.52
4	77.70	81.60	84.90
5	77.81	81.84	84.94
6	73.80	77.70	81.00
7	74.40	78.43	81.53
8	79.98	84.32	87.73
9	83.10	87.60	90.90
10	81.22	84.94	88.04
11	74.10	77.40	80.10
12	77.50	81.53	84.32
Average	**943.1**	**990.5**	**1,027.9**
Change (%)	**0**	**5**	**9**

Source: Abt Associates

These projections only take into account temperature changes, not changes in other weather variables and the atmospheric CO_2 concentration.

Figure 6.1 Evapotranspiration (mm) Changes Due to Temperature Changes, Resina Station



Source: Abt Associates

6.1.2. Change in water availability due to climate change

The changes in ETo and rainfall for each climate change scenario analyzed were previously calibrated at the Suaza River Basin.

Table 6.2 shows the average flows in San Marcos (SM), Puente Garcés (PG) and at the confluence with the River Magdalena (Suaza), for each scenario. Table 6.3 presents these results in relation to the current situation without the effect of climate change.

Table 6.2 Average Flows at San Marcos (SM), Puente Garcés (PG) and the Confluence With the Magdalena River (Suaza) (m^3/s)

Scenarios	SM	PG	Suaza
Baseline	26.0	44.0	53.6
Esc-I	24.0	39.1	47.4
Esc-II	22.3	35.7	43.1
Esc-III	20.7	32.9	39.5

Source: Abt Associates

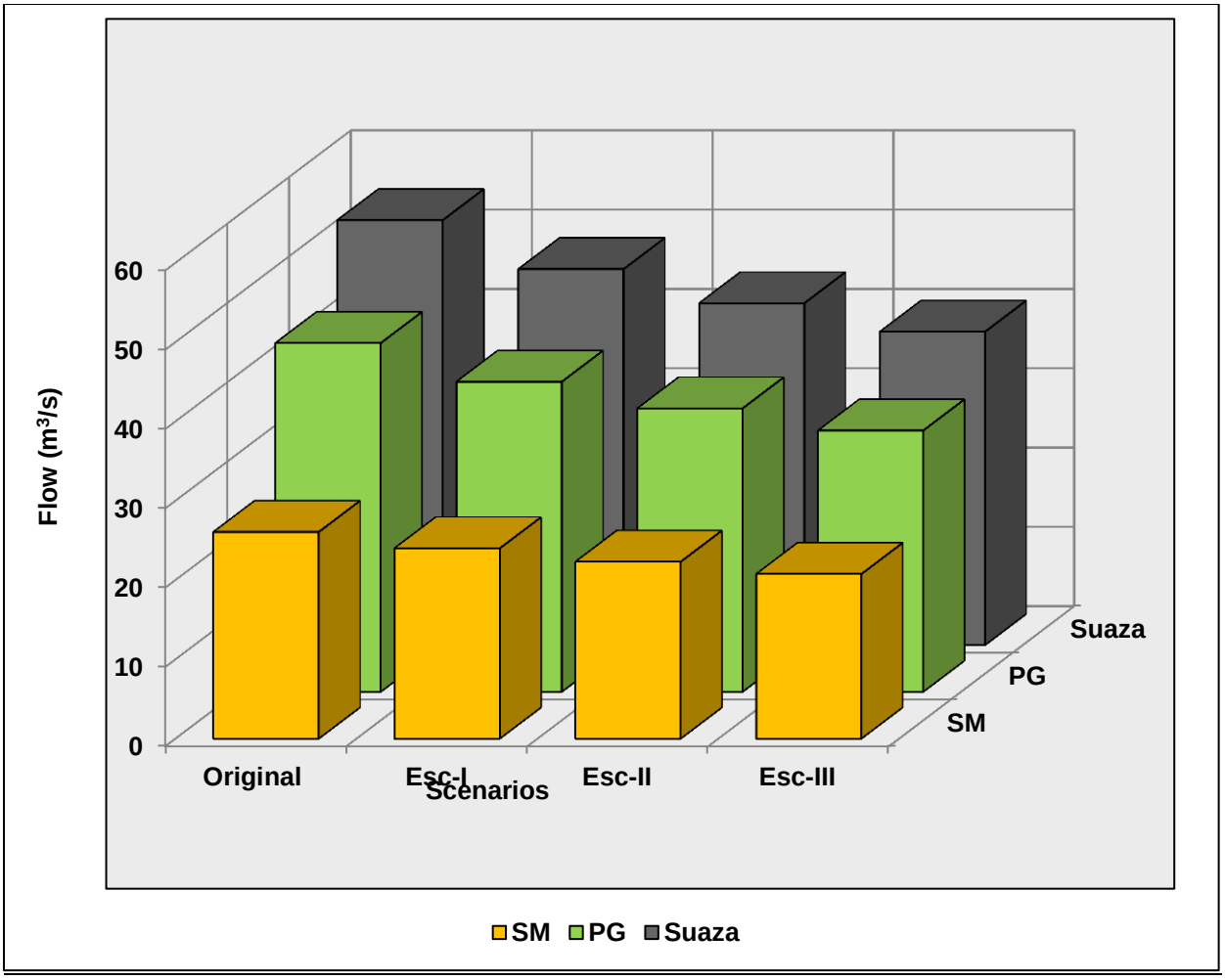
Table 6.3 Ratio of Average Flowsat Each Site and Climate Change Scenario Under the Current Situation

Scenarios	SM	PG	Suaza	Average
Baseline	1.00	1.00	1.00	1.00
Esc-I	0.92	0.89	0.88	0.90
Esc-II	0.86	0.81	0.80	0.82
Esc-III	0.80	0.75	0.74	0.76

Source: Abt Associates

The variability of the climate change effect at each site was evident. Scenarios Esc-I, Esc-II, and Esc-III were projected to reduce the availability of water resources in the Suaza River Basin by 10 percent, 20 percent, and 25 percent, respectively.

Figure 6.2 Mean Flows at San Marcos (SM), Puente Garcés (PG) and the Confluence With the Magdalena River (Suaza), Under the Climate Change Scenarios With the SIHIM Model



Source: Abt Associates

6.2. The Effects of Climate Change Scenarios Based on the SWAT Model

6.2.1. Methods

The SWAT model was used to estimate the effects of climate change on runoff in Suaza River Basin using information available on the effect of climate change on rainfall, temperature, and atmospheric CO_2 .

These factors were introduced in the SWAT input data characterizing the sub-basins (*. Sub). This had either a multiplicative or additive effect as explained below.

- **Rainfall**: This adjustment factor had a multiplier effect on this variable, expressed in percentages.

- $R_{day} = R_{day} \times \left[1 + \frac{adj_{pcp}}{100}\right]$ (6.1)
  - R_{day} is the daily rainfall (mm) and adj_{pcp} is the rainfall adjustment factor (%) at the sub-basin. If the factor was 10, the rainfall increased by 10 percent; if -10, it dropped 10 percent.

- **Temperature**: This adjustment factor had an additive effect on daily maximum and minimum temperature data.
  - $T_{mx} = T_{mx} + adj_{tmp}$ (6.2)
  - $T_{mn} = T_{mn} + adj_{tmp}$ (6.3)
  - T_{mx} y T_{mn}, is the daily maximum and minimum temperature data in °C, while adj_{tmp} is the adjustment factor expressed in °C.

- **CO_2**: The SWAT program assumed an atmospheric carbon dioxide concentration of 330 ppm by default, but this value can be changed on the screen that contains the characteristics of the sub-basins

As carbon dioxide increases, plant productivity, of "C3 Plants" increases, which determines the reduction in water requirements (evapotranspiration rate). This type of plant must make a tradeoff when keeping its stomata open to allow CO_2 into its leaves for photosynthesis, because this also causes the loss of water through transpiration. If atmospheric CO_2 concentrations increase, the pressure of this tradeoff is reduced and more growth can occur with less water loss. This "CO_2 fertilization effect" is particularly important for the group of plants that use this pathway for photosynthesis. These plants are called C3, after the number of carbon atoms in the compounds involved at a key point of photosynthesis (Jablonski et al, 2002). Experimental evidence has shown that stomatal conductance of C3 plants declines as CO_2 increases, resulting in a reduction in transpiration (Tyree and Alexander (1993), Hendry, Lewin and Nagy (1993)). SWAT program used a modified version of the Penman-Monteith method to take into consideration the "CO_2 fertilization effect" on the potential evapotranspiration rate estimation for this type of plants (Neitsch, et al, 2009).

6.2.2. Results achieved

Table 6.4 and Table 6.5 summarize the results of the SWAT model under the climate change scenarios. Table 6.4 and Figure 6.3 show the results expressed in terms of annual average flows at San Marcos, Puente Garcés, and the confluence of Suaza River with the Magdalena River.

Table 6.4 Mean Flows at San Marcos (SM), Puente Garcés (PG), and the Confluence With the Magdalena River (Suaza) (m^3/s)

Scenarios	SM	PG	Suaza
Baseline	26.42	44.53	53.61
Esc-I	24.03	39.08	47.46
Esc-II	22.10	35.62	43.21
Esc-III	21.97	35.71	43.31

Source: Abt Associates

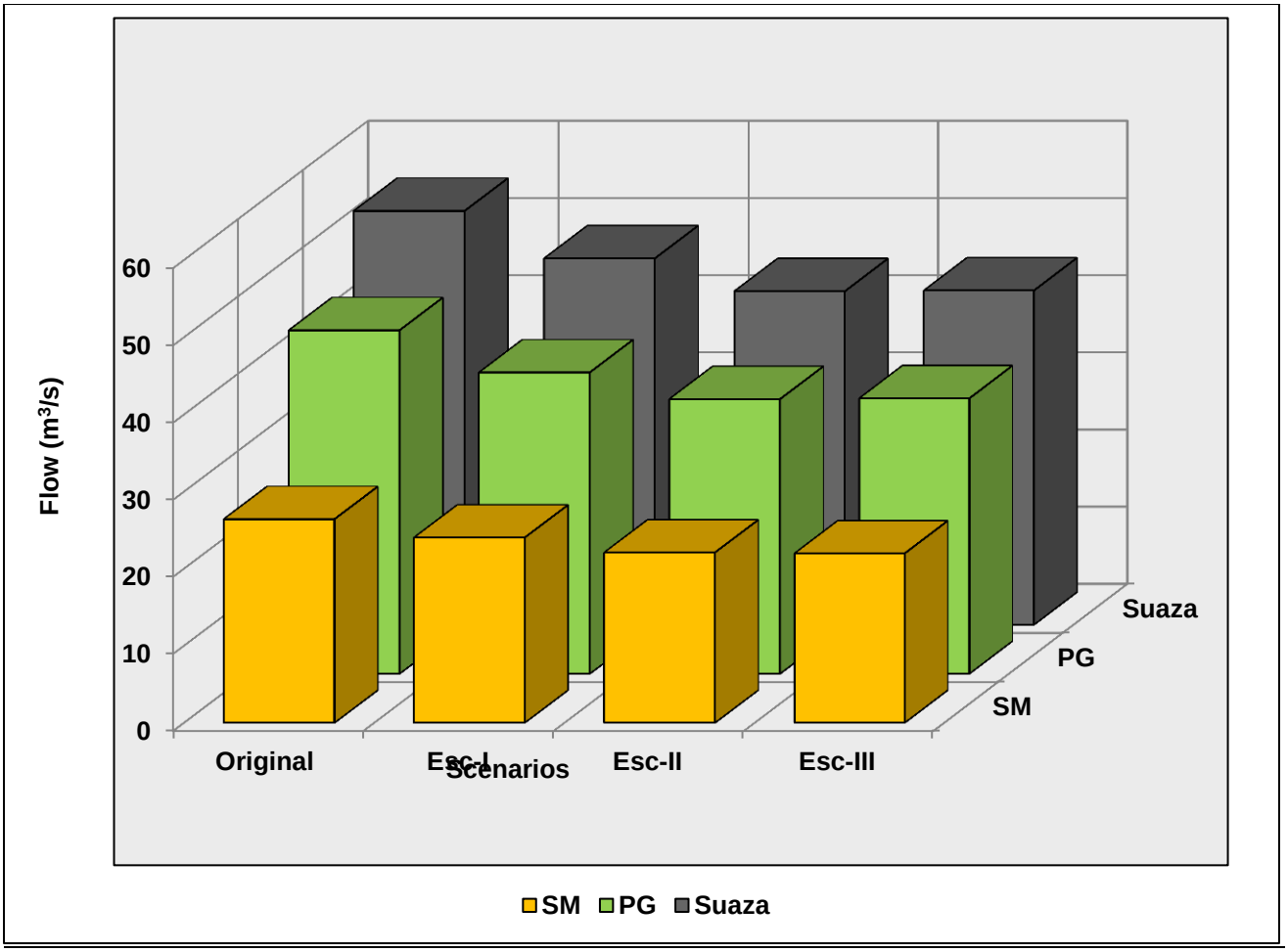
Table 6.5 presents the relationship between mean flows in each site for each climate change scenario, compared to the baseline. We estimated a 10 percent to 20 percent reduction in water availability depending on the climate change scenario.

Table 6.5 Ratio of Mean Flows at Each Site and Climate Change Scenario, Under the Current Situation (Baseline)

Scenarios	SM	PG	Suaza	Average
Baseline	1.00	1.00	1.00	1.00
Esc-I	0.91	0.88	0.89	0.89
Esc-II	0.84	0.80	0.81	0.81
Esc-III	0.83	0.80	0.81	0.81

Source: Abt Associates

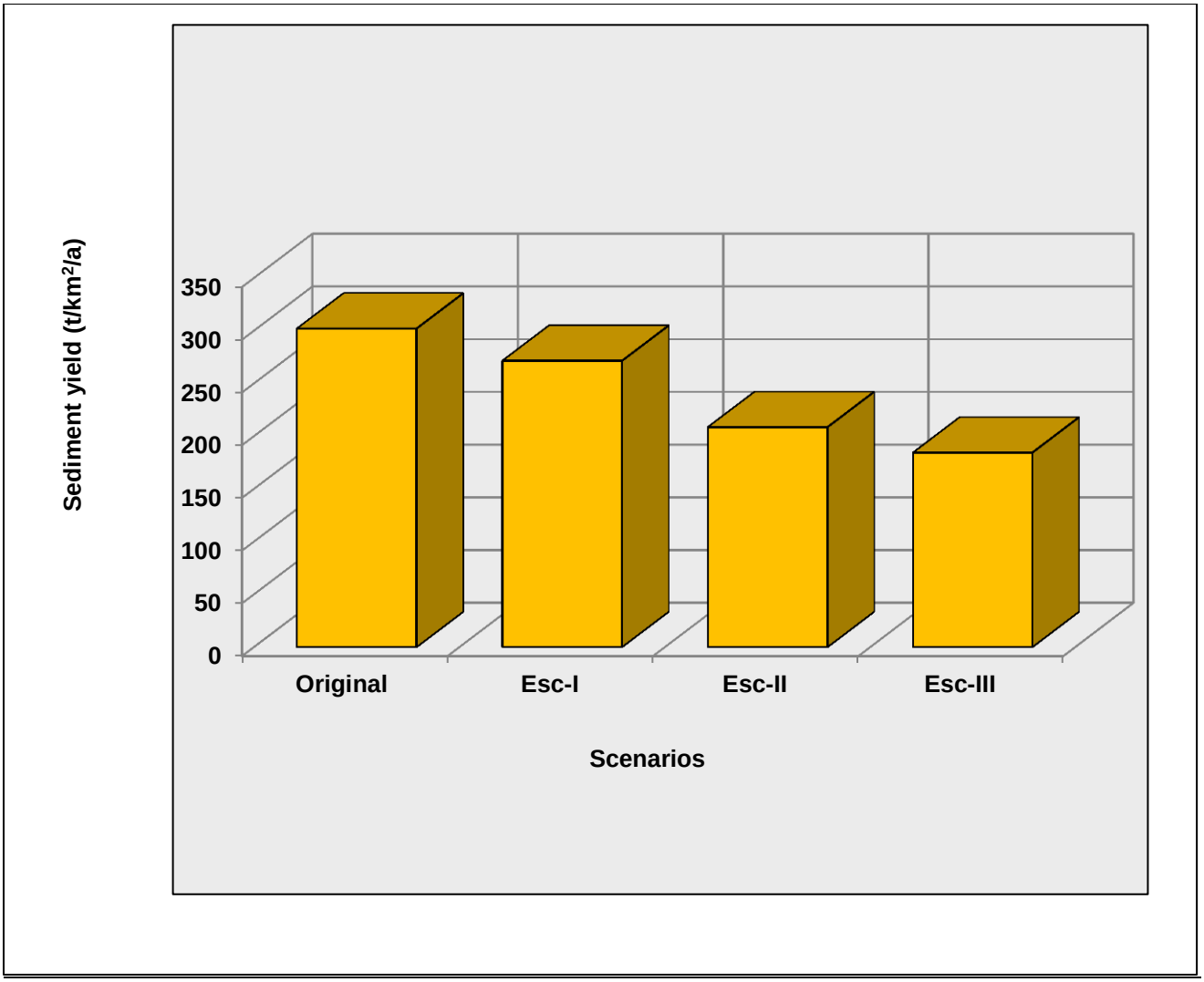
Figure 6.3 Mean Flows at San Marcos (SM), Puente Garcés (PG) and the Confluence With the Magdalena River (Suaza), Under the Climate Change Scenarios
SWAT Model



Source: Abt Associates

Another important factor is the sediment yield variation as a function of climate change on the Suaza River Basin. Figure 6.4 shows the variation of sediment yield per unit area in t/km^2/year at the Suaza River tributary basin up to the Puente Garcés gauging station. The net effect was a reduction of sediment yield in the watershed between 10 percent and 40 percent.

Figure 6.4 Variation of Sediment Yield Modules at the Effluent Basin to Puente Garcés (PG), as a Function of Climate Change Scenarios, SWAT Model

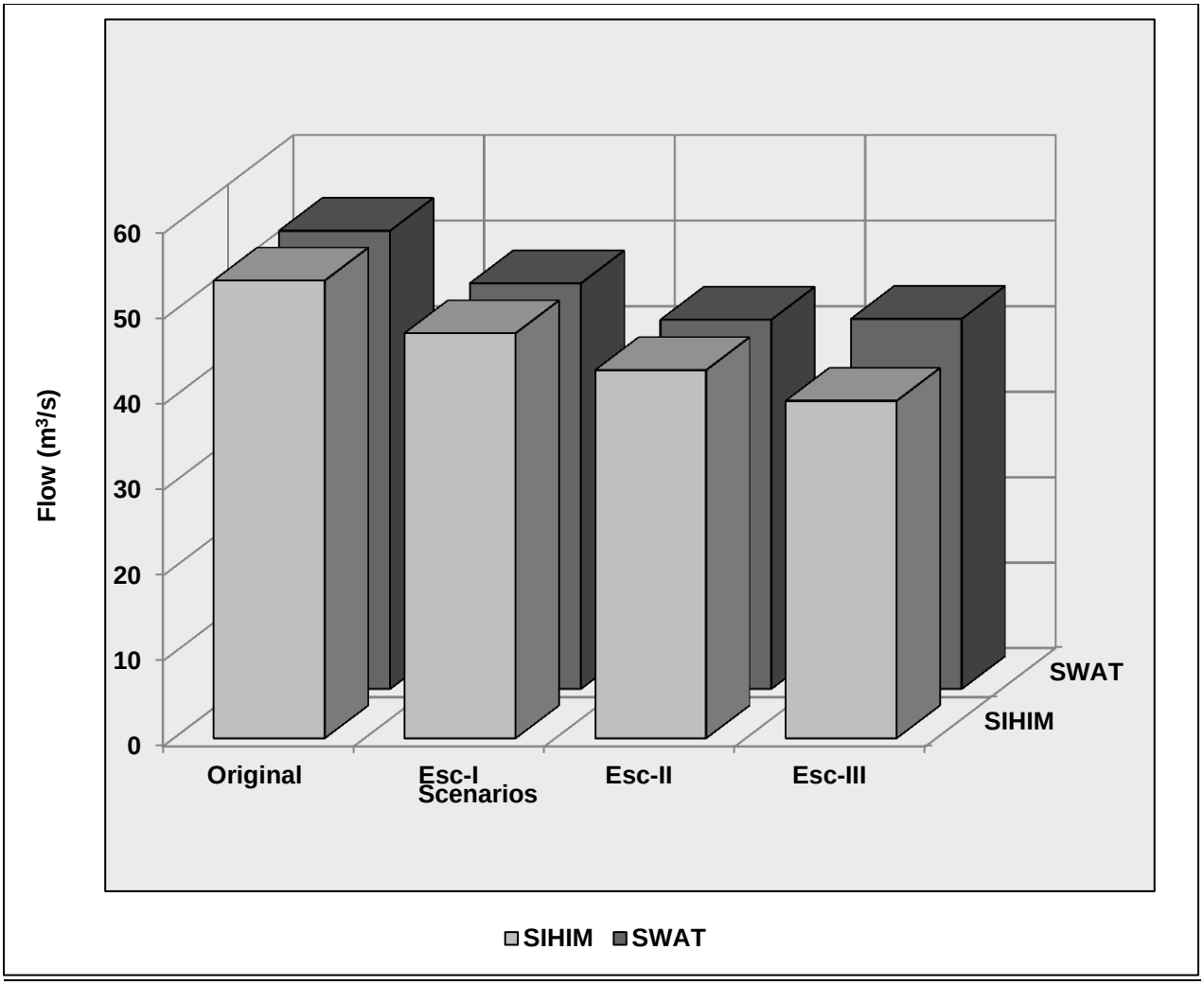


Source: Abt Associates

6.3. Comparison of Outcomes by Applying the SIHIM and SWAT Models

Figure 6.4 summarizes the climate change effects on rainfall and temperature through 2050 using the SIHIM and SWAT models. The results are presented for the entire Suaza River Basin to its confluence with the Magdalena River for the baseline and the three climate change scenarios.

Figure 6.5 Comparison of the Climate Change Outcomes With Applying the SIHIM and SWAT Models



Source: Abt Associates

The two models provided very similar results, except in the most extreme scenario (Esc-III). , where the monthly model resulted in a reduction in water flows at around 25 percent, while the daily model resulted in a 20 percent reduction.

7. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Suaza River Basin up to its confluence with the Magdalena River was selected as the pilot basin due to data availability. The study projected the effects of climate change on water availability. The digital terrain model was analyzed using geographical information systems that defined the Suaza River Basin and its major sub-basins. The spatial variation of soil information, vegetation cover, and current land use were also analyzed.

- The temporal and spatial variation of the variables that define the weather at the basin stations were characterized using the climate data from eight rainfall stations and three weather stations.
- The spatial variation of rainfall was analyzed. The upper basin rainfall exhibited unimodal temporal variation, while the middle and lower basin had a bimodal distribution accentuated in the south-north direction.
- The temporal and spatial variation of evapotranspiration was analyzed using the weather station data and the Penman-Monteith, and the potential evapotranspiration rate and the CROPWAT program (FAO 1998).
- Hydrometric data of the Suaza River at San Marcos and at Puente Garcés Stations were used. The data on transported suspended sediments were collected from the Puente Garcés Station.
- Vegetation and land use data of the area were verified through field visits. Data were also collected on water concessions in the basin, by municipality and watercourse, but these did not affect the calibration of the rainfall-runoff models.

Rainfall runoff models were applied in two stages. In the first stage, a monthly model was calibrated and applied to estimate the representative rainfall in each sub-basin, the weights associated to each station for calculating the areal average rainfall in the sub-basin. The second stage involved calibration and application of a daily hydrological model. After analyzing the available weather and hydrometric data, it was decided to use 1986 to 2007 as the baseline period.

The first stage adopted the Monthly Hydrological Simulation Model (SIHIM), which is widely used in Latin America (Duque 1985). The model was first implemented and calibrated up to the station of San Marcos, obtaining a correlation coefficient of 0.85. It was then calibrated up to Puente Garcés with a correlation coefficient of 0.88. Next, the model was applied throughout the Suaza River up to its confluence with the Magdalena River, yielding an average annual flow of about 53.6 m^3/s.

The second stage used the SWAT model, which works on a daily time step (Neitsch, Arnold, J. Kiniry, and JR Williams 2009). This model estimated runoff and sediment yield generated in a basin due to the combined occurrence of rainfall and evapotranspiration processes. This model was calibrated up to San Marcos and Puente Garcés, with correlation coefficients above 0.85 similar to those obtained with the monthly model. Subsequently, it was applied over the entire Suaza River Basin, generating a monthly series with a correlation coefficient of 0.95 for the series generated with the monthly model.

IDEAM provided information on climate changes in three scenarios covering the period 2011 to 2100 for the five rainfall stations covering the entire basin. IDEAM also provided projected average monthly temperatures for the same period based on one weather station and the concentration of atmospheric carbon dioxide under the climate change scenarios. The planning horizon for this study extended to the year 2050.

First, the effects of evapotranspiration were projected using a monthly model. Then, the hydrological model was applied, varying the rainfall. The results showed that the three climate change scenarios may reduce the availability of water resources in the Suaza River Basin by 10 to 25 percent.

Then, the daily SWAT model was applied, assessing the changes in rainfall, temperature, and atmospheric CO_2. Unlike the monthly model, SWAT allowed an assessment of the effect of changes in temperature and CO_2 on evapotranspiration. This model projected a 10-20 percent reduction in the availability of water resources in the Suaza River Basin.

Both models showed very similar results, except in the most extreme scenario where the results of the monthly model predicted a reduction of around 25 percent, compared to 20 percent with the daily model. The daily model also projected a 10-40 percent reduction of sediment yield at the Suaza River Basin due to climate change. Because the results of the simpler and more complex models were similar in the analyzed watershed, this study recommended using the simpler, monthly model to analyze the effects of climate change in all basins of the Department of Huila.

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9. ANNEXES

Annex 2.1. Series of weather and hydrometric data provided by IDEAM

Annex 2.2. Profile of representative soils at the Suaza River Basin

Annex 2.3. Concession for the use of water at the Suaza River Basin

Annex 3.1. Estimation of potential evapotranspiration

Annex 4.1. Intensity-Duration-Frequency Curves and Depth-Duration-Frequency Curves at the Guadalupe, El Líbano, and Resina Stations

Annex 4.2. Series of monthly and annual flows estimated with the SWAT method at the eight sub-basins for the 1986-2007 period.

Annex 5.1. Climate change scenarios for representative rainfall stations at the Suaza River Basin

Annex 5.2. Climate change scenarios at the Resina Station for the average temperature variable

Annex 6.1. Monthly rainfall-runoff hydrological model—Theoretical description: SIHIME model

Annex 2.1 Weather and Hydrometric Data from IDEAM

Monthly Rainfall

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

TOTAL RAINFALL MONTHLY VALUES (mms)

PROCESS DATE : 2013/02/28 STATION : 21030060 SAN ADOLFO

LATITUDE 0142 N ST TYPE PM DEPT HUILA INSTALLATION DATE 1964-MAY

LONGITUDE 7601 W ENTITY 01 IDEAM MUNICIPALITY ACEVEDO SUSPENSION DATE

ELEVATION 1345 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL
1972	2	01	141.0	136.0	188.0	217.0	364.0	480.0	440.0	194.0	225.0	224.0	236.0	73.0	2918.0
1973	2	01	111.0	43.0	131.0	86.0	249.0	194.0	341.0	432.0	225.0	103.0	222.0	102.0	2239.0
1974	2	01	93.0	163.0	125.0	150.0	215.0	361.0	293.0	273.0	113.0	158.0	152.0	123.0	2219.0
1975	2	01	37.0	83.0	313.0	179.0	205.0	212.0	153.0	250.0	179.0	83.0	143.0	103.0	1940.0
1976	2	01	7.0	78.0	189.0	241.0	288.0	228.0	327.0	333.0	191.0	156.0	152.0	164.0	2354.0
1977	2	01	12.0	108.0	138.0	113.0	354.0	244.0	449.0	304.0	212.0	231.0	146.0	106.0	2417.0
1978	2	01	14.0	105.0	301.0	231.0 3	324.2 9	306.4 9	321.3 9	242.0	312.0	180.0	183.0	232.0	2751.9 3
1979	2	01	99.0	14.0	140.0	336.0	450.0	315.0	204.0	170.0	56.0 3	37.0	119.0	41.0	1981.0 3
1980	2	01	72.0	47.0	111.0	194.0	160.0	330.0	387.0	174.0	144.0	136.0	27.0	14.0	1796.0
1981	2	01	103.0	145.0	206.0	195.0	162.0	288.0	180.0	150.0	238.0	151.0	143.0	70.7 9	2031.7
1982	2	01	218.0	50.0	156.0	101.0	120.0	93.0	234.0	224.0	76.0	69.0	61.0	38.0	1440.0
1983	2	01	46.0	262.0	116.0	94.0	146.0	79.0	171.0	110.0	80.0	86.0	73.0	116.0	1379.0
1984	2	01	56.0	90.0	33.0	61.0	86.0	163.0	127.0	138.0	69.0	101.0	135.0	177.0	1236.0
1985	2	01	29.0	58.0	104.0	93.0	146.0	177.0	110.0	280.0	123.0	131.0	86.0	49.0	1386.0
1986	2	01	87.0	81.0	215.0	132.0	130.0	293.0	282.0	179.0	309.0	95.0	89.0	137.0	2029.0
1987	2	01	78.0	193.0	96.0	279.0	126.0	235.0	286.0	223.0	63.0	74.0	56.0	64.0	1773.0
1988	2	01	53.0	71.0	80.0	192.0	185.0	312.0	138.0	163.0	151.0	89.0	199.0	66.0	1699.0
1989	2	01	136.0	102.0	183.0	249.0	308.0	470.0	249.0	213.0	175.0	155.0	202.0	58.0	2500.0
1990	2	01	135.0	69.0	177.0	201.0	234.0	271.0	196.0	225.0	214.0	86.0	138.0	141.0	2087.0
1991	2	01	25.0	119.0	100.0	181.0	314.0	366.0	311.0	427.0	191.0	105.0	147.0	55.0	2341.0
1992	2	01	124.0	145.0	175.0	289.0	195.0	232.0	369.0	205.0	134.0	136.0	127.0	96.0	2227.0
1993	2	01	78.0	70.0	253.0	167.0	338.0	355.0	368.0	326.0	107.0	189.0	236.0	136.0	2623.0
1994	1	01	104.0	62.0	179.0	341.0	381.0	398.0	151.0	264.0	277.0	140.0	190.9	129.6	2617.5
1995	2	01	69.6	54.2	130.2	249.6	244.1	254.3	216.6	81.2	142.3	134.7	77.2	91.6	1745.6
1996	2	01	99.9	228.3	167.4	180.3	177.9	162.1	340.7	211.2	285.7	118.9	82.3	165.7	2220.4
1997	2	01	103.5	211.5	175.1	152.3	391.2	190.1	194.8	235.5	143.0	91.3	96.8	83.0	2068.1
1998	2	01	47.3	91.7	237.2	135.0	217.1	384.6	270.7	244.7	147.7	155.9	109.0	94.6	2135.5
1999	2	01	202.7	126.8	109.8	386.9	192.8	263.9	327.0	189.7	129.9	132.7	175.4	121.6	2359.2
2000	2	01	88.7	84.9	145.7	161.3	413.6	74.5	111.4	373.6	107.9	250.2	179.1	121.1	2112.0
2001	2	01	18.8	120.3	77.6	324.1	233.9	224.6	237.2	186.0	218.5	118.3	120.1	184.6	2064.0
2002	2	01	73.6	96.5	163.2	196.8	341.7	229.2	227.8	282.8	157.5	164.6	98.9	46.9	2079.5
2003	1	01	48.8	43.2	131.7	109.1	179.3	160.3	245.9	118.1	151.7	144.3	69.8	154.2	1556.4
2004	1	01	22.7	48.6	188.6	281.9	230.4	329.3	214.4	205.7	234.6	112.8	77.5	66.7	2013.2

2005	1	01	106.3	167.6	119.3	373.0	141.5	359.9	195.9	177.5	185.9	188.4	105.2	110.4	2230.9
2006	1	01	139.0	107.4	118.7	160.5	185.6	200.7	275.6	221.8	212.4	153.7	52.8	99.3	1927.5
2007	1	01	33.6	85.1	140.7	149.0	316.3	368.2	148.9	373.1	230.3	137.4	99.7	123.1	2205.4
2008	1	01	34.5	122.6	71.1	98.9	222.4	274.5	261.4	209.3	176.6	224.1	129.0	106.9	1931.3
2009	1	01	110.1	94.5	219.5	170.1	202.0	304.6	478.8	257.2	194.8	131.5	32.3	33.1	2228.5
2010	1	01	10.1	101.3	207.2	286.1	306.0	331.0	202.0	131.0	174.0	196.0	131.0	33.0	2108.7
2011	1	01	24.0	85.0	111.0	136.0	118.0	125.0	218.0	150.0	159.0	109.0	170.0	135.0	1540.0
MEAN			77.3	104.1	155.6	196.8	239.9	266.0	256.4	228.7	172.9	137.0	126.7	101.6	2062.8
MAX			218.0	262.0	313.0	386.9	450.0	480.0	478.8	432.0	312.0	250.2	236.0	232.0	480.0
MIN			7.0	14.0	33.0	61.0	86.0	74.5	110.0	81.2	56.0	37.0	27.0	14.0	7.0

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL TOTAL MONTHLY VALUES (mms)

