4.10 Pilot Study

Pilot Study for artificial recharge was implemented by actually injecting water into a well to make clear of possibility and problem of the artificial recharge, and to get basic information to formulate a plan of artificial recharge project.

(1) Selection of Pilot Study Site

JICA Study Team proposed four sites for Pilot Study for artificial recharge.

① Vitelma
② La Aguadora
③ La Salle
④ Subachoque

Target of artificial recharge in site ①~③ is Cretaceous Formation and Quaternary in site ④. Pilot Study for artificial recharge to Cretaceous Formation was examined in this Study. From the proposed site of ①~③, ①Vitelma site was finally selected for site for Pilot Study. The reason is explained below:

- San Cristobal River flows near Vitelma site, where it is possible to get enough water during the Pilot Study period.
- There is a settling pond of EAAB in Vitelma site. Therefore, it is easy to get clean water for Pilot Study.
- Vitelma site is located at the altitude of 2,800m. It seems no possibility of flowing well and suitable for Pilot Study.

(2) Method of Pilot Study

Procedure of the Pilot Study (artificial recharge test) is as follows. EAAB drilled two wells in Vitelma site, one well for artificial recharge and the other for observation. Geological condition of wells is shown in Table-4.27.

Table-4.27 Geological condition of Vitelma Well

Well	Depth	Diameter	S.W.L.	Geology	Depth	Rock face
Recharge well	300m	8 inch	GL-6.63m	Colluvial	0-22	Gravel, sand, silt
				Labor · Tierna	22-180	Sandstone dominant alternation
				Chipaque	180-300	Shale
Monitoring well	240m	4 inch	GL－6.84m	Colluvial	0-36	Gravel, sand, silt
				Labor · Tierna	36-188	Sandstone dominant alternation
				Chipaque	188-240	Shale

Note) S.W.L. of monitoring well is from ground level of recharge well.

According to pumping test in Vitelma wells, specific capacity of recharge well is 62m^2/day, which shows high production capacity of this well. The distance between the two wells is 120m and the influence of pumping of recharge well was observed in monitoring well within only 15 minutes after pumping stated. This result shows that response between wells of Cretaceous aquifer is vary fast because of highly confined state of Cretaceous aquifer. From this, it is expected that effect of artificial recharge will travel fast toward surrounding wells.

(3) Procedure of Pilot Study

Procedure of Pilot Study is explained below.

Water pumped up from the settling pond was injected into the recharge well. Concrete tank with volume of 400m^3 was constructed near the recharge well, and pumped water was conveyed into the concrete tank. The tank and the recharge well were connected by pipe, and water inside the tank entered into the recharge well with gravity. Then recharged water infiltrated into the deep aquifer through screen of the well. The design of tank and recharge system is shown in Figure-4.29.

- Recharge rate was measured by observing water draw-down inside the concrete tank. At the same time, recharge rate was measured by flow-meter installed to pipe which connects concrete tank and recharge well. Cycle of observation is shown in Figure-4.28.
- Influence of the artificial recharge on surrounding aquifer was investigated by observing groundwater level of the observation well.
- It was anticipated that recharge rate would decrease with time. Decrease of recharge rate was judged by speed of water level drawdown in concrete tank.
- When the recharge rate decreases to same extent, water recharge was stopped. Then a pump was installed into the recharge well to conduct pumping test. By the pumping test, silt clogging the recharge well was removed. The pumping test continued for three days. After the pumping test, water recharge test started again.

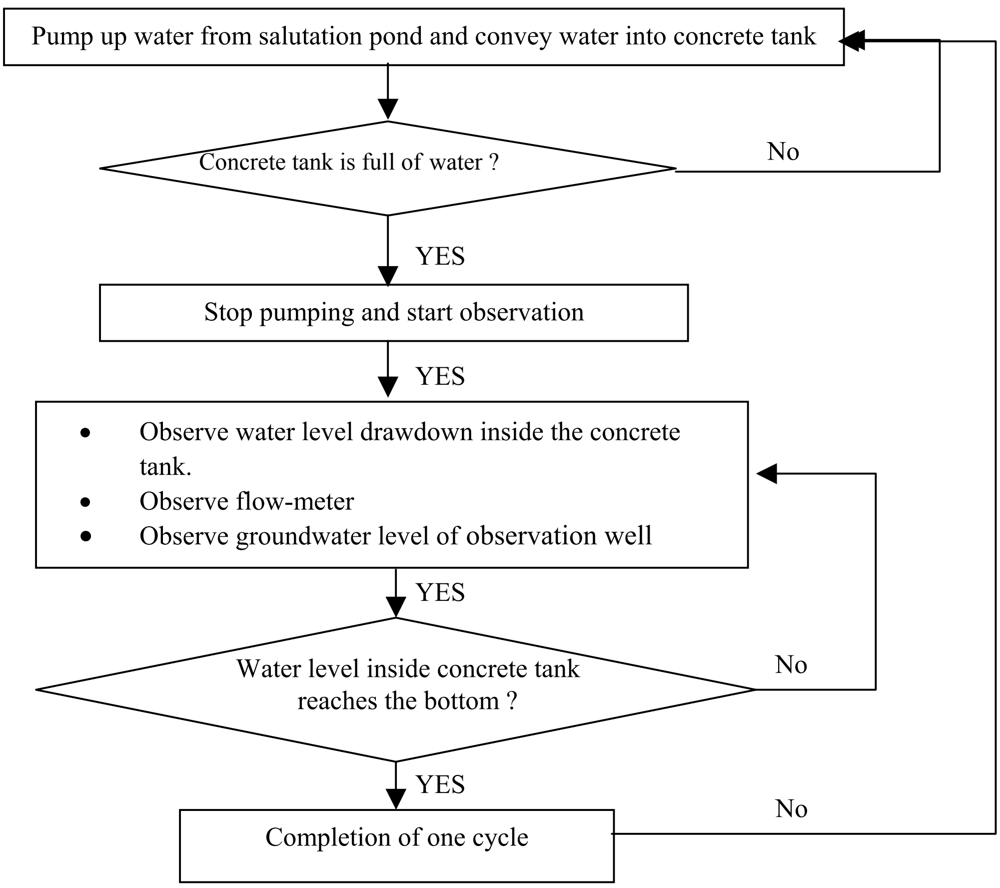


Figure-4.28 Observation Cycle of Pilot Study

(4) Result of Pilot Study

One example of result of Pilot Study is shown in Figure-4.30. The figure shows fluctuation of groundwater level inside recharge well during water injection, from16th to 26th Nov. 2002. This result is summarized in Table-4.28.

Table-4.28 Result of Artificial Recharge

Injection rate	Pressure head of injection	Specific injection	Specific capacity in Pumping Test
864 m^3/day	8.41 m	103 m^3/day	69 m^3/day (pumping rate1,296 m^3/day)

Efficiency of artificial recharge is judged from specific injection (=injection rate/increase of groundwater level of well). Specific injection has almost same meaning of specific capacity. The former shows capacity of injection and the latter shows capacity of pumping. Specific injection will decrease as injection rate increase. Specific injection of 103m^3/day in Table-4.28 is for injection rate of 864m^3/day. From the Pilot Study, it was proved that value of specific injection is more than that of specific capacity of pumping test.

