BOGOTÁ WATER SUPPLY
AND SEWAGE COMPANY
(ACUEDUCTO)

STUDY ON SUSTAINABLE WATER SUPPLY FOR BOGOTÁ CITY AND SURROUNDING AREA BASED ON THE INTEGRATED WATER RESOURCES MANAGEMENT IN THE REPUBLIC OF COLOMBIA

FINAL REPORT
SUPPORTING REPORT

March 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.

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PART 1

PROPOSED WELL

Final Report

(Supporting Report)

PART 1 PROPOSED WELL

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PART 1 PROPOSED WELL

CHAPTER 1. PROPOSED WELL SITES IN EASTEN PROJECT

Name	E-1	**Reagion**	Eastern hill	Bogota City	
Latitude	4° 33'46.8"N	**Longitude**	74° 03'55.2"W	**Elevation**	2810

Surface Geology

K2d, hanging wall of Bogota fault

Aerial Photograph

Local Situation

Note

Vitelma(pilot plant of ACUEDUCTO)

Name	E-3	**Reagion**	Eastern hill	Bogota City	
Latitude	4° 37'37.4"N	**Longitude**	74° 03'18.7"W	**Elevation**	2825

Surface Geology

K2d, near the geologic boundary of K2p

Aerial Photograph

Local Situation

Note

On the road beside PARAISO III tank

Name	TA-1	**Reagion**	Eastern hill	Bogota City	
Latitude	4°41'06.5"N	**Longitude**	74°01'46,6"W	**Elevation**	2621

Surface Geology

K2t, footwall of E-W fault

Aerial Photograph

Local Situation

Note

by the side of the road to Santa Ana tank

Name	TA-2	**Reagion**	Eastern hill	Bogota City	
Latitude	4°41'02.1"N	**Longitude**	74°01'39.8"W	**Elevation**	2674

Surface Geology

K2t, footwall of E-W fault

Aerial Photograph

Local Situation

Note

by the side of the road to Santa Ana tank

Name	E-5	Reagion	Eastern hill	Bogota City	
Latitude	4°41'32.1"N	Longitude	74°01'27.1"W	Elevation	2688

Surface Geology

K2t, footwall of E-W fault

Aerial Photograph

Local Situation

Note

By the side of the road to Santa Ana tank

Name	E-6	Reagion	Eastern hill	Bogota City	
Latitude	4˚ 41'34.1"N	Longitude	74˚ 01'32.6"W	Elevation	2643

Surface Geology

K2t, on E-W fault

aerial photograph

local situation

Note

End of forest(exploratry well of ACUEDUCT0)

Name	E-7	Reagion	Eastern hill	Bogota City	
Latitude	4˚ 42'43.2"N	Longitude	74˚ 01'44.3"W	Elevation	2583

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Blank space for building site

Name	E-14	Reagion	Eastern hill	Bogota City	
Latitude	4˚ 45'17.4"N	Longitude	74˚ 01'22.5"W	Elevation	2605

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

La Salle existing well (confined-water well)

Name	E-9	Reagion	Eastern hill	Bogota City	
Latitude	4° 43'38.4"N	Longitude	74° 01'22.5"W	Elevation	2597

Surface Geology

K2t

Aerial Photograph

Local Situation

Note

Storage site for material under the unwrought quarry

Name	E-10	Reagion	Eastern hill	Bogota City	
Latitude	4° 44'01.6"N	Longitude	74° 01'24.4"W	Elevation	2587

Surface Geology

K2t

Aerial Photograph

Local Situation

Note

Under the remain of quarry

Name	E-11	Reagion	Eastern hill	Bogota City	
Latitude	4° 44'09.6"N	Longitude	74° 01'26.4"W	Elevation	2577

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

E-11 well point is in the remain of quarry.