PROCESS DATE : 2013/02/28 STATION : 21030080 ACEVEDO

LATITUDE 0148 N ST TYPE PM DEPT HUILA INSTALLATION DATE 1971-MAR

LONGITUDE 7553 W ENTITY 01 IDEAM MUNICIPALITY ACEVEDO SUSPENSION DATE

ELEVATION 1350 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1972	2	01	49.0	54.0	126.0	163.0	175.0	274.0	238.0	135.0	71.0	101.0	186.0	35.0	1607.0
1973	2	01	44.0	58.0	54.0	91.0	155.0	124.0	254.0	175.0	95.0	44.0	44.0	21.0	1159.0
1974	2	01	45.0	141.0	98.0	191.0	220.0	261.0	420.0	85.0	112.0	116.0	88.0	87.0	1864.0
1975	2	01	49.0	76.0	229.0 3	118.0	61.0	373.0	36.0	80.0	94.0	83.0	102.0	61.0	1362.0 3
1976	2	01	52.0	57.0	39.0	148.0	277.0	360.0	151.0	248.0	125.0	75.0	198.0	185.0	1915.0
1977	2	01	2.0	76.0	193.0	565.0	349.0	162.0	123.0	90.0	259.0	173.0	41.0	69.9 8	2102.9
1978	2	01	140.0	36.0	99.0	142.0	132.0	197.0	180.0	132.0	325.0	269.0	41.0	64.0	1757.0
1979	2	01	44.0	25.0	165.0	190.0	228.0	134.0	135.0	90.0	125.0	115.0	45.0	20.0	1316.0
1980	2	01	34.0	51.0	194.0	377.0	242.0	307.0	322.0	200.0	241.0	166.0	38.0	81.0	2253.0
1981	2	01	122.0	107.0	119.0	24.0	111.0	146.0	156.0	48.0	146.0	101.0	53.0	140.0	1273.0
1982	2	01	149.0	186.0	234.0	186.0	182.0	177.0	207.0	364.0	275.0	150.0	92.0	67.0	2269.0
1983	2	01	44.0	155.0	146.0	201.0	232.0	145.0	251.0	103.0	242.0	67.0	136.0	23.0	1745.0
1984	2	01	119.0 3	74.0	123.0	132.0	128.0	242.0	338.0	252.0	102.0	83.0	237.0	100.0	1930.0 3
1985	2	01	40.0	70.0	154.0	139.0	98.0	106.0	162.0	197.0	38.0	46.0	72.0	52.0	1174.0
1986	2	01	107.0	119.0	72.0	87.0	181.0	279.0	115.0	92.0	184.0	190.0	83.0	40.0	1549.0
1987	2	01	28.0	84.0	74.0	144.0	188.0	116.0	126.0	169.0	83.0	75.0	29.0	153.0	1269.0
1988	2	01	85.0	170.0	50.0	165.0	234.0	357.0	82.0	127.0	132.0	96.0	221.0	85.0	1804.0
1989	2	01	82.0	131.0	175.0	95.0	232.0	177.0	174.0	182.0	125.0	96.0	134.0	19.0	1622.0
1990	2	01	23.0	70.0	124.0	132.0	139.0	194.0	157.0	122.0	124.0	41.0	87.0	194.0	1407.0
1991	2	01	26.0	45.0	97.0	30.0	34.0	89.0	204.0	87.0	75.0	40.0	50.0	60.0	837.0
1992	2	01	47.0	62.0	75.0	106.0	122.0	89.0	102.0	111.0	20.0	20.0	92.0	38.0	884.0
1993	2	01	35.0	101.0	161.0	45.0	172.0	88.0	166.0	114.0	80.0	238.0	72.0	68.0	1340.0
1994	1	01	96.0	57.0	182.0	123.0	249.0	189.0	133.0	215.0	120.0	93.0	151.0	79.0	1687.0
1995	2	01	75.0	19.0	146.0	253.0	148.0	178.0	105.0	66.0	178.0	67.0	49.0	47.0	1331.0
1996	2	01	73.0	106.0	130.0	166.0	63.0	237.0	167.0	104.0	145.0	138.0	62.0	111.0	1502.0
1997	2	01	131.0	88.0	193.0	167.0	243.0	155.0	157.0	158.0	116.0	102.0	75.0	51.0	1636.0
1998	2	01	9.0	78.0	141.0	76.0	107.0	203.0	203.0	111.0	60.0	68.0	87.0	94.0	1237.0
1999	2	01	59.6 8	76.1 8	*	272.0	134.0	164.4 8	110.0	83.0	145.0	196.0	106.0	159.0	1505.1 3
2000	2	01	144.0	195.0	198.0	132.0	389.0	168.0	113.0	281.0	197.0	149.0	78.0	114.0	2158.0
2001	2	01	27.0	50.0	152.0	228.0	252.0	183.0	192.0	98.0	176.0	125.0	140.0	113.0	1736.0
2002	2	01	55.0	77.0	101.0	150.0	215.0	144.0	220.0	244.0	113.0	97.0	87.0	97.0	1600.0
2003	1	01	44.0	52.0	70.0	172.0	219.0	141.0	151.0	118.0	174.0	173.0	111.0	89.0	1514.0
2004	1	01	67.0	41.0	85.0	222.0	301.0	253.0	233.0	217.0	227.0	101.0	133.0	94.0	1974.0
2005	1	01	247.0	183.0	149.0	299.0	230.0	332.0	160.0	137.0	224.0	267.0	133.0	105.0	2466.0
2006	1	01	153.0	38.0	197.0	162.0	115.0	189.0	189.0	126.0	99.0	89.0	108.0	105.0	1570.0
2007	1	01	24.0	57.0	161.0	162.0	256.0	329.0	110.0	178.0	147.0	141.0	118.0	83.0	1766.0

2008	1	01	40.0	109.0	124.0	130.0	159.0	217.0	220.0	108.0	99.0	120.0	191.0	104.0	1621.0
2009	1	01	111.0	89.0	113.0	132.0	201.0	235.0	215.0	140.0	107.0	49.0	42.0	54.0	1488.0
2010	1	01	20.0	85.0 3	130.0	245.0	164.0	276.0	150.0	49.0	107.0	203.0	122.0	97.0	1648.0 3
2011	1	01	65.0	104.0	143.0	248.0	272.0	168.0	160.0	48.0	168.0	118.0	118.0	97.0	1709.0

MEAN	70.2	86.3	133.7	170.3	190.2	204.0	177.2	142.1	141.9	117.0	101.3	83.9	1618.0
MAX	247.0	195.0	234.0	565.0	389.0	373.0	420.0	364.0	325.0	269.0	237.0	194.0	565.0
MIN	2.0	19.0	39.0	24.0	34.0	88.0	36.0	48.0	20.0	20.0	29.0	19.0	2.0

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL TOTAL MONTHLY VALUES (mms)

PROCESS DATE 2013/02/28 ESTACION : 21035040 LIBANO EL

LATITUDE 0152 N ST TYPE CO DEPT HUILA INSTALATION DATE 1985-DEC

LONGITUDE 7549 W ENTITY 01 IDEAM MUNICIPALITY SUAZA SUSPENSION DATE

ELEVATION 1045 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1986	2	01	49.5	168.4	95.8	112.8	127.0	181.8	115.0	72.0	181.7	131.1	130.1	35.0	1400.2
1987	2	01	31.1 3	56.7	106.9	164.8	106.3	109.3	316.6	149.1	77.6	128.5	39.1	59.9	1345.9 3
1988	2	01	28.7	118.2	73.8	123.8	127.5	264.9	86.2	73.0	105.2	149.7	119.5	56.8	1327.3
1989	2	01	54.5	51.5	231.4	152.7	184.9 3	128.2	144.6	102.0	65.1	29.4	7.6	43.9	1195.8 3
1990	2	01	40.7	103.3	88.0	84.3	57.5 3	96.3	118.1	76.0	135.5	130.6	58.5	108.0	1096.8 3
1991	2	01	13.5	43.1	133.5	106.1	87.3	155.2	146.8	111.3	89.3	68.9	75.7	73.8	1104.5
1992	2	01	67.6	132.7	96.9	92.7	65.3	61.1	107.2	151.6	51.0	40.4	84.3	52.8	1003.6
1993	2	01	31.3	64.5	109.7	141.4	113.9	107.7	156.3	92.3	58.0	230.1	104.4	145.6	1355.2
1994	2	01	133.0	65.5	158.6	146.5	232.6	180.5	110.4	101.1	145.4	139.8	119.0	52.1	1584.5
1995	2	01	30.5	26.3	95.2	174.2	157.2	155.8	95.7	35.8	126.6	56.5	57.7	62.2	1073.7
1996	2	01	64.5	108.1	71.8	116.3	138.5	147.1	80.8	83.1	139.2	182.7	59.3	62.8	1254.2
1997	2	01	61.4	90.2	126.8	92.4	180.5	118.9	80.7	103.5	90.5 8	73.3	75.4	47.0	1140.6
1998	1	01	6.5	76.5	103.4	83.8	110.4	133.9	117.2	90.8	76.7	72.8	93.4	58.5	1023.9
1999	2	01	59.3	145.9	81.4	205.0	124.2	115.7	122.0	50.9	117.6	92.8	72.2	80.3	1267.3
2000	2	01	65.6	182.2	132.5	99.0	275.8	103.5	68.8	193.5	102.5	106.2	46.4	50.2	1426.2
2001	2	01	26.8	42.9	105.0	178.7	86.1	87.7	117.4	66.6	89.5	71.5	95.5	71.4	1039.1
2002	2	01	21.4	98.7	221.1	185.6	212.5	131.7	139.7	118.7	58.0	66.6	54.2	70.1	1378.3
2003	1	01	41.2	50.6	59.7	93.8	49.8	33.8	48.6	41.1	43.8	114.2	93.0	35.4	705.0
2004	1	01	77.1	51.1	50.2	104.6	130.6	139.5	142.1	68.0	144.0	62.3	75.7	67.6	1112.8
2005	1	01	41.5	133.3	141.2 3	208.5	165.2	213.2	86.8	65.9	118.4	178.4	41.4	56.6	1450.4 3
2006	1	01	145.1	16.8	190.6	125.6 3	56.6	82.4	122.2	35.8	75.9	75.5	136.3	57.3	1120.1 3
2007	1	01	19.4	13.5	130.6	62.2	211.2	132.5	17.6	86.1	95.4	129.5	96.1	33.9	1028.0
2008	1	01	29.5	40.4	60.1	125.3	133.0	163.5	147.6	76.4	63.6	117.4	156.6	126.2	1239.6
2009	1	01	74.9	78.3	118.6	91.3	104.8	112.7	143.9	87.5 3	83.2	109.1	46.0	38.6	1088.9 3
2010	1	01	30.6	87.7	109.0	180.4	201.6	203.7	130.4	73.2	83.3	140.0	97.7	81.6 3	1419.2 3
2011	1	01	48.9 3	118.4	159.3	210.8	203.7	96.8	107.4	38.7	136.3	122.2	171.0	133.3	1546.8 3
MEAN			49.8	83.3	117.4	133.2	140.2	133.0	118.1	86.3	98.2	108.4	84.9	67.7	1220.3
MAX			145.1	182.2	231.4	210.8	275.8	264.9	316.6	193.5	181.7	230.1	171.0	145.6	316.6
MIN			6.5	13.5	50.2	62.2	49.8	33.8	17.6	35.8	43.8	29.4	7.6	33.9	6.5

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL TOTAL MONTHLY VALUES (mms)

FECHA DE PROCESO : 2013/02/28 STATION : 21030050 GUADALUPE

LATITUDE 0201 N ST TYPE PM DEPT HUILA INSTALLATION DATE 1964-ABR

LONGITUDE 7546 W ENTITY 01 IDEAM MUNICIPALITY GUADALUPE SUSPENSION DATE

ELEVATION 0893 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1972	2	01	138.0	71.0	124.0	151.0	122.0	166.0	117.0	73.0	58.0	144.0	249.0	62.0	1475.0
1973	2	01	52.0	59.0	80.0	116.0	119.0	99.0	165.0	155.0	115.0	75.0	117.0	294.0	1446.0
1974	2	01	96.0	224.0	156.0	118.0	50.0	101.0	68.0	54.0	41.0	122.0	136.0	113.0	1279.0
1975	2	01	17.0	231.0	132.0	75.0	143.0	230.0	80.0	89.0	83.0	139.0	99.0	125.0	1443.0
1976	2	01	35.0	159.0	172.0	179.0	194.0	128.0	123.0	94.0	73.0	157.0	111.0	90.0	1515.0
1977	2	01	16.0	58.0	89.0	159.0	113.0	168.0	99.0	102.0	174.0	127.0	123.0	15.0	1243.0
1978	2	01	5.0	24.0	108.0	194.0	80.0	98.0	82.0	48.0	83.0	57.0	20.0	46.0	845.0
1979	2	01	55.0	154.0	102.0	138.0	120.0	50.0	75.0	70.0	93.0	83.0	201.0	55.0	1196.0
1980	2	01	115.0	40.0	66.0	73.0	63.0	87.0	89.0 3	104.0	72.0	57.0	35.0	33.0	834.0 3
1981	2	01	62.0	67.0	91.0	89.0	108.0	78.0	65.0	31.0	65.0	68.0	101.0	105.0	930.0
1982	2	01	220.0	88.0	153.0	175.0	160.0	107.0	125.0	87.0	65.0	86.0	152.0	145.0	1563.0
1983	2	01	154.0	134.0	211.0	278.0	170.0	147.0	129.0	106.0	118.0	108.0	75.0	91.0	1721.0
1984	2	01	131.0	98.0	159.0	102.0	102.0	145.0	46.0	61.0	114.0	133.0	173.0	51.0	1315.0
1985	2	01	47.0	35.0	41.0	80.0	138.0	94.0	84.0	112.0	26.0	66.0	220.0	56.0	999.0
1986	2	01	68.0	183.0	147.0	77.0	98.0	118.0	82.0	42.0	91.0	148.0	118.0	18.0	1190.0
1987	2	01	44.0	9.0	63.0	140.0	188.0	38.0	129.0	88.0	25.0	151.0	157.0	39.0	1071.0
1988	2	01	30.0	381.0	54.0	65.0	76.0	148.0	53.0	8.0	137.0	131.0	221.0	63.0	1367.0
1989	2	01	78.0	63.0	257.0	139.0	109.0	38.0	130.0	37.0	119.0	74.0	99.0	82.0	1225.0
1990	2	01	33.0	119.0	73.0	71.0	90.0	66.0	79.0	33.0	63.0	93.0	92.0	117.0	929.0
1991	2	01	17.0	38.0	159.0	45.0	69.0	77.0	62.0	118.0	20.0	12.0	107.0	133.0	857.0
1992	2	01	16.0	80.0	75.0	44.0	36.0	41.0	69.0	84.0	19.0	25.0	126.0	148.0	763.0
1993	2	01	62.0	118.0	99.0	95.0	105.0	104.0	91.0	103.0	19.0	178.0	188.0	90.0	1252.0
1994	2	01	178.0	81.0	134.0	127.0	181.0	118.0	88.0	75.0	68.0	83.0	102.0	36.0	1271.0
1995	2	01	25.0	46.0	78.0	123.0	83.0	125.0	138.0	27.0	117.0	105.0	92.0	14.0	973.0
1996	2	01	82.0	309.0	119.0	61.0	103.0	105.0	83.0	71.0	49.0	139.0	86.0	68.0	1275.0
1997	2	01	128.0	41.0	52.0	80.0	124.0	76.0	70.0	57.0	28.0	43.0	39.0	20.0	758.0
1998	1	01	6.0	133.0	167.0	86.0	53.0	132.0	109.0	47.0	43.0	57.0	121.0	49.0	1003.0
1999	2	01	171.0	212.0	153.0	356.0	218.0	126.0	124.0	52.0	134.0	54.0	189.0	126.0	1915.0
2000	2	01	103.0	167.0	137.0	115.0	257.0	57.0	41.0	117.0	87.0	108.0	44.0	49.0	1282.0
2001	2	01	6.0	88.0	145.0	132.0	66.0	36.0	49.0	16.0	50.0	85.0	82.0	67.0	822.0
2002	2	01	39.0	61.0	182.0	132.0	172.0	138.0	93.0	63.0	60.0	62.0	12.0	66.0	1080.0
2003	1	01	21.0	176.0	63.0	67.0	119.0	64.0	77.0	41.0	95.0	312.0	101.0	38.0	1174.0
2004	1	01	43.0	72.0	48.0	145.0	80.0	79.0	105.0	30.0	91.0	111.0	180.0	73.0	1057.0
2005	1	01	16.0	211.0	176.0	290.0	110.0	89.0	50.0	38.0	60.0	212.0	230.0	299.0	1781.0
2006	1	01	261.0	141.0	297.0	384.0	113.0	91.0	77.0	78.0	70.0	133.0	189.0	64.0	1898.0
2007	1	01	41.0	81.0	82.0	99.0	260.0	142.0	29.0	62.0	56.0	149.0	140.0	91.0	1232.0
2008	1	01	37.0	127.0	140.0	91.0	145.0	92.0	60.0	50.0	37.0	161.0	206.0	130.0	1276.0
2009	1	01	182.0	159.0	174.0	69.0	116.0	59.0	115.0	64.0	49.0	134.0	91.0	36.0	1248.0

2010	1	01	1.0	79.0	58.0	140.0	152.0	137.0	104.0	74.0	33.0	112.0	189.0	136.0	1215.0
2011	1	01	19.0	53.0	132.0	180.0	163.0	85.0	105.0	4.0	81.0	35.0	163.0	178.0	1198.0

MEAN	71.3	116.8	123.7	132.0	124.2	102.0	89.0	66.6	72.0	108.2	129.4	87.8	1222.9
MAX	261.0	381.0	297.0	384.0	260.0	230.0	165.0	155.0	174.0	312.0	249.0	299.0	384.0
MIN	1.0	9.0	41.0	44.0	36.0	36.0	29.0	4.0	19.0	12.0	12.0	14.0	1.0

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL TOTAL MONTHLY VALUES (mms)

PROCESS DATE : 2013/02/28 STATION : 21030110 SAN ANTONIO DEL PE

LATITUDE 0204 N ST TYPE PM DEPT HUILA INSTALLATION DATE 1980-MAY

LONGITUDE 7540 W ENTITY 01 IDEAM MUNICIPLITY GARZON SUSPENSION DATE

ELEVATION 1190 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1980	2	01					60.0	140.0 3	143.0	130.0	100.0	145.0	83.0	84.0	885.0 3
1981	2	01	60.0	77.0	88.0	119.0	74.0	134.0	70.0	37.0	70.0	66.0	106.0	76.0	977.0
1982	2	01	257.0	110.0	135.0	255.0	108.0	73.0	134.0	55.0	85.0	69.0	106.0	86.0	1473.0
1983	2	01	117.0	85.0	104.5	302.0	117.0	110.0	107.0	49.0	108.0	174.0	118.0	119.0	1510.5
1984	1	01	97.0	124.0	116.0	119.0	168.0	249.0	137.0	59.0	164.0	264.0	249.0	42.0	1788.0
1985	2	01	123.0	76.0	121.0	88.0	149.0	88.0	110.0	193.0	32.0	71.0	159.0	67.0	1277.0
1986	2	01	101.0	223.0	110.0	163.0	81.0	180.0	72.0	57.0	189.0	269.0	156.0	54.0	1655.0
1987	2	01	28.0	100.0	84.0	174.0	146.0	101.0	190.0	81.0	58.0	162.0	224.0	78.0	1426.0
1988	2	01	30.0	191.0	60.0	98.0	113.0	270.0	84.0	73.0	72.0	238.0	238.0	148.0	1615.0
1989	2	01	86.0	232.0	313.0	139.0	238.0	116.0	98.0	96.0	155.0	159.0	83.0	113.0	1828.0
1990	2	01	21.0	136.0	198.0	138.0	72.0	89.0	146.0	130.0	34.0	157.0	227.0	136.0	1484.0
1991	2	01	80.1 8	118.4 8	134.9 8	135.2 8	123.6 8	109.7 8	87.2 8	55.4 8	66.8 8	100.2 8	106.7 8	59.8 8	1178.0
1992	2	01	113.0	79.0	61.0	55.0	59.0	58.0	45.0	82.0	16.0	42.0	124.0	71.0	805.0
1993	2	01	104.0	95.0	192.0	144.0	184.0	74.0	76.0	181.0	79.0	268.0	374.0	144.0	1915.0
1994	2	01	183.0	54.0	237.0	97.0	163.0	160.0	148.0	48.0	145.0	143.0	67.0	18.0	1463.0
1995	2	01	19.0	142.0	285.0	125.0	162.0	153.0	214.0	25.0	104.0	97.0	195.0	74.0	1595.0
1996	1	01	298.0	541.0	387.0	303.0	401.0	271.0	174.0	112.0	125.0	172.0	126.0	56.0	2966.0
1997	2	01	91.0	68.0	54.0	122.0	192.0	142.0	38.0	67.0	50.0	60.0	57.0	60.0	1001.0
1998	1	01	4.0	110.0	181.0	137.0	152.0	99.0	188.0	78.0	100.0	126.0	220.0	74.0	1469.0
1999	2	01	236.0	338.0	132.0	174.0	235.0	85.0	63.0	34.0	130.0	185.0	143.0	170.0	1925.0
2000	2	01	119.0	172.0	172.0	152.0	232.0	141.0	60.0	63.0	56.0	120.0	102.0	84.0	1473.0
2001	2	01	22.0	85.0	186.0	134.0	117.0	66.0	100.0	13.0	81.0	158.0	109.0	111.0	1182.0
2002	2	01	17.0	83.0	182.0	213.0	188.0	141.0	113.0	136.0	174.0	40.0	184.0	54.0	1525.0
2003	1	01	123.0	56.0	83.0	116.0	45.0	140.0	48.0	20.0	55.0	154.0	74.0	95.0	1009.0
2004	1	01	77.0	73.0	131.0	156.0	170.0	109.0	127.0	50.0	96.0	88.0	241.0	41.0	1359.0
2005	1	01	40.0	206.0	139.0	197.0	136.0	109.0	56.0	44.0	79.0	222.0	139.0	271.0	1638.0
2006	1	01	94.0	83.0	318.0	219.0	106.0	147.0	124.0	62.0	100.0	203.0	221.0	155.0	1832.0
2007	1	01	78.0	13.0	109.0	147.0	199.0	176.0	78.0	75.0	72.0	206.0	129.0	142.0	1424.0
2008	1	01	67.0	148.0	161.0	177.0	187.0	169.0	115.0	129.0	85.0	236.0	296.0	149.0	1919.0
2009	1	01	223.0	183.0	266.0	156.0	155.0	123.0	92.0	153.0	62.0	197.0	64.0	44.0	1718.0
2010	1	01	.0	68.0	94.0	176.0	184.0	146.0	210.0	89.0	71.0	107.0	250.0	128.0	1523.0
2011	1	01	75.0	213.0	162.0	359.0	216.0	221.0	121.0	45.0	88.0	192.0	318.0	346.0	2356.0
MEAN			96.2	138.1	161.2	164.2	154.1	137.2	111.5	78.8	90.7	152.8	165.3	104.7	1554.8
MAX			298.0	541.0	387.0	359.0	401.0	271.0	214.0	193.0	189.0	269.0	374.0	346.0	541.0
MIN			0.0	13.0	54.0	55.0	45.0	58.0	38.0	13.0	16.0	40.0	57.0	18.0	0.0

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL TOTAL MONTHLY VALUES (mms

PROCESS DATE : 2013/02/28 STATION : 21035020 RESINA

LATITUDE 0154 N ST TYPE CO DEPT HUILA INSTALLATION DATE 1971-ABR

LONGITUDE 7540 W ENTITY 01 IDEAM MUNICIPALITY GUADALUPE SUSPENSION DATE 2010-AGO

ELEVATION 2102 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL
1972	2	01	103.1	118.6 8	171.9 3	210.5	250.2	279.7	271.0	124.6	153.5	239.5	215.6	62.6	2200.8 3
1973	2	01	52.7	50.9	58.1	149.6	175.4	215.4	265.3	306.2	221.3	204.4	198.6	158.5	2056.4
1974	2	01	96.3	143.6	134.7	178.7	188.0	284.4	306.9	186.5	211.3	221.9	150.5	60.6	2163.4
1975	2	01	44.2	150.9	165.5	87.9	178.1	228.6 8	174.5	152.3	196.4	269.2	196.9	128.6	1973.1
1976	2	01	50.7	155.2	167.5	236.2	341.4	370.7	386.4	254.6	214.1 3	117.2	171.9	83.1	2549.0 3
1977	1	01	24.7	115.2	112.2	205.6	278.3	328.7 3	223.4	218.3	357.1	264.9 3	238.2	39.0	2405.6 3
1978	2	01	49.9	23.1	78.9	264.5	192.0	268.0	283.6	278.4	207.2	119.0	82.4	134.7	1981.7
1979	2	01	53.8 3	22.8	134.0	207.8	304.4	231.5	238.5	180.2	255.8	125.7 3	219.9	163.4	2137.8 3
1980	2	01	101.5	97.7	183.3	199.5	231.4	325.8	305.1	192.0 3	222.0	190.0	89.9	113.5	2251.7 3
1981	2	01	67.6	100.2	179.6	186.6	272.8	215.3	204.1	166.8	174.8	136.9 3	189.5	82.5	1976.7 3
1982	2	01	226.1	219.8	219.2	249.6	321.1	199.2	312.0	283.4	196.6	144.8 3	82.7	94.4	2548.9 3
1983	1	01	99.2	178.5	106.4	269.3	169.4	200.7	223.4	168.5	236.4 3	229.7	97.9	154.1	2133.5 3
1984	2	01	87.2 3	126.6	137.9	156.7	175.9	308.5	339.5	191.8	197.4	184.6	156.7	93.8	2156.6 3
1985	2	01	110.0	92.3	67.3	141.3	236.9	268.4	319.6 3	256.4	164.2	107.7	101.7	105.8	1971.6 3
1986	2	01	62.4	146.3	261.5	219.9	268.4	367.3	407.2	191.2	272.6	214.1	228.2	59.1	2698.2
1987	2	01	65.6	108.1	115.1	295.3	237.0	226.4	341.9	261.0	136.3	203.3	188.5	54.6	2233.1
1988	2	01	76.4	85.8	69.7	213.8	164.4	428.1	307.3	217.9 8	205.4	154.5	236.0	120.4	2279.7
1989	2	01	113.3	123.6	235.3	203.6	285.9	197.0	318.4	190.3	199.6	263.9	149.9	102.4	2383.2
1990	2	01	83.2	157.3	166.3	111.7	200.6	267.1	364.7	330.6	208.1	237.1	152.7	130.3	2409.7
1991	2	01	26.8	75.5 3	158.6	143.8	115.8	248.7	329.6	325.7	205.8	127.0	124.9	121.9	2004.1 3
1992	2	01	75.7	81.8	129.6	206.3	177.0	218.1	463.1	301.1	107.8	100.1	223.4	68.0	2152.0
1993	2	01	86.9 3	78.0	194.7	210.8	202.7	297.2	313.8	180.2	115.2 3	220.1 3	131.0 3	107.6	2138.2 3
1994	2	01	122.8	100.7 3	314.6 3	263.9	349.0	273.7	302.4	151.9	173.7	210.0	126.9	88.4	2478.0 3
1995	2	01	65.6	142.9	194.0	257.6	238.3	302.6	253.2	156.1	195.1	156.8	137.0	142.2	2241.4
1996	1	01	95.6	168.6	158.6	165.5	194.1	275.8	339.8	182.6	185.1	213.0	128.5	79.5	2186.7
1997	2	01	156.8	142.7	66.0	157.6	302.5	206.1	403.9	315.7	106.0	122.2	111.6	54.2	2145.3
1998	1	01	38.9	73.0	224.5	148.2	272.4	300.6	276.2	202.7	135.7	168.0	102.9	144.9	2088.0
1999	2	01	182.4	184.5	128.1	266.0	278.2	237.9	208.7	139.3	230.5	156.8	111.0	203.4	2326.8
2000	2	01	112.4	84.3	159.0	188.8	375.7	164.2	180.5	311.4	213.1	217.4	81.5	111.2	2199.5
2001	2	01	36.3	63.8	124.9	251.2	172.4	253.7	201.3	210.4	141.2	158.1	121.0	129.1	1863.4
2002	2	01	121.5	61.3	190.2	183.8	343.9	329.7	275.2	256.9	169.9	177.8	182.3	155.5	2448.0
2003	1	01	106.4 3	79.3	162.5	162.2	209.1	221.0	249.8	175.5	193.1	262.2	119.0	74.0	2014.1 3
2004	1	01	42.4	75.0	97.8	253.0 3	312.5 3	352.1	298.0		219.0	137.8	170.0 3	174.9	2132.5 3
2005	1	01	61.6	139.8			196.1	306.4 3	225.8	232.7 3	145.6 3		118.5	96.1	1522.6 3
2006	1	01	78.0 3				146.1	276.5	271.8	159.1	190.3	133.3	202.0	117.6	1574.7 3
2007	1	01	48.2	43.5	191.8	261.4	234.1	139.7 3	146.2	179.9	152.5 3				1397.3 3
MEAN			84.1	108.9	154.7	203.2	238.7	267.1	287.0	218.1	191.9	182.0	152.5	108.9	2197.0

MAX	226.1	219.8	314.6	295.3	375.7	428.1	463.1	330.6	357.1	269.2	238.2	203.4	463.1
MIN	24.7	22.8	58.1	87.9	115.8	139.7	146.2	124.6	106.0	100.1	81.5	39.0	22.8

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL TOTAL MONTHLY VALUES (mms)

PROCESS DATE : 2013/02/28 STATION : 21030090 JAGUA LA

LATITUDE 0210 N ST TYPE PM DEPT HUILA INSTALLATION DATE 1971-JUN

LONGITUDE 7540 W ENTITY 01 IDEAM MUNICIPALITY GARZON SUSPENSION DATE

ELEVATION 0755 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL * *
1972	2	01	101.0	79.0	138.0	103.5	99.0	58.0	48.5	14.0	23.0	46.5	153.0	68.0	931.5
1973	2	01	9.0	3.5	75.0	46.0	105.5	53.0	49.5	113.0	104.5	74.0	83.0	179.0	895.0
1974	2	01	164.5	83.0	181.0	88.0	34.0	66.0	21.0	19.0	19.0	84.0	105.0	70.0	934.5
1975	2	01	46.0	123.0	116.0	22.0	28.0	123.0	45.0	28.0	40.0	97.0	105.0	114.0	887.0
1976	2	01	36.0	148.0	131.0	116.0	98.0	63.0	54.0	56.0	20.0	142.0	107.0	78.0	1049.0
1977	2	01	3.0	31.0	118.0	83.0	94.0	74.0	29.0	43.0	83.0	100.0	135.0	19.0	812.0
1978	2	01	2.0	71.0	89.0	173.0	99.0	74.0	46.0	25.0 3	58.0	107.0	68.0	71.0 3	883.0 3
1979	2	01	20.0	55.0	128.0	103.0	79.0	34.0	66.0	35.0	68.0	45.0	369.0	47.0	1049.0
1980	2	01	120.0	113.0	105.0	151.0	61.0	110.0	64.0	46.0	19.0	30.0	111.0	56.0	986.0
1981	2	01	36.0	106.0	62.0	106.0	150.0	33.0	25.0	18.0	57.0	106.0	175.0	30.0	904.0
1982	2	01	219.0	121.0	186.0	174.0	125.0	43.0	48.0	17.0	67.0	116.0	101.0	89.0	1306.0
1983	2	01	69.0	88.0	48.0	281.0	66.0	58.0	52.0	19.0	54.0	99.0	66.0	43.0	943.0
1984	2	01	110.0	78.0	58.0	111.0	189.0	99.0	41.0	69.0	111.0	132.0	307.0	66.0	1371.0
1985	1	01	36.0	28.0	84.0	139.0	104.0	81.0	52.0	79.0	30.0	95.0	137.0	45.0	910.0
1986	2	01	58.0	160.0	95.0	69.0	151.0	56.0	32.0	32.0	60.0	184.0	66.0	23.0	986.0
1987	2	01	39.0	31.0	72.0	154.0	140.0	29.0	112.0	25.0	31.0	133.0	154.0	51.0	971.0
1988	2	01	37.0	33.0	34.0	60.0	56.0	114.0	58.0	21.0	59.0	175.0	105.0	40.0	792.0
1989	2	01	60.0	99.0	193.0	76.0	103.0	94.0	77.0	56.0	74.0	86.0	51.0	209.0	1178.0
1990	2	01	59.0	140.0	150.0	130.0	57.0	90.0	56.0	26.0	49.0	96.0	112.0	141.0	1106.0
1991	2	01	19.0	6.0	204.0	52.0	54.0	75.0	66.0	51.0	27.0	29.0	109.0	204.0	896.0
1992	2	01	44.0	18.0	75.0	28.0	27.0	29.0	25.0	33.0	29.0	29.0	195.0	118.0	650.0
1993	2	01	80.0	97.0	207.0	58.0	125.0	66.0	74.0	43.0	19.0	140.0	244.0	68.0	1221.0
1994	2	01	75.0	109.0	205.0	133.0	132.0	95.0	56.0	33.0	70.0	55.0	85.0	39.0	1087.0
1995	2	01	19.0	72.0	96.0	162.0	51.0	70.0	105.0	18.0	30.0	147.0	121.0	66.0	957.0
1996	2	01	93.0	158.0	104.0	69.0	63.0	90.0	47.0	58.0	34.0	130.0	57.0	48.0	951.0
1997	2	01	156.0	22.0	57.0	69.0	113.0	77.0	24.0	27.0	31.0	55.0	44.0	40.0	715.0
1998	1	01	8.0	79.0	116.0	78.0	67.0	91.0	69.0	38.0	37.0	142.0	204.0	43.0	972.0
1999	2	01	191.0	236.0	129.0	165.0	117.0	55.0	51.0	33.0	133.0	126.0	128.0	205.0	1569.0
2000	2	01	74.0	120.0	145.0	87.0	208.0	56.0	39.0	48.0	71.0	90.0	59.0	71.0	1068.0
2001	2	01	4.0	67.0	134.0	70.0	80.0	56.0	54.0	17.0	42.0	109.0	118.0	55.0	806.0
2002	2	01	33.0	50.0	136.0	140.0	118.0	120.0	49.0	25.0	37.0	62.0	21.0	22.0	813.0
2003	1	01	65.0	44.0	91.0	100.0	72.0	43.0	24.0	13.0	59.0	145.0	61.0	60.0	777.0
2004	1	01	90.0	48.0	79.0	135.0	69.0	75.0	76.0	35.0	35.0	61.0	341.0	80.0	1124.0
2005	1	01	18.0	106.0	107.0	133.0	107.0	66.0	21.0	32.0	51.0	144.0	58.0	117.0	960.0
2006	1	01	112.0	72.0	220.0	171.0	60.0	165.0	70.0	35.0	84.0	153.0	112.0	156.0	1410.0
2007	1	01	85.0	5.0	89.0	156.0	122.0	109.0	28.0	26.0	51.0	168.0	115.0	104.0	1058.0