It is expected that efficiency of artificial recharge will decrease as injection continues. Injection rate is so far gradually decreasing from 1,300 to 864m^3/day. It is due to clogging of aquifer surrounding recharge well. However, injection rate will recover by pumping.

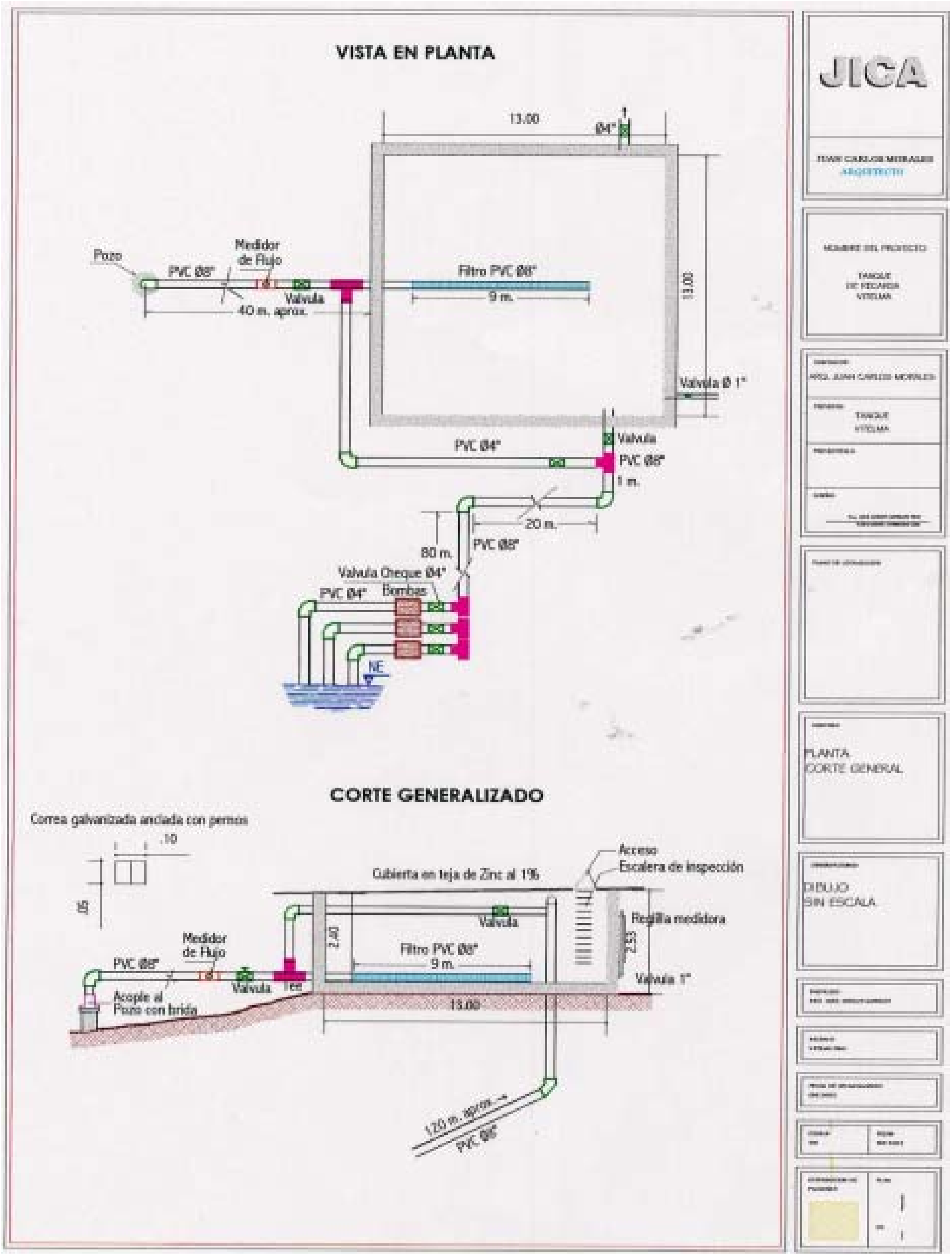


Figure-4.29 Facilities for Pilot Study

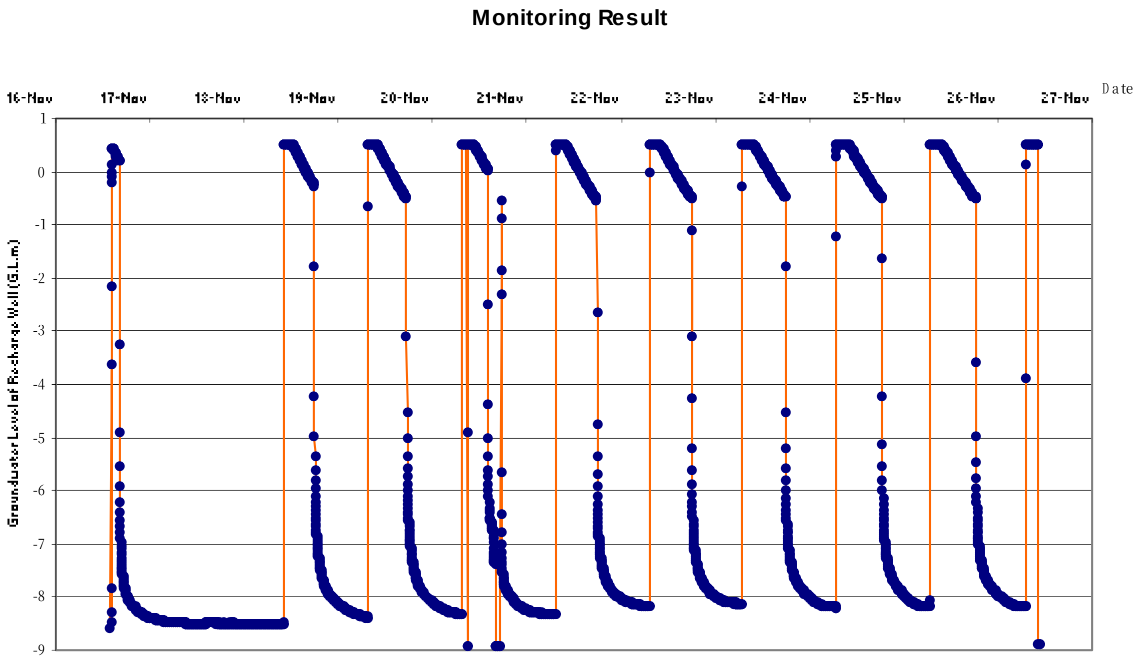


Figure-4.30 Result of Pilot Study

4.11 GIS Database

4.11.1 GIS System

(1) Installation of GIS and production of database

For the purpose to manage the data relating to groundwater resource, the JICA Study team introduced GIS to support building database of the study results. Each organization, which concerns with groundwater projects, has developed their own GIS and database without collaboration. Therefore, these data have not been mutually shared among the agencies. Meanwhile, each organization has held a common problem to make it difficult to share the data among agencies.