Name	E-12	Reagion	Eastern hill	Bogota City	
Latitude	4° 44'24.6"N	Longitude	74° 01'20.9"W	Elevation	2583

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Compound of Servita company

Name	E-13	Reagion	Eastern hill	Bogota City	
Latitude	4° 44'42.8"N	Longitude	74° 01'19.2"W	Elevation	2592

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Unwrought quarry

Name	E-14	Reagion	Eastern hill	Bogota City	
Latitude	4° 45'17.4"N	Longitude	74° 01'22.5"W	Elevation	2605

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

La Salle existing well (confined-water well)

Name	E-15	Reagion	Eastern hill	Bogota City	
Latitude	4° 45'45.5"N	Longitude	74° 01'36.8"W	Elevation	2578

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

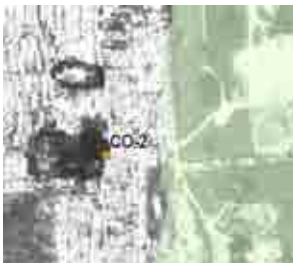
Grassland by the side of road (7 avenue)

Name	CO-2	Reagion	Eastern hill	Bogota City	
Latitude	4°45'53.4"N	Longitude	74°01'26.6"W	Elevation	2643

Surface Geology

Q2c(K2t)

Aerial Photograph



Local Situation

Note

Suba existing well

Name	E-16	Reagion	Eastern hill	Bogota City	
Latitude	4° 45'27.00"N	Longitude	74° 04'42.2"W	Elevation	2581

Surface Geology

K2E1g(K2t)

Aerial Photograph

Local Situation

Note

Suba existing well

Name	E-17	Reagion	Eastern hill	Bogota City	
Latitude	4° 45'40.0"N	Longitude	74° 4'53.4"W	Elevation	2575

Surface Geology

Q1sa(K2E1g,K2t)

Aerial Photograph

Local Situation

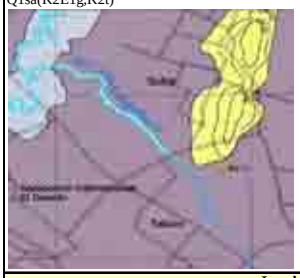
Note

Marical Sucre existing well

Name	ST-1	Reagion	Eastern hill	Bogota City	
Latitude	4°42'42.2"N	Longitude	74°05'00.2"W	Elevation	

Surface Geology

Q1sa(K2E1g,K2t)



Aerial Photograph

Local Situation

Note

Marical Sucre existing well

Name	ST-2	Reagion	Eastern hill	Bogota City	
Latitude	4°42'43.6"N	Longitude	74°05'03.6"	Elevation	2588

Surface Geology

Q1sa(K2E1g,K2t)

Aerial Photograph

Local Situation

Note

Mariscal Sucre existing well

Name	ST-3	Reagion	Eastern hill	Bogota City	
Latitude	4°42'45.0"N	Longitude	74°05'05.4"W	Elevation	

Surface Geology

Q1sa(K2E1g,K2t)

Aerial Photograph

Local Situation

Note

Maricial Sucre existing well

Name	Y-1	Reagion	Yerba Buena	Bogota City	
Latitude	4˚ 46'14.1"N	Longitude	74˚ 01'38.4"W	Elevation	2570

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Grassland in the factory of AMERICAN PIPE

Name	Y-2	Reagion	Yerba Buena	Bogota City	
Latitude	4˚ 46'28.3"N	Longitude	74˚ 01'36.9"W	Elevation	2571

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Meadow

Name	Y-3	Reagion	Yerba Buena	Bogota City	
Latitude	4˚ 46'34.6"N	Longitude	74˚ 01'35.8"W	Elevation	2571

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Meadow by the side of substation

Name	Y-4	Reagion	Yerba Buena	Bogota City	
Latitude	4° 47'04.4"N	Longitude	74° 01'42.3"W	Elevation	2575

Surface Geology

Q2c(K2p)

Aerial Photograph

Local Situation

Note

game place

Name	Y-5	Reagion	Yerba Buena	Bogota City	
Latitude	4° 47'10.5"N	Longitude	74° 01'40.4"W	Elevation	2582

Surface Geology

Q2c(K2p)

Aerial Photograph

Local Situation

Note

Meadow

Name	Y-6	Reagion	Yerba Buena	Bogota City	
Latitude	4° 47'21.3"N	Longitude	74° 01'42.9"W	Elevation	2571

Surface Geology

Q2c(K2p)

Aerial Photograph

Local Situation

Note

Meadow

Name	Y-7	Reagion	Yerba Buena	Bogota City	
Latitude	4° 47'32.2"N	Longitude	74° 01'45.9"W	Elevation	2573