2008	1	01	102.0	176.0	125.0	118.0	105.0	42.0	64.0	38.0	27.0	196.0	158.0	87.0	1238.0
2009	1	01	102.0	91.0	208.0	61.0	108.0	26.0	58.0	124.0	8.0	99.0	93.0	59.0	1037.0
2010	1	01	1.0	34.0	33.0	121.0	110.0	91.0	82.0	23.0	60.0	81.0	139.0	59.0	834.0
2011	1	01	45.0	76.0	144.0	169.0	188.0	131.0	76.0	53.0	43.0	95.0	185.0	323.0	1528.0

MEAN	66.0	81.9	119.2	111.5	98.4	74.5	53.4	38.6	50.1	105.1	128.9	86.6	1014.1
MAX	219.0	236.0	220.0	281.0	208.0	165.0	112.0	124.0	133.0	196.0	369.0	323.0	369.0
MIN	1.0	3.5	33.0	22.0	27.0	26.0	21.0	13.0	8.0	29.0	21.0	19.0	1.0

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NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

RAINFALL MONTHLY TOTAL VALUES (mms)

PROCESS DATE: 2013/02/28 STATION : 21025030 ALTAMIRA EL GRIFO

LATITUDE 0204 N ST TYPE CO DEPT HUILA INSTALLATION DATE 1995-DEC

LONGITUDE 7544 W ENTITY 01 IDEAM MUNICIPALITY ALTAMIRA SUSPENSION DATE

ELEVATION 1368 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1995	1	01													
1996	2	01	83.1	181.0	118.4	93.7	145.7	149.6	77.4	72.5	56.2	155.9	104.7	68.8	1307.0
1997	2	01	116.4	56.3	60.2	126.0	137.3	95.9	54.0	48.0	27.6	87.8	40.0	29.3	878.8
1998	1	01	10.4	94.2	132.7	70.2	89.2	111.2	102.4	57.6	89.8	80.4	395.2	79.5	1312.8
1999	2	01	175.6	212.7	79.0	169.2	191.5	142.3	69.8	50.8	84.3	95.6	157.6	170.5	1598.9
2000	2	01	120.3	201.1	100.9	100.0	229.1	88.5	48.4	108.6	107.0	148.0	51.2	79.8	1382.9
2001	2	01	27.8	140.0	181.6	113.8	150.2	82.7	73.4	32.5	85.1	120.3	126.9	93.9	1228.2
2002	2	01	33.0	60.9	122.4	203.9	196.2	95.1 3	90.1	48.1	66.2	86.9	30.5	49.3	1082.6 3
2003	1	01	82.3	55.6	86.5	148.9	122.1	76.3	54.7	26.4	95.4	236.4	72.0	46.9	1103.5
2004	1	01	123.0	35.9	79.8	191.1	117.2	105.3	110.0	33.8	81.8	90.6	194.6	68.0	1231.1
2005	1	01	54.1	189.9	111.4	149.9	151.6	96.6	59.2	45.8	84.8	209.3	91.6	122.4	1366.6
2006	1	01	91.7	40.9	299.9	175.3	73.7	127.9	107.2	44.4	75.7	184.5	173.6	115.3	1510.1
2007	1	01	22.9	81.9	109.1	102.7	173.7	136.1	39.7	48.2	51.0	140.4	148.5	127.4	1181.6
2008	1	01						89.6	82.2	69.7	52.8	144.2	118.0 3		556.5 3
2009	1	01	81.8	145.8	229.6	93.0	166.3	63.8	73.0	66.7	43.9	130.5	98.4	54.9	1247.7
2010	1	01	2.6	87.3	65.9	172.0	211.0	131.6	171.0	38.7	43.9	168.5	201.7	110.0	1404.2
2011	1	01	77.5	140.5	147.8	266.7	182.8	134.4 3	128.7	14.9	91.3	115.8	217.7	344.3	1862.4 3
MEAN			73.5	114.9	128.3	145.1	155.8	107.9	83.8	50.4	71.1	137.2	138.9	104.0	1311.0
MAX			175.6	212.7	299.9	266.7	229.1	149.6	171.0	108.6	107.0	236.4	395.2	344.3	395.2
MIN			2.6	35.9	60.2	70.2	73.7	63.8	39.7	14.9	27.6	80.4	30.5	29.3	2.6

Maximum and Minimum Temperatures and Dew Point – Resina Station

- **Maximum temperature – Resina Station**

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	19.8	19.8	19.9	19.9	20.0	19.8	19.6	19.9	19.9	19.8	20.0	20.3	19.9
1987	20.9	20.4	20.9	21.2	20.9	20.8	21.5	21.6	21.7	22.2	22.2	22.4	21.4
1988	22.0	21.8	21.8	21.3	21.1	20.4	19.4	19.0	20.4	20.2	20.7	20.6	20.7
1989	20.6	20.3	20.4	20.9	19.6	19.9	19.0	20.5	21.2	21.1	21.4	20.6	20.5
1990	22.2	21.6	20.1	19.8	19.3	19.4	19.0	19.4	19.4	19.8	19.7	20.0	20.0
1991	21.0	21.1	22.0	21.3	21.1	20.2	19.1	18.9	19.9	20.7	20.9	21.1	20.6
1992	21.8	20.9	22.1	21.3	21.0	20.3	18.8	18.8	20.1	20.3	20.3	20.1	20.5
1993	20.1	20.1	20.0	20.2	20.2	19.7	19.3	19.3	20.2	20.1	19.6	20.5	19.9
1994	20.7	20.8	19.9	20.3	20.6	19.9	19.0	18.7	20.1	20.2	20.5	20.9	20.1
1995	21.9	21.7	20.6	20.3	20.2	20.1	20.4	19.8	20.6	21.0	21.0	20.8	20.7
1996	20.8	20.1	20.4	20.8	20.8	19.1	18.8	20.0	21.1	20.6	21.6	20.6	20.4
1997	19.6	21.1	21.5	20.5	19.8	21.4	18.3	19.7	21.7	22.8	20.8	21.7	20.7
1998	23.0	22.7	22.0	22.9	19.2	18.7	19.0	20.9	21.3	20.6	20.8	20.5	21.0
1999	20.4	20.7	21.0	21.2	20.6	19.9	18.8	18.8	20.1	20.3	20.3	19.8	20.2
2000	19.9	20.0	20.0	19.9	19.6	19.6	18.7	18.9	20.2	20.2	20.1	20.3	19.8
2001	21.3	20.6	20.5	20.6	20.2	18.7	19.0	18.3	20.8	21.4	20.3	20.4	20.2
2002	21.2	21.6	20.8	20.5	19.6	18.2	19.1	18.8	20.5	20.8	20.1	21.2	20.2
2003	21.6	21.1	20.5	19.9	19.7	19.5	17.7	19.0	19.7	20.6	21.0	20.2	20.0
2004	21.2	21.8	21.9	20.5	20.1	20.4	19.5	19.8	20.1	21.0	20.8	20.4	20.6
2005	21.2	21.4	21.6	21.2	19.9	20.1	19.2	18.9	20.9	21.2	21.2	21.2	20.7
2006	21.5	21.4	21.3	21.2	20.6	19.4	19.6	19.1	20.3	21.3	21.2	21.2	20.7
2007	22.1	22.5	21.9	21.8	21.2	20.9	20.2	20.5	21.5	22.0	21.9	21.8	21.5
Mean	21.1	21.1	21.0	20.8	20.3	19.8	19.2	19.5	20.5	20.8	20.7	20.8	20.5
Deviation	0.86	0.79	0.77	0.74	0.61	0.75	0.77	0.82	0.66	0.78	0.67	0.64	0.46
Max	23.0	22.7	22.1	22.9	21.2	21.4	21.5	21.6	21.7	22.8	22.2	22.4	21.5
Min	19.6	19.8	19.9	19.8	19.2	18.2	17.7	18.3	19.4	19.8	19.6	19.8	19.8

Note: Information collected from the IDEAM daily data.

- **Minimum Temperature – Resina Station**

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	13.0	12.8	12.9	13.4	13.4	12.4	11.4	12.5	12.8	12.9	13.2	13.3	12.8
1987	13.1	13.6	13.7	13.7	13.6	13.1	13.3	12.9	13.3	13.6	13.7	13.4	13.4
1988	13.4	13.7	13.5	13.4	13.4	12.5	11.3	12.2	12.5	13.1	13.1	12.6	12.9
1989	12.9	12.6	12.5	13.1	12.6	12.8	11.7	12.2	12.6	12.9	13.4	13.2	12.7
1990	13.2	13.1	13.3	13.7	13.2	12.7	12.2	12.4	12.9	13.6	13.7	13.8	13.2
1991	13.6	13.8	14.1	13.8	14.0	13.7	12.5	12.2	13.1	12.7	13.6	14.0	13.4
1992	13.7	13.9	14.4	14.1	14.1	13.1	11.8	12.4	12.9	12.9	13.3	13.1	13.3
1993	13.2	13.4	13.3	13.7	13.7	13.2	12.7	12.4	12.9	13.5	13.5	13.7	13.3
1994	13.6	13.5	13.6	13.6	13.6	12.8	12.2	12.1	12.9	13.4	13.4	13.7	13.2
1995	13.3	13.5	13.9	14.1	13.7	13.3	12.9	13.0	13.2	13.4	13.6	13.2	13.4
1996	13.3	13.4	13.6	13.8	13.5	12.9	12.1	12.7	13.0	13.4	13.5	13.2	13.2
1997	13.3	13.2	13.3	13.5	13.1	12.8	11.6	12.1	13.3	13.2	13.3	13.3	13.0
1998	13.8	14.4	14.2	14.1	13.9	13.1	11.9	12.5	13.4	13.1	13.2	13.2	13.4
1999	12.9	13.0	13.1	12.9	12.9	13.0	12.1	12.1	13.1	13.1	13.4	13.7	12.9
2000	13.3	13.3	13.4	13.3	13.6	13.4	12.6	12.6	13.2	13.4	13.7	13.6	13.3
2001	13.1	13.2	13.4	13.7	13.8	12.6	12.8	12.2	13.1	13.9	13.8	14.2	13.3
2002	14.0	13.9	14.1	13.8	13.5	12.4	13.0	12.5	13.2	13.4	13.5	13.8	13.4
2003	13.8	14.0	13.9	13.8	13.7	13.4	12.3	13.1	13.1	13.7	13.6	13.9	13.5
2004	13.8	13.6	13.8	13.7	13.7	12.8	12.6	12.7	12.2	13.4	13.9	13.4	13.3
2005	13.7	13.8	13.9	13.9	13.9	13.3	12.8	12.9	13.2	13.6	13.9	13.9	13.6
2006	13.7	13.8	13.9	13.9	13.9	13.0	12.6	12.9	12.4	13.6	13.8	14.0	13.4
2007	14.0	13.6	14.3	14.3	14.2	13.7	12.8	12.7	12.8	14.1	14.3	14.3	13.8
Mean	13.4	13.5	13.6	13.7	13.6	13.0	12.3	12.5	13.0	13.4	13.6	13.6	13.3
Deviation	0.35	0.41	0.46	0.33	0.39	0.37	0.54	0.31	0.31	0.35	0.29	0.42	0.26
Max	14.0	14.4	14.4	14.3	14.2	13.7	13.3	13.1	13.4	14.1	14.3	14.3	13.8
Min	12.9	12.6	12.5	12.9	12.6	12.4	11.3	12.1	12.2	12.7	13.1	12.6	12.7

Note: Information collected from the IDEAM daily data.

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

DEW POINT MONTHLY AVERAGE VALUES (oC)

PROCESS DATE : 2013/02/28 STATION : 21035020 RESINA

LATITUDE 0154 N ST TYPE CO DEPT HUILA INSTALLATION DATE 1971-APRIL

LONGITUDE 7540 W ENTITY 01 IDEAM MUNICIPALITY GUADALUPE SUSPENSION DATE 2010-AUG

ELEVATION 2102 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB*	MARCH*	APRIL *	MAY *	JUNE *	JULY*	AUGT *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1972	2	01			12.9	13.0	14.0	13.1	13.2	12.7	13.1	13.5	13.4	13.7	13.3 3
1973	2	01	13.4 3	13.7	13.3 3	13.3 3	12.7 3	12.3 3	12.1 3	12.1 3	12.4 3		14.2	13.9	13.0 3
1974	2	01	13.1	13.4 3	14.1 3	13.5 3	13.3	13.3 3	11.8 3	12.5 3					13.1 3
1975	2	01								13.5 3	13.2 3				13.4 3
1976	2	01					14.1					14.0	13.5	13.7	13.8 3
1977	2	01			13.6	14.5	13.8	14.1 3	13.9		14.0	14.7	14.3	13.9	14.1 3
1978	2	01					14.2 3	13.7							14.0 3
1979	2	01	13.5 3	13.9	13.7 3		13.9								13.8 3
1980	2	01												13.1 3	13.1 3
1981	2	01	12.9 3	13.1	13.6 3	13.3 3			11.8 3	12.5 3					12.9 3
1983	2	01	13.9 3	13.8 3	14.4 3	14.6 3	15.2 3	14.3 3	13.7 3	13.2 3	13.3 3	13.2 3	13.4 3		13.9 3
1984	2	01	13.4 3	13.2 3	13.7 3	14.0 3	14.2 3	13.5 3	12.7 3	12.8 3	13.0 3	13.4 3	13.7 3	13.9 3	13.5 3
1985	2	01			13.9	14.2 3	13.6 3	13.1 3	12.3 3	12.4 3	13.0 3	13.6 3	13.8 3	13.9 3	13.4 3
1986	2	01	13.7 3	13.4 3	13.8 3	14.1 3	14.2 3	13.8 3	13.0 3	13.3 3	13.3 3	14.1 3	14.2 3	13.6 3	13.7 3
1987	2	01	13.9 3	14.0 3	14.3 3	14.3 3	14.5 3	13.9 3	13.0 3	13.5 3	13.5 3	14.2 3	14.5 3	13.8 3	14.0 3
1988	2	01	13.9 3	14.3 3	13.9	14.3 3	13.7 3	13.5	12.7 3		13.5 3	14.0 3	13.8 3	13.7 3	13.8 3
1989	2	01	13.5 3	13.3	13.6 3	13.2 3	13.2 3	13.0 3	12.0 3	12.9 3	12.9 3	13.3	14.0 3	13.7	13.2 3
1990	2	01	13.4 3	13.9 3	13.7	13.9 3	14.1 3	13.5 3	12.9 3	13.1 3	14.1 3	14.7 3	14.5	14.4 3	13.9 3
1991	2	01	14.0 3	13.8 3	14.4 3	14.0 3	14.1	13.9 3	13.7 3	12.9 3	13.5 3	13.6 3	14.6	14.8 3	13.9 3
1992	2	01	13.8 3	14.4 3	14.3 3	15.3 3	14.8 3	14.0 3	13.0	13.0 3	13.4 3	13.6 3	14.2 3	14.1 3	14.0 3
1993	2	01	14.1 3	14.1 3	13.9	14.2 3	14.3 3	13.8 3	13.3 3	13.1 3	13.4 3	13.9	14.6 3	13.9 3	13.9 3
1994	2	01	14.1 3	13.5 3	14.0 3	14.0 3	14.1 3	13.6 3	13.1	12.9 3	13.7 3	14.2 3	14.7	14.5 3	13.9 3
1995	1	01	13.4	13.6 3	14.4	14.6 3	14.1 3	13.5	13.1	13.1 3	13.5 3	13.7	14.5	14.4	13.8 3
1996	1	01	14.2 3	14.0 3	14.3 3	14.2 3	14.0 3	13.7 3	12.6 3	13.0 3	13.1 3	14.0 3	14.3 3	13.8 3	13.8 3
1997	1	01	14.3 3	13.3 3	13.9 3	14.0 3	13.8 3	13.6 3	12.6 3		13.2 3	13.8 3	14.1 3	13.7 3	13.7 3
1998	1	01	14.1 3	14.5 3				13.4 3	12.9 3					14.6 3	13.9 3
1999	1	01	13.8 3	13.6 3	13.5 3	13.3 3		13.4 3	12.2 3				14.1 3	14.7 3	13.6 3
2000	1	01	13.8 3	13.4 3	13.4	13.4 3	13.7 3	13.1 3	12.8 3	12.8 3	13.3 3	13.9 3	13.7 3	13.5 3	13.4 3
2001	1	01	12.7 3	12.3 3	12.8 3	13.3 3	13.6 3	12.4 3	12.5 3	12.0 3	12.7 3	13.6 3	14.2 3	14.7 3	13.1 3
2002	1	01	13.9 3	14.0 3	14.0 3	14.2	13.9 3	12.7 3	13.1 3	12.9 3	13.2 3	13.0 3	13.5 3	13.7 3	13.5 3
2003	1	01	14.3 3	14.0 3	14.2 3	14.0 3	14.0 3	13.8 3	13.0 3	13.1 3	13.8 3	14.4 3	14.4 3	14.2 3	13.9 3
2004	1	01	14.2 3	12.9 3	13.5 3	14.3 3	14.2 3						14.7 3		14.0 3
2007	1	01		14.9 3											14.9 3
MID			13.7	13.7	13.8	14.0	14.0	13.5	12.8	12.9	13.3	13.8	14.1	14.0	13.6
MAX			14.3	14.9	14.4	15.3	15.2	14.3	13.9	13.5	14.1	14.7	14.7	14.8	15.3
MIN			12.7	12.3	12.8	13.0	12.7	12.3	11.8	12.0	12.4	13.0	13.4	13.1	11.8

Relative Humidity – Resina Station

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFRMATION SYSTEM

RELATIVE HUMIDITY MONTHLY AVERAGE VALUES (%) PROCESS DATE : 2013/02/28
STATION : 21035020 RESINA

LATITUDE	0154 N	ST TYPE	CO	DEPTO	HUILA	INSTALLATION DATE	1971-APRIL
LONGITUDE	7540 W	ENTITY	01 IDEAM	MUNICIPALITY	GUADALUPE	SUSPENSION DATE	2010-AUGUST
ELEVATION	2102 m.s.n.m	REGIONAL	04 HUILA-CAQUET	CURRENT	SUAZA		

Year	ST	ENT	JAN*	FEB *	MARCH *	APRIL *	MAY *	JUNE *	JULY *	AUG *	SEPT *	OCT *	NOV *	DECEMBER *	VR	ANNUAL *
1972	2	01				83	84	88	85	86	82	83	84	84	83	84 3
1973	2	01	77 3	80	78 3	81 3	80 3	79 3	81 3	80 3	80 3		83 3	87 3		81 3
1974	2	01	83	87 3	86 3	84 3	85	84 3	83 3	84 3						85 3
1975	2	01								87 3	84 3					86 3
1976	2	01					88					93	88	89		90 3
1977	2	01				85	91	92	95 3	93	94	95	91	91		92 3
1978	2	01				89 3	88 3	91 3	87 3							89 3
1979	2	01	86 3	83 3	87 3	87 3	87 3	91 3	88 3	90 3	87 3	88 3	91 3	90 3		88 3
1980	2	01												84 3		84 3
1981	2	01	83 3	82 3	81 3	83 3	85 3	84 3	86 3	84 3	83 3	82 3	87 3	85 3		84 3
1982	2	01	*	*	*	*	*	*	86 3	*	*	*	*	*		86 3
1983	2	01	84 3	85 3	85 3	87 3	88 3	86 3	87 3	85 3	85 3	84 3	83 3	*		85 3
1984	2	01	87 3	86 3	86 3	88 3	87 3	87 3	88 3	85 3	87 3	86 3	89 3	83 3		87 3
1985	2	01			87 1	89 3	87 3	91 3	88 3	89 3	87 3	86 3	90 3	87 3		88 3
1986	2	01	85 3	90 3	90 3	87 3	86 3	90 3	89 3	86 3	86 3	90 3	91 3	85 3		88 3
1987	2	01	87 3	86 3	89 3	87 3	89 3	88 3	84 3	86 3	84 3	86 3	86 3	84 3		86 3
1988	2	01	85 3	86 3	85 1	89 3	86 3	88 1	89 3		87 3	88 3	87 3	90 3		87 3
1989	2	01	86 3	88 1	89 3	83 3	89 3	85 3	85 3	85 3	84 3	85 1	85 3	86 1		86 3
1990	2	01	83 3	87 3	86 1	87 3	88 3	86 3	87 3	88 3	88 3	90 3	89 1	89 3		87 3
1991	2	01	84 3	84 3	86 3	86 3	86 1	86 3	89 3	89 3	87 3	86 3	89 1	88 3		87 3
1992	2	01	82 3	86 3	85 3	90 3	89 3	88 3	89 1	88 3	85 3	84 3	88 3	87 3		87 3
1993	2	01	87 3	88 3	87 1	86 3	87 3	87 3	88 3	86 3	85 3	84 1	91 3	85 3		87 3
1994	2	01	85 3	83 3	87 3	87 3	87 3	88 3	87 1	87 3	86 3	89 3	88 1	87 3		87 3
1995	1	01	82 1	84 3	89 1	89 3	88 3	86 1	86 1	85 3	85 3	85 1	89 1	89 1		86 3
1996	1	01	87 3	90 3	89 3	88 3	88 3	90 3	87 3	85 3	84 3	88 3	87 3	85 3		87 3
1997	1	01	92 3	84 3	86 3	87 3	87 3	87 3	87 3	*	81 3	82 3	86 3	81 3		85 3
1998	1	01	82 3	81 3	*	*	*	87 3	87 3	*	*	*	*	88 3		85 3
1999	1	01	87 3	87 3	87 3	86 3	*	87 3	86 3		*	88 3	89 3	91 3		88 3
2000	1	01	89 3	87 3	86 1	87 3	89 3	85 3	87 3	88 3	88 3	89 3	87 3	85 3		87 3
2001	1	01	81 3	80 3	82 3	85 3	85 3	87 3	86 3	85 3	82 3	83 3	88 3	89 3		84 3
2002	1	01	85 3	85 3	86 3	89 1	89 3	91 3	88 3	88 3	85 3	83 3	86 3	84 3		87 3
2003	1	01	85 3	85 3	87 3	88 3	89 3	88 3	91 3	87 3	88 3	88 3	87 3	87 3		88 3
2004	1	01	86 3	79 3	81 3	88 3	87 3	*	*		*	*	87 3	*		85 3
2005	1	01	91 3				*			*						91 3
2006	1	01						90 3								90 3
2007	1	01		85 3			*									85 3

MID	85	85	86	87	87	87	87	86	85	87	88	87	86
MAX	92	90	90	91	92	95	93	90	94	95	91	91	95
MIN	77	79	78	81	80	79	81	80	80	82	83	81	77

Sunshine – Resina Station

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

TOTAL MONTHLY SUNSHINE VALUES (HOURS)

PROCESS DATE : 2013/02/28 STATION: 21035020 RESINA

LATITUDE 0154 N ST TYPE CO DEPTO HUILA INSTALLATION DATE 1971-APRIL

LONGITUDE 7540 W ENTITY 01 IDEAM MUNICIPALITY GUADALUPE SUSPENSION DATE 2010-AGO

ELEVATION 2102 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZA

YEAR	ST	ENT	JAN *	FEB *	MARCH *	APRIL *	MAY *	JUNE*	JULY*	AUG *	SEPT *	OCT *	NOV *	DECEMBER *	VR ANNUAL *
1973	2	01					35.6 3	100.5 3	99.1	92.4	85.6	80.8	87.5	62.8	644.3 3
1974	2	01	105.3 3	46.9	64.4	68.9	77.5	114.1 3	94.0	99.1	39.6	69.5	55.2	30.2	864.7 3
1975	2	01	79.1	48.1	87.3	82.3	83.1	110.3 3	72.6						562.8 3
1977	2	01		110.7											110.7 3
1978	2	01	140.0	91.2	89.8	49.2 3	104.1	94.9	126.9	94.7	133.5	82.5	109.2 3	100.9 3	1216.9 3
1979	1	01	89.4 3	126.2	86.1	64.5 3	57.3 3	54.5 3	95.2 3	89.0 3	110.5	71.6 3	45.9 3	76.0 3	966.2 3
1980	2	01	106.2	98.4 3	74.0 3	72.8	107.3	62.4 3	87.0	118.8 3	86.6 3	104.0 3	70.5 3	88.4 3	1076.4 3
1981	2	01	127.9 3	104.9	107.4 3	82.6 3	65.8 3	78.5 3	67.9	118.6	119.5	105.2	64.2 3		1042.5 3
1982	2	01	99.1 3	70.3	54.4 3	61.8 3	89.6 3	119.0 3	95.7 3	84.3 3	81.3 3	71.7 3		92.6 3	919.8 3
1983	2	01	90.9 3	110.3 3	106.3	76.7 3	123.5 3	126.0 3	128.0 3	117.7 3	144.7 3	83.6 3	96.1 3	72.0 3	1275.8 3
1984	2	01	63.7 3	80.0 3	86.5 3	78.5 3	114.1 3	111.4 3	89.0 3	105.6 3	86.6	69.1 3	80.0 3	151.1	1115.6 3
1985	2	01	80.8 3	119.9 3	85.8	87.9 3	103.3 3	86.4 3	118.0 3	116.4 3	117.2 3	98.5 3	106.4	90.8 3	1211.4 3
1986	2	01	80.0 3	56.4 3	45.7 3	101.7 3	125.3 3	90.0 3	76.5 3	118.6 3	78.8 3	61.7 3	67.6 3	134.2 3	1036.5 3
1987	2	01	145.3 3	114.4	88.2	128.9	111.2 3	98.3	135.2	114.1	137.7	106.8 3	118.3	163.6 3	1462.0 3
1988	2	01	128.6 3	97.6 3	136.4	55.7	97.6	98.9 3	78.7	118.5	120.5	54.5 3	67.7 3	78.6 3	1133.3 3
1989	2	01	120.7 3	95.9 3	89.5 3	98.7 3	105.6 3	109.8 3	108.6 3	130.9 3	117.7 3	114.1 3	115.4 3	129.9 3	1336.8 3
1990	2	01	124.2 3	56.4 3	90.0 3	80.1 3	95.5 3	126.5 3	93.1 3	122.8 3	152.9 3	95.5 3	102.0 3	93.1 3	1232.1 3
1991	2	01	151.6 3	97.5 3	100.1 3	101.3 3	106.5 3	118.3 3	77.9 3	71.4 3	74.3 3	132.1 3	65.8 3	98.3 3	1195.1 3
1992	2	01	128.0 3		115.0 3	104.4 3	103.1 3	118.5 3	87.6 3	123.5 3	111.9 3	123.8 3	82.3	84.4 3	1182.5 3
1993	2	01	110.9	73.0 3	53.3	68.3 3	84.6	83.1 3	107.8 3	128.7 3	104.4 3	95.3	83.0 3	112.2 3	1104.6 3
1994	2	01	100.0 3	94.6 3	54.8 3	58.7 3	107.2 3	105.0 3	47.5	29.6 3	90.3 3	98.5	81.5	127.8 3	995.5 3
1995	2	01	149.1	119.0 3	82.0	72.3 3	85.9 3	103.5	120.5	112.1 3	124.1	103.2	95.4	100.6	1267.7 3
1996	2	01	89.5 3	67.8	70.3 3	84.9	93.6	53.8 3	93.5	122.9	121.0 3	91.4 3	117.2	105.1 3	1111.0 3
1997	2	01	49.2 3	119.2	126.0 3	85.6 3	82.8 3	136.8	70.0 3	130.4 3	116.6 3	*	75.2 3	150.9 3	1142.7 3
1998	1	01	148.4	109.4 3	74.4	103.1 3	77.9 3	109.4	83.1 3	128.9 3	122.1 3	91.2 3	68.8 3	89.6 3	1206.3 3
1999	1	01	82.1	21.4 3	30.3	77.2 3	96.0 3	104.7 3	102.0	88.0 3	46.7 3	73.3	48.3	56.1 3	826.1 3
2000	1	01	80.2 3	83.8 3	99.9	75.9 3	80.2	141.1	130.7	133.5	101.4	90.3	88.8	100.6	1206.4 3
2001	1	01	152.8	109.1	98.3	107.6 3	93.3	105.5	118.0	89.8	124.9	127.5	81.4	81.8	1290.0 3
2002	1	01	138.9	101.9	93.0 3	80.1	77.9	84.9	111.8 3	101.4	138.4	116.9 3	94.3 3	117.7 3	1257.2 3
2003	1	01	96.3 3	78.4	81.2 3	78.3 3	99.0 3	95.6 3	84.9 3	96.8 3	91.2 3	103.5 3	110.6 3	81.8 3	1097.6 3
2004	1	01	110.5 3	123.8 3	142.1 3	89.9 3	*				105.7 3	92.3 3	64.4 3	71.1 3	799.8 3
2005	1	01	79.9 3			*	59.5 3	64.7 3	89.8 3	93.6 3	85.8 3	*	*	58.7 3	532.0 3
2006	1	01	51.9 3				*	45.1 3	70.7 3	120.9 3	98.0 3	80.5 3	66.8 3	61.3 3	595.2 3
2007	1	01	99.0 3	125.2 3	72.0 3	56.4 3			117.5 3	71.7 3	*				541.8 3

MID	106.2	91.7	86.2	81.1	91.5	98.4	96.2	106.0	105.5	92.7	83.1	95.4	1134.0
MAXS	152.8	126.2	142.1	128.9	125.3	141.1	135.2	133.5	152.9	132.1	118.3	163.6	163.6
MIN	49.2	21.4	30.3	49.2	35.6	45.1	47.5	29.6	39.6	54.5	45.9	30.2	21.4

Wind Speed – Resina station

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

WIND SPEED AVERAGE VALUES (m/s)

PROCESS DATE: 2013/02/28 STATION : 21035020 RESINA

LATITUDE	0154 N	ST TYPE	CO	DEPTO	HUILA
LONGITUDE	7540 W	ENTITY	01 IDEAM	MUNICIPALITY	GUADALUPE
ELEVATION	2102 m.s.n.m	REGIONAL	04 HUILA-CAQUET	CURRENT	SUAZA

INSTALLATION DATE 1971-ABR

SUSPENSION DATE 2010-AGO

YEAR	ST	ENT	JAN *	FEB *	MARCH*	APRIL *	MAY *	JUNE*	JULY*	AUGT *	SEPTI *	OCT *	NOV *	DEC *	VR ANNUAL *
1974	1	01		S 1.7	NW 2.5	SE 4.1	E 1.8	SE 3.2	SE 3.5	S 1.7				SE 1.3	NW 1.5
1975	1	01	SE 1.8					SE 2.9	SE 1.8	SE 3.4	SE 3.0	SE 2.0		SE .5	NW 1.0
1976	1	01	SE 1.2	SE 1.2	SE 2.2	SE 2.1	SE 3.2	SE 4.0							
1977	1	01													SE 3.1
1978	1	01		SE 2.1	SE 2.5		SE 2.3	SE 3.1	SE 3.4	SE 3.6	SE 3.6			SE .8	SE 3.1
1982	1	01					SE 4.7								
1983	1	01											SW 1.7		
1984	1	01	SW 1.7												
1985	1	01					SW 2.0				W 2.9		W 1.1		W .3
1986	1	01										SW 3.5	S 1.2	SE .4	N 2.3
1987	1	01	N 2.6	N 3.3		N 2.4	N 1.9		N 2.9			NW 2.7			
1988	1	01	NW 2.2									W 2.1	W .8	W 1.0	SE .5
1989	1	01	NW 2.3	SE 1.9	SE .5		E 2.3							E 1.1	W .4
1990	1	01		W .2	W 2.1	W 1.9	W 2.0	NW 3.2	NW 3.2						
1991	1	01					NW 2.4	NW 2.8							
1992	1	01									N 3.1				
1996	1	01					SE 1.6	SE 2.3	SE 2.5	SE 2.9					E 1.3
1997	1	01			SE 2.4	SE 2.8		SE 1.6	SE 2.1			SE 2.3			SE 2.5
1998	1	01	SE 2.9	SE 2.2	E 1.5	SE 2.4	SE 1.1					NE 1.7			
1999	1	01	NW 3.0											NW .5	NW 1.2
2000	1	01	NW .6	SE 2.3	SE 1.3	SE 1.7		SE 2.4	SE 2.4	SE 2.9	SE 1.9	SE 2.2		NW .6	SE 1.3
2001	1	01	SE 1.4	SE 2.1	SE 1.9	SE 2.1	SE 2.3	SE 2.4	SE 2.0					SE 1.5	NW 3.0
2002	1	01	SE 1.1	SE 2.2	SE 2.0		SE 1.9	SE 1.8	SE 2.7	SE 2.4	SE 2.4	SE 1.9		SE 1.6	E 1.9
2003	1	01	E 1.3	E 1.8	SE 1.3	SE 1.0		E 2.2		SE 2.6	SE 1.9	SE 1.2		SE .9	SE 1.1
2004	1	01	SE .9	SE 1.2			SE 1.8	SE 2.5	SE 2.2	SE 2.4	SE 1.8	SE .8		SE .5	SE 1.7
2005	1	01	N .2	SE 1.4	SE .8	SE 1.4	SE 1.5	SE 1.8	SE 1.9	SE 2.3	SE 1.8	SE .9		NW .2	SW .5
2006	1	01	SE 1.3	E .2			SE 2.3	SE 1.6	SE 1.9	SE 2.0	SE 2.1	E .5		NW 1.9	SE 1.1
2007	1	01	SE 2.1	SE 2.8	SE 1.7	E 1.5	SE 1.5		SE 1.9	SE 1.7					
MAX			NW 3.0	N 3.3	NW 2.5	SE 4.1	SE 4.7	SE 4.0	SE 3.5	SE 3.6	SE 3.6	SE 2.2	NW 1.9	SE 3.1	SE 4.7
MIN			N .2	W .2	SE .5	SE 1.0	SE 1.1	SE 1.6	SE 1.8	S 1.7	NE 1.7	E .5	NW .2	W .3	N .2