To produce database effectively in the study, it was expected to use currently available GIS system and database at maximum. However, there was some difficulty to utilize the existing information in reality and, hence, it took much manpower and times.

Each organization wishes to build up a sharable GIS database. Throughout situations that the existing data were unified and managed in the database produced in the study, it was expected that the present status for data infrastructure was recognized among agencies and also it would help to evaluate the feature data infrastructure. The items of GIS database produced in the study are listed as the followings.

<u>GIS database as thematic map</u>

- Base map
- Satellite image data
- Topography and Geology data are elevation map, river stream map, watershed map, landform map, geology map, hydrogeology map.
- Land use map and land use planning map
- Administrative boundary map and population statistic data

- Water demand map
- Facility map for water supply and sewerage
- Environmental conservation map
- Natural hazard map
- Visualization of data is for water quality analysis, geophysical exploratory result and well depth distribution map.

Database about the observation data

- Well inventory data
- Meteorological observation data and hydrological observation data
- Database about national census survey
- Data in the result of geophysics survey
- Data in water quality analysis
- Data in the pumping test in the JICA Study

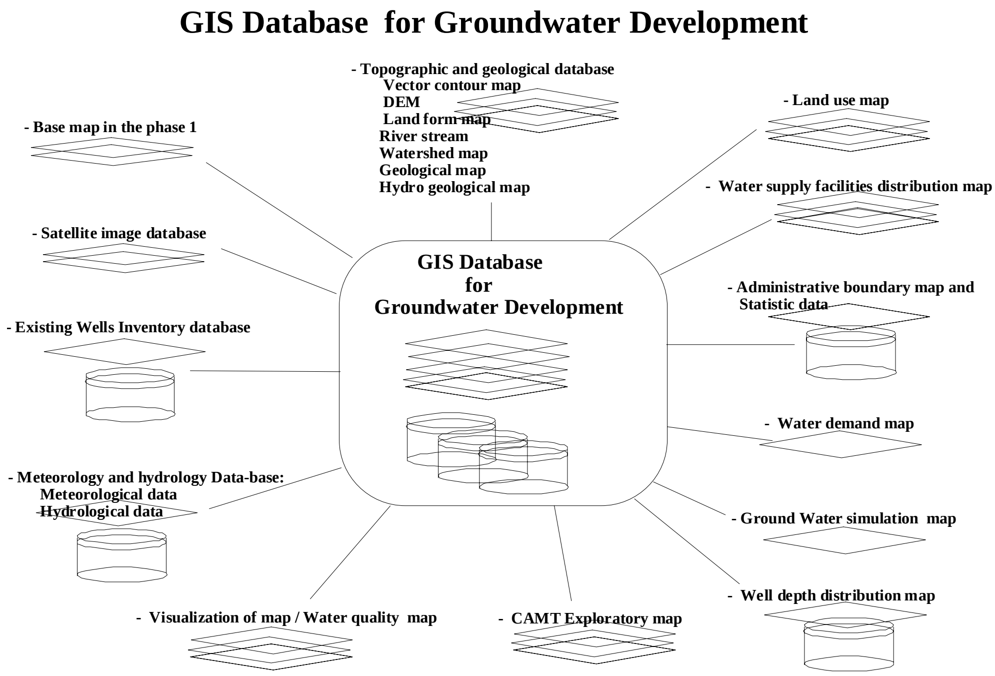


Figure-4.31 Scheme of GIS database

(2) GIS Supporting System

The JICA study team introduced GIS equipments including two sets of PC system to support GIS and groundwater simulation. ArcView3.2（ESRI Corporation） and Spatial Analyst, which assists extending the module for grid data processing, were installed to support GIS data processing. The software, Visual Modflow (DHI Software Corporation), was installed to support the groundwater simulation.ArcView is the GIS software which provides overall function of map data management and map printing including display of maps, reference of data, query, spatial analysis, tabulation, printing of map. Extension module of ArcView provides the following functions: the surface module for interpolation from point data, for map algebra of grid data, for tabulation and for data conversion between vector and grid.
GIS system was connected to Local Area Network (LAN) in EAAB and the system equips color plotter and other out put devices to print out a large-scale map. The configuration of GIS system is shown in Figure-4.32. The detail of GIS system is described in the supporting

report.

GIS database follows the Shape format, which is a standard format in ArcView. Database format of Shape file is supported by dBASE format. External database of well inventory data and other observation data are imported to GIS data by using modules of the external data connectivity of ODBC and SQL command provided in ArcView.

GIS System Configuration for Water Resources Development

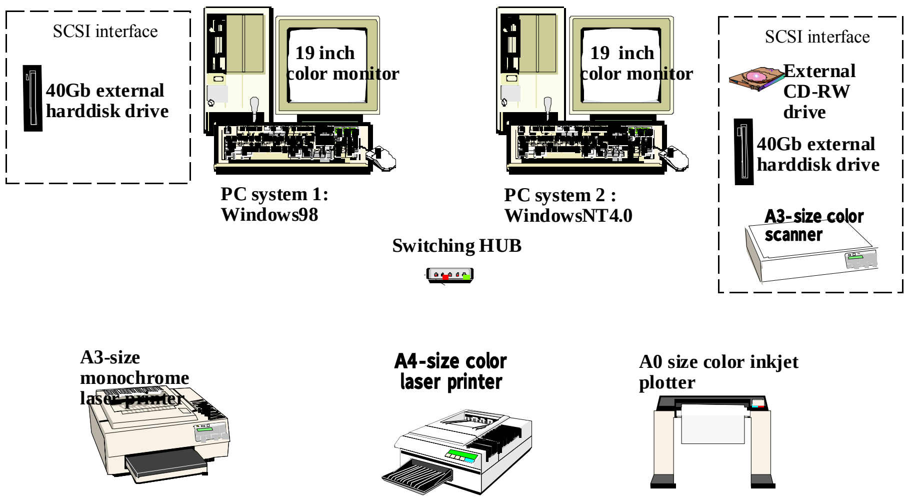


Figure-4.32 System Configuration of GIS equipments

4.11.2 Production of GIS database

(1) Definition of GIS database

GIS database was defined as data specification shown in Table-4.29, which considered with distributions of the study area and the index map of topographic map from IGAC, the origin coordinates on map of vector data and raster data, the resolution of grid cell. The study area is shown in Figure-4.33.

DEM data uses for grid data analysis in ArcView and the groundwater simulation in Visual Modflow. Considered map scale of 1:100,000 and the contour interval in map the maximum resolution of DEM was decided to 100 meters.