Surface Geology

Q2c(K2p)

Aerial Photograph

Local Situation

Note

Meadow

Name	Y-8	Reagion	Yerba Buena	Bogota City	
Latitude	4° 47'44.9"N	Longitude	74° 01'53.8"W	Elevation	2581

Surface Geology

Q2c(K2t)

Aerial Photograph

Local Situation

Note

Meadow

Name	Y-9	Reagion	Yerba Buena	Bogota City	
Latitude	4° 48'20.5"N	Longitude	74° 01'48.5"W	Elevation	2568

Surface Geology

K2t

Aerial Photograph

Local Situation

Note

Grassland of ivent place

Name	Y-10	Reagion	Yerba Buena	Bogota City	
Latitude	4° 48'34.4"N	Longitude	74° 01'50.3"W	Elevation	2570

Surface Geology

Q2c,Q2ch

Aerial Photograph

Local Situation

Note

Grassland

Name	Y-11	Reagion	Yerba Buena	Bogota City	
Latitude	4° 49'02.2"N	Longitude	74° 01'51.6"W	Elevation	2569

Surface Geology

Q2c,Q2ch

Aerial Photograph

Local Situation

Note

Grassland

Name	Y-12	**Reagion**	Yerba Buena	Bogota City	
Latitude	4° 49'17.7"N	**Longitude**	74° 01'53.4"W	**Elevation**	2586

Surface Geology

K2t, west limb of anticline

Aerial Photograph

Local Situation

Note

Meadow near the remain of factory

CHAPTER 2. PROPOSED WELL SITES IN SOUTERN HILLS

Name	B-1	Reagion	Ciudad Bolivar	Bogota City	
Latitude	4˚32'21.9"N	Longitude	74˚09'37.7"W	Elevation	2835

Surface Geology

K2p, east limb of anticline

Aerial Photograph

Local Situation

Note

Grassland at confluence of two valley

Name	EX-2	Reagion	Ciudad Bolivar	Bogota City	
Latitude	4˚32'14.4"N	Longitude	74˚09'51.7"W	Elevation	2867

Surface Geology

K2p, axis of anticline

Aerial Photograph

Local Situation

Note

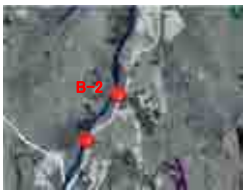
Exploratory well, grassland

Name	B-2	Reagion	Ciudad Bolivar	Bogota City	
Latitude	4˚32'02.7"N	Longitude	74˚09'56.1"W	Elevation	2907

Surface Geology

K2p, axis of anticline

Aerial Photograph



Local Situation

Note

Grassland near the river

Name	B-3	Reagion	Ciudad Bolivar	Bogota City	
Latitude	4°31'58.2"N	Longitude	74°10'01.4"W	Elevation	2918

Surface Geology

K2p, axis of anticline

Aerial Photograph

Local Situation

Note

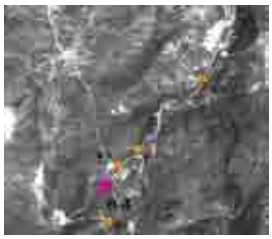
Grassland near the river

Name	B-4	**Reagion**	Soacha	Soacha City	
Latitude	4°31'52.3"N	**Longitude**	74°10'04.0"W	**Elevation**	2945

Surface Geology

K2d, hanging wall of fault

Aerial Photograph



Local Situation

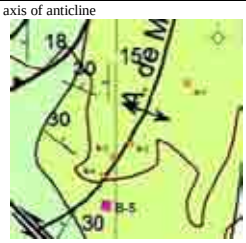
Note

Exploratory well, near the pond in meadow

Name	B-5	**Reagion**	Ciudad Bolivar	Bogota City	
Latitude	4°31'42.7"N	**Longitude**	74°10'04.4"W	**Elevation**	2987

Surface Geology

K2p, axis of anticline



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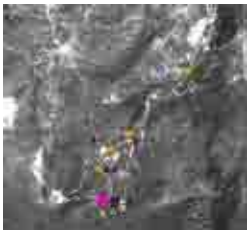