Hydrometric Information – Average Monthly Flows at the San Marcos and Puente Garcés Stations

Sediment Transport at Puente Garcés

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

FLOW AVERAGE MONTHLY VALUES (m3/seg) PROCESS DATE : 2013/02/28
STATION : 21037020 SAN MARCOS

LATITUDE	0145 N	ST TYPE	LM	DEPTO HUILA	ISTALLATION DATE 1971-ABR
LONGITUDE	7556 W	ENTITY	01 IDEAM	MUNICIPALITY ACEVEDO	SUSPENSION DATE
ELEVATION	1291 m.s.n.m	REGIONAL	04 HUILA-CAQUET	CURRENTE SUAZA	

A#O	EST	ENT	JAN *	FEB *	MARCH *	APRIL *	MAY *	JUNE *	JULY*	AUG *	SEPTI *	OCT *	NOV *	DEC *	VR	ANNUAL *
1972	2	01	21.45	17.30	19.77 1	17.86	35.00 1	39.56 8	44.15	34.19	28.68	23.39 1	20.51 1	17.56 1		26.62
1973	2	01	13.67 1	12.86 1	13.40 1	11.65 1	20.45 1	23.04 1	28.82 1	30.13 1	24.67	16.74 1	19.26 1	15.29 1		19.17
1974	2	01	12.00 1	18.38 1	15.83 1	23.83 1	21.25 1	31.62 1	40.57	31.03	26.15	23.80 1	22.33 1	16.36 1		23.60
1975	2	01	17.10 1	14.78 1	23.14 1	18.63 1	21.54 1	35.08 1	29.75 1	25.42 1	31.18 8	21.15 1	22.15	20.21		23.34
1976	2	01	13.86	14.16 1	22.09 1	23.39 1	47.99 8	42.48 1	54.20 8	40.03	34.34	27.00 1	24.52 1	23.80 1		30.66
1977	2	01	15.23 1	20.36 1	21.37 1	26.31 8	35.85 8	41.29	47.92	25.64 6	33.10	27.00	19.87	18.75		27.72
1978	2	01	12.76	11.97	18.35 1	25.00	24.77	28.30 1	30.54	27.71	22.29	24.97	19.22	16.77		21.89
1979	2	01	12.80 6	10.90 6	17.86 6	27.40	28.00	31.79	35.91	21.24	20.37 1	17.22 1	18.68 1	17.61		21.65
1980	2	01	14.95	11.53	21.27	23.42 1	27.74 1	30.36	34.00	30.62	23.40 1	28.27 1	19.00 1	15.15 1		23.31
1981	2	01	11.46 1	15.10 1	16.20 1	28.79	25.11	29.23	33.00	20.81	23.16	24.59	19.06	18.91		22.12
1982	2	01	17.79	16.22	20.80	24.04	24.95	36.54	44.33	38.51	36.23	27.08	21.09	19.60		27.27
1983	2	01	21.17	30.79 8	30.38	36.21	33.20	29.30	34.25	33.02	35.88	25.91	23.18	22.72		29.67
1984	2	01	18.79	16.25	16.69	17.41	18.07	29.00	29.47	25.73	22.72	25.54	35.39	33.77 8		24.07
1985	2	01	13.39	9.036	10.79	12.56	24.45	45.55	31.46	47.95	28.98	19.31	18.69	12.24		22.87
1986	2	01	12.62	16.37	19.25	25.88	29.34	31.47	52.65	29.32	33.62	26.76	27.88	19.28		27.04
1987	2	01	21.93 8	22.43 8	19.33 8	28.68 8	26.10 8	31.97 8	39.09 8	42.37 8	25.28 8	21.62 8	18.07	17.11		26.17
1988	2	01	15.56 8	20.42 8	14.32 8	18.98 8	30.42 8	43.74 8	41.16 8	25.97 8	25.40 8	22.69 8	20.02 8	16.64 8		24.61
1989	2	01	18.12 8	13.83 8	21.94 8	27.29 8	36.93 8	57.87 8	62.70 8	33.04 8	24.56 8	26.18 8	27.89 8	11.96		30.19
1990	2	01	15.54 8	15.13 8	23.04 8	20.46 8	35.86 8	38.31 8	43.07 8	28.68 8	25.76	19.41 8	21.97 8	17.93		25.43
1991	2	01	13.53 8	11.66 8	16.21 8	15.47 8	24.24 8	33.50 8	47.57 8	39.52 8	32.89 8	20.67	18.09	12.86 8		23.85
1992	2	01	12.76 8	10.05 8	14.43 8	20.29 8	17.96	22.73	37.94 8	35.20 8	18.59 8	17.03	13.99 8	12.02 8		19.42
1993	2	01	15.31	18.73	22.94 8	21.25	29.43 8	37.16 8	39.59 8	30.12 8	23.75 8	20.66 8	21.84 8	16.12 1		24.74
1994	2	01	15.00 8	14.40 8	19.30 8	32.60 8	36.30 8	48.00 8	37.60 8	36.90 8	28.60 8	21.80 8	19.20 8	23.10 6		27.73
1995	2	01	12.60 8	10.40 8	14.29 8	20.34 8	32.90 8	32.33 8	26.31 8	17.61	20.34 8	19.60	17.56 8	14.69 8		19.91
2006	1	01	10.83 8	10.85 8	14.99 8	18.38 8	20.24 8	22.99 8	17.15 8	17.03	13.43	16.45 3	18.46	18.42		16.60 3
2007	1	01	18.34	18.23	20.73	18.89	24.84	19.70 8	12.91 8	28.38 8	29.76 8	19.71	17.18 8	14.36		20.25
2008	1	01	14.65	16.59	13.25	13.83	16.35	20.59 8	29.96	26.67	22.32	22.45	18.00	16.78 8		19.29
2009	1	01	21.08	21.77 7	20.37	31.68 3	*	42.21 8	93.73 8	58.13 8	45.20 7	19.64 8	17.62 8	16.80 8		35.29 3
2010	1	01	13.00 8	13.35 8	25.66 8	27.00 8	23.38 8	31.41	25.33	17.29 8	20.83 8	19.90 8	14.52 8	13.48 8		20.43
2011	1	01	10.05	8.314	11.71 8	21.82 8	27.78 8	26.07 8	34.99 8	19.69 8	24.95 8	17.91	13.19	17.57		19.50
MIDS			15.25	15.41	18.66	22.65	27.60	33.77	38.67	30.60	26.88	22.15	20.28	17.60		24.13
MAXS			21.93	30.79	30.38	36.21	47.99	57.87	93.73	58.13	45.20	28.27	35.39	33.77		93.73
MIN			10.05	8.314	10.79	11.65	16.35	19.70	12.91	17.03	13.43	16.45	13.19	11.96		8.31

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

AVERAGE

FLOW AVERAGE AMONTHLY VALUES

(m3/seg)

PROCESS DATE : 2013/02/28 STATION : 21037010 PTE GARCES

LATITUDE 0201 N TYPE ST LG DEPTO HUILA DATE INSTALLATION 1964-APR

LONGITUDE 7546 W ENTITYD 01 IDEAM MUNICIPALITY GUADALUPE DATE SUSPENSION

ELEVATION 0893 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT sUAZA

A#O	EST	ENT	** JAN *	FEB *	MARCH *	APRIL *	MAY *	JUNE *	JULY *	AUGT *	SEPTI *	OCT *	NOV *	DECE *	VR ANNUAL
1972	2	01	38.65 1	29.22	34.53	40.65 1	72.66 1	54.29 1	95.03 1	54.29	45.73 1	39.14 1	39.87 1	34.81 1	48.24
1973	2	01	25.28 1	21.97 1	22.20 1	19.51 1	33.51 1	39.58	50.67 1	61.67 1	52.82 1	33.41 1	36.48 1	32.94 1	35.84
1974	2	01	20.69 1	27.36	25.63 1	40.38 1	40.77 1	50.85 1	67.77 1	56.12 1	45.40 1	39.06 1	43.59 1	29.82	40.62
1975	2	01	27.80 1	27.57 1	41.57 1	38.02 1	41.44 1	76.32 1	52.99 1	49.26	50.09 1	39.02 1	38.79 1	36.27 1	43.26
1976	2	01	27.11	29.13 1	46.39	56.56	91.20	83.76	96.74	82.42	64.43	48.60	48.21	42.77	59.78
1977	2	01	20.82	24.76 1	27.27 1	50.55 1	54.19	50.08	71.83	59.46	57.88 1	47.64 1	38.62	30.16	44.44
1978	2	01	23.28	20.39	27.05 1	41.61	38.17	49.65 1	60.97 1	61.26 1	45.15 1	45.59 1	34.04 1	30.40 1	39.80
1979	2	01	20.36 1	16.59	29.75	51.37 1	63.48	60.48 6	65.34 1	40.20 1	38.66 1	25.93 1	33.73 1	29.69 1	39.63
1980	2	01	23.72	17.75	30.63 1	36.06 1	52.44 8	57.20 1	64.92 1	51.20	45.39 1	45.32 1	30.38 1	23.85 1	39.91
1981	2	01	20.81 1	24.83 1	28.79 1	41.78 1	40.23 1	50.28 1	59.93	35.99 1	39.99 1	38.86	34.39	29.46 1	37.11
1982	2	01	24.97 1	23.50	28.28	34.12	36.82	48.76	59.75 1	54.57	51.34	42.66	35.43	31.86	39.34
1983	2	01	41.74	46.74 8	46.15	55.02 8	62.89	55.60	63.49 1	52.58 1	44.38 1	44.86	38.17	38.31 1	49.16
1984	2	01	29.11	24.90	26.17 8	29.14 8	32.58 8	60.55 8	58.78 8	45.25 8	32.55 8	41.48 8	48.29 8	42.43 8	39.27
1985	2	01	19.16	16.02	18.72	23.10 8	37.49 8	64.48 8	68.07 8	72.56 8	44.54 8	29.00	26.19 8	18.68 1	36.50
1986	2	01	20.03	24.38	30.03	39.49	46.31 1	74.48 1	97.40 1	49.06 1	63.19 1	58.76 1	54.81 1	34.71 1	49.39
1987	2	01	31.00 8	32.59 8	28.52 8	46.75 8	40.12 8	57.51 8	73.17 8	82.23 8	46.82 8	40.45 8	30.32 8	28.34 8	44.82
1988	2	01	20.66 8	31.84 8	21.46 8	27.94 8	41.52 8	79.06 8	71.46 8	46.29 8	40.98 1	39.47 8	43.57 8	29.73 1	41.17
1989	2	01	31.25 8	24.60 8	45.30 8	53.71 8	77.34 8	87.66 8	87.51 8	57.38 8	45.39 8	46.69 8	43.89 8	23.61 8	52.03
1990	2	01	30.30 8	30.77 1	37.78 1	41.98 8	60.62 8	73.19 8	70.22 8	62.23 8	53.20 8	34.62 8	38.68 8	33.65	47.27
1991	2	01	21.98	17.23 8	24.81	27.44	41.27 8	58.72 8	78.77 8	69.74 8	60.36 8	36.46 8	30.77	21.48	40.75
1992	2	01	19.69 8	18.50 8	23.84 8	30.44 8	30.97 8	42.99 8	69.03 8	67.39 8	35.84 1	29.22	27.76	24.28 1	35.00
1993	2	01	23.48 8	24.96 8	38.03 8	36.52 8	43.95 8	71.35 8	65.14 8	60.29 8	45.50 1	39.70 8	44.94 8	36.68 8	44.21
1994	2	01	22.84	23.70 8	37.30 8	58.59 8	69.88 8	80.00 8	70.85 8	67.17 8	43.76 8	31.37 8	31.07 8	28.04 8	47.05
1995	2	01	18.00 8	13.10 8	18.60 8	31.30 8	49.40 8	49.00 8	42.60 8	24.00 1	28.10 8	30.50 8	24.20 8	19.60 8	29.03
1996	1	01	21.40 8	33.24 8	31.96 8	35.39 8	44.05 8	48.97 8	59.27 8	45.62 8	43.83 8	45.27 8	28.13 1	28.69 8	38.82
1997	1	01	19.92 8	34.91 8	28.57 8	29.20 8	55.62 8	40.02 8	62.47 8	63.93 8	38.28	30.74 8	29.99 1	22.44 8	38.01
1998	1	01	17.38	23.25	31.30 8	33.36 8	34.02 8	65.26 8	66.32 8	45.40 8	37.68 8	29.46 1	26.94 1	23.21 1	36.13
1999	1	01	31.71 8	40.67	31.46 1	63.93 8	50.90 8	62.28 8	52.25 8	54.69 8	49.53 8	42.95 8	30.55 1	33.81 8	45.39
2000	1	01	24.44 1	29.60 8	36.18 8	38.03 1	90.42 8	101.7 8	95.54 8	107.7 8	94.18 8	89.60 8	71.63 8	71.18 8	70.85
2003	1	01	21.23 8	29.99 8	24.16 8	31.76 8	46.08 8	42.01 8	50.80 8	39.61 8	36.90 8	45.80 8	27.97	31.67 8	35.67
2004	1	01	24.94 8	16.29 8	24.61 8	42.22 8	64.97 8	100.0 8	67.37 8	65.03 8	62.09 8	42.16 8	35.02	33.97 8	48.22
2005	1	01	26.00	42.99 8	30.99	74.79 8	53.09 8	61.55 8	59.25 8	51.27 8	46.09 8	50.61 8	49.04 8	34.26 8	48.33
2006	1	01	34.06 8	29.35 8	39.32 8	41.80 8	50.50 8	59.66 8	58.60 8	48.85 8	37.98 8	39.28 8	43.89 8	37.51 8	43.40
2007	1	01	27.73 8	19.97 8	32.15 8	43.25 8	59.71 8	82.64 8	48.36 8	50.33 8	45.43 8	38.43 8	44.93 8	30.88 8	43.65
2008	1	01	26.71 8	29.49 8	27.50 8	26.51 8	35.51 8	41.14 8	37.70 8	31.91 8	26.60 8	26.73 8	29.51 8	26.72 8	30.50
2009	1	01	27.42 8	26.28 8	31.45 8	32.66 8	35.05 8	47.34 8	78.06 8	56.57 8	45.94 8	35.29 8	29.39 8	22.08 8	38.96

2010	1	01	15.63 8	17.76 8	29.24 8	38.62 8	49.11 8	67.02 8	50.98 8	34.27 8	33.15 8	35.12 8	29.67 1	23.66 8	35.35
2011	1	01	19.38 8	19.68 8	36.22 8	46.79 8	61.33 8	47.55 8	61.12 8	38.24 8	50.87 8	38.81 8	30.64 8	47.51 8	41.51

MID	24.76	25.94	30.89	40.27	50.78	61.66	66.07	55.16	46.58	40.48	36.93	31.56	42.59
MAX	41.74	46.74	46.39	74.79	91.20	101.7	97.40	107.7	94.18	89.60	71.63	71.18	107.70
MIN	15.63	13.10	18.60	19.51	30.97	39.58	37.70	24.00	26.60	25.93	24.20	18.68	13.10

I D E A M - INSTITUTO DE HIDROLOGIA, METEOROLOGIA Y ESTUDIOS AMBIENTALES

NATIONAL ENVIRONMENTAL INFORMATION SYSTEM

TRANSPORT TOTAL MONTHLY VALUES (KTon/Mes)

PROCESS DATE : 2013/02/28 STATION : 21037010 PTE GARCES

LATITUDE 0201 N ST. TYPE LG DEPTO HUILA DATE INSTALLATION 1964-ABR

LONGITUDE 7546 W ENTITY 01 IDEAM MUNICIPALITY GUADALUPE DATE SUSPENDED

ELEVATION 0893 m.s.n.m REGIONAL 04 HUILA-CAQUET CURRENT SUAZADATE

SUSPENDED**********

A#O	EST	ENT	JAN *	FEB *	MARCH *	APRIL *	MAY *	JUNE *	JULY *	AUGT *	SEPTI *	OCT *	NOV *	DECE *	VR ANNUAL *
1981	1	01	5.582	19.70	8.872	77.94	45.93	153.0 8	531.0	52.28	34.09 8	94.53	200.5 8	32.22	1255.64
1982	1	01	30.77 8	38.29 8	68.38 8	36.80	155.0 8	114.6 8	103.7	74.66	31.71	18.60	13.88	15.24	701.63
1983	1	01	32.25 8	165.0	68.41 8	154.7	236.0	177.3 8	221.5	42.95 8	86.01 8	50.00	45.53 8	22.77 8	1302.42
1984	1	01	19.61 8	13.23	17.97	61.19	29.99	280.9 8	99.99	38.66	15.76 8	59.62	159.8	182.5	979.22
1985	1	01	9.775	2.002 8	8.476 8	35.00	102.6	128.1	120.6	204.5	68.24	12.87	22.90 8	4.074 8	719.14
1986	1	01	9.915	15.75 8	31.83 8	18.40	60.80	132.5 8	243.5	51.55	88.48	82.26	52.35	26.02	813.36
1987	1	01	18.23	16.90	16.07	125.9 8	21.04 8	67.43	91.49	145.2	15.72	52.57 8	22.90	24.54	617.99
1988	1	01	5.489	46.17	23.24	10.09	23.37	133.9	65.72	45.85	13.64 8	44.51	54.86 8	12.73 8	479.57
1989	1	01	13.78 8	10.45	115.1	18.25 8	232.7 8	79.74	214.7	54.30	15.03	39.33	111.7	2.499	907.58
1990	1	01	8.677 8	6.565	14.20 8	24.80	27.32	60.84	99.15 8	30.30	82.36	7.914 8	31.91	11.27	405.31
1991	1	01	3.133 8	4.498	8.685 8	10.37 8	51.54 8	55.53 8	55.38 8	40.43	22.40 8	15.12	15.95 8	5.902 8	288.94
1992	1	01	9.762 8	1.377 8	6.657 8	9.517	4.591 8	10.08	39.86 8	20.28	9.740	3.651	3.980 8	3.536 8	123.03
1993	1	01	2.894	2.978	29.60 8	13.26 8	7.038	51.29 8	42.57	26.34	11.89	9.653	35.32	33.19	266.02
1994	1	01	8.000	4.700	47.00	66.70	103.8	141.4	94.30 8	96.20	26.20 8	7.600	13.10	7.300	616.30
1995	1	01	2.910	2.700	3.630	7.810	14.24	24.67	9.730 8	4.430	7.530	13.92	13.44	8.560	113.57
1996	1	01	10.14	12.54	8.040	21.60	31.40	34.98	20.99	11.12	17.62	32.10	5.050	6.330	211.91
1997	1	01	5.440 8	20.12	8.220	10.48	30.39	10.07	35.87	27.11	9.760	5.780	3.710 8	2.400 8	169.35
1998	1	01	1.300 8	12.00 8	9.700	16.80	19.00	49.80	120.4	51.10 8	28.30	7.700	14.10	7.600	337.80
1999	1	01	12.60 8	26.20 8	10.70 8	107.5 8	46.40 8	100.0 8	66.10 8	64.60 8	39.70 8	29.40 8	10.10 8	20.00 8	533.30
2000	1	01	7.400 8	13.00 8	24.80 8	33.10 8	67.50	119.2	31.40 8	29.70	40.60	98.60	11.00	29.50	505.80
2003	1	01	5.124	5.922	4.384 8	6.648	21.97	9.360	31.47	15.28	13.26	40.30	8.008	46.94	208.67
2004	1	01	23.14	1.289	7.591	50.55	218.8 8	417.8 8	128.7 8	91.73 8	109.2 8	8.712	10.54	9.129	1077.18
2005	1	01	3.658	8.648	3.183	31.09	5.845	16.28	5.669	9.559	4.753	19.64	9.542	15.05	132.92
2006	1	01	15.41	3.166	14.77	19.11	7.176 8	28.96	6.370	15.25	2.931	12.22 8	14.10	9.584	149.05
2007	1	01	6.576	1.710	6.245	16.61	22.74 8	29.86	14.04	9.306	5.013	17.49	35.77	15.11	180.47
2008	1	01	4.896 8	10.32	17.24	3.229	4.726	15.37	4.651 8	4.383 8	2.676 8	13.31 8	6.259	1.449	88.51
2009	1	01	1.715	5.721	1.890	1.597	2.372	4.097	38.73 8	7.404	8.610 8	2.350	2.585	.999 8	78.07
2010	1	01	.581	1.006	4.181	3.448	7.962	6.993	4.941 8	1.986	1.328	1.204	1.033	.833	35.50
2011	1	01	.412	.907	33.26 8	6.200 8	5.097	2.726	4.226 8	9.214 8	2.439	1.492	5.437	35.32	106.73
MID			9.627	16.31	21.46	34.44	55.43	84.72	87.82	43.99	28.10	27.67	32.25	20.43	462.24
MAX			32.25	165.0	115.1	154.7	236.0	417.8	531.0	204.5	109.2	98.60	200.5	182.5	531.00
MIN			0.412	0.907	1.890	1.597	2.372	2.726	4.226	1.986	1.328	1.204	1.033	0.833	0.41

** C O N V E N TIONS **

EST = STATUS OF INFORMATION

1 : PreliminarT Ideam
2 : DefinitivE Ideam
3 : Preliminary other entity
4 : Definitive other entity

** MISSING DATA **

1 : Absence of observ
2 : Instrum. Failure
3 : Lack of instrument
4 : Reject4ed data
6 : Higher level
7 : Lower level
8 : Expense curve
9 : Unstable section
A : Instr. sedimented
M : Max not extrapolated.

** DATA SOURCE **

1 : Recordeds
3 : Incomplete
4 : Doubtful
6 : Est. Regressionn
7 : Est. Interpolation
8 : Est. Other methods
9 : Generated (Series)

* : Insuficient data

Annex 2.2 Profiles of Representative Soils at the Suaza River Basin

Map Unit Symbol	Taxonomy	Profile No. 1	Horizon		Granul. %				%C	PH 1:1	CIC m.e/100g		
			Prof.	Nom.	A	L	Ar	Text.			CIC A	CICE	CIC V
Asociación MQA	Oxic Dystropepts	PH-22	0-23	Ap	22	34	44	Ar	4.5	4.9	25.8	7	18.8
			23-70	BW	4	32	64	Ar	0.47	5	11.2	7.2	4
			70-150	C	6	26	68	Ar	0.27	5.1	12.8	3.6	9.2
	Typic Troporthents	PH-24	0-10	Ap	34	42	24	F	1.01	5.2	11.2	6	5.2
			10-150	C	36	38	26	F	0.6	5.3	9.6	6.7	2.9
	Lithic Troporthent	PG-233	0-20	Ap	70	14	16	FAGr	2.62	6.1	21.9	18	3.9
			20-200	R	Roca alterada								
Asociación MQC	Typic Humitropepts	PH-50	0-16	Ap	38	34	28	FAr	3.4	5.5	26.4	8.3	12.1
			16-39	BW1	16	30	54	Ar	1.7	5.2	20.2	6.3	13.9
			39-76	BW2	16	34	50	Ar	0.7	5.4	21.8	9.5	12.2
			76-110	BW3	14	22	52	Ar	0.5	5.6	21.8	-	-
Asociación MQE	Entic Hapludolls	PS-9	0-24	Ap	66	18	16	FA	0.6	5.9	13.0	18.7	
			24-58	Ac	64	20	16	A	0.6	6.5	12.2	16.7	
			58-150	C	66	26	8	FA	0.1	6.6	16.8	38.5	

Map Unit Symbol	Taxonomy	Profile No	Horizon		Change Cat. : m.e/100g					Saturation %			P ppm	CO_3
			Prof.	Nom.	Ca	Mg	K	Na	Al	SBA	SBE	SAL		
Asociación MQA	Oxic Dystropepts	PH-22	0-23	Ap	1.6	0.8	0.3	0.1	4.2	10.8	4	60	1	
			23-70	BW	1.2	0.8	0.05	0.1	5	18.7	3	80	1	
			70-150	C	1.2	0.4	0.1	0.1	1.8	14	5	50	1	
	Typic Troporthents	PH-24	0-10	Ap	2	1.2	0.6	0.6	1.6	39.3	73	27	29	
			10-150	C	2	2	0.7	0.7	1.66	53.1	76	24	6	
	Lithic Troporthent	PG-233	0-20	Ap	13.4	3.1	1.1	0.4	-	82.1	100	-	65	73
			20-200	R										
Asociación MQC	Typic Humitropepts	PH-50	0-16	Ap	5.3	1.8	0.7	0.2	0.3	30.3	96.3	3.6	3.0	
			16-39	BW1	1.3	0.4	0.6	0.1	3.9	11.9	38.0	62.0	1.0	
			39-76	BW2	3.0	1.3	0.6	0.1	4.6	22.9	52.0	48.0	1.0	
			76-110	BW3	5.6	3.0	0.5	0.2	-	42.7	100.0	-	1.0	
Asociación MQE	Entic Hapludolls	PS-9	0-24	Ap	12.6	5.9	0.1	0.1					13.0	
			24-58	Ac	11.2	5.3	0.1	0.1					9.0	
			58-150	C	24.3	13.9	0.1	0.2					23.0	

Annex 2.3 Confessions for the Use of Water at the Suaza River Basin

Order	User	Lot	Municipality	Location	Water body	Concession lps
1	Junta acción comunal vda. La Marimba	Community aqueduct	Acevedo	Marimba	Quebrada Sabanilla	1.45
2	Junta administradora Acueducto vda. La Independencia	vda. La Independencia Community aqueduct	Acevedo	Independencia	Quebrada La Carbona	1.28
3	Junta administradora acueducto vda. Bajo Encanto	Community aqueduct	Acevedo	Bajo Encanto	Nacimiento Natural Bajo Encanto	2.80
4	Junta acción comunal vda. San Antonio	Community aqueduct	Acevedo	San Antonio	Quebrada La Anayaco	2.36
5	Junta administradora acueducto vda. San Marcos	Community aqueduct	Acevedo	San Marcos	Quebrada La Calle	4.45
6	Junta administradora acueductos San Adolfo	Acueducto comunal Aguas Claras	Acevedo	Aguas Claras	Quebrada La Guayacana	2.00
7	Junta administradora acueducto San Adolfo	La Monus Community aqueduct	Acevedo	Monus	Quebrada La Guayacana	2.00
8	Grupo asociativo San Isidro	San Isidro	Acevedo	San Isidro	Quebrada La Palma	1.20
9	Junta acción comunal vda. Santa Ana	Community aqueduct	Acevedo	Santa Ana	Nacimiento natural Santa Ana	3.00
10	Junta acción comunal vda. Siberia	Community aqueduct La Esperanza	Acevedo	Siberia	Quebrada La Naya	4.33
11	Junta administradora acueducto Pueblo Viejo - Anayaco	Las Bateas	Acevedo	Anayaco	Quebrada Bateas	3.10
12	Junta acción comunal vda. El Salado	Community aqueduct	Acevedo	Laureles	Quebrada La Chorrosa	2.00
13	Junta administradora acueducto vda. Las Delicias	Lucitania	Acevedo	Delicias	Quebrada La Anayaco	3.49

14	Junta administradora acueducto regional La Danta	Community aqueduct	Acevedo	Copalito	Quebrada La Danta	4.00
15	Junta acción comunal vda. El Bolívar	Community aqueduct	Acevedo	Bolivar	Quebrada La Cristalina	7.00
16	Junta administradora acueducto vda. La Unión - Victoria - Cristo Rey	Community aqueduct vda. La Union - Victoria - Cristo Rey	Acevedo	Unión	Quebrada La Marimba	4.50
17	Municipio de Acevedo	Municipal aqueduct	Acevedo	Aguas Claras	Quebrada La Correntosa	18.00
18	Emilio Prada Montes	La Esperanza	Acevedo	Buenavista	Quebrada Charco Negro	0.10
19	Hernan Anturi Soto	La floresta Lote B	Acevedo	Pueblo Viejo	Nacimiento natural Agua Linda	0.20
20	J.A.C. vda. El Jardín	Community aqueduct	Acevedo	Jardín	quebrada La Callada	0.90
21	Junta de acción comunal vda. Playitas	Community aqueduct vda. Playitas	Acevedo	vda. Playitas - insp. San Adolfo	Quebrada N.N. Playitas	1.05
22	Junta acción comunal vda. Bajo Encanto	Community aqueduct vda. Bajo Encanto	Acevedo	vda. Bajo Encanto - Alto Encanto	Quebrada La Carbona	0.62
23	Junta administradora del acueducto vda. La Victoria	Community aqueduct vda. La Victoria	Acevedo	vda, La Victoria	Quebrada El Manantial	0.90
24	J. A. C. Vereda Mesa Alta	Aqueduct	Acevedo	vda. Mesa Alta	Quebrada La Cristalina	0.10
25	luis Carlos Torres Casanova	Service station San Francisco	Acevedo	Casco Urbano	Quebrada La Guache	0.50
26	Luis Carlos Torres Casanova	Service station San Francisco	Acevedo	Casco Urbano	Quebrada La Guache	0.50
27	Asociación usuarios acueducto rural vda. San Isidro	Community aqueduct vda. San Isidro	Acevedo	vda. San Isidro	Quebrada lAs Coloradas	1.00
Total Concession at the Municipality of Acevedo High Basin (27 users)						**72.83**
28	Arcesio Plazas	San Jose	Suaza	Guayabal	Quebrada Las Tapias	2.60

29	Graciliano Duran	Horizonte	Suaza	El Horizonte	Nacimiento natural Las perLas	5.30
30	Jorge Eduardo Facundo	El Diamante	Suaza	Picuma	Quebrada La Calderona	2.44
31	Junta acción comunal vdas. Guayabal - Las Tapias	Community aqueduct El Líbano	Suaza	Guayabal	Quebrada La Cuerva	18.00
32	Junta acción comunal vda. La Esmeralda	Community aqueduct vda. La Esmeralda	Suaza	La Esmeralda	Quebrada El Arenoso	1.48
33	Luz Nancy Quintero Ramirez	San Luis	Suaza	El Avispero	Nacimiento natural Dos Cabezas	3.00
34	Israel Manchola Mendez	Potosi	Suaza	Gallardo	Quebrada La Carbona	0.50
35	Estación de servicio Las Delicias -Fanny Sánchez Quesada	Las Delicias via Suaza-Florencia	Suaza	Municipio Suaza	Aguas Subterraneas - Suaza	0.17
36	Leonel Silva	Toribio	Suaza	El Vergel	Nacimiento natural jacue Dos Afluentes	0.29
37	Jairo Celemin Clavijo	Lote 2 La Delgadita	Suaza	Satia	Quebrada satia - La Delgadita	0.05
38	Junta acción comunal vda. El Cerrito	Community aqueduct	Suaza	El Cerrito	Quebrada La Carbona	0.78
39	Junta administradora acueducto Nuevo Horizonte	Community aqueduct Divino Niño	Suaza	Divino Niño	Quebrada Divino Niño	0.62
40	Miguel Angel Fajardo	S.N. Miguel Angel Fajardo	Suaza	vda. La Independencia	Quebrada La Carbona	0.50
41	Jesus Antonio Claros	S.N. Jesus Antonio Claros	Suaza	vda. Independencia	Quebrada La Carbona	0.50
42	Asociación usuarios Distrito Riego San Isidro	Aqueduct Distrito Riego	Suaza	vda. San Isidro	Quebrada El Emaya	30.00
43	Aguas del Huila s. a. - esp. Municipio de Suaza	Municipal Aqueduct	Suaza	vda. El Salado - San Calixto	Quebrada El Emaya	13.00
Total Concession at the Municipality of Suaza Mid Basin (16 users)						**79.23**