Table-4.29 Definition of GIS data

Definition of database	Contents
Range of map coordinate of X (EAST)	940,000 m - 1,070,000m
Range of map coordinate of Y (NORTH)	960,000 m - 1,080,000m
Origin of GRID CELL : (X, Y)	X = 940,000 m, Y = 1,080,000m
Resolution of DEM and GRID CELL	100m, 250m, 500m
Map projection	Gauss conformed
ESFEROID:	International
ZONE ORIGEN GEOGRAPHICAL COORDINATES:	LATITUD; NORTH 4 ° 35 ' 56.57"
	LONGITUDE; WEST 74° 04 ' 51.30 "
PLAIN COORDINATES;	1'000.000 METRERS NORTH;
	1'000.000 METRERS EAST;
VERTICAL DATUM:	MEAN LEVEL OF THE OCEAN IN BUENAVENTURA
HORIZONATAL DATUM:	BOGOTÁ

(2) Database item

GIS database consists of the following items: base map of topography, AutoCAD file for cartography, thematic map and evaluation map and non-spatial database such as statistic data and observation data. Data items in the JICA Study are shown in Table-4.30.

The following explains each database item. Lists of GIS database are shown in Appendix. The detail of data specification is referred to the Manual for GIS database.

Table-4.30 List of GIS database

Database item	Contents of database
(a) Base map	Compilation map of topographic map of 1:100,000 topographic map from IGAC including contour line, road, administrative boundary, river, settlement, annotation of topographic map etc.
	A series of AutoCAD file about the survey activity
(b) Satellite image database	Color composite image, Land cover map, Normalized Vegetation Index map, Edge enhancement map for geological interpretation.
(c) Well inventory database: (Results of Survey)	Results of existing wells inventory
(d) Meteorology and hydrology database: (Observation data)	Monthly data at the meteorological observation station: Precipitation, Temperature, Humidity, Evaporation, Solar Radiation. Monthly data at the hydrological observation station: Mean discharge (m^3/sec), Flood discharge hour (hours)
(e) Topographic and geological Database	Contour map
	DEM (100meter, 250meter, 500 meter)
	River stream map
	River basin map
	Land form map
	Geological map
	Hydro geological map
(f) Land use map	Land cover map from satellite image data
	Present land use map, land use planning map
(g) Administrative boundary map and relevant statistic data: (Statistic data)	Administrative boundary map of municipality in 1993, 2000, Sector map of Bogotá City
	National census survey data in 1993 and the other statistic data related to data analysis of water demand analysis.
(h) Water demand map	
(i) Water supply facilities and sewerage facilities	Water supply network and water supply facilities
	Sewerage network, drainage, and sewerage facilities
(j) Environmental conservation map	Protection area and Conservation area for ecological protection and protection for development
(k) Hazard zones and historical map	Inundation, soil erosion, landslide, zoning map of seismic hazard and etc.
(l) Observation data and Visualization map of observation data	Well map for water quality, Well map for pumping test
	Water quality distribution map,
	Well depth distribution map
	CSAMT Exploratory map (Observation data)

(a) Base map

Base map was compiled to digital map from topographic map of 1:100,000 from IGAC. Necessary layers were processed to several thematic maps of GIS data supported by Shape file in ArcView. The list of base map consists of the following items.

GIS Data	Road and railway, Main contour line and internal contour line, Reservoir and lagoon, Study area, Administrative boundary of municipality, Map sheet of 1:25,000 topographic map, Settlement area in municipality, Main river, Secondary river, Branch stream, Stream, River basin area prepared by the study team, annotation of map on topographic map, Primary road, Second road and Other road; Base map of the study area is shown in Figure-4.33.
Drawing file of AutoCAD	Topographic base map, Location maps concerned to project activities and etc. Exploratory Drilling in Phase1, Exploratory Drilling in Phase2, Meteorological and hydrological observation station, Proposed site map for Artificial Recharge, and Sampling points at rivers and surrounding wells for Isotopic analysis Carbon14 and Tritium Deuterium; A drawing file of the study area is shown in Figure-4.34.

(b) Satellite image database

The Study team employed satellite image data of LANDSAT to monitor and to analyze the present land cover and geological photograph interpretation in reconnaissance survey and several thematic maps of image data. The followings were produced in the phase 1 study.

- Color composite image with false color
- Land cover image
- Normalized Vegetation Index image
- Enhanced image of interpretation for hydrology and geological structure

The acquired satellite image data in the phase 1 was not clear for the present land cover. It was hard to process data for geological structural analysis because of the cloud cover at some parts in the study area. ESPACIO MAPAS, which was satellite image data of LANDSAT5-TM in 1995 at IGAC, was recommended to recover the cloudy parts. The map sheet of this image corresponds to that of topographic map of 1:100,000 as shown in Figure-4.35. To support geological interpretation for structural geology was produced by the enhancement data analysis to detect the direction of NW where there is the major geological structure in the Bogotá plain. (See Figure-4.36)

(c) Existing well inventory data

GIS database of well inventory was prepared for a point data make data properties of wells to provide against the location of well. GIS database were prepared for results of the JICA inventory survey in Figure-4.37 and those of INGEOMINAS inventory data in Figure-4.38.

(d) Meteorological database and hydrological database

Meteorological database and hydrological database were compiled to GIS data by the total of 158 gages at the observation station in the study area. The contents of the number of gage at the station were: 110 gages in CAR, 34 gages in EAAB, 12 gages in IDEAM and 2 gages in EEEB; The item of the observation record (monthly record) in database is as follows:

For the meteorological observation	Precipitation, Temperature, Humidity, Evaporation, Solar radiation and Soil temperature
For the hydrological observation	Mean discharge (m^3/sec) and Flood discharge hour (hours)

Meteorological and hydrological observation databases were added the following general information at the station about location of the stations, map coordinates, grand elevation, address of station, year of installation and description of the term and equipment.

GIS data was a point data of the observation station and observation data was linked to data for the property. An example of precipitation data at the meteorological station is shown in Figure-4.39.

(e) Topographic and geological database

Database of topography and geology that consisted of several thematic maps related to topographic elevation, land form, geology and hydrogeology and the following thematic map was produced to GIS database by the available existing data in the study area and results prepared by the JICA Study team.

<Elevation map>

Thematic map to show topographic elevation is used for topographic analysis, hydrological and geological analysis, groundwater simulation and other spatial data analysis. Elevation map of contour and DEM is shown in Figure-4.40. The produced data is as follows:

Vector contour map

The vector contour map was compiled from the main contour line of 100 meter and the inter contour line of 25 or 50 meter on topographic maps of 1:100,000 in IGAC.

DEM

DEM was produced by the interpolation module of the surface model from the vector contour map not only for topographic data analysis of the hydrogeological but also for groundwater simulation. Considered the precise of the map scale of contour map, DEM was processed to the three types of data: 100 meter, 250 meter and 500 meter;

<River stream and river basin map>

Thematic maps of river stream and river basin including the network of river are the significant GIS data for topography, hydrology and geology. These maps were digitized and compiled to GIS data from delineated maps on topographic map interpreted by the Study team as shown in Figure-4.41.