44	Asociación usuarios distrito de adecuación tierras vda. Los Cauchos	"Distrito de Riego ""Aso Los Cauchos"""	Guadalupe	Los Cauchos	Quebrada La Pintada	33.00
45	Junta administradora acueducto El Carmen	Community aqueduct El Carmen	Guadalupe	El Carmelo	Quebrada La Pintada	3.00
46	Junta acción comunal vda. Marmato	Community aqueduct	Guadalupe	Marmato	Quebrada El Salado	1.28
47	Junta acción comunal vda. Las Brisas	Community aqueduct Las Brisas	Guadalupe	Las Brisas	Quebrada La Bernarda	1.06
48	Junta administradora acueducto vda. Los Cauchos	Community aqueduct	Guadalupe	Los Cauchos	Quebrada La Pintada	3.78
49	Junta accion comunal vda. Corozal	Community aqueduct vda. Corozal	Guadalupe	Corozal	Quebrada La Pintada	1.07
50	Junta de acción comunal vda. Rancherias	Community aqueduct vda. Rancherias	Guadalupe	Rancheria	Quebrada Rancherias	3.94
51	Empresa servicios públicos Altamira e. S. P.	Municipal aqueduct Altamira	Guadalupe	La Danta	Quebrada La Perica	12.32
52	Junta acción comunal vda. Buenos Aires	Community aqueduct buenos aires - El Vegon	Guadalupe	Buenos Aires	Quebrada La Cedra	4.32
53	Asociación usuarios acueducto vdas. El Mirador - Barquetas	Community aqueduct	Guadalupe	Mirador	Quebrada La Pioja	1.96
54	Empresa Servicios Publicos Guadalupe	Municipal aqueduct	Guadalupe	Planta	Quebrada La Viciosa	23.10
55	Junta acción comunal vda. Miraflores	Community aqueduct	Guadalupe	mirafLores	Quebrada Chontaduro	2.39
56	Junta acción comunal vda. Marmato	Community aqueduct vda. Marmato	Guadalupe	Marmato	Quebrada El Emaya	2.39
57	Junta acción comunal vda. Chontaduro	Community aqueduct vda. Chontaduro	Guadalupe	Chontaduro	Quebrada Chontaduro	1.35
58	Junta de acción comunal vda. las palmeras, Jose Alfredo Cruz Suarez	Aqueduct la vereda Las Palmeras	Guadalupe	Las Palmeras	Quebrada Aguas Claras	1.19

59	Junta de acción comunal de la vda. Alto Meson-Yobani Artunduaga Collazos	Aqueduct vda. Alto Meson	Guadalupe	El Meson	Quebrada La Raisosa	2.82
60	Junta de acción comunal vda. La Bernarda	Community aqueduct vda. La Bernarda	Guadalupe	La Bernarda	Quebrada El Corazon	3.00
61	Junta acción comunal vda. Chorrillos	Community aqueduct vda. Chorrillos	Guadalupe	Chorrillos	Quebrada Chorrillos	0.50
62	Junta acción comunal vda. Betania	Community aqueduct Betania	Guadalupe	Betania	Quebrada Buenos Aires	0.95
Total Concession at the Municipality of Altamira (19 users)						**103.42**
63	Asociación usuarios distrito riego Miraguas	"Distrito Riego ""Asomiraguas"""	Altamira	Llano de La Virgen	Quebrada Agua Caliente	85.70
64	Asociación de usuarios del acueducto rural de Rancho Espinal	Community aqueduct	Altamira	Llano de La Virgen	Quebrada La Pescada	8.32
65	Didier Edilberto Cano Campos	Rancho Espinal	Altamira	Llano de La Virgen	Quebrada La Callejona	3.16
66	Junta de acción comunal vda. El Puente	Community aqueduct vda. El Puente	Altamira	El Puente	Quebrada La Singa	1.63
67	Asociación usuarios distrito riego "Llano de La Virgen"	"Distrito riego ""Llano de La Virgen"""	Altamira	Llano de La Virgen	Quebrada La Pescada	180.00
68	David Arce Rojas	La Providencia	Altamira	Pajiji	Quebrada El Azufral	0.50
69	Jaime tOle Hernandez	Buenos Aires	Altamira	Pajiji	Quebrada El Azufral	0.50
70	Jose Ramiro y Luis Eduardo Chavarro Medina	El Carrizal	Altamira	Llano de La Virgen	Quebrada La Cimarrona	0.87
71	Junta acción Comunal Llano de La Virgen	Aqueduct Minas – Miraguas	Altamira	Llano de La Virgen	Quebrada Agua Caliente	1.00
72	Mercedes Trujillo Vasquez	Potrerito	Altamira	Sempero	Quebrada Potrerillos	0.03
73	Junta administradora acueducto Rancho Espinal	Community aqueduct	Altamira	vda. Rancho Espinal	Quebrada La Callejona	5.00

74	Floresmiro Puentes Sanchez	Buenos Aires	Altamira		Nacimiento	0.50
Total Concession at the Municipality of Garzón (12 users)						**395.08**
75	Distrito de Riego Asorompeson	Distrito de Riego en Proyecto	Garzón	Vereda Rosario-San Antonio del Pescado	Quebrada La Pescada	94.00
76	Delia del Socorro Poveda	Lote # 1 – Yunguita	Garzon	vda. Las Damas	Quebrada Agua Caliente	70.00
77	Junta administradora acueducto vda. San Luis	Community aqueduct vda. San luls	Garzon	San Luis	Quebrada Los Tullidos	3.86
78	Junta administradora acueducto vda. La Jagua	Community aqueduct vda. La Jagua	Garzon	La Jagua	Quebrada Agua Caliente	16.20
79	Junta administradora acueducto regional la Cristalina	Regional Aqueduct La Cristalina	Garzon	Las Delicias	Quebrada La Cristalina	2.84
80	alejAndro y Mario Enrique Cedeño	Lote # 1 - Yunga	Garzon	El Caguan	Quebrada Agua Caliente	100.00
81	Asociación usuarios acueducto vda. Puerto Asis	Community aqueduct	Garzon	Villa Rica	Quebrada el Salado	2.22
82	Asociacion distrito riego Asodescanso	Distrito de Riego	Garzon	El Descanso	Quebrada Agua Caliente	40.00
83	Celso Cano Angucho	Community aqueduct	Garzon	El Descanso	Quebrada Agua Caliente	9.76
84	Gilberto Gomez	Aqueduct vda. san Antonio del Pescado	Garzon	San Antonio	Quebrada Chontaduro	6.88
85	Grupo asociativo agropecuario La Esmeralda	Fishery La Esmeralda	Garzon	El Viso	Quebrada Agua Caliente	16.70
86	junta acción Comunal vda. La Union - Aguacaliente	Irrigation District	Garzon	Union Agua Caliente	Quebrada Agua Caliente	60.00
87	junta acción comunal vda. La Union - Agua Caliente	Aqueduct Irrigation District	Garzon	Union Agua Caliente	Quebrada Agua Caliente	56.36

88	Junta administradora acueducto vda. Campo Bello - Albania	Community aqueduct vda. Campo Bello – Albania	Garzon	Campo Bello	Quebrada La Cristalina	5.11
89	Rafael Eduardo Mauricio Luna Cabrera	La Luna	Garzon	Municipio Garzon	Nacimiento natural Agua Caliente	10.00
90	Alba Nelly Narvaez Chincangana	La Melba	Garzon	El Descanso	Quebrada Agua Caliente	0.30
91	Asociación usuarios servicio agua potable Villa Majo	Community aqueduct Villa Majo	Garzon	Villa Rica	Quebrada El Salado	0.62
92	Gentil Rengifo Muñoz	El Caf etal	Garzon	El Descanso	Quebrada Agua Caliente	0.40
Total Concession at the Municipality of Guadalupe, Low Basin (18 users)						**495.25**
TOTAL CURRENT CONCESSION AT THE SUAZA RIVER BASIN						**1145.81**

Annex 3.1 Estimate Potential Evapotranspiration

Resina Station

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	13.4	21.1	85	144	3.4	14	2.68	83.08
2	13.5	21.1	85	153	3.3	14.4	2.76	77.28
3	13.6	21	86	151	2.8	13.8	2.69	83.39
4	13.7	20.8	87	184	2.7	13.4	2.6	78.00
5	13	19.8	87	186	3	13.2	2.47	76.57
6	13	19.8	87	218	3.3	13.2	2.44	73.20
7	12.3	19.2	87	212	3.1	13.1	2.39	74.09
8	12.5	19.5	86	225	3.4	14.1	2.57	79.67
9	13	20.5	85	205	3.5	14.7	2.77	83.10
10	13.4	20.8	87	112	3	13.9	2.63	81.53
11	13.6	20.7	88	79	2.8	13.1	2.48	74.40
12	13.6	20.8	87	133	3.1	13.3	2.51	77.81
Mean	**13.2**	**20.4**	**86**	**167**	**3.1**	**13.7**	**2.58**	**942.12**

Evapotranspiration Estimates, Sub-Basin 1

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	13.7	21.9	84	144	3.6	14.3	2.76	85.56
2	13.7	21.9	84	153	3.4	14.5	2.83	79.24
3	13.9	21.7	85	151	2.9	14	2.75	85.25
4	13.9	21.6	86	184	2.8	13.5	2.66	79.80
5	13.8	21	86	186	3.1	13.3	2.57	79.67
6	13.2	20.6	86	218	3.4	13.3	2.53	75.90
7	12.5	20	86	212	3.2	13.2	2.47	76.57
8	12.7	20.2	85	225	3.6	14.4	2.66	82.46
9	13.2	21.3	84	205	3.7	15	2.87	86.10
10	13.6	21.6	86	112	3.1	14	2.69	83.39
11	13.8	21.5	87	79	2.9	13.3	2.53	75.90
12	13.8	21.5	86	133	3.2	13.4	2.57	79.67
Mean	**13.5**	**21.2**	**86**	**167**	**3.2**	**13.9**	**13.5**	**969.51**

Evapotranspiration Estimates, Sub-Basin 2

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	15.2	24.5	83.0	144.0	4.1	15.0	15.2	94.24
2	15.2	24.5	83.0	153.0	3.9	15.3	15.2	87.36
3	15.4	24.4	84.0	151.0	3.3	14.6	15.4	93.62
4	15.5	24.2	85.0	184.0	3.2	14.2	15.5	88.50
5	15.3	23.5	85.0	186.0	3.5	13.9	15.3	88.04
6	14.7	23.0	85.0	218.0	3.9	14.0	14.7	84.30
7	13.9	22.3	85.0	212.0	3.7	13.9	13.9	84.94
8	14.1	22.6	84.0	225.0	4.1	15.2	14.1	91.76
9	14.6	23.9	83.0	205.0	4.2	15.8	14.6	95.40
10	15.1	24.2	85.0	112.0	3.6	14.8	15.1	91.14
11	15.3	24.1	86.0	79.0	3.3	13.9	15.3	82.20
12	15.3	24.1	85.0	133.0	3.7	14.2	15.3	87.73
Mean	**15.0**	**23.8**	**84.0**	**167.0**	**3.7**	**14.6**	**2.93**	**1069.23**

Evapotranspiration Estimates, Sub-Basin 3

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	15.2	24.5	83	144	4.1	15	3.03	93.93
2	15.2	24.5	83	153	3.9	15.3	3.12	87.36
3	15.4	24.4	84	151	3.3	14.6	3.02	93.62
4	15.5	24.2	85	184	3.2	14.2	2.95	88.50
5	15.3	23.5	85	186	3.5	13.9	2.84	88.04
6	14.7	23	85	218	3.9	14.1	2.82	84.60
7	13.9	22.3	85	212	3.7	13.9	2.74	84.94
8	14.1	22.6	84	225	4.1	15.2	2.96	91.76
9	14.6	23.9	83	205	4.2	15.8	3.18	95.40
10	15.1	24.2	85	112	3.6	14.8	2.94	91.14
11	15.3	24.1	86	79	3.3	13.9	2.74	82.20
12	15.3	24.1	85	133	3.7	14.2	2.83	87.73
Mean	**15**	**23.8**	**84**	**167**	**3.7**	**14.6**	**2.93**	**1069.22**

Evapotranspiration Estimates, Sub-Basin 4

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	15.1	24.4	83	144	4.1	15	3.03	93.93
2	15.2	24.4	83	153	3.9	15.3	3.11	87.08
3	15.3	24.3	84	151	3.3	14.6	3.02	93.62
4	15.4	24.1	85	184	3.2	14.2	2.94	88.20
5	15.3	23.4	85	186	3.5	13.9	2.83	87.73
6	14.6	22.9	85	218	3.9	14.1	2.81	84.30
7	13.9	22.3	85	212	3.7	13.9	2.74	84.94
8	14.1	22.5	84	225	4.1	15.2	2.95	91.45
9	14.6	23.8	83	205	4.2	15.8	3.18	95.40
10	15	24.1	85	112	3.6	14.8	2.94	91.14
11	15.3	24	86	79	3.3	13.9	2.73	81.90
12	15.3	24	85	133	3.7	14.1	2.82	87.42
Mean	**14.9**	**23.7**	**84**	**167**	**3.7**	**14.6**	**2.92**	**1067.11**

Evapotranspiration Estimates, Sub-Basin 5

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	15.4	25.0	82.0	144.0	4.2	15.1	3.09	95.79
2	15.5	24.9	82.0	153.0	4.0	15.4	3.17	88.76
3	15.7	24.8	83.0	151.0	3.4	14.8	3.08	95.48
4	15.7	24.6	84.0	184.0	3.3	14.3	3.00	90.00
5	15.6	24.0	84.0	186.0	3.6	14.1	2.9	89.90
6	14.9	23.5	84.0	218.0	4.0	14.2	2.88	86.40
7	14.2	22.8	84.0	212.0	3.8	14.1	2.8	86.80
8	14.4	23.1	83.0	225.0	4.2	15.3	3.03	93.93
9	14.9	24.3	82.0	205.0	4.3	16.0	3.24	97.20
10	15.3	24.6	84.0	112.0	3.7	14.9	2.99	92.69
11	15.6	24.6	85.0	79.0	3.4	14.0	2.78	83.40
12	15.6	24.6	84.0	133.0	3.8	14.3	2.88	89.28
Mean	**15.2**	**24.2**	**84**	**167**	**3.8**	**14.7**	**2.99**	**1089.63**

Evapotranspiration Estimates, Sub-Basin 6

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	18.1	29.5	79	144	5.1	16.5	3.64	112.84
2	18.1	29.4	79	153	4.9	16.8	3.75	105.00
3	18.2	29.2	80	151	4.2	16	3.61	111.91
4	18.3	29	81	184	4.1	15.6	3.57	107.10
5	18.2	28.2	81	186	4.4	15.3	3.44	106.64
6	17.4	27.7	81	218	4.9	15.5	3.45	103.50
7	16.5	26.8	81	212	4.7	15.4	3.34	103.54
8	16.7	27.2	80	225	5.1	16.7	3.61	111.91
9	17.3	28.6	79	205	5.3	17.5	3.88	116.40
10	17.9	29	81	112	4.5	16.2	3.47	107.57
11	18.1	28.9	82	79	4.2	15.2	3.2	96.00
12	18.1	28.9	81	133	4.6	15.4	3.35	103.85
Mean	**17.7**	**28.5**	**81**	**167**	**4.7**	**16**	**3.53**	**1286.26**

Evapotranspiration Estimates, Sub-Basin 7

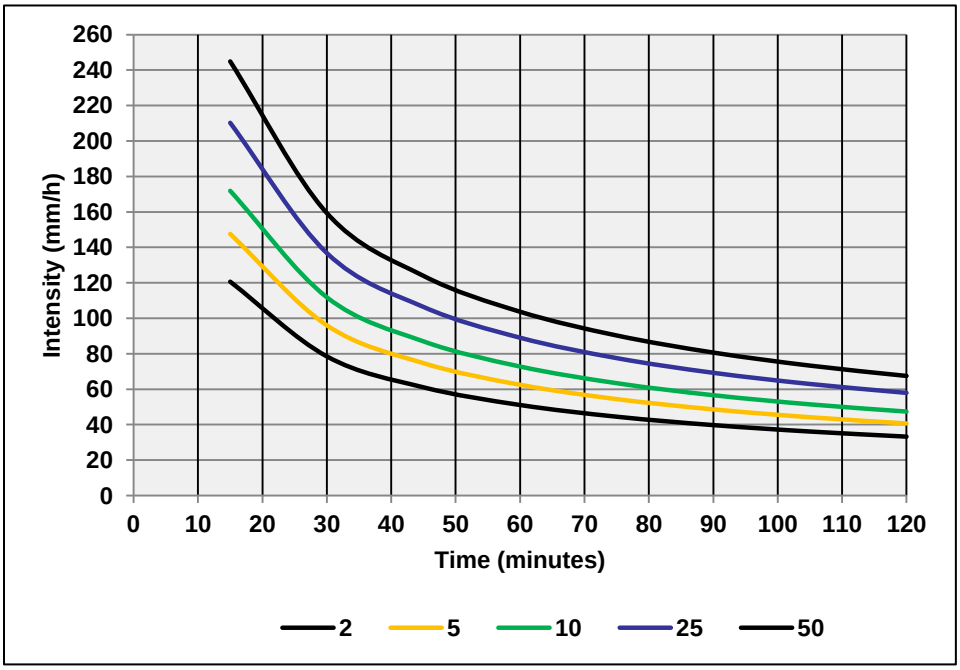
Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	16.8	27.3	81.0	144.0	4.7	15.9	3.36	104.16
2	16.8	27.2	81.0	153.0	4.5	16.2	3.46	96.88
3	17.0	27.1	82.0	151.0	3.8	15.4	3.34	103.54
4	17.0	26.9	83.0	184.0	3.7	14.9	3.28	98.40
5	16.9	26.2	83.0	186.0	4.0	14.7	3.17	98.27
6	16.2	25.6	83.0	218.0	4.5	14.9	3.16	94.80
7	15.4	24.9	83.0	212.0	4.2	14.7	3.06	94.86
8	15.6	25.2	82.0	225.0	4.7	16.1	3.32	102.92
9	16.1	26.5	81.0	205.0	4.8	16.7	3.55	106.50
10	16.6	26.9	83.0	112.0	4.1	15.5	3.22	99.82
11	16.9	26.8	84.0	79.0	3.8	14.6	2.98	89.40
12	16.9	26.8	83.0	133.0	4.2	14.8	3.11	96.41
Mean	**16.5**	**26.4**	**82**	**167**	**4.3**	**15.4**	**3.25**	**1185.96**

Evapotranspiration Estimates, Sub-Basin 8

Month	Minimum Temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Wind (km/day)	Sunshine (h/day)	Solar Radiation MJ/m²/ day	Evapotranspiration (ETo)	
							mm/day	mm/month
1	17.4	28.4	80.0	144.0	4.9	16.1	3.49	108.19
2	17.4	28.3	80.0	153.0	4.7	16.5	3.6	100.80
3	17.6	28.2	81.0	151.0	4.0	15.7	3.48	107.88
4	17.7	27.9	82.0	184.0	3.9	15.3	3.42	102.60
5	17.6	27.2	82.0	186.0	4.2	15.0	3.3	102.30
6	16.8	26.6	82.0	218.0	4.7	15.2	3.31	99.30
7	15.9	25.8	82.0	212.0	4.5	15.1	3.21	99.51
8	16.2	26.2	81.0	225.0	4.9	16.4	3.46	107.26
9	16.7	27.6	80.0	205.0	5.0	17.1	3.71	111.30
10	17.2	28.0	82.0	112.0	4.3	15.8	3.35	103.85
11	17.5	27.9	83.0	79.0	4.0	14.9	3.09	92.70
12	17.5	27.9	82.0	133.0	4.4	15.1	3.23	100.13
Mean	**17.1**	**27.5**	**81**	**167**	**4.5**	**15.7**	**3.39**	**1235.82**

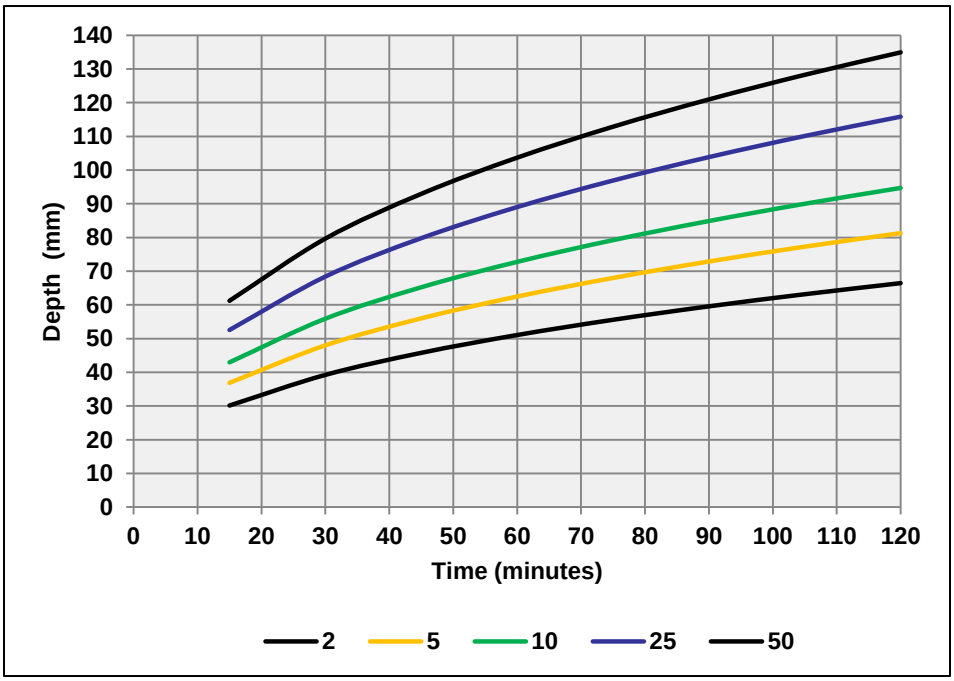
Annex 4.1 Intensity-Duration-Frequency Curves and Depth-Duration-Frequency Curves at the Guadalupe, El Líbano, and Resina Stations

Intensity-Duration-Frequency Curves – Guadalupe Station



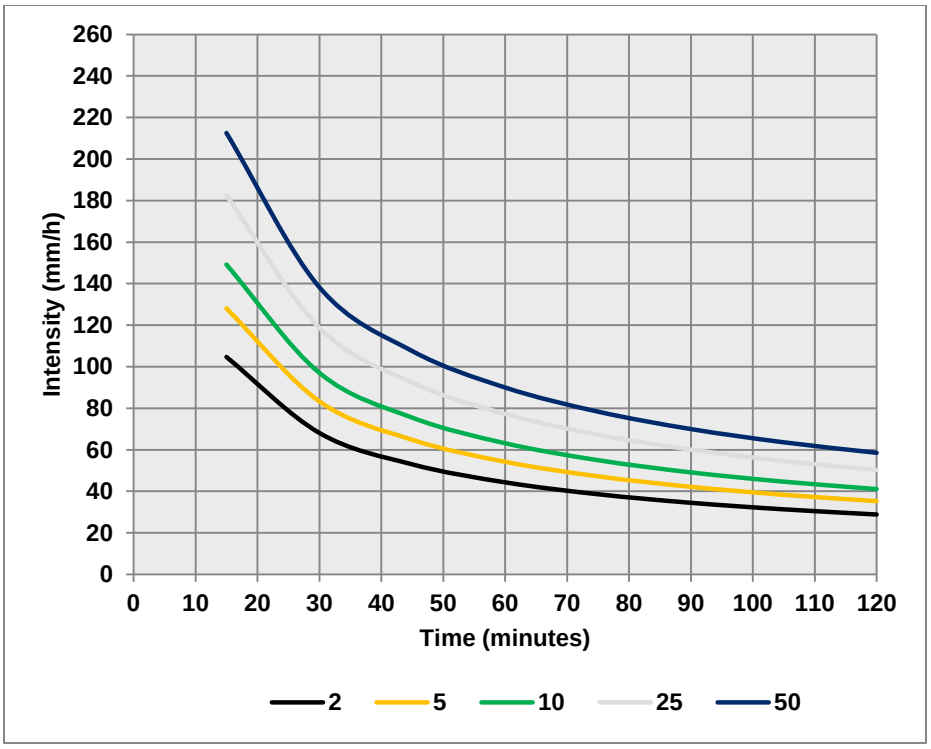
Source: UNC (2009)

Depth-Duration-Frequency Curves – Guadalupe Station

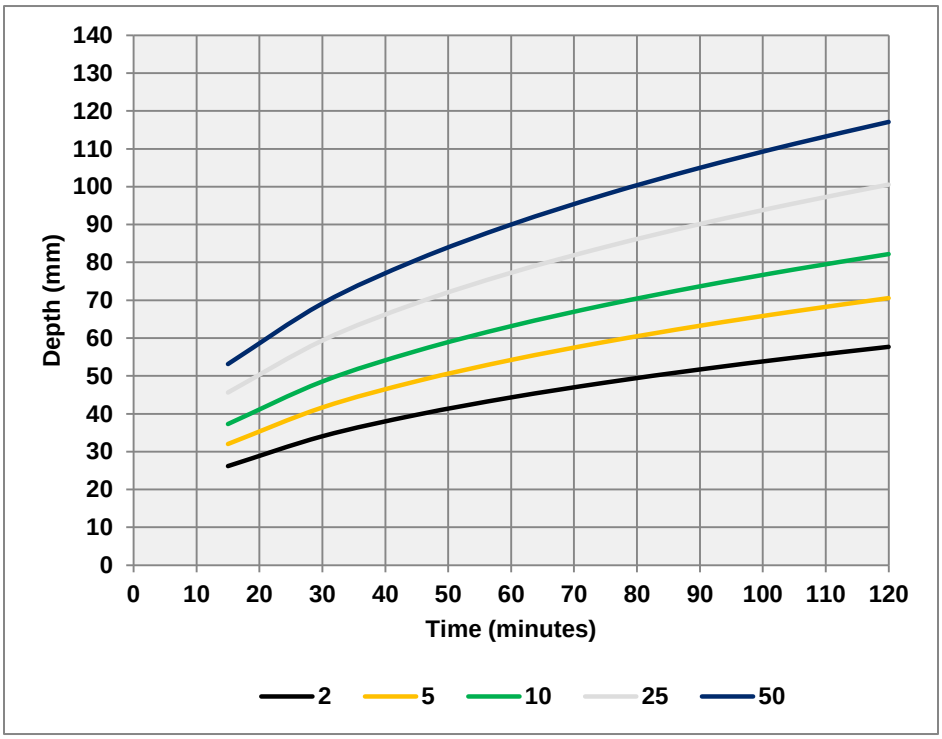


Source: UNC (2009)

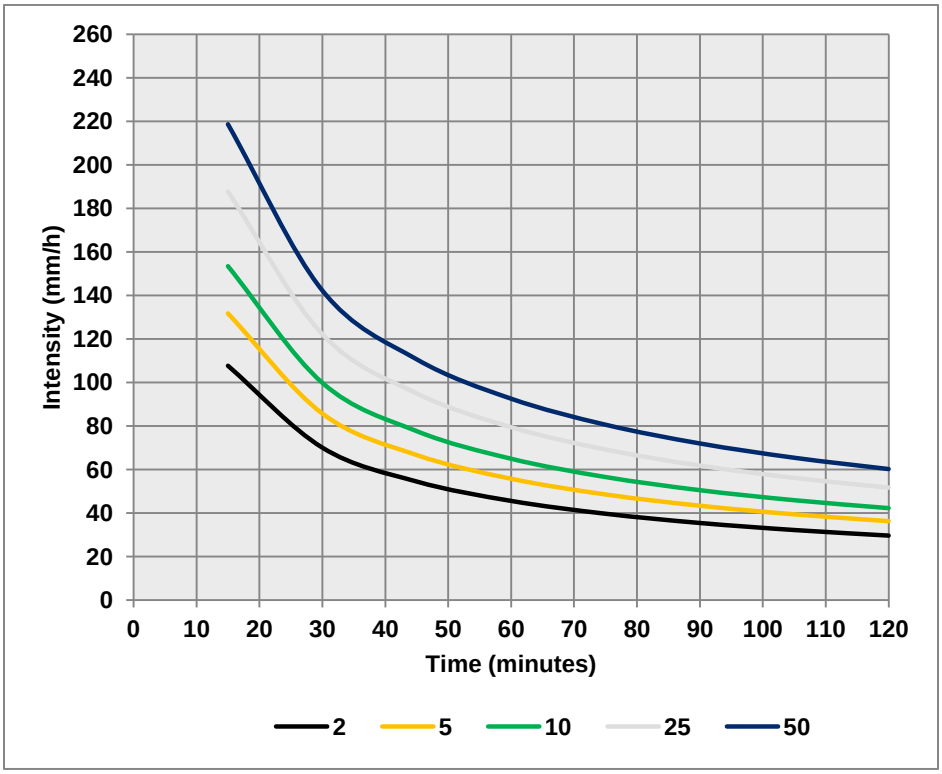
Intensity-Duration-Frequency Curves – El Líbano Station



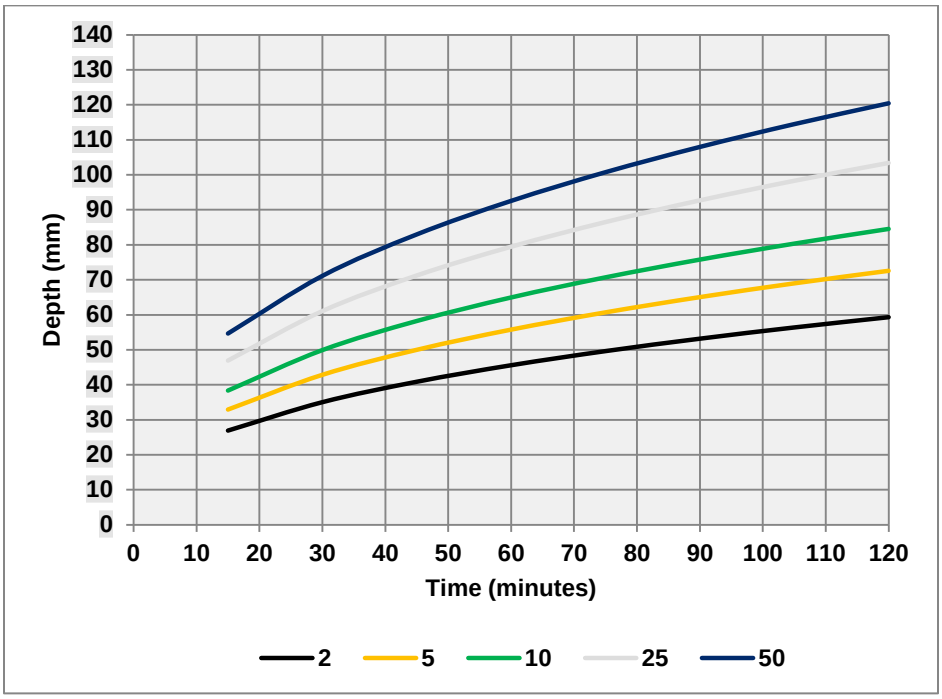
Depth-Duration-Frequency Curves, El Líbano Station



Intensity-Duration-Frequency, Resina Station



Depth-Duration-Frequency Curves, Resina Station



Annex 4.2 Monthly Flows Estimated with the SWAT Model in Each Sub-Basin of the Suaza River

Sub-Basin 1

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	7.63	7.91	11.55	12.53	12.89	18.11	27.15	20.46	26.58	17.99	15.32	13.35	15.96
1987	9.93	10.54	11.97	17.68	15.37	20.23	23.21	20.48	17.04	11.19	8.69	7.62	14.50
1988	5.24	5.27	4.38	8.18	13.09	21.71	20.48	16.52	14.51	12.14	14.29	12.95	12.40
1989	13.79	8.87	12.43	15.40	24.42	34.09	33.90	25.69	21.23	18.67	20.82	11.92	20.10
1990	11.28	8.90	8.98	11.36	16.89	23.71	21.99	18.66	22.25	13.51	11.92	11.49	15.08
1991	9.41	7.35	7.38	8.79	19.71	24.86	26.83	36.48	27.22	17.82	14.64	10.22	17.56
1992	10.01	10.54	12.21	18.42	18.20	20.42	26.95	27.60	18.80	16.48	12.23	12.44	17.03
1993	10.38	6.95	13.54	12.60	23.38	31.27	29.02	33.10	27.02	22.04	21.47	21.19	21.00
1994	15.61	10.54	10.43	22.88	30.37	39.61	23.55	26.21	24.36	19.36	19.56	16.17	21.55
1995	11.74	7.19	8.91	13.04	18.89	22.84	23.59	15.87	13.45	13.40	11.65	8.90	14.12
1996	8.43	13.03	17.57	15.31	16.33	13.84	22.14	20.59	30.18	17.34	12.02	12.36	16.60
1997	12.09	14.45	17.91	14.40	24.31	24.29	23.18	23.62	19.34	13.81	9.89	8.63	17.16
1998	5.66	5.96	11.31	11.22	15.98	26.94	28.31	23.52	22.80	17.85	14.61	12.01	16.35
1999	14.32	13.48	11.10	22.76	22.25	28.72	26.57	26.05	18.44	17.38	14.75	16.14	19.33
2000	10.78	9.49	12.38	11.65	27.67	19.34	14.72	20.42	20.66	22.26	19.39	15.54	17.03
2001	10.31	7.40	7.04	17.07	19.01	24.07	23.06	21.94	23.91	17.09	13.26	16.15	16.69
2002	12.26	10.08	9.85	12.93	23.15	26.92	23.26	26.51	23.82	17.60	14.32	10.28	17.58
2003	6.65	4.71	5.52	7.33	10.43	12.20	18.36	15.12	14.77	13.05	9.74	12.31	10.85
2004	7.91	5.26	8.42	19.84	17.53	30.49	23.84	23.30	25.63	23.18	14.95	10.37	17.56
2005	10.54	15.95	12.24	23.39	18.15	26.61	24.30	24.37	21.24	17.57	16.00	12.79	18.60
2006	11.70	12.64	10.89	12.51	17.02	16.72	24.96	23.51	20.16	20.53	13.55	11.06	16.27
2007	8.41	6.72	9.39	10.66	16.16	29.38	22.17	30.43	24.85	19.49	15.97	12.07	17.14
Mean	**10.19**	**9.24**	**10.70**	**14.54**	**19.15**	**24.38**	**24.16**	**23.66**	**21.74**	**17.26**	**14.50**	**12.54**	**16.84**

Monthly and Annual Average Flows at Sub-Basin 2

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	13.76	12.97	16.44	17.10	20.82	32.07	40.02	29.50	37.16	31.46	25.46	20.18	24.74
1987	13.50	13.93	15.42	21.71	24.63	30.03	30.86	30.32	25.21	17.41	13.14	16.46	21.05
1988	9.32	11.07	9.17	14.73	24.03	45.32	33.42	26.86	24.18	20.63	28.89	23.40	22.58
1989	20.91	16.32	21.42	22.48	37.04	48.42	50.04	38.63	32.57	28.05	31.82	17.64	30.44
1990	14.33	11.60	12.98	16.66	24.48	35.36	33.44	28.46	33.76	19.37	16.98	21.30	22.39
1991	15.67	10.92	10.62	11.45	22.09	27.68	37.17	43.32	35.22	23.19	19.52	13.86	22.56
1992	13.95	13.85	15.22	21.98	24.48	26.51	35.06	36.99	23.94	19.53	15.97	16.24	21.98
1993	13.17	9.99	20.73	17.22	30.17	39.88	38.85	43.22	36.87	34.10	31.11	29.42	28.73
1994	21.78	14.96	17.14	32.78	46.37	55.80	36.76	41.79	36.90	28.95	29.60	25.50	32.36
1995	19.37	11.40	13.82	23.27	29.63	35.68	35.62	24.50	24.86	21.79	18.36	13.62	22.66
1996	12.21	19.18	25.88	23.79	23.56	24.10	34.23	32.45	41.04	29.27	20.92	21.47	25.67
1997	20.65	22.34	28.27	23.84	38.89	37.54	36.32	38.22	31.30	22.80	16.39	14.14	27.56
1998	8.35	8.42	15.72	15.86	21.33	37.71	42.56	35.78	31.93	24.59	21.68	19.29	23.60
1999	20.22	18.50	14.81	34.69	33.95	42.63	36.11	36.17	28.15	31.56	26.13	29.61	29.38
2000	20.20	20.55	25.52	22.19	52.71	35.62	27.03	36.19	40.24	36.65	29.55	23.87	30.86
2001	16.19	10.73	12.67	27.57	34.12	40.64	38.01	35.07	39.06	27.89	26.86	26.30	27.93
2002	20.42	15.23	14.23	19.02	34.36	40.70	37.18	44.50	37.31	27.40	22.95	18.36	27.64
2003	11.75	7.90	8.06	12.91	19.87	23.65	31.13	25.95	28.05	26.11	21.18	22.50	19.92
2004	15.23	9.48	11.68	29.17	31.36	49.69	41.83	43.28	46.32	37.56	24.87	19.34	29.99
2005	25.76	29.53	23.60	40.31	33.99	49.47	41.45	40.47	38.50	36.03	31.72	23.74	34.55
2006	22.02	20.00	19.19	21.53	27.50	29.51	38.35	36.44	31.20	30.83	21.64	19.61	26.48
2007	13.72	10.12	14.15	18.51	29.36	51.21	37.05	47.08	37.89	31.29	28.00	20.38	28.23
Mean	**16.48**	**14.50**	**16.67**	**22.22**	**30.22**	**38.15**	**36.93**	**36.14**	**33.71**	**27.56**	**23.76**	**20.74**	**26.42**

Monthly and Annual Average Flows at Sub-Basin 3

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	15.84	15.26	19.15	19.95	23.80	36.83	47.03	34.88	43.39	37.42	30.21	23.73	28.96
1987	15.84	16.27	18.02	25.02	28.64	34.55	35.80	35.36	29.60	20.27	15.31	19.03	24.48
1988	10.99	13.09	11.20	17.55	27.89	52.77	40.14	31.70	28.39	24.49	33.93	28.21	26.70
1989	24.64	19.36	25.45	26.44	42.91	57.73	60.37	46.47	38.95	33.61	38.04	21.54	36.29
1990	16.84	13.96	15.53	19.40	28.71	41.44	39.34	33.73	40.44	23.38	20.12	25.42	26.53
1991	19.09	13.10	12.83	13.56	25.01	31.27	44.61	51.18	42.83	28.28	23.51	16.64	26.83
1992	16.47	16.36	17.88	24.97	28.52	30.98	41.02	43.98	28.60	22.94	18.75	19.27	25.81
1993	15.43	11.76	24.22	20.37	34.34	46.91	45.62	51.23	44.41	40.29	37.42	35.61	33.97
1994	25.96	17.92	20.07	38.25	54.68	66.70	44.10	50.47	44.51	35.11	35.50	30.76	38.67
1995	23.19	13.82	16.41	27.17	34.94	41.82	42.17	29.29	29.28	26.07	22.06	16.30	26.88
1996	14.37	22.53	30.51	28.03	27.40	27.81	40.29	38.84	48.96	35.71	25.45	25.71	30.47
1997	24.53	26.61	33.27	28.16	45.97	45.01	43.60	46.10	37.77	27.37	19.82	16.95	32.93
1998	10.05	10.06	18.20	18.52	24.36	43.66	51.28	43.19	38.67	29.61	26.00	23.23	28.07
1999	24.04	22.21	17.62	40.30	40.74	50.93	42.78	43.49	33.63	37.73	31.62	36.07	35.10
2000	24.12	24.40	30.43	26.48	62.69	43.39	32.83	43.05	48.97	44.53	36.03	29.14	37.17
2001	19.76	13.01	15.12	31.69	40.47	48.72	45.80	42.43	47.40	33.90	32.56	32.13	33.58
2002	25.09	18.39	16.83	22.12	40.18	48.55	44.12	53.54	45.55	33.33	27.97	22.20	33.16
2003	14.29	9.64	9.66	15.11	23.10	27.54	36.85	30.96	33.30	31.68	25.87	27.47	23.79
2004	18.63	11.65	13.86	33.95	36.94	59.52	50.17	52.39	55.98	45.80	30.06	23.26	36.02
2005	30.14	35.82	28.65	47.75	40.41	58.99	50.89	49.38	46.93	43.55	39.09	29.04	41.72
2006	26.57	24.10	22.71	25.17	31.94	34.51	45.59	44.00	37.55	37.48	26.19	23.50	31.61
2007	16.47	12.05	16.64	21.73	33.93	61.10	45.09	56.98	46.36	38.64	34.51	25.02	34.04
Mean	**19.65**	**17.34**	**19.74**	**25.99**	**35.34**	**45.03**	**44.07**	**43.30**	**40.52**	**33.24**	**28.64**	**25.01**	**31.49**

Monthly and Annual Average Flows at Sub-Basin 4

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	19.47	19.12	23.32	23.54	27.97	43.89	54.65	41.01	49.25	45.42	37.66	29.29	34.55
1987	19.54	19.27	21.02	28.02	33.26	39.79	40.93	41.29	35.00	24.77	19.11	23.83	28.82
1988	14.26	16.69	15.20	21.67	32.98	63.62	48.89	38.38	34.34	30.19	41.83	35.30	32.78
1989	30.04	24.85	31.72	31.90	50.03	65.48	69.99	54.06	46.15	39.69	43.45	25.86	42.77
1990	19.79	16.59	18.42	22.46	32.41	46.35	44.85	38.86	46.56	27.99	23.74	30.78	30.73
1991	23.81	16.41	15.90	16.33	27.28	33.31	49.44	55.04	46.73	31.53	26.40	18.97	30.10
1992	18.89	18.91	20.25	27.38	31.43	34.17	44.49	47.75	31.79	25.27	20.96	21.76	28.59
1993	17.40	13.70	27.45	23.46	37.87	50.92	49.77	55.82	49.41	45.45	43.98	41.39	38.05
1994	30.49	21.93	24.23	43.81	61.86	75.13	52.01	59.13	52.12	41.65	41.84	36.88	45.09
1995	28.22	17.54	19.97	32.35	41.15	48.63	48.75	34.59	34.68	31.16	26.34	19.58	31.91
1996	17.04	25.84	34.56	32.24	31.51	32.58	46.37	44.91	54.69	42.77	31.60	31.48	35.47
1997	29.64	31.59	38.19	33.47	52.97	52.32	50.98	54.39	45.06	33.49	25.02	21.53	39.06
1998	13.00	12.59	21.13	21.48	27.26	47.98	57.89	49.55	44.33	34.10	30.44	27.91	32.31
1999	28.00	25.72	20.71	45.07	46.99	57.22	48.43	48.71	38.55	43.74	37.83	42.70	40.31
2000	29.27	30.35	37.89	33.41	73.53	54.59	42.33	52.06	60.59	54.30	43.94	35.49	45.65
2001	24.87	16.56	18.96	36.47	47.78	57.04	53.58	49.63	54.93	40.21	39.83	38.24	39.84
2002	30.37	22.45	20.40	26.10	46.23	56.09	51.26	63.20	53.85	40.02	34.17	27.96	39.34
2003	18.75	13.01	12.40	18.34	27.22	32.42	42.32	36.08	38.68	37.89	31.98	33.27	28.53
2004	23.35	15.38	16.91	38.45	42.86	68.90	59.50	62.95	66.94	55.22	37.38	30.05	43.16
2005	38.79	44.59	36.57	56.99	49.54	71.62	63.09	59.94	57.53	55.32	50.65	37.82	51.87
2006	34.29	30.65	28.49	30.95	37.71	40.44	51.67	50.45	43.17	42.96	31.25	28.74	37.56
2007	20.38	14.95	19.86	25.86	39.54	70.90	53.99	65.40	54.00	45.90	42.20	30.93	40.33
Mean	**24.08**	**21.30**	**23.80**	**30.44**	**40.88**	**51.97**	**51.14**	**50.15**	**47.20**	**39.50**	**34.62**	**30.44**	**37.13**

Monthly and Annual Average Flows at Sub-Basin 5

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	21.72	21.60	28.13	28.71	34.62	52.70	67.22	49.85	56.84	52.08	45.85	33.89	41.10
1987	22.10	21.31	23.38	31.89	38.87	45.79	49.98	49.73	41.70	30.93	24.98	27.51	34.01
1988	16.53	18.79	16.92	24.37	36.83	71.61	57.89	46.11	40.85	36.39	48.17	40.82	37.94
1989	34.45	27.99	36.81	37.57	57.05	72.21	80.23	59.96	52.05	45.96	48.98	29.67	48.58
1990	22.73	19.95	21.79	25.23	35.32	51.24	52.70	48.24	55.82	35.27	30.00	35.72	36.17
1991	27.15	18.30	19.18	18.99	29.85	36.49	57.07	63.73	56.22	37.72	31.16	22.91	34.90
1992	21.71	21.75	22.85	30.34	34.92	38.78	53.69	57.76	39.20	30.03	25.45	26.15	33.55
1993	20.43	15.99	30.25	27.42	42.38	57.87	58.08	63.18	55.21	51.81	49.77	46.95	43.28
1994	34.83	25.14	29.43	52.68	70.05	84.89	60.66	65.91	57.75	47.79	46.96	41.28	51.45
1995	31.03	19.92	23.36	36.64	47.16	56.88	56.43	40.97	40.67	36.60	31.66	23.62	37.08
1996	20.74	30.12	39.03	35.64	35.58	38.20	53.57	52.44	61.66	50.08	37.63	36.07	40.90
1997	33.70	36.27	41.33	36.11	57.82	57.68	59.86	65.11	52.29	38.38	29.14	24.63	44.36
1998	14.73	14.08	23.20	24.52	31.62	55.09	65.62	56.40	50.57	39.75	35.23	31.80	36.88
1999	33.19	30.04	25.19	51.20	54.54	65.10	55.13	55.17	44.03	49.78	42.37	48.01	46.15
2000	33.58	33.71	41.38	37.20	81.76	62.31	48.71	59.32	69.86	62.09	49.97	40.37	51.69
2001	27.58	18.33	20.79	39.76	52.12	62.46	59.67	55.96	60.82	45.38	44.47	42.76	44.17
2002	35.55	25.08	23.26	29.65	52.94	65.69	60.56	72.77	61.57	46.30	40.83	34.40	45.72
2003	23.15	15.82	14.77	21.45	30.80	37.02	48.48	41.36	44.41	45.22	37.90	37.89	33.19
2004	26.22	17.27	18.69	42.39	47.33	78.13	67.11	71.26	74.93	60.93	42.37	35.32	48.50
2005	42.65	48.51	40.01	61.84	54.60	78.60	70.96	69.26	65.24	62.48	56.86	42.19	57.77
2006	37.56	33.17	31.78	34.69	41.19	44.89	58.55	56.54	48.32	47.92	37.21	33.97	42.15
2007	23.47	16.78	22.05	30.48	44.66	76.64	58.08	69.79	59.29	51.32	47.83	34.81	44.60
Mean	**27.49**	**24.09**	**26.98**	**34.49**	**46.00**	**58.65**	**59.10**	**57.76**	**54.06**	**45.65**	**40.22**	**35.03**	**42.46**

Monthly and Annual Average Flows at Sub-Basin 6

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	22.26	22.70	30.59	30.97	37.47	57.11	73.38	53.39	59.83	54.86	49.64	35.42	43.97
1987	22.78	22.05	24.43	33.85	41.56	48.46	53.87	53.40	44.06	33.19	27.39	28.71	36.14
1988	17.22	19.60	17.62	25.85	38.72	75.55	61.99	48.78	43.15	38.48	50.33	42.86	40.01
1989	35.82	29.00	39.36	39.88	60.34	75.07	84.78	62.04	54.00	48.38	50.93	30.93	50.88
1990	23.63	21.31	23.21	26.35	36.65	53.56	55.93	51.99	59.48	37.85	32.00	37.29	38.27
1991	28.01	18.73	20.70	20.23	31.00	37.91	60.96	67.16	59.69	39.45	32.44	23.97	36.69
1992	22.43	22.73	23.87	31.76	36.60	40.92	57.98	62.06	41.56	31.18	27.00	27.78	35.49
1993	21.29	16.67	31.57	28.96	44.63	61.19	61.54	66.10	57.12	53.81	52.06	48.95	45.33
1994	36.16	26.24	31.89	56.72	73.66	89.27	64.21	68.58	59.72	49.97	48.95	42.72	54.01
1995	31.87	20.78	25.25	38.78	50.13	60.46	59.74	43.22	42.64	38.61	33.69	24.98	39.18
1996	22.01	31.90	40.79	37.04	37.45	40.70	57.13	55.72	64.17	52.71	39.69	37.41	43.06
1997	35.08	38.12	42.33	37.20	60.42	59.81	63.95	69.66	54.58	39.64	30.34	25.47	46.38
1998	15.09	14.62	24.32	26.12	33.85	58.64	69.00	58.83	52.72	41.64	36.78	32.99	38.72
1999	35.30	31.66	27.00	54.02	57.88	68.36	57.33	57.57	45.83	51.76	43.59	49.87	48.35
2000	34.79	34.75	42.82	38.74	85.44	65.81	50.99	62.26	73.44	64.82	51.69	41.74	53.94
2001	28.13	18.78	21.55	41.56	54.25	64.84	62.17	58.29	62.68	46.73	45.81	44.14	45.74
2002	37.07	25.81	24.47	31.37	56.26	70.21	64.04	76.36	63.73	47.97	43.15	36.55	48.08
2003	24.46	16.61	15.68	22.95	32.41	39.14	51.21	43.18	46.28	47.89	40.10	39.24	34.93
2004	26.89	17.78	19.42	44.53	49.37	82.63	70.09	74.26	77.68	62.58	43.75	37.10	50.51
2005	43.69	49.92	41.53	64.16	56.70	81.67	74.10	72.48	67.61	64.36	58.81	43.19	59.85
2006	38.32	33.89	33.52	36.53	42.59	47.03	61.96	58.86	50.10	49.45	39.67	35.69	43.97
2007	24.19	17.21	23.12	33.07	46.96	79.18	59.50	71.27	61.19	53.10	49.81	36.03	46.22
Mean	**28.48**	**25.04**	**28.41**	**36.39**	**48.38**	**61.71**	**62.54**	**60.70**	**56.42**	**47.66**	**42.16**	**36.50**	**44.53**

Monthly and Annual Average Flows at Sub-Basin 7

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	28.87	29.45	38.90	39.12	45.25	66.32	83.35	62.22	67.88	64.43	60.52	44.18	52.54
1987	29.41	27.50	29.35	39.19	48.32	55.50	61.43	61.41	51.17	40.63	36.68	36.62	43.10
1988	23.19	26.63	23.92	31.71	44.49	82.84	70.47	56.06	49.81	46.03	59.36	52.92	47.29
1989	44.90	36.36	49.39	50.05	71.53	84.75	96.22	70.29	62.34	56.58	58.98	37.81	59.93
1990	29.65	27.05	28.97	31.92	42.26	59.24	62.46	58.97	66.71	44.66	39.16	45.65	44.72
1991	35.48	24.48	27.16	26.12	36.32	43.10	67.33	73.75	66.41	45.22	38.27	29.38	42.75
1992	27.25	27.52	28.04	35.86	40.67	44.97	63.00	67.87	47.00	35.56	31.30	33.35	40.20
1993	26.30	21.35	36.72	34.39	50.80	68.18	68.60	72.97	64.15	60.64	61.46	59.04	52.05
1994	45.85	34.70	40.24	66.99	83.10	99.85	74.02	77.73	67.46	57.47	55.75	48.72	62.66
1995	36.61	24.94	31.06	45.24	57.51	68.58	68.89	51.57	49.68	45.50	41.33	31.55	46.04
1996	28.22	44.60	54.92	49.25	50.30	53.46	69.82	67.21	74.37	61.99	48.69	45.21	54.00
1997	41.91	44.84	47.92	42.13	66.41	66.02	71.03	77.18	61.11	44.91	35.06	29.70	52.35
1998	18.28	18.24	28.00	31.34	39.26	65.41	76.46	66.22	59.42	47.81	43.77	39.37	44.47
1999	42.45	40.19	36.37	64.93	71.31	80.30	67.34	66.44	53.66	59.45	51.29	58.17	57.66
2000	42.86	42.32	50.55	46.46	95.55	76.17	60.11	70.27	81.54	71.96	58.56	48.34	62.06
2001	32.93	22.66	26.06	46.98	60.08	70.80	67.95	63.85	67.82	51.92	51.23	49.54	50.99
2002	42.48	30.32	29.33	37.00	63.69	80.23	73.56	85.72	72.51	55.55	51.10	43.55	55.42
2003	31.00	21.98	20.71	27.90	37.56	44.61	57.13	48.35	50.90	54.21	46.79	45.50	40.55
2004	32.08	22.29	23.60	49.94	55.10	90.20	77.46	81.57	84.75	68.96	50.89	44.28	56.76
2005	49.73	57.13	48.20	72.32	65.32	90.46	82.70	80.33	74.55	71.49	68.20	54.53	67.91
2006	48.66	42.88	43.67	48.92	54.08	57.19	71.74	67.58	57.67	57.05	49.41	44.70	53.63
2007	31.55	23.12	28.41	39.27	53.88	87.65	66.89	77.68	67.11	59.21	57.24	42.63	52.89
Mean	**34.98**	**31.39**	**35.07**	**43.50**	**56.04**	**69.81**	**70.82**	**68.42**	**63.55**	**54.60**	**49.78**	**43.85**	**51.82**

Series of Monthly and Annual Average Flows at Sub-Basin 8

Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1986	29.98	31.51	41.38	41.14	47.00	68.55	84.71	63.05	68.68	67.43	63.48	46.00	54.41
1987	30.44	28.34	30.41	40.87	50.36	57.18	62.99	62.88	52.13	41.91	38.98	39.33	44.65
1988	24.52	27.72	25.14	32.84	45.66	84.70	72.37	57.09	50.68	47.86	62.25	55.84	48.89
1989	46.81	38.22	52.99	53.35	74.50	86.85	98.16	71.50	63.88	58.19	60.42	39.42	62.02
1990	31.73	29.02	30.97	34.25	44.17	60.62	63.95	60.10	67.77	45.87	40.84	49.01	46.53
1991	37.70	25.60	29.30	28.10	37.72	44.51	68.90	74.86	67.27	46.02	39.81	30.87	44.22
1992	28.85	29.04	29.03	36.79	41.35	45.49	63.52	68.36	47.48	35.94	32.48	35.46	41.15
1993	27.80	22.81	38.76	36.63	53.06	69.96	70.01	74.17	65.60	62.51	66.26	63.18	54.23
1994	48.85	36.78	42.44	70.73	85.66	102.13	75.83	79.11	68.51	58.98	56.95	49.79	64.65
1995	37.17	25.71	33.28	47.58	59.84	70.45	71.07	53.14	50.55	46.94	43.89	33.44	47.75
1996	30.07	50.92	61.80	53.51	54.37	57.16	73.04	69.23	76.01	63.63	50.35	46.50	57.22
1997	43.21	46.30	48.90	43.10	68.00	67.78	72.46	78.11	61.86	45.46	35.77	30.57	53.46
1998	18.70	19.18	29.06	33.31	40.90	67.37	78.20	67.65	60.50	49.03	47.20	41.82	46.08
1999	45.31	44.28	40.66	67.98	74.92	82.75	68.76	67.45	54.78	60.93	53.78	61.45	60.25
2000	45.66	44.39	53.27	49.12	98.47	79.24	62.08	71.38	82.54	72.86	59.96	49.99	64.08
2001	33.76	23.26	27.66	48.82	61.59	72.28	68.97	64.62	68.49	52.93	52.96	51.19	52.21
2002	43.64	31.29	30.75	38.61	66.49	83.74	75.62	87.20	73.99	56.79	52.66	44.66	57.12
2003	31.99	23.02	21.69	29.17	38.92	45.83	58.12	48.89	51.27	55.58	48.08	46.89	41.62
2004	33.34	23.36	24.79	51.90	56.88	92.04	78.88	82.77	85.73	69.74	54.16	47.00	58.38
2005	51.26	59.09	50.08	74.68	67.56	92.50	84.04	81.07	75.11	72.85	70.70	57.36	69.69
2006	51.28	44.67	47.17	53.07	57.03	59.71	73.63	68.94	58.84	58.99	52.68	47.85	56.16
2007	33.59	24.43	29.42	40.93	55.95	90.40	68.65	78.69	67.96	60.86	59.91	44.66	54.62
Mean	**36.62**	**33.13**	**37.22**	**45.75**	**58.20**	**71.87**	**72.45**	**69.56**	**64.53**	**55.97**	**51.98**	**46.01**	**53.61**

Annex 5.1 Climate Change Scenarios at Representative Rainfall Stations of the Suaza River Basin

Guadalupe Station – Code: 21030050

Year	Scenarios			
	A2[5]	B2[3]	AIB-ECHAM5[3]	Trend
1971	1641	1641	1641	1641
1972	1475	1475	1475	1475
1973	1446	1446	1446	1446
1974	1279	1279	1279	1279
1975	1443	1443	1443	1443
1976	1515	1515	1515	1515
1977	1243	1243	1243	1243
1978	845	845	845	845
1979	1196	1196	1196	1196
1980	834	834	834	834
1981	930	930	930	930
1982	1563	1563	1563	1563
1983	1721	1721	1721	1721
1984	1315	1315	1315	1315
1985	999	999	999	999
1986	1190	1190	1190	1190
1987	1071	1071	1071	1071
1988	1367	1367	1367	1367
1989	1225	1225	1225	1225
1990	929	929	929	929
1991	857	857	857	857
1992	763	763	763	763
1993	1252	1252	1252	1252
1994	1271	1271	1271	1271
1995	973	973	973	973
1996	1275	1275	1275	1275
1997	758	758	758	758
1998	1003	1003	1003	1003
1999	1915	1915	1915	1915
2000	1282	1282	1282	1282
2001	822	822	822	1219

[5] See Section V.1. for definitions of climate change scenarios

Year	Scenarios			
	A2[5]	B2[3]	AIB-ECHAM5[3]	Trend
2002	1080	1080	1080	1219
2003	1174	1174	1174	1218
2004	1057	1057	1057	1218
2005	1781	1781	1781	1218
2006	1898	1898	1898	1217
2007	1232	1232	1232	1217
2008	1276	1276	1276	1217
2009	1248	1248	1248	1217
2010	1215	1215	1215	1216
2011	1296	1316	1353	1216
2012	1116	1144	1224	1216
2013	1143	1123	1247	1215
2014	1044	1055	1079	1215
2015	1146	1158	1233	1215
2016	1187	1201	1239	1215
2017	1049	1036	1045	1214
2018	673	678	686	1214
2019	982	978	992	1214
2020	695	687	707	1213
2021	724	731	779	1213
2022	1204	1222	1298	1213
2023	1387	1397	1413	1213
2024	1089	1092	1117	1212
2025	728	739	829	1212
2026	995	999	998	1212
2027	779	797	843	1211
2028	1174	1173	1174	1211
2029	1022	1011	1021	1211
2030	740	743	782	1211
2031	665	658	746	1210
2032	594	588	663	1210
2033	967	983	1039	1210
2034	989	1005	1046	1209
2035	780	783	805	1209
2036	1061	1068	1072	1209
2037	569	583	617	1209
2038	785	795	849	1208

Year	Scenarios			
	A2[5]	B2[3]	AIB-ECHAM5[3]	Trend
2039	1502	1525	1559	1208
2040	1058	1053	1047	1208
2041	1458	1358	1456	1207
2042	1254	1171	1324	1207
2043	1333	1221	1365	1207
2044	1185	1077	1163	1206
2045	1330	1193	1314	1206
2046	1352	1247	1319	1206
2047	1172	1084	1100	1206
2048	742	701	715	1205
2049	1099	1016	1054	1205
2050	803	747	774	1205
2051	813	755	837	1204
2052	1362	1281	1421	1204
2053	1554	1458	1512	1204
2054	1211	1124	1192	1204
2055	846	786	898	1203
2056	1120	1023	1057	1203
2057	891	838	920	1203
2058	1322	1169	1248	1202
2059	1119	1066	1057	1202
2060	842	766	844	1202
2061	779	724	784	1202
2062	697	634	715	1201
2063	1118	1018	1135	1201
2064	1118	1054	1132	1201
2065	862	804	847	1200
2066	1232	1102	1159	1200
2067	655	618	681	1200
2068	889	820	876	1200
2069	1659	1558	1669	1199
2070	1216	1124	1127	1199
2071	795	688	1533	1199
2072	739	634	1410	1198
2073	785	623	1534	1198
2074	633	529	1230	1198
2075	746	611	1431	1198

Year	Scenarios			
	A2[5]	B2[3]	AIB-ECHAM5[3]	Trend
2076	750	619	1411	1197
2077	655	534	1219	1197
2078	412	331	774	1197
2079	596	497	1141	1196
2080	444	367	840	1196
2081	459	384	905	1196
2082	764	650	1506	1196
2083	834	693	1605	1195
2084	660	560	1283	1195
2085	524	441	988	1195
2086	596	502	1125	1194
2087	534	452	974	1194
2088	691	578	1342	1194
2089	598	493	1150	1194
2090	469	387	912	1193
2091	460	367	892	1193
2092	412	329	804	1193
2093	646	542	1212	1192
2094	615	529	1194	1192
2095	498	413	920	1192
2096	641	535	1222	1192
2097	368	318	711	1191
2098	511	419	958	1191
2099	893	753	1762	1191
2100	621	519	1199	1190

San Adolfo Station – Series: 21030060

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
1971	2434	2434	2434	2434
1972	2918	2918	2918	2918
1973	2239	2239	2239	2239
1974	2219	2219	2219	2219
1975	1940	1940	1940	1940
1976	2354	2354	2354	2354
1977	2417	2417	2417	2417
1978	2745	2745	2745	2745
1979	1981	1981	1981	1981
1980	1796	1796	1796	1796
1981	2051	2051	2051	2051
1982	1440	1440	1440	1440
1983	1379	1379	1379	1379
1984	1236	1236	1236	1236
1985	1386	1386	1386	1386
1986	2029	2029	2029	2029
1987	1773	1773	1773	1773
1988	1699	1699	1699	1699
1989	2500	2500	2500	2500
1990	2087	2087	2087	2087
1991	2341	2341	2341	2341
1992	2227	2227	2227	2227
1993	2623	2623	2623	2623
1994	2618	2618	2618	2618
1995	1746	1746	1746	1746
1996	2220	2220	2220	2220
1997	2068	2068	2068	2068
1998	2136	2136	2136	2136
1999	2359	2359	2359	2359
2000	2112	2112	2112	2112
2001	2064	2064	2064	2064
2002	2080	2080	2080	2080
2003	1556	1556	1556	1556
2004	2013	2013	2013	2013
2005	2231	2231	2231	2231
2006	1928	1928	1928	1928

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2007	2205	2205	2205	2205
2008	1931	1931	1931	1931
2009	2229	2229	2229	2229
2010	2109	2109	2109	2109
2011	2034	1951	2124	2101
2012	2260	2227	2516	2101
2013	1936	1806	2020	2101
2014	1758	1714	1960	2101
2015	1653	1559	1723	2101
2016	1949	1858	2061	2101
2017	1984	1895	2105	2101
2018	2305	2192	2415	2101
2019	1399	1417	1643	2100
2020	1426	1399	1554	2100
2021	1736	1660	1801	2100
2022	1197	1146	1257	2100
2023	1138	1091	1194	2100
2024	977	952	1107	2100
2025	1220	1140	1248	2100
2026	1772	1664	1828	2100
2027	1415	1387	1528	2100
2028	1351	1317	1491	2100
2029	1942	1912	2171	2099
2030	1725	1649	1841	2099
2031	1955	1853	2092	2099
2032	1775	1737	1904	2099
2033	2032	1988	2292	2099
2034	2134	2053	2276	2099
2035	1343	1330	1472	2099
2036	1944	1825	1957	2099
2037	1675	1602	1783	2099
2038	1719	1664	1896	2099
2039	1835	1820	1997	2098
2040	1753	1663	1812	2098
2041	2314	2153	2362	2098
2042	2631	2443	2792	2098
2043	2293	2091	2249	2098

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2044	2091	1906	2182	2098
2045	1885	1746	1835	2098
2046	2268	2082	2265	2098
2047	2340	2140	2332	2098
2048	2621	2428	2627	2098
2049	1642	1556	1828	2097
2050	1679	1559	1743	2097
2051	1952	1812	1962	2097
2052	1417	1315	1425	2097
2053	1323	1206	1296	2097
2054	1149	1038	1249	2097
2055	1432	1295	1373	2097
2056	2001	1859	2000	2097
2057	1677	1539	1700	2097
2058	1554	1435	1643	2097
2059	2253	2093	2400	2096
2060	1972	1833	2038	2096
2061	2334	2122	2311	2096
2062	2061	1914	2115	2096
2063	2414	2218	2527	2096
2064	2416	2250	2507	2096
2065	1522	1432	1634	2096
2066	2214	2042	2153	2096
2067	1957	1806	1951	2096
2068	2016	1853	2071	2095
2069	2114	1973	2257	2095
2070	2051	1866	2012	2095
2071	1428	1141	2615	2095
2072	1734	1403	3128	2095
2073	1454	1159	2569	2095
2074	1367	1088	2463	2095
2075	1156	915	2092	2095
2076	1445	1140	2566	2095
2077	1512	1203	2648	2095
2078	1656	1303	2982	2094
2079	1110	903	2023	2094
2080	1122	893	1959	2094

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2081	1195	960	2192	2094
2082	872	708	1562	2094
2083	791	619	1447	2094
2084	750	596	1401	2094
2085	885	705	1561	2094
2086	1247	985	2276	2094
2087	1071	839	1893	2094
2088	1014	816	1853	2093
2089	1474	1194	2687	2093
2090	1237	993	2282	2093
2091	1513	1194	2658	2093
2092	1311	1045	2341	2093
2093	1599	1280	2860	2093
2094	1521	1228	2801	2093
2095	985	795	1800	2093
2096	1334	1048	2415	2093
2097	1200	961	2186	2093
2098	1316	1045	2362	2092
2099	1350	1090	2454	2092
2100	1238	1011	2218	2092

Acevedo Station – Series: 21030080

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
1971	1653	1653	1653	1653
1972	1607	1607	1607	1607
1973	1159	1159	1159	1159
1974	1864	1864	1864	1864
1975	1362	1362	1362	1362
1976	1915	1915	1915	1915
1977	2095	2095	2095	2095
1978	1757	1757	1757	1757
1979	1316	1316	1316	1316
1980	2253	2253	2253	2253
1981	1273	1273	1273	1273
1982	2269	2269	2269	2269
1983	1745	1745	1745	1745
1984	1930	1930	1930	1930
1985	1174	1174	1174	1174
1986	1549	1549	1549	1549
1987	1269	1269	1269	1269
1988	1804	1804	1804	1804
1989	1622	1622	1622	1622
1990	1407	1407	1407	1407
1991	837	837	837	837
1992	884	884	884	884
1993	1340	1340	1340	1340
1994	1687	1687	1687	1687
1995	1331	1331	1331	1331
1996	1502	1502	1502	1502
1997	1636	1636	1636	1636
1998	1237	1237	1237	1237
1999	1798	1798	1798	1798
2000	2158	2158	2158	2158
2001	1736	1736	1736	1736
2002	1600	1600	1600	1600
2003	1514	1514	1514	1514
2004	1974	1974	1974	1974
2005	2466	2466	2466	2466
2006	1570	1570	1570	1570

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2007	1766	1766	1766	1766
2008	1621	1621	1621	1621
2009	1488	1488	1488	1488
2010	1648	1648	1648	1648
2011	1355	1310	1428	1579
2012	1208	1205	1384	1578
2013	953	909	1012	1578
2014	1400	1397	1579	1578
2015	1075	1060	1227	1578
2016	1471	1436	1709	1577
2017	1738	1681	1696	1577
2018	1603	1500	1535	1577
2019	1063	1030	1099	1577
2020	1862	1797	1926	1577
2021	1049	1007	1125	1576
2022	2075	1919	2024	1576
2023	1484	1406	1494	1576
2024	1529	1489	1709	1576
2025	965	927	1029	1575
2026	1284	1239	1351	1575
2027	1028	986	1106	1575
2028	1392	1372	1578	1575
2029	1336	1277	1413	1575
2030	1123	1084	1252	1574
2031	696	665	749	1574
2032	677	666	759	1574
2033	1103	1064	1142	1574
2034	1368	1312	1477	1573
2035	1108	1068	1131	1573
2036	1246	1208	1319	1573
2037	1324	1278	1398	1573
2038	957	940	1094	1572
2039	1427	1412	1538	1572
2040	1833	1725	1881	1572
2041	1562	1447	1603	1572
2042	1421	1317	1524	1572
2043	1140	1049	1132	1571