<Landform map>

Landform map was produced to GIS data from existing map in CAR so called "Mapa geomorfológico" from Atlas de la CAR 2000. The legend includes as follows: mountain, glacier, mountain structural erosion, structural hills, terraces, deltaic fan, alluvial plane, flood plain and etc. Landform map is shown in Figure-4.42.

<Geological map>

Geological map was compiled to GIS database by the interpretation of hydrogeology and the delineation of structural geological feature, based on the convention geological map referred to data source: INGEOMINAS Geological map 2000. Geological interpretation was referred to the lineament information of edge enhancement image extracted by satellite image data. GIS data was produced about polygon feature of the geological unit and line feature of the geological line structure of fault and fold as shown in Figure-4.43. A cross section map of geological map is shown in Figure-4.44.

< Hydro geological map>

Hydrogeological map provides with the database for groundwater simulation based on the results of the existing well inventory. Mapping unit of hydrogeological map uses the same unit of the conventional geological map. The database consists of the following items.

Name of captured aquifer, Aquifer thickness [m], Specific capacity [m^3/day/m], Hydraulic conductivity (k) [L/T], Transmisivity [m^2/day], Coefficient of storage [-], Coefficient of storage specifies [m^{-1}], Total porosity [-], Effective porosity [-], Strativity [-], Captured aquifer, Groundwater recharge [mm/year] and Symbol of aquifer

Hydrogeology map is shown in Figure-4.45 and a cross section map of map is shown in Figure-4.46.

(f) Land use map and Land use planning map

To accumulate the present land use and the feature land use planning in the study area, thematic maps were compiled to show the following theme from data resources of POT among municipalities as follows:

- Urban area and rural area
- Zoning area of land use planning including the developable site, the protected area for development.
- Planning area for the feature project.

Furthermore, thematic maps regarding to public equipment and road planning in land use were produced. To monitor the recent land cover condition, thematic map of land cover was processed from satellite image data and land status was analyzed in the phase 1. Compiled land use map from POT is shown in Figure-4.47.

(g) Administrative boundary map and relevant statistic data

Administrative boundary map was produced to GIS data from administrative boundary of DANE in 1993 and in 2000. The present administrative boundary corresponds to latest national census survey done by DANE in 1993. After the last census in 1993, the definition boundary in some municipalities had been changed in the study area. Especially El Rosal was split in Subachoque. So the boundary was edited on the last data. The property of administrative boundary was linked to administrative code to figure of GIS incorporate though a key field of administrative code used in the census survey. Properties of the census were incorporated to GIS data about the supposed data for the water demand analysis including statistic data about population, household and others.

Sector map in Figure-4.49 about more than 400 sectors in the Bogotá city delineated by EAAB was compiled to the additional thematic map to assist the water demand study.

(h) Water demand map

Water demand map is the map to simulate water demand volume for water supply due to the growth of population and the development of municipality in 2015. Necessary GIS database for water demand analysis was supposed to use the following data: consumption volume due to individual water use, the unit volume of water, agricultural and industrial census, national census and other statistic data.

GIS database treats statistic data in each administrative boundary. Hence, the data was prepared for available data according to the collected statistic data. The map will be produced by the simulation results on tabular data for the water demand analysis linked to the administrative boundary unit.

(i) Water supply facility map and sewerage facility map

Thematic maps of facility map for water supply and sewerage were produced as some compiled maps with unification in the study area from EAAB data and POT data among municipalities. There were different data format, different legend of map and different map project among data at the present, so it was hard to edit maps. Nevertheless, GIS database was produced:

<u>For water facility</u>

- Main water pipe line of water supply
- Related facility for water supply including tanks, pumping station, flow meter, plugs, valves, existing well for portable water
- Type of water supply including service area in urban area and rural area and others

<u>For sewerage facility</u>

- Main sewerage pipeline
- Manhole and drainage
- Treatment plant and tanks for wasted water
- Rainwater network
- Type of facility including service area in urban area and rural area, project area and etc.

Maps of the results are shown in Figure-4.50 and Figure-4.51.

(j) Environmental conservation map

Environmental conservation map was compiled to thematic map for environmental management to show the protection area and the conservation area of forestry, vegetation, ecology and swamp. Most of data resources in POT use the ecological map from CAR "Estructura ecológica principal" del Atlas de la CAR 2000 (Thomas Van Der Hammen 2000). Items of thematic map were as follows: protection of natural forest, natural forest area, floor erosion area, Bogotá plain are, flood plain, important area for topography, geology and ecology, natural park and etc. Map result is as shown in Figure-4.52.

(k) Hazard zones and historical map

Hazard zones and historical map were compiled to GIS database from POT map about risk map and natural hazard map including erosion, earthquake, mass movement, inundation, natural fire, other accident. POT data was dispersed about data item and contents of legend among municipalities, so data was arranged and unified to each thematic map in the study as shown in Figure-4.53.

(l) Observation data and Visualization map of the observation data

Observation data is managed by observation data as a property against the observation point. GIS data were produced: wells for water quality and wells for pumping test.

<Wells for Water quality>

About results of water quality analysis surveyed through two campaigns in the study, well observation data was produced as a point data.

<Wells for pumping test>

About results of pumping test surveyed through three campaigns in the study, wells observation data was produced as a point data.

Software function " Visualization of the observation data" is available to produce visual map from the observation data (not image data). In the study following thematic maps were produced from the observation data in the field and data of analysis results by using display module and the interpolation module ArcView provided: water quality distribution map, well depth distribution map and CSAMT Exploratory map;

<Water quality distribution map>

Water quality distribution map in ArcView directly uses a point data provided with map coordinates (North, East) at the observation and results of water analysis in the database of water quality analysis. Thematic map is easily produced by the interpolation calculation of the surface model in ArcView. The software can directly import contents of database as a point data through SQL command from water quality data arranged to tabular data. An example of water quality map is shown in Figure-4.54.

<Well depth distribution map>

Water depth distribution map used database of the existing well inventory survey including data information about the location of well, grand elevation, information of aquifer and pumping and location of screen and etc. Thematic map is the map to make a well location to plot on map due to the depth of aquifer after imported this database to ArcView. Thematic map is shown in Figure-4.55. The bottom level of aquifer depth will be estimated by the surface model in ArcView for the groundwater simulation.

<CSAMT Exploratory Map>

CSAMT Exploratory Map was produced to thematic map to display results of CSAMT exploratory survey on ArcView. Result of Geophysics analysis in the phase 1 was compiled to database including the map coordinate of North and East, altitude, registivity and depth level and figure of cross section image of registivity at each observation point. Result is shown in Figure-4. 56.