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2044	1646	1531	1760	1571
2045	1220	1133	1308	1571
2046	1740	1589	1915	1571
2047	1863	1778	1834	1570
2048	1764	1639	1725	1570
2049	1191	1125	1195	1570
2050	2104	1969	2120	1570
2051	1190	1104	1256	1570
2052	2375	2179	2212	1569
2053	1663	1558	1609	1569
2054	1821	1670	1908	1569
2055	1142	1049	1120	1569
2056	1457	1344	1504	1568
2057	1197	1096	1233	1568
2058	1608	1478	1741	1568
2059	1555	1435	1532	1568
2060	1288	1191	1378	1567
2061	818	754	823	1567
2062	803	742	835	1567
2063	1272	1162	1249	1567
2064	1588	1468	1618	1567
2065	1208	1151	1237	1566
2066	1412	1304	1458	1566
2067	1520	1420	1537	1566
2068	1131	1039	1192	1566
2069	1603	1481	1734	1565
2070	2113	1944	2066	1565
2071	981	793	1770	1565
2072	960	773	1717	1565
2073	741	585	1286	1565
2074	1108	876	1971	1564
2075	794	635	1491	1564
2076	1175	938	2179	1564
2077	1091	880	1971	1564
2078	1038	852	1881	1563
2079	733	596	1314	1563
2080	1330	1056	2360	1563

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2081	733	590	1391	1563
2082	1387	1105	2479	1562
2083	1009	804	1807	1562
2084	1206	963	2157	1562
2085	719	565	1266	1562
2086	902	739	1663	1562
2087	751	590	1378	1561
2088	1042	844	1952	1561
2089	961	774	1727	1561
2090	837	654	1565	1561
2091	534	416	943	1560
2092	517	413	934	1560
2093	774	628	1375	1560
2094	996	805	1817	1560
2095	735	595	1356	1560
2096	883	703	1619	1559
2097	929	754	1693	1559
2098	757	593	1365	1559
2099	999	809	1876	1559
2100	1249	1007	2297	1558

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Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
1971	1171	1171	1171	1171
1972	920	920	920	920
1973	852	852	852	852
1974	913	913	913	913
1975	887	887	887	887
1976	1049	1049	1049	1049
1977	812	812	812	812
1978	883	883	883	883
1979	1049	1049	1049	1049
1980	986	986	986	986
1981	904	904	904	904
1982	1306	1306	1306	1306
1983	943	943	943	943
1984	1371	1371	1371	1371
1985	910	910	910	910
1986	986	986	986	986
1987	971	971	971	971
1988	792	792	792	792
1989	1178	1178	1178	1178
1990	1106	1106	1106	1106
1991	896	896	896	896
1992	650	650	650	650
1993	1221	1221	1221	1221
1994	1087	1087	1087	1087
1995	957	957	957	957
1996	951	951	951	951
1997	715	715	715	715
1998	972	972	972	972
1999	1569	1569	1569	1569
2000	1068	1068	1068	1068
2001	806	806	806	806
2002	813	813	813	813
2003	777	777	777	777
2004	1124	1124	1124	1124
2005	960	960	960	960
2006	1410	1410	1410	1410

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2007	1058	1058	1058	1058
2008	1238	1238	1238	1238
2009	1037	1037	1037	1037
2010	834	834	834	834
2011	916	968	783	1004
2012	678	735	623	1004
2013	736	705	619	1004
2014	744	794	660	1004
2015	702	757	639	1004
2016	823	871	704	1004
2017	676	696	547	1004
2018	671	716	558	1005
2019	817	839	755	1005
2020	734	801	653	1005
2021	709	735	594	1005
2022	1074	1117	901	1005
2023	725	770	587	1005
2024	1103	1122	936	1005
2025	684	720	582	1005
2026	822	856	646	1005
2027	673	723	592	1006
2028	610	657	516	1006
2029	942	980	831	1006
2030	870	925	775	1006
2031	663	703	650	1006
2032	515	518	503	1006
2033	927	991	843	1006
2034	858	920	715	1006
2035	691	756	613	1006
2036	793	833	654	1007
2037	543	580	459	1007
2038	737	792	658	1007
2039	1362	1370	1142	1007
2040	857	888	694	1007
2041	1011	978	848	1007
2042	750	723	674	1007
2043	850	821	646	1007

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2044	820	782	723	1007
2045	819	745	701	1008
2046	973	899	777	1008
2047	728	702	562	1008
2048	752	707	605	1008
2049	865	850	768	1008
2050	848	813	720	1008
2051	776	721	643	1008
2052	1165	1116	992	1008
2053	789	749	658	1008
2054	1200	1142	1008	1009
2055	792	770	631	1009
2056	938	850	719	1009
2057	761	744	649	1009
2058	678	626	579	1009
2059	1098	1041	888	1009
2060	993	922	845	1009
2061	779	768	677	1009
2062	569	549	533	1009
2063	1054	1008	904	1010
2064	953	922	747	1010
2065	788	746	676	1010
2066	934	857	731	1010
2067	603	587	520	1010
2068	836	786	707	1010
2069	1505	1390	1256	1010
2070	978	927	743	1010
2071	338	280	909	1010
2072	268	223	736	1011
2073	293	202	787	1011
2074	277	231	776	1011
2075	291	229	781	1011
2076	326	249	831	1011
2077	250	191	627	1011
2078	248	182	649	1011
2079	363	299	899	1011
2080	277	216	771	1012

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2081	270	221	689	1012
2082	367	302	1053	1012
2083	247	185	671	1012
2084	430	349	1121	1012
2085	274	203	691	1012
2086	289	229	741	1012
2087	285	221	708	1012
2088	248	196	621	1012
2089	365	268	1021	1013
2090	342	265	932	1013
2091	299	219	819	1013
2092	240	196	638	1013
2093	395	324	1001	1013
2094	295	226	809	1013
2095	292	223	729	1013
2096	291	225	769	1013
2097	183	151	547	1013
2098	321	254	780	1014
2099	481	382	1378	1014
2100	294	224	805	1014

San Antonio del Pescador – Code: 21030110

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
1971	2570	2570	2570	2570
1972	2027	2027	2027	2027
1973	2003	2003	2003	2003
1974	2114	2114	2114	2114
1975	2252	2252	2252	2252
1976	1940	1940	1940	1940
1977	1461	1461	1461	1461
1978	1700	1700	1700	1700
1979	1730	1730	1730	1730
1980	1334	1334	1334	1334
1981	977	977	977	977
1982	1473	1473	1473	1473
1983	1503	1503	1503	1503
1984	1788	1788	1788	1788
1985	1277	1277	1277	1277
1986	1655	1655	1655	1655
1987	1426	1426	1426	1426
1988	1615	1615	1615	1615
1989	1828	1828	1828	1828
1990	1484	1484	1484	1484
1991	1442	1442	1442	1442
1992	805	805	805	805
1993	1915	1915	1915	1915
1994	1463	1463	1463	1463
1995	1595	1595	1595	1595
1996	2966	2966	2966	2966
1997	1001	1001	1001	1001
1998	1469	1469	1469	1469
1999	1925	1925	1925	1925
2000	1473	1473	1473	1473
2001	1182	1182	1182	1182
2002	1525	1525	1525	1525
2003	1009	1009	1009	1009
2004	1359	1359	1359	1359
2005	1638	1638	1638	1638
2006	1832	1832	1832	1832

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2007	1424	1424	1424	1424
2008	1919	1919	1919	1919
2009	1718	1718	1718	1718
2010	1523	1523	1523	1523
2011	1917	2052	1656	1668
2012	1594	1651	1355	1668
2013	1665	1691	1333	1667
2014	1798	1847	1458	1667
2015	1602	1783	1388	1666
2016	1700	1756	1352	1666
2017	1237	1261	999	1665
2018	1391	1406	1099	1665
2019	1479	1465	1176	1664
2020	1111	1138	899	1664
2021	743	800	645	1663
2022	1169	1217	980	1663
2023	1174	1229	973	1662
2024	1405	1500	1170	1662
2025	1028	1033	858	1661
2026	1465	1503	1152	1661
2027	1021	1090	897	1661
2028	1205	1315	1077	1660
2029	1550	1595	1241	1660
2030	1160	1206	1027	1659
2031	1201	1231	1004	1659
2032	651	663	571	1658
2033	1591	1590	1352	1658
2034	1182	1256	952	1657
2035	1155	1276	1028	1657
2036	2327	2511	1907	1656
2037	726	785	604	1656
2038	1111	1171	958	1655
2039	1609	1652	1331	1655
2040	1116	1201	940	1654
2041	2163	2072	1844	1654
2042	1782	1738	1460	1653
2043	1952	1895	1414	1653

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2044	1984	1875	1543	1652
2045	1916	1794	1509	1652
2046	1855	1717	1446	1651
2047	1356	1299	1050	1651
2048	1575	1526	1160	1650
2049	1744	1709	1235	1650
2050	1315	1249	980	1649
2051	837	798	696	1649
2052	1292	1272	1077	1648
2053	1294	1238	1074	1648
2054	1555	1460	1266	1647
2055	1259	1242	921	1647
2056	1601	1464	1254	1646
2057	1203	1160	974	1646
2058	1423	1278	1211	1645
2059	1763	1672	1299	1645
2060	1390	1330	1100	1644
2061	1338	1315	1020	1644
2062	773	740	631	1643
2063	1824	1742	1461	1643
2064	1291	1278	999	1642
2065	1313	1284	1054	1642
2066	2714	2540	2082	1641
2067	852	813	670	1641
2068	1278	1246	993	1641
2069	1810	1652	1486	1640
2070	1295	1219	1032	1640
2071	695	570	1934	1639
2072	597	459	1599	1639
2073	633	447	1622	1638
2074	637	490	1690	1638
2075	632	469	1657	1637
2076	572	446	1540	1637
2077	447	332	1176	1636
2078	501	350	1298	1636
2079	563	395	1402	1635
2080	416	295	1085	1635

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2081	282	214	769	1634
2082	403	314	1160	1634
2083	426	320	1154	1633
2084	538	423	1379	1633
2085	406	290	1043	1632
2086	511	397	1339	1632
2087	441	329	1086	1631
2088	516	400	1318	1631
2089	532	394	1431	1630
2090	503	371	1248	1630
2091	444	327	1186	1629
2092	261	202	703	1629
2093	657	508	1638	1628
2094	396	305	1095	1628
2095	464	352	1198	1627
2096	783	606	2166	1627
2097	254	188	714	1626
2098	456	337	1136	1626
2099	560	453	1581	1625
2100	401	309	1095	1625

Annex 5.2 Climate change scenarios at the Resina station for average Annual temperatures

Code: 21035020

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
1971	15.9	15.9	15.9	15.9
1972	15.9	15.9	15.9	15.9
1973	15.9	15.9	15.9	15.9
1974	15.9	15.9	15.9	15.9
1975	15.9	15.9	15.9	15.9
1976	15.4	15.4	15.4	15.4
1977	15.7	15.7	15.7	15.7
1978	15.6	15.6	15.6	15.6
1979	15.7	15.7	15.7	15.7
1980	16.0	16.0	16.0	16.0
1981	16.0	16.0	16.0	16.0
1982	15.9	15.9	15.9	15.9
1983	16.0	16.0	16.0	16.0
1984	15.8	15.8	15.8	15.8
1985	15.5	15.5	15.5	15.5
1986	15.7	15.7	15.7	15.7
1987	16.2	16.2	16.2	16.2
1988	15.7	15.7	15.7	15.7
1989	15.6	15.6	15.6	15.6
1990	15.9	15.9	15.9	15.9
1991	16.2	16.2	16.2	16.2
1992	16.1	16.1	16.1	16.1
1993	16.1	16.1	16.1	16.1
1994	16.1	16.1	16.1	16.1
1995	16.0	16.0	16.0	16.0
1996	15.8	15.8	15.8	15.8
1997	16.3	16.3	16.3	16.3
1998	16.1	16.1	16.1	16.1
1999	15.7	15.7	15.7	15.7
2000	15.5	15.5	15.5	15.5
2001	15.7	15.7	15.7	15.7
2002	15.7	15.7	15.7	15.7
2003	16.0	16.0	16.0	16.0

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2004	16.4	16.4	16.4	16.4
2005	15.9	15.9	15.9	15.9
2006	16.0	16.0	16.0	16.0
2007	16.1	16.1	16.1	16.1
2008	15.7	15.7	15.7	15.7
2009	16.2	16.2	16.2	16.2
2010	16.1	16.1	16.1	16.1
2011	18.2	18.3	16.6	15.9
2012	18.2	18.3	16.6	15.9
2013	18.2	18.3	16.6	15.9
2014	18.2	18.3	16.6	15.9
2015	18.2	18.3	16.6	15.9
2016	17.7	17.7	16.0	15.9
2017	18.0	18.1	16.4	15.9
2018	17.9	18.0	16.3	15.9
2019	18.0	18.1	16.4	15.9
2020	18.3	18.4	16.7	15.9
2021	18.3	18.4	16.7	15.9
2022	18.2	18.3	16.6	15.9
2023	18.3	18.4	16.7	15.9
2024	18.1	18.2	16.5	15.9
2025	17.8	17.9	16.2	15.9
2026	18.0	18.0	16.3	15.9
2027	18.6	18.6	16.9	15.9
2028	18.0	18.1	16.4	15.9
2029	17.9	18.0	16.3	15.9
2030	18.2	18.3	16.6	15.9
2031	18.5	18.6	16.9	15.9
2032	18.4	18.5	16.8	15.9
2033	18.4	18.5	16.8	15.9
2034	18.4	18.5	16.8	15.9
2035	18.4	18.4	16.7	15.9
2036	18.1	18.2	16.5	15.9
2037	18.6	18.7	17.0	15.9
2038	18.4	18.5	16.8	15.9
2039	18.0	18.1	16.4	15.9
2040	17.8	17.9	16.2	15.9

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2041	19.5	19.3	18.0	15.9
2042	19.5	19.3	18.0	15.9
2043	19.5	19.3	18.0	15.9
2044	19.5	19.3	18.0	15.9
2045	19.5	19.3	18.0	15.9
2046	19.0	18.8	17.5	15.9
2047	19.3	19.1	17.8	15.9
2048	19.2	19.0	17.7	15.9
2049	19.3	19.1	17.8	15.9
2050	19.7	19.5	18.1	15.9
2051	19.6	19.4	18.1	15.9
2052	19.5	19.3	18.0	15.9
2053	19.6	19.4	18.1	15.9
2054	19.4	19.2	17.9	15.9
2055	19.1	18.9	17.6	15.9
2056	19.3	19.1	17.8	15.9
2057	19.9	19.7	18.3	15.9
2058	19.4	19.2	17.8	15.9
2059	19.2	19.0	17.7	15.9
2060	19.6	19.4	18.0	15.9
2061	19.8	19.6	18.3	15.9
2062	19.8	19.5	18.2	15.9
2063	19.7	19.5	18.2	15.9
2064	19.7	19.5	18.2	15.9
2065	19.7	19.5	18.2	15.9
2066	19.5	19.2	17.9	15.9
2067	19.9	19.7	18.4	15.9
2068	19.8	19.6	18.2	15.9
2069	19.3	19.1	17.8	15.9
2070	19.1	18.9	17.6	15.9
2071	19.2	18.4	19.4	15.9
2072	19.2	18.4	19.4	15.9
2073	19.2	18.4	19.4	15.9
2074	19.2	18.4	19.4	15.9
2075	19.2	18.4	19.4	15.9
2076	18.7	17.8	18.8	15.9
2077	19.0	18.1	19.2	15.9

Year	Scenarios			
	A2	B2	AIB-ECHAM5	Trend
2078	18.9	18.0	19.0	15.9
2079	19.0	18.1	19.2	15.9
2080	19.3	18.5	19.5	15.9
2081	19.3	18.4	19.4	15.9
2082	19.2	18.4	19.4	15.9
2083	19.3	18.5	19.5	15.9
2084	19.1	18.3	19.3	15.9
2085	18.8	17.9	19.0	15.9
2086	18.9	18.1	19.1	15.9
2087	19.5	18.7	19.7	15.9
2088	19.0	18.2	19.2	15.9
2089	18.9	18.1	19.1	15.9
2090	19.2	18.4	19.4	15.9
2091	19.5	18.6	19.7	15.9
2092	19.4	18.6	19.6	15.9
2093	19.4	18.6	19.6	15.9
2094	19.4	18.5	19.6	15.9
2095	19.3	18.5	19.5	15.9
2096	19.1	18.3	19.3	15.9
2097	19.6	18.8	19.8	15.9
2098	19.4	18.6	19.6	15.9
2099	19.0	18.2	19.2	15.9
2100	18.8	17.9	19.0	15.9

Annex 6.1 Monthly Rainfall-Runoff Hydrological Model—Theoretical Description: SIHIM Model

1. Introduction

The quantification of the components and interrelationships in the hydrological cycle are complex and subject to temporal and spatial variation. One way of addressing this problem is to simplify it, using the systems concept. According to this methodology, components are grouped into subsystems that are analyzed separately and the results are then combinedbased on their interactions.

This type of representation is used in the development of the so-called rainfall-runoff models. These models use mathematical equations to represent each of the processes that make up the water cycle and define their interrelationship, allowing for the transformation of rainfall data in the surface runoff it produces. Watershed features—in terms of soil, geomorphology, vegetation, and current land use—are introduced into these models through the so-called parameters. The most important use of these model types is the estimation of surface runoff in hydraulic harvesting sites (reservoirs, direct derivations, etc.) that do not have any information recorded in the hydrometric measuring stations.

There is a great variety of rainfall-runoff simulation models in literature that can be used to estimate surface rainfall-runoff to the stations. One of those models that is widely used in Latin America is the SIHIM model (Monthly Hydrological Simulation Model) developed at the American Center for Land and Water Development (CIDIAT). Following are the bibliographic references supporting this model:

- Duque R. 1985. "*Desarrollo de un modelo de simulación hidrológica a escala mensual*". Report to advance to associate professor. The American Center for Land and Water Development (CIDIAT) Mérida. Venezuela.
- Duque R. and A. Barrios. 1988. "*Modelo de simulación hidrológica a nivel mensual*". The American Center for Land and Water Development (CIDIAT) Mérida. Venezuela.

However, one problem with this model is that the source program is in FORTRAN, which only works in the MSDOS environment. For this reason, this document sets out a new version of the model, changing some methodological issues and creating an interface that allows using the model from an Excel book. The new version is given the name of SIHIME, since the theoretical development follows, for the most part, the one described by Duque (1985); the most important thing is the creation of the interface, through the Excel program (which adds the letter E to the original name), which makes it more user friendly.

2. Hydrological cycle: Theoretical description

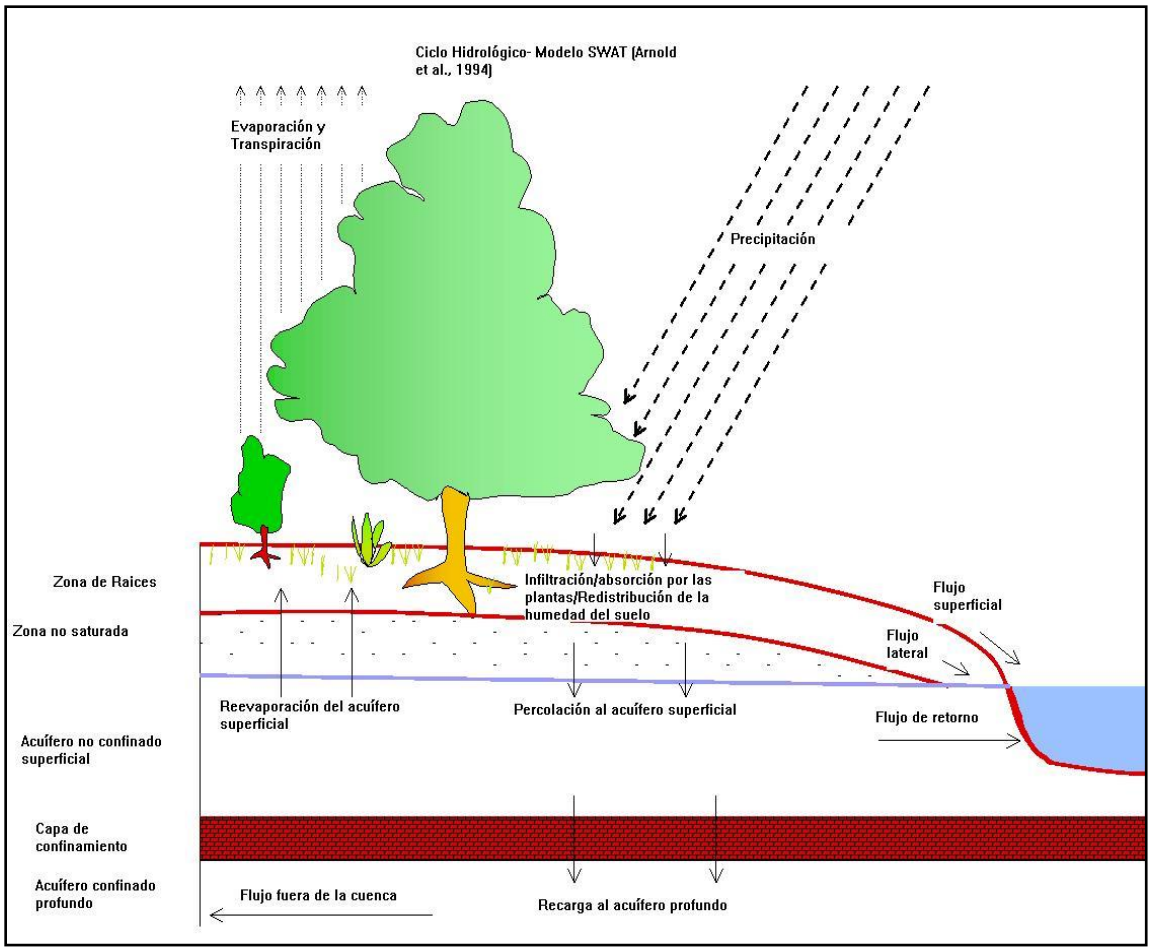
This section is based on the information described in the Cordova and Rodriguez-Iturbe (2013) reference.

During this cycle, water can change from gaseous (water vapor), to liquid and solid (ice). Water evaporates from the oceans and land surface, rising into the atmosphere and then falling as rain and/or snow and/or hail, and up to the surface of the earth where part of the precipitation is intercepted by the foliage of plants; another part infiltrates the soil surface and the remainder runs until reaching a watercourse. Part of the infiltrated water is stored in the soil and feeds the evapotranspiration process, while the excess flows out under the surface and/or feeds the water zone where groundwater is stored. Both the surface and subsurface runoff and groundwater feed the watershed drainage network, which eventually discharges its water into the ocean. The cycle has no beginning or end, processes occur simultaneously and continuously, while the total volume of water in the cycle is finite.

Components integrating the hydrological cycle are illustrated in Figure 2.1 (taken from Neitsch S., et al. (2009)), while the description of each is included below:

- **Precipitation**: The process by which water in its liquid and/or solid state reaches the earth's surface from the troposphere, as rain, drizzle, snow, sleet and/or hail. Precipitation is the driving force behind the earth´s water cycle, and its stochastic nature provides most of the randomness that characterizes this cycle.
- **Evaporation**: A physical process, involving the change of water from a liquid state to a gaseous state, from different types of surfaces, such as lakes, rivers, wetlands, impervious areas, soil, and plant foliage. Evaporation occurs at any temperature, but its rate increases as the temperature becomes warmer.
- **Transpiration**: The process that involves the vaporization of the water contained in a plant´s tissue, which then rises into the atmosphere. Plant water loss due to transpiration occurs through the stomata, which are small openings located on the underside of the leaves (between two cells called guardians) and allow the CO_2 and oxygen required by plants for photosynthesis and respiration to enter the plant.

Figure 2.1 Components of the Hydrological Cycle



Source: Neitsch S. et al. (2009)

- **Evapotranspiration**: The transpiration and evaporation processes occur simultaneously, which makes it difficult to separate them; for this reason, they have been combined into the evapotranspiration process. The potential evapotranspiration rates depend on the supply of the energy required by the process, through solar radiation, temperature of the environment, relative humidity, and wind velocity. The wind removes the air saturated by water vapor, creating a moisture gradient between the evaporating surface and the surrounding air. The rate also depends on the type of vegetation and represents the maximum rate at which a plant can evapotranspire, given the weather conditions. The actual evapotranspiration has to be considered, which is the real component of the hydrological cycle as it represents the actual rate at which water loss occurs through the foliage. It is dependent upon the potential rate and the availability of water in the soil. When sufficient water is stored in the soil, plants evotranspire at a potential rate, whereas when water storage in soil is reduced, the evapotranspiration rate is generally lower than the potential rate.
- **Interception:** The process by which precipitation is retained in the foliage of plants. The water intercepted by the leaves evaporates directly into the atmosphere, without reaching the ground surface. The water intercepted is a function of plant biomass. Forests intercept greater amounts

of water than grass.

- **Infiltration:** The process by which water penetrates the soil. Capacity or infiltration rate of a particular soil type corresponds to the speed at which water penetrates the soil and depends on many factors such as texture, soil structure, and the amount of water stored in the soil. Some soils have contrasting texture horizons, such as a compact clay layer that limits the rate of infiltration. In general, this rate decreases with time as the soil´s porous spaces are filled with water. It has a constant value, which is characteristic of each type of soil. This is known as the basic infiltration rate.
- **Surface flow:** Part of the rainfall that is not intercepted by the foliage of plants, which falls on the ground. Part of this water is infiltrated and the rest is stored in the surface and/or moves as a surface flow or surface runoff.
- **Streamflow**: Surface flow eventually reaches a stream, which is part of the basin drainage network, becoming surface runoff, which will add to the flow of water that transports water furrows, streams, and rivers into the ocean (or lakes if the basin is endorheic).
- **Subsurface flow**: Part of the infiltrated water is stored in the ground, adhered to the mineral particles in this porous medium by adhesive and cohesive forces. When the soil reaches a saturation level where the adhesive and cohesive forces of external molecules located on the film of water and adhered to the mineral particles are less than the force of gravity, a percolation process occurs. During this process, excess water drains and returns to the aquifer zone. Water movement in the unsaturated zone of the soil is known as subsurface flow. Sometimes this type of flow, together with the flow of groundwater, can rise to the surface of the ground through springs.
- **Groundwater recharge**: Groundwater is water stored in the ground, forming what is known as an aquifer, which is an area where the porous medium is completely saturated. That area has a set thickness, with a higher level that is known as a water table. This level is the boundary between the unsaturated and saturated zones of the soil profile. The percolation process that drains gravitational water from the unsaturated zone reloads the groundwater stored in the aquifer zone.
- **Groundwater flow**: The water table connects hydraulically to the water level that carries the drainage network. This connection allows groundwater to flow between the channels as a base stream. This flow represents the contribution of groundwater to the flow observed in the drainage network, which allows many streams to not dry up during the summer when rainfall reaches its minimum values. When a watercourse dries up, the water table may not exist (there is no water zone) or might be located below the minimum level of the water channel.
- **Runoff into rivers and oceans**: The sum of surface runoff, subsurface flow, and groundwater flow (baseflow) is the runoff observed in the course of rivers; if the basin is exorheic (like most basins), it is discharged into the ocean.

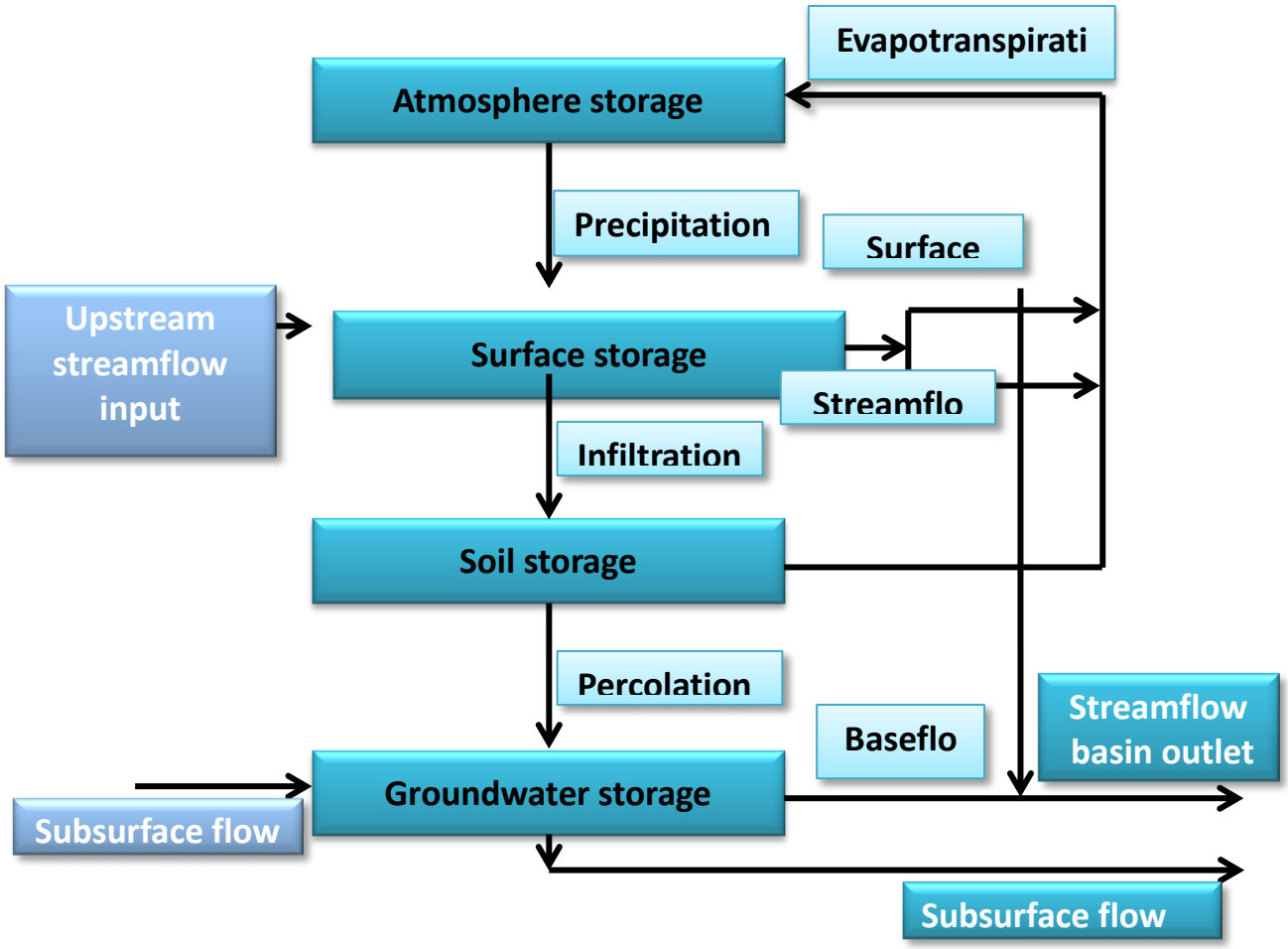
3. Theoretical description of the rainfall-runoff hydrological model

Figure 3.1 shows a schematic model of the SIHIM components (Duque 1985), which uses monthly rainfall and evapotranspiration totals as basic data, representing each of the sub-basins. To calibrate this

model, it requires that monthly average flows for the calibration period be concomitant with rainfall and evapotranspiration periods. The model considers the rainfall, evapotranspiration, infiltration, percolation, and baseflow from underground storage. Additionally, it considers surface storage and surface and groundwater flows coming from upper watersheds and flows that leave the sub-basins, towards underlying sub-basins downstream of the latter. To carry out the calibration and application of this model, the following activities should be executed:

- Using map data and/or digital elevation models, delineate both the basin as well as the main sub-basins that comprise it.
- Based on available information and the importance of hydrometric or gauging stations (representative), select those stations that will be used in the model calibration process.
- Once hydrometric stations have been selected, analyze the series of monthly mean flows for each, in order to choose a reporting period that is concomitant with climatic information representative of the sub-basins that make up the total basin.
- Subsequently, analyze the characteristics of the sub-basins, including vegetation, land use, and soil types, and calculate their morphometric characteristics.
- With all this information, the values for model inputs based on the above data will be selected and proceed to calibrate the same, changing the initial parameter values until achieving a better match between the series of historical flows and the series of simulated flows during the selected calibration period.
- Subsequently, the model will be applied throughout the entire basin and for the entire period with adequate climate information.

Figure 3.1 Components of the SIHIME Model



The following is a description of the equations used to represent each component of the hydrological cycle considered in the rainfall-runoff model.

a. Temporary and spatial variation of rainfall

Rainfall is the process that moves the terrestrial phase of the water cycle. Its stochastic nature feeds most of the randomness that characterizes this cycle. This process varies in time and space; therefore, in order to apply the model, the areal average precipitation should be estimated for each sub-basin for each month and year of the model´s implementation period.

The equation used is the following:

$$P_{i,j}(n\ P_{i,j}(n) = FCP(n) \cdot \left(\sum_{k=1}^{NEP} PM_{i,j,k} \cdot FP_k(n) \right)$$

$PM_{i,j,k}$ Rainfall observed in rain gauge *k*, month *j*, year *i*.