(3) Summary of GIS database and issues

In the process to produce database it became obvious that there were some issues in the present situation about data as follows:

- It takes a lot of time for data collection and procedure to get the permission for data use and it is hard to use data source especially digital data.
- Data precise and data format in the existing well inventory data are dispersed among agencies, so it is hard to arrange and to unify data.
- Data structure and data media are dispersed among every agency, it is different to unify data. Data precise and data quality is different from each other.
- Data specification is not opened for users, so problems happen about data after imported data.
- Most of POT's data does not have a digital data, so it takes a lot of time to make digital data.
- Each organization uses different map projection for their data. Imported data, the location of figure is shifted.
- There is different map projection in the field observation among agencies, so the location

plotted from data on map does not match each other.

Issues relating to data specification, utility and arrangement can be solved by efforts done by relevant organizations and time. But problems caused by map projection make all Geographic Information affect. So it is necessary for persons in charge of the survey and GIS to recognize the understanding for map projection.

Each agencies has reasons mentioned the above and other else administrative reason, so it is not easy to make a consensus to share database. Steering committee expects database in the study team and the constructive opinions are recommended.

Database production needs to take much budget and much time for data entry and data editing, it is requested to carry out good working effectively. It is expected to assist to make consensus grow for database production to support groundwater development for relevant agencies in Colombia government.

It is necessary for database production to make information open about data specification for data production to keep data quality good and then it is necessary to accumulate data with sharing. Against this performance, it is necessary to establish a guideline for the procedure and data specification of database production as same as the one of POT that IGAC is carrying the administrative guidance to municipalities.

It is recommended that the necessary guideline is prepared for database production in each agency and this event continues to establish Spatial Data Infrastructure for relating groundwater development with the correspondence for Data Standard of GIS data in ISO/TC211.

As the technology transfer of GIS and database in the study the JICA study carried out ArcView' operation about import and export of data, production of thematic map and evaluation map and map production, maintenance of database and maintenance of system through a series of the process of GIS database production.

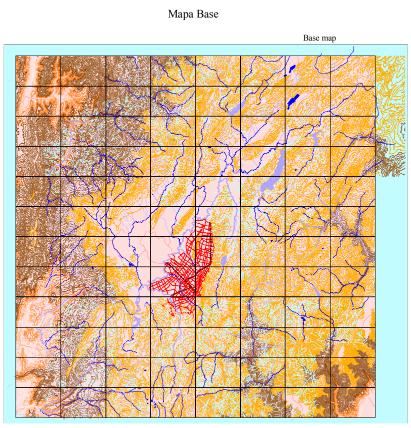


Figure-4.33 Base map in the study

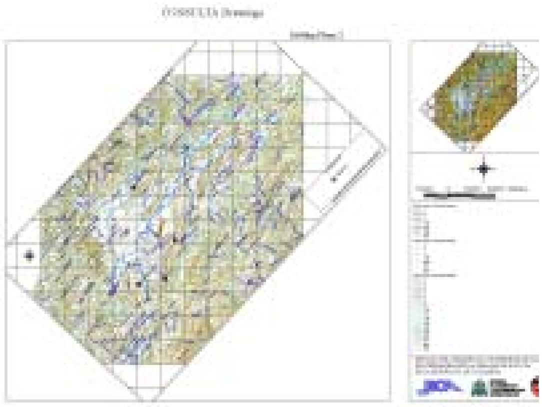


Figure-4.34 Drawing file

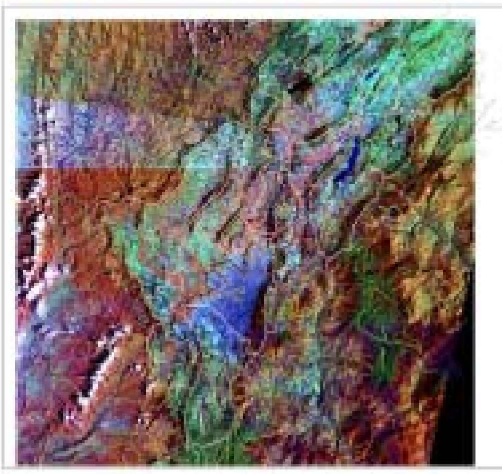


Figure-4.35 Spatial Map of LANDSAT5 from IGAC in 1995

The mosaic image of "ESPACIO MAPAS" is used for land cover monitoring, which map sheets consisted of PL-208, PL-209, PL-227, PL-228, PL-246, PL-247. Thematic maps of the study area, main river and secondary river are overlaid on the image.

Figure-4.36 Edge enhance image of NW direction

Satellite shows the edge of NW direction as the major direction of geological structure in the Bogotá plain.
The enhancement factor was extracted as the edge from the satellite image data.

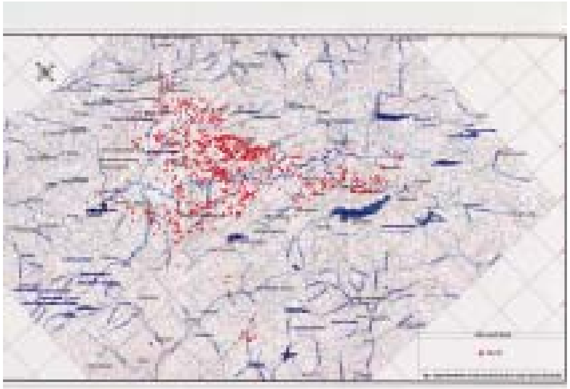


Figure-4.37 Result of JICA well inventory

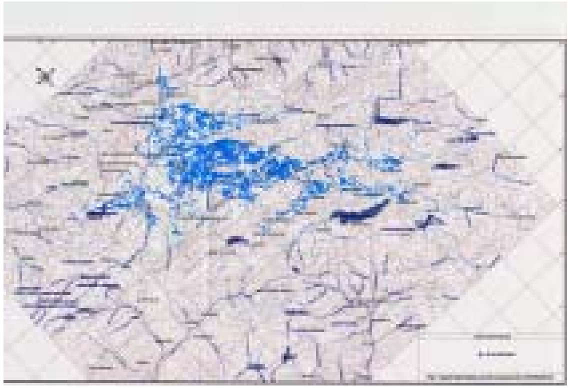


Figure-4.38 Result of INGEOMINAS well data

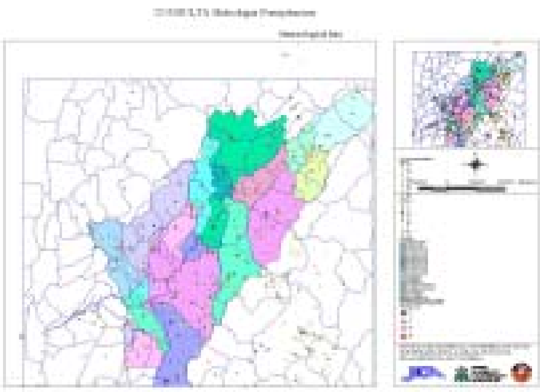


Figure-4.39 Map of meteorological observation station location

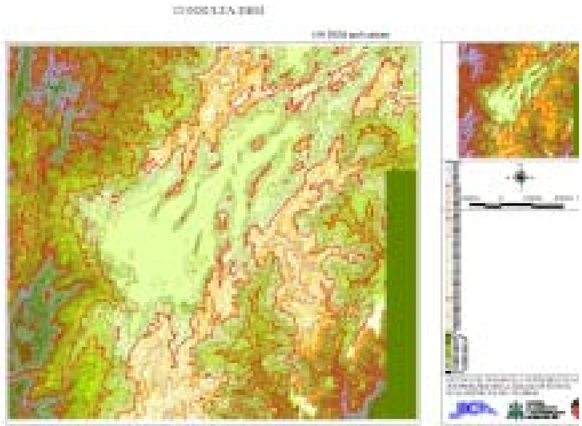


Figure-4.40 Elevation map of contour and DEM

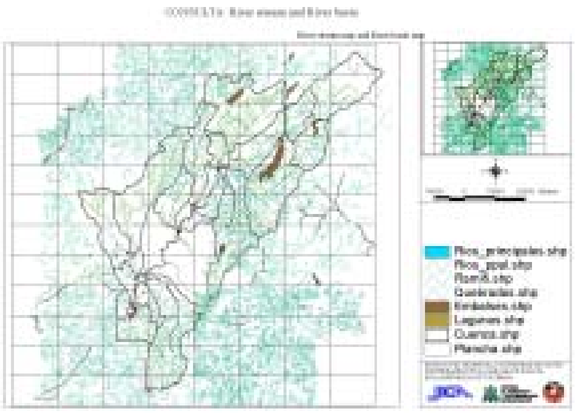


Figure-4.41 River stream map and river basin map

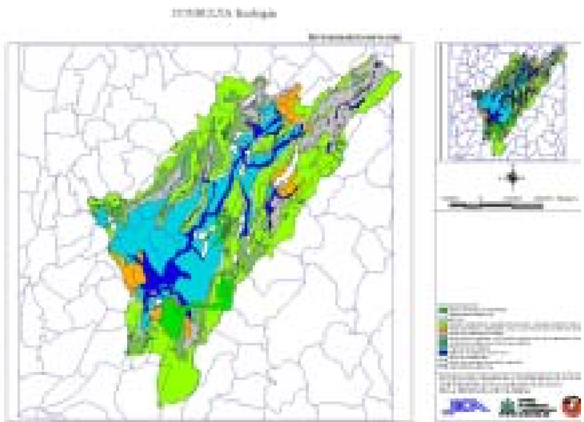


Figure-4.42 Land form map

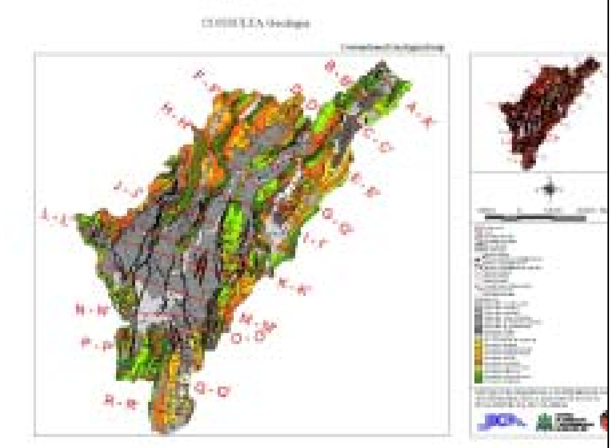


Figure-4.43 Conventional geological map in the study

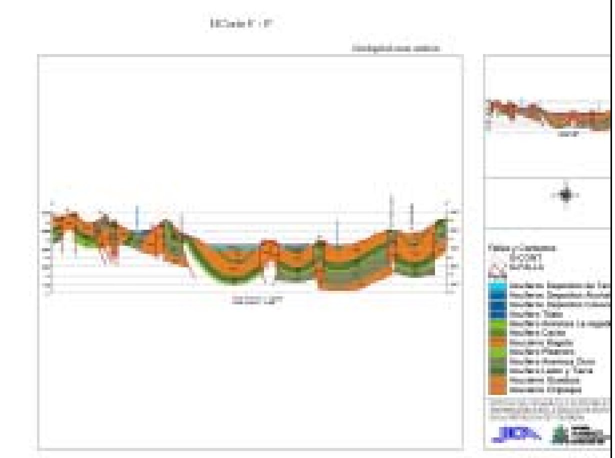


Figure-4.44 Cross section map of geological map

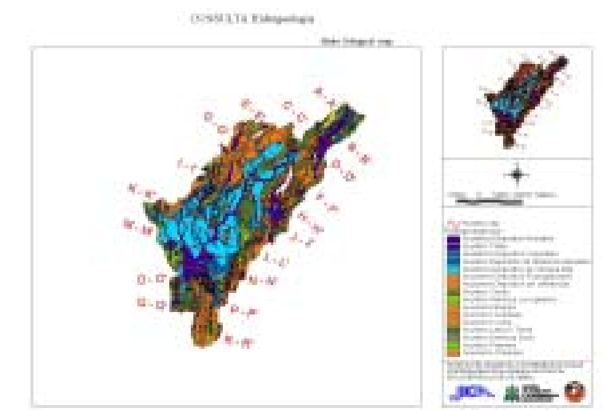


Figure-4.45 Hydrogeological map

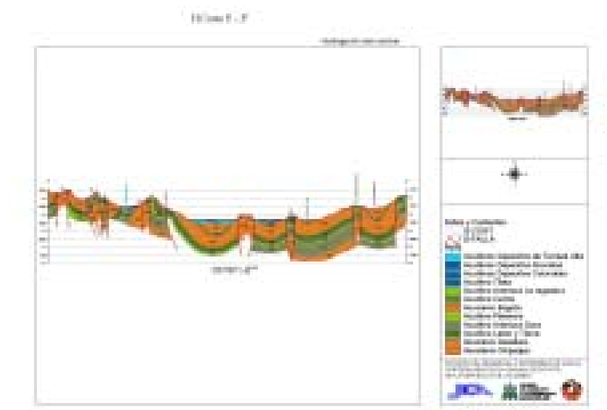


Figure-4.46 Cross section map of hydrogeological map