FP_k (n) Fraction of sub-basin *n*, represented by rain gauge *k*.

NEP Number of rain stations.

FCP(n) Areal mean rainfall adjustment factor at sub-basin *n*.

Weighting factors FP_k (n) for each sub-basin can be determined using areal average estimation methods, for example, through maps of isohyets processed with geographical information systems.

The adjustment factor for areal average precipitation in each sub-basin, FCP (n), initially equal to the unit, can be later used as a calibration parameter.

b. Estimation of potential evapotranspiration

Potential evapotranspiration rates depend on the supply of the energy required by the process, through solar radiation, ambient temperature, relative humidity and wind speed which replaces saturated air of the water vapor for dry air, creating a moisture gradient between the evaporating surface and the surrounding air. Additionally, this rate also depends on the type of vegetation, and represents the maximum rate at which a plant can evapotranspire, given existing climatic conditions.

The following is a description of the methodology recommended by FAO (1998) to estimate the potential evapotranspiration rate of a reference crop (ETo). These values so obtained are later multiplied by a Kc factor, which depends on the type of vegetation to determine potential evapotranspiration associated to the different types of vegetation (typical values of this factor are described in the FAO reference, 1998).

c. Method to estimate evapotranspiration

The Penman-Monteith method, recommended by the FAO (1998), is the standard method using weather information for estimating the potential evapotranspiration of a reference crop (ETo), equivalent to grass with 12-inches height, an albedo of 0.23, and a surface resistance of 70 m s-1.

The Penman-Monteith equation is as follows, and represents a modification of the original Penman equation:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

In this equation ETo is expressed in mm per day –1.

Where:

$R_{n:}$ Net Radiation (MJ m^{-2} $día^{-1}$)

G Heat flow towards the ground (MJ m^{-2} $día^{-1}$)

γ Psychrometric Constant (kPa °C^{-1}).

This constant is estimated in accordance with the equation:

$$\gamma = \frac{C_p P}{\varepsilon \lambda_v} = 0.000665P$$

P atmospheric pressure [kPa]

λ_v vaporization latent heat, 2.45 [MJ kg^{-1}]

C_p water specific heat, 1.013 10^{-3} [MJ kg^{-1} °C^{-1}]

ε ratio between water vapor molecular weight / dry air = 0.622.

T Mean temperature (°C)

$$T = \frac{T_{Máx} + T_{Mín}}{2}$$

e_s Saturation vapor pressure at a T [kPa] temperature

Estimated according to equation:

$$e_s = 0.6108 \exp\left(\frac{17.27T}{T + 237.3}\right)$$

Given that the equation is not linear, the best saturation vapor pressure estimator is the one obtained from averaging results of daily maximum and minimum temperature, according to the following equation:

$$e_s = \frac{e_s(T_{máx}) + e_s(T_{mín})}{2}$$

Δ Slope of the saturation vapor pressure curve (kPa °C^{-1})

$$\Delta = 4098\left[\frac{0.6108 \exp\left(\frac{17.27T}{T + 237.3}\right)}{(T + 237.3)^2}\right]$$

e_a Actual vapor pressure (kPa)

$$e_a = \frac{\frac{e_s(T_{mín})RH_{máx}}{100} + \frac{e_s(T_{máx})RH_{mín}}{100}}{2}$$

e_s (T_{min}) Saturation vapor pressure at the minimum daily temperature [kPa]

e_s (T_{max}) Saturation vapor pressure at the maximum daily temperature [kPa]

RH_{max} Maximum daily relative humidity [%]

RH_{min} Minimum daily relative humidity [%]

In the case that the RH_{max} and RH_{min} figures are available, the equation recommended is the one based on the mean relative humidity:

$$e_a = \frac{RH_{media}}{100}\left[\frac{e_s(T_{máx}) + e_s(T_{mín})}{2}\right]$$

RH_{med} Daily mean relative humidity [%]

u_2 wind speed at 2 meters height [m s^{-1}]

To calculate ETo, it is recommended to use the CROPWAT program (developed by the FAO (1998) which estimates the evapotranspiration rate in mm/month.

If no climate data is available for the application of the Penman-Monteith equation for the tropics, it is recommended to use the equation developed by Lopez (1968), using data from solar evaporation basins observed in type A evaporimetric tubs.

d. Estimation of the aerial average potential evapotranspiration rate at each sub-basin, using the hydrological model

Following is the equation to estimate the potential average areal evapotranspiration rate of the reference crop, in each sub-basin:

$$ETo_{i,j}(n) = FCE(n) \cdot \left(\sum_{m=1}^{NEE} EToM_{i,j,m} \cdot FE_m(n) \right)$$

Where:

$ETo_{i,j}$ (n) Potential Evapotranspiration of the reference crop (ETo), mean areal, Mmonth j, year i, sub-basin n.

$EToM_{i,j,m}$ Potential Evapotranspiration, ETo, estimated in each station m, month j, year i.

FE_m (n) Fraction of sub-basin n, represented by station m.

NEE Number of station with ETo estimates.

FCE (n) Areal mean evapotranspiration adjustment factor at sub-basin n.

The weighting factors FEm (n), for each sub-basin, can be determined using areal average estimation methods, for example, through ETo isoline maps, processed with geographic information systems. The adjustment factor of the Et_o areal average in each sub-basin, FCE (n), can be initially equaled to the unit, and then used as a calibration parameter.

4. Estimation of actual evapotranspiration

The actual evapotranspiration is the real component of the hydrological cycle, as it represents the actual rate at which water loss occurs through the foliage and soil. It is a function of the potential rate and the availability of water in the soil. When sufficient water is stored in the soil, the plants

evapotranspire at a potential rate, whereas with reduced water storage in soil, evapotranspiration rates are lower than the potential.

The equation used to estimate the areal mean actual evapotranspiration rate is the following:

$$ETR_{i,j}(n) = \begin{cases} ETP_{i,j}(\mathrm{n}) \ \ldots\ldots\ldots\ldots\ldots\ldots \ Si\ HSM_{i,j}(n) > TS(n) \\ ETP_{i,j}(n).\dfrac{HSM_{i,j}(n)}{TS(n)} \ldots. Si\ HSM_{i,j}(n) \leq TS(n) \end{cases}$$

$$ETP_{i,j}(n) = ETo_{i,j}(\mathrm{n}).\mathrm{Kc}(\mathrm{n})$$

$$TS(n) = FHS \cdot HSN(n)$$

$ETP_{i,j}$ (n)	Potential Evapotranspiration, month j, year i, sub-basin n.
$ETo_{i,j}$ (n)	Potential Evapotranspiration, of the reference crop (ETo), month j, year i, sub-basin n.
Kc (n)	Coefficient in terms of the type of vegetation.
$HSM_{i,j}$ (n)	Average humidity stored in the ground in month j, year i, sub-basin n.
FHS (n)	Factor that allows estimating the threshold of humidity in the ground.
TS (n)	Threshold of humidity in the ground from which $ETR_{i,j}$ (n) = $ETP_{i,j}$ (n).
HSN (n)	Ground humidity storage capacity in sub-basin n.

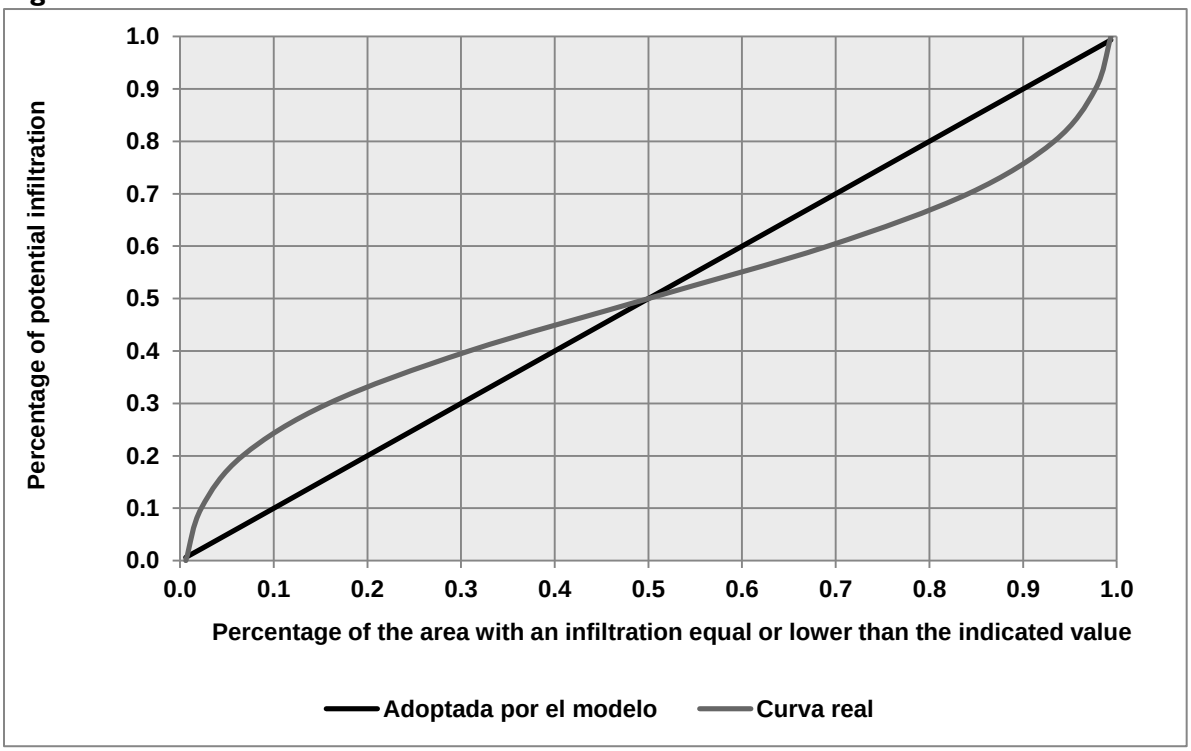
In the original SIHIM model, FSH is equal to 0.25 (Duque, 1985).

5. Infiltration

Infiltration is the process by which water penetrates the soil. Capacity or infiltration rate of a particular soil type corresponds to the speed at which water penetrates the soil, and depends on many factors such as texture, soil structure and the amount of water stored in the soil. Some soils have contrasting texture horizons, such as a compact clay layer that limits the rate of infiltration. In general, this rate decreases with time as the soil´s porous spaces are filled with water, and has a constant value, characteristic of each type of soil, which is known as the basic infiltration rate.

The model considers this rate as the potential infiltration rate that occurs when there is no water supply limitation. A water supply above this rate will generate surface storage and/or surface runoff. Figure 3.2 shows how the areal percentage of the sub-basin varies with an infiltration value equal to or below the indicated value representing a potential infiltration rate that characterizes the sub-basin. This figure shows two curves, one example of what could be the actual behavior of this relationship and the curve adopted by the model. This representation of infiltration is an adaptation by Duque (1985) of the methodology that uses the "Stanford Watershed Model IV" model described in Crawford et al. (1966).

Figure 3.2 Distribution of the Potential Infiltration Rate in a Sub-Basin



Source: Duque (1985)

Potential infiltration for 100 percent of the watershed area is defined as $INFP_{i,j}$ (n), and is a function of the infiltration capacity of the type of soil that characterizes the sub-basin, storage capacity of the soil , HSN (n), and the average moisture content in the soil, in the month j year i, HSMI, j (n) according to the following relationship:

$$INFP_{i,j}(n) = CINF(n) \cdot \left(\frac{HSN(n)}{HSM_{i,j}(n)} \right)^2$$

vvhere:

$INFP_{i,j}$ (n) Potential infiltration, month j, year i, sub-basin n.

CINF(n) Infiltration capacity, sub-basin n.

$HSM_{i,j}$ (n) Soil stored average humidity, month j, year i, sub-basin n.

HSN (n) Ground humidity storage capacity, sub-basin n.

Actual infiltration that occurs in the sub-basin, INFRi, j (n) depends on the potential infiltration, INFPi,j (n), and the availability of water to infiltrate, HDIi,j (n) which is equal to areal average rainfall Pi,j (n) plus surface water storage at the beginning of month j, ASUP i,j (n). The infiltrated sheet is calculated as the area that is located below HDIi,j (n) in Figure 3.3.

$$HDI_{i,j}(n) = P_{i,j}(n) + ASUP_{i,j-1}(n)$$

$$INFR_{i,j}(n) = \begin{cases} 0.5 \cdot INFP_{i,j}(\mathrm{n}) & \text{Si } \mathrm{HDI}_{\mathrm{i,j}}(\mathrm{n}) > INFP_{i,j}(\mathrm{n}) \\ \mathrm{HDI}_{\mathrm{i,j}}(\mathrm{n}) - \dfrac{\mathrm{HDI}_{\mathrm{i,j}}(\mathrm{n})^2}{2.0 \cdot INFP_{i,j}(\mathrm{n})} & \text{Si } \mathrm{HDI}_{\mathrm{i,j}}(\mathrm{n}) \leq INFP_{i,j}(\mathrm{n}) \end{cases}$$

$INFR_{i,j}$ (n) Actual infiltration, month j, year i, sub-basin n.

$HDI_{i,j}$ (n) Availability of water to infiltrate, month j, year i, sub-basin n.

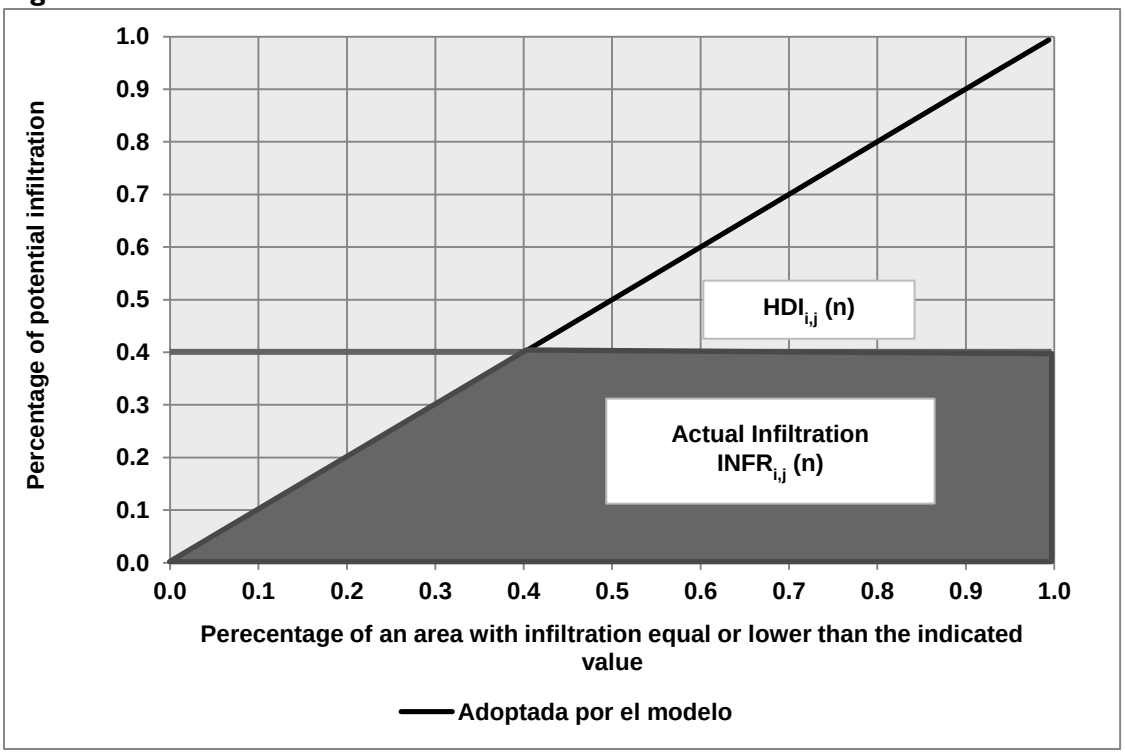
$ASUP_{i,j-1}$ (n) Surface storage at the end of the months j-1, year i, sub-basin n.

6. Percolation

Part of the infiltrated water is stored in the ground, adhering to the mineral particles of this porous medium, through adhesive and cohesive forces. Percolation, or the drainage of excess water from the soil, back into the aquifer zone occurs when the soil reaches a saturation level such that the adhesive and cohesive forces of the molecules located on the outside of the water film, that adhere to the mineral particles, are below the force of gravity.

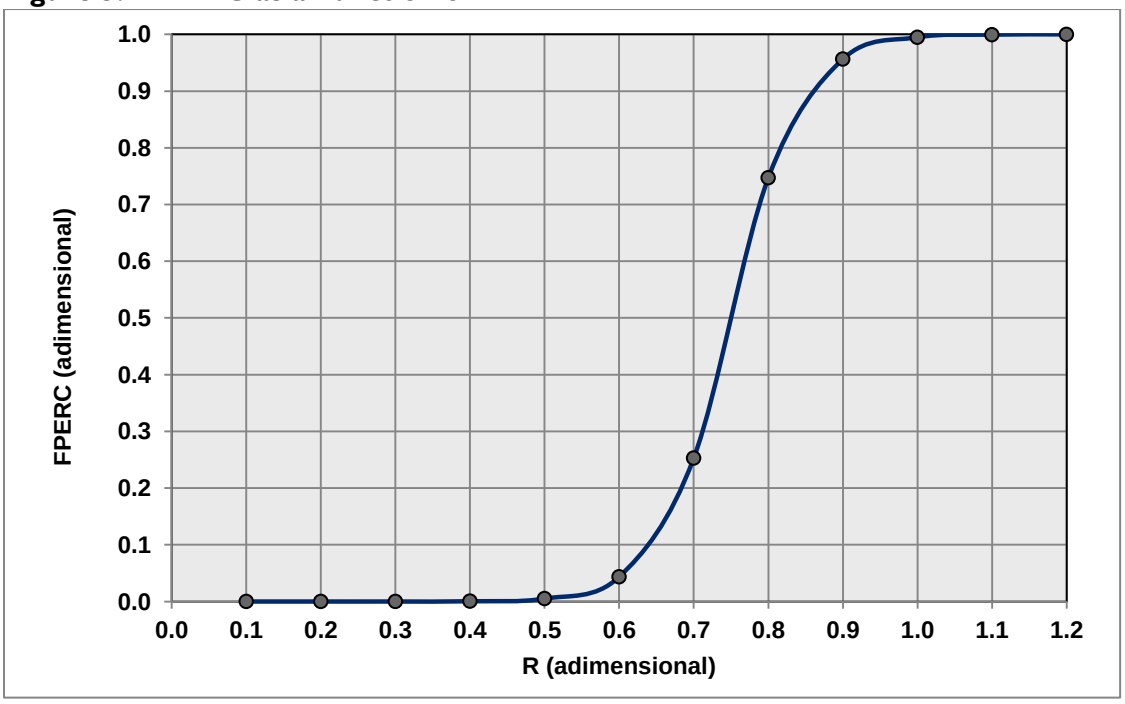
The model assumes that a fraction of infiltrated water, $FPERC_{i,j}$ (n) passes to the groundwater storage. This fraction is a function of the $R_{i,j}$ (n), ratio, (n) between the average water storage in soil, $HSM_{i,j}$ (n), and the storage capacity of the soil HSN (n), as shown in Figure 3.4. As in the case of infiltration, the representation of percolation is an adaptation by Duque (1985) of the methodology used by the "Stanford Watershed Model IV" described in Crawford et al. (1966).

Figure 3.3 Estimation of the Actual Infiltration in a Sub-Basin



Source: Duque (1985)

Figure 3.4 FPERC as a Function of R



Source: Duque (1985)

Following are the equations used in the model to determine percolation, $PERC_{i,j}$ (n):

$$PERC_{i,j}(n) = FPER_{i,j}(n) \cdot INFR_{i,j}(n)$$

$$R_{i,j}(n) = \frac{HSM_{i,j}(n)}{HSN(n)}$$

$$POT_{i,j}(n) = 10 \cdot ABS\left(R_{i,j}(n) - 0.75\right) + 1$$

$$FPER_{i,j}(n) = \begin{cases} \left(\dfrac{1.0}{1.0 + POT_{i,j}(n)}\right)^{POT_{i,j}(n)} & \text{Si } R_{i,j}(n) < 0.75 \\ 1.0 - \left(\dfrac{1.0}{1.0 + POT_{i,j}(n)}\right)^{POT_{i,j}(n)} & \text{Si } R_{i,j}(n) \geq 0.75 \end{cases}$$

Where:

$PERC_{i,j}$ (n)	Percolation, month j, year i, sub-basin n.
$FPER_{i,j}$ (n)	Fraction of the infiltration that percolates, month j, year i, sub-basin n.
$R_{i,j}$ (n)	Ratio of ground humidity, month j, year i, sub-basin n.
$POT_{i,j}$ (n)	Factor that allows estimating $FPER_{i,j}$ (n), as a function of $R_{i,j}$ (n).

7. Surface storage

The model assumes that rainfall enters this storage, $ASUP_{i,j}$(n), from which water leaves for infiltration and surface runoff. The model uses the following balance equation:

$$ASUP_{i,j}(n) = HDI_{i,j}(n) - INFR_{i,j}(n)$$

$$HDI_{i,j}(n) = P_{i,j}(n) + ASUP_{i,j-1}(n)$$

8. Soil water storage

Figure 3.5 includes the components of the soil water balance. This balance is achieved by using the following equations:

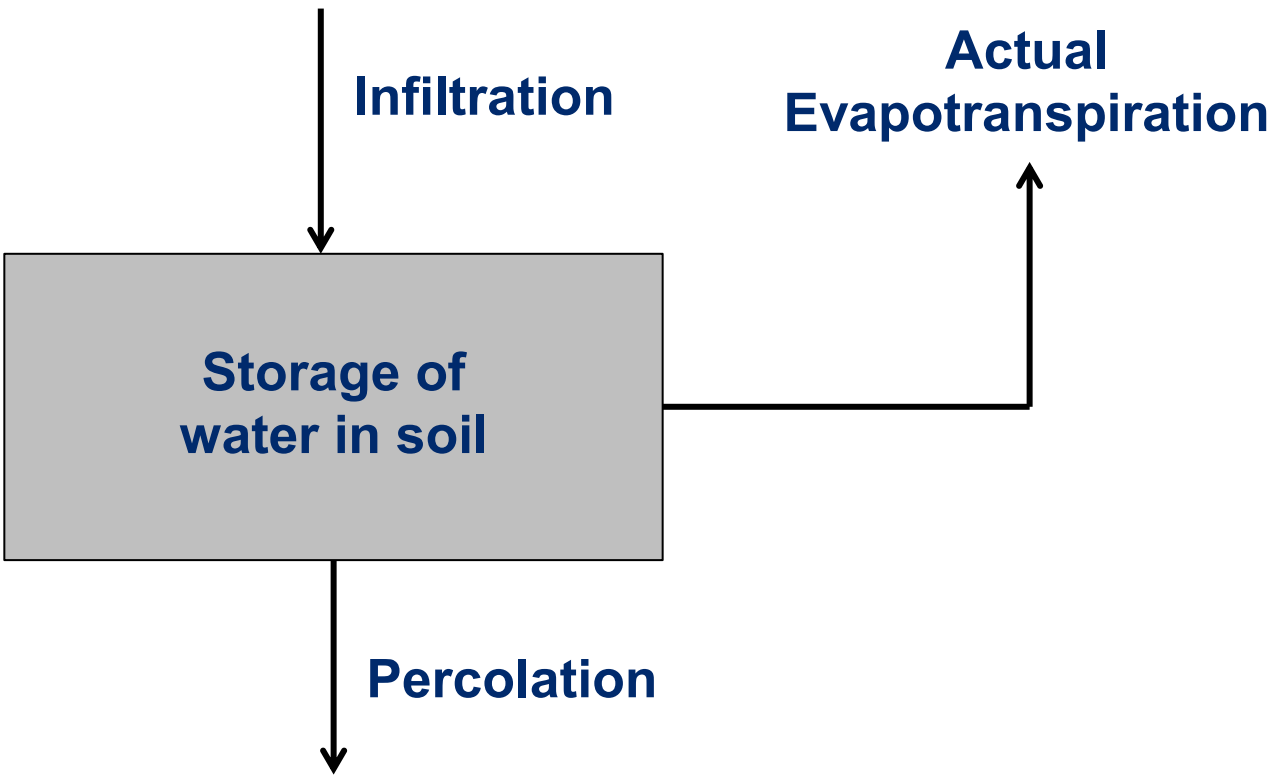
$$HS_{i,j}(n) = HS_{i,j-1}(n) + FNPER_{i,j}(n) \cdot INFR_{i,j}(n) - ETR_{i,j}(n)$$

$$HSM_{i,j}(n) = 0.5 \cdot (HS_{i,j}(n) + HS_{i,j-1}(n))$$

$$FNPER_{i,j}(n) = 1.0 - FPER_{i,j}(n)$$

$HS_{i,j}$ (n)	Humidity stored in the soil at month end j, year i, sub-basin n.
$FNPER_{i,j}$ (n)	Fraction of infiltration that does not percolate, month j, year i, sub-basin n.
$FPER_{i,j}$ (n)	Fraction of infiltration that percolates, month j, year i, sub-basin n.
$HSM_{i,j}$ (n)	Soil humidity average storage, month j, year i, sub-basin n.

Figure 3.5 Balance of Soil Water Storage



9. Groundwater storage

Figure 3.6 shows the components of the water balance in underground storage. The model achieves this balance using the following equations:

$$ASUB_{i,j}(n) = ASUB_{i,j-1}(n) + PERC_{i,j}(n) + FSA_{i,j}(n) - QB_{i,j}(n) - FSE_{i,j}(n)$$

$$ASUBM_{i,j}(n) = 0.5 \cdot \left(ASUB_{i,j}(n) + ASUB_{i,j-1}(n)\right)$$

$$QB_{i,j}(n) = PQB_{i,j}(n) \cdot ASUBM_{i,j}(n)$$

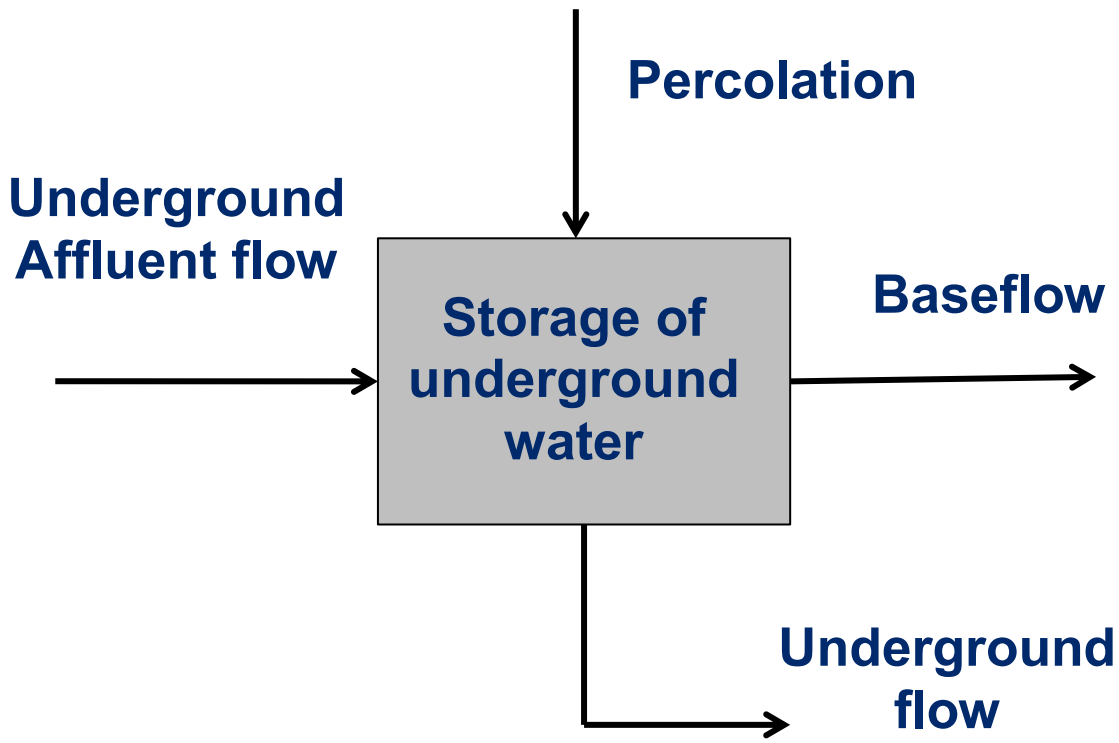
$$FSE_{i,j}(n) = FFSE(n) \cdot ASUBM_{i,j}(n)$$

$$PQB(n) + FFSE(n) \leq 1.0$$

Where:

$ASUB_{i,j}$ (n)	Underground storage at the end of month j, year i, sub-basin n.
$PERC_{i,j}$ (n)	Percolation in month j, year i, sub-basin n.
$FSA_{i,j}$ (n)	Affluent underground flow in month j, year i, sub-basin n.
$QB_{i,j}$ (n)	Baseflow in month j, year i, sub-basin n.
$ASUBM_{i,j}$ (n)	Average storage in month j, year i, sub-basin n.
$FSE_{i,j}$ (n)	Effluent underground flow in month j, year i, sub-basin n.
PQB (n)	Fraction of underground storage that leaves as baseflow in sub-basin n.
FFSE (n)	Fraction of underground storage that leaves as effluent underground flow, sub-basin n.

Figure 3.6 Balance of Underground Water Storage



10. Runoff

The runoff that reaches the watershed outlet is equal to the surface runoff plus the baseflow plus the runoff from contributing sub-basins (located upstream) and the runoff that did not leave during the previous time interval (delayed).

Following are the equations used to calculate the runoff model and runoff leaving the flow at the end of each sub-basin.

$$Q_{i,j}(n) = ESCD_{i,j}(n) + ESCORR_{i,j}(n) + QB_{i,j}(n)$$

$$ESCORR_{i,j}(n) = PESC(n) \cdot \left(ESCORA_{i,j}(n) + ESCOR_{i,j-1}(n)\right)$$

$$ESCOR_{i,j}(n) = (1 - PESC(n)) \cdot \left(ESCORA_{i,j}(n) + ESCOR_{i,j-1}(n)\right)$$

$$ESCD_{i,j}(n) = PESC(n) \cdot ASUP_{i,j}(n)$$

Where:

$Q_{i,j}$ (n)	Total runoff, month j, year i, sub-basin n.
$ESCORR_{i,j}$(n)	Runoff, month j, year i, sub-basin n.
$ESCORA_{i,j}$ (n)	Affluent runoff, month j, year i, sub-basin n.
$ESCOR_{i,j-1}$ (n)	Delayed runoff from month j-1, year i, sub-basin n.
$ESCOR_{i,j}$ (n)	Delayed runoff for the next month.
PESC (n)	Fraction that leaves as runoff.

11. Model parameters

According to the equations in the above sections, the model parameters for each sub-basin are:

FP_k (n)	Fraction of the sub-basin n, represented by rain station k.
FCP(n)	Areal mean rainfall adjustment factor in sub-basin n.
FE_m (n)	Fraction of the sub-basin n, represented by weather station m.
FCE (n)	Areal mean evotranspiration adjustment factor in sub-basin n.
Kc (n)	Coefficient as a function of vegetation type, sub-basin n.
HSN (n)	Soil humidity storage capacity, sub-basin n.
CINF(n)	Infiltration capacity, sub-basin n.
PQB (n)	Fraction of underground storage that leaves as baseflow, in sub-basin n.
FFSE (n)	Fraction of underground storage that leaves as effluent underground flow during month j, year i, sub-basin n.
PESC (n)	Fraction that leaves as runoff.

All parameters are non-dimensional, with the exception of HSN (n) and CINF (n), which are expressed in millimeters.

Additionally, to start the execution of the model it will be necessary to start up storages; therefore, initial values are needed only for the first time interval. Following are these storages, expressed in millimeters:

AIHS (n) Initial soil water storage.

AIAS (n) Initial underground water storage.

AISUP (n) Initial surface water storage.

12. Estimation of the model parameters and initial storage values

Following are some recommendations to estimate the model parameters and initial storage.

- FPk (n): Can be estimated using the isohyets method.
- FCP(n): Initially it is considered the same as the unit.
- FEm (n): Can be estimated using isolines with the same ETo.
- FCE (n): Initially it is considered the same as the unit.
- Kc (n): Represents the weighted value of Kc values of the various types of vegetation found at the sub-basin
- To estimate the HSN (n) values Table 3.1 can be used, where they are defined as a function of texture and ground depth.
- At the beginning, the value of CINF (n) can be equal to HSN (n).
- The PQB (n), PFSE (n) and PESC (n) values, vary between 0 and 1. Initially they can be assigned a value of 0.5.
- The initial AIHS (n) value can be the same as HSN (n).
- The initial value of AISUP (n), can be varied between 0 and 10 mm.
- The initial value of AIAS (n), can be varied between 50 and 100 mm.

Table 3.1 HSN Values (mm)

Type of texture	Texture class	Shallow soil (≤0.5 m)	Mid deep soil (≤1.0 m)	Deep soils (>1.0 m)
Coarse	Sandy Sandy loam	42.5 (31.0-54.0)	85.0 (62.0-108.0)	127.5 (93.0-162.0)
Moderately coarse	Sandy loam	61.0 (42.0-80.0)	122.0 (84.0-160.0)	183.0 (126.0-240.0)
Medium	Loamy Silt loam	86.0 (67.0-105.0)	172.5 (135.0-210.0)	259.0 (203.0-315.0)
Moderately fine	Sandy clay loam clay loam Silty clay loam	95.0 (78.0-112.0)	190.0 (156.0-224.0)	285.0 (234.0-336.0)
Fine	sandy clay clay loam clayey	109.0 (92.0-126.0)	218.0 (184.0-252.0)	327.0 (276.0-378.0)

Source: Duque (1998)