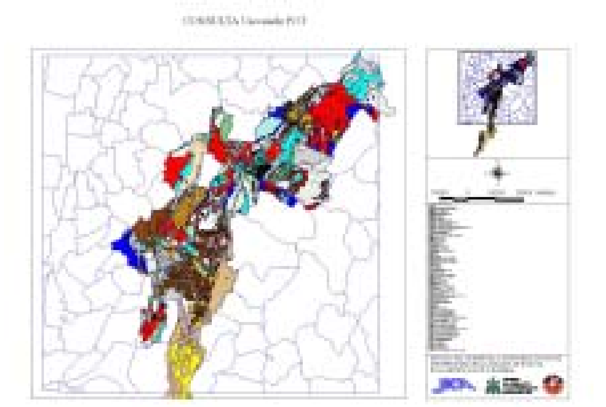


Figure-4.47 Compiled land use and land use planning map in POT

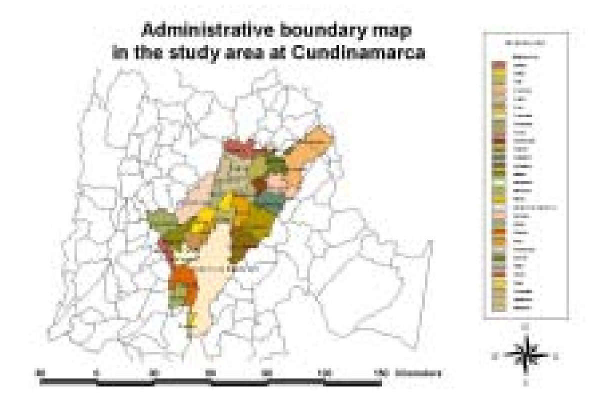


Figure-4.48 Administrative boundary map of DANE in 2000

Figure-4.49 Sector map of EAAB in Bogotá city

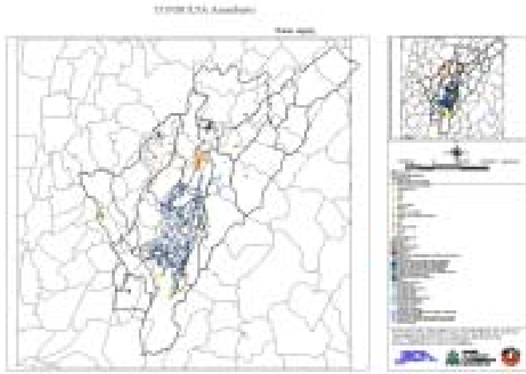


Figure-4.50 Compiled water supply map of POT

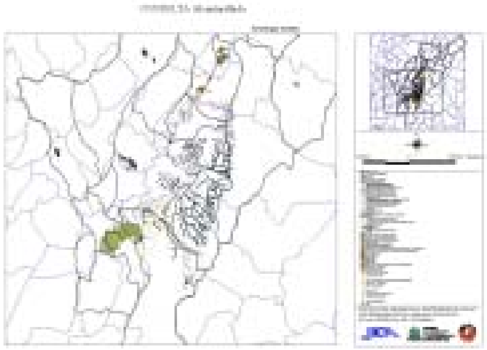


Figure-4.51 Compiled sewerage map of POT

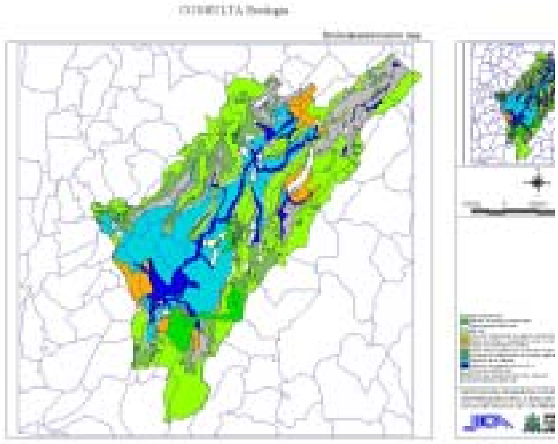


Figure-4.52 Environmental conservation map

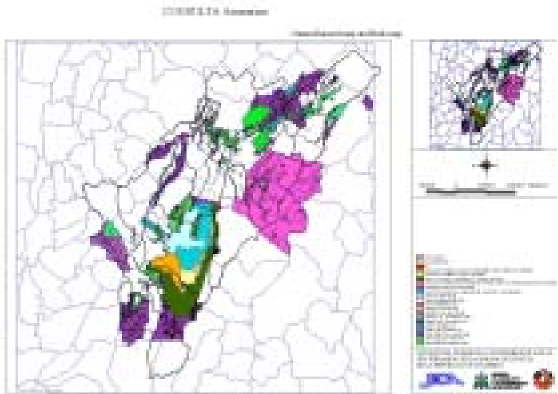


Figure-4.53 Natural hazard map and risk map

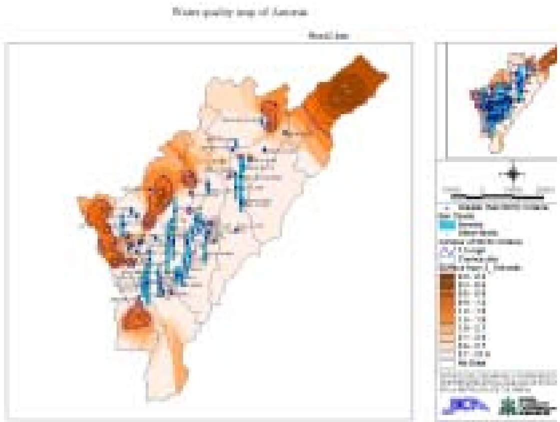
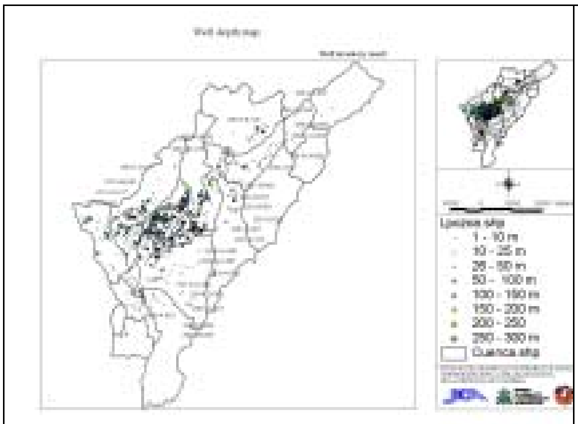
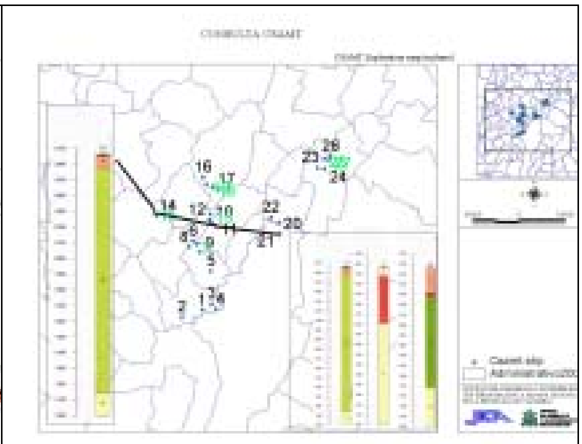


Figure-4.54 Example of water quality map Of Ammonia

 **Figure-4.55 Example of well depth map**	 **Figure-4. 56 CSAMT Geophysics explorer map**