Local Situation

Note

Grassland near the river

Name	S-1	**Reagion**	Soacha	Soacha City	
Latitude	4° 33'43.3"N	**Longitude**	74° 11'20.8"W	**Elevation**	2746

Surface Geology

K2d,west limb of anticline

Aerial Photograph

Local Situation

Note

Remain of quarry

Name	EX-1	**Reagion**	Soacha	Soacha City	
Latitude	4° 33'21.7"N	**Longitude**	74° 10'46.4"W	**Elevation**	2786

Surface Geology

K2d, hanging wall of fault

Aerial Photograph

Local Situation

Note

Exploratory well, near the pond in meadow

Name	S-2	Reagion	Soacha	Soacha City	
Latitude	4° 33'42.2"N	Longitude	74° 11'08.2"W	Elevation	2760

Surface Geology

K2d,west limb of anticline

Aerial Photograph

Local Situation

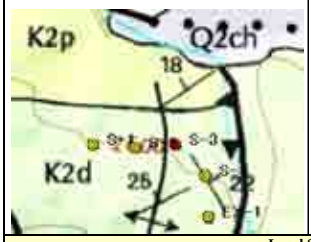
Note

Grassland near the road

Name	S-3	Reagion	Soacha	Soacha City	
Latitude	4° 33'43.3"N	Longitude	74° 10'56.4"W	Elevation	2748

Surface Geology

K2d, axis of anticline



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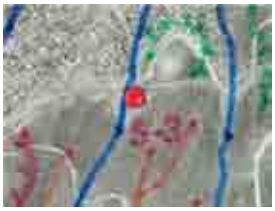


Local Situation

Note

grassland by the side of soccer ground

Name	S-4	Reagion	Soacha	Soacha City	
Latitude	4° 33'33.6"N	Longitude	74° 10'47.6"W	Elevation	2762

Surface Geology

K2d, east limb of anticline

Aerial Photograph

Local Situation

Note

grassland near the road

Name	S-5	Reagion	Soacha	Soacha City	
Latitude	4° 33'08.9"N	Longitude	74° 10'49.9"W	Elevation	2809

Surface Geology

K2d, hanging wall of fault

Aerial Photograph

Local Situation

Note

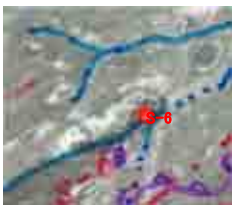
Valley in meadow

Name	S-6	**Reagion**	Soacha	Soacha City	
Latitude	4° 33'00.4"N	**Longitude**	74° 10'56.3"W	**Elevation**	2837

Surface Geology

K2d, hanging wall of fault

Aerial Photograph



Local Situation

Note

Confluence of two valley in meadow

Name	EX-3	**Reagion**	Usme	Bogota City	
Latitude	4° 29'38.1"N	**Longitude**	74° 04'51.5"W	**Elevation**	3073

Surface Geology

E1b, footwall of Bogota fault

Aerial Photograph

Local Situation

Note

Exploratory well, remain of bear factory

CHAPTER 3. PROPOSED WELL SITES IN YERBABUENA

Name	Y-13	Reagion	Yerba Buena	Chia City	
Latitude	4° 49'45.4"N	Longitude	74° 01'51.7"W	Elevation	2566

Surface Geology

K2t, west limb of anticline

Aerial Photograph

Local Situation

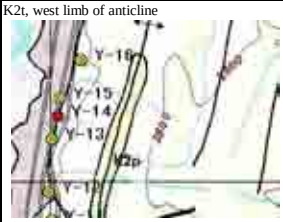
Note

Meadow

Name	Y-14	Reagion	Yerba Buena	Chia City	
Latitude	4° 49'57.4"N	Longitude	74° 01'48.4"W	Elevation	2564

Surface Geology

K2t, west limb of anticline



Aerial Photograph

Local Situation

Note

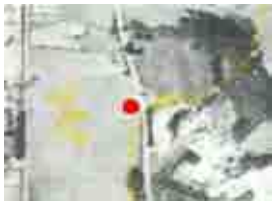
Grassland

Name	Y-15	Reagion	Yerba Buena	Chia City	
Latitude	4° 50'07.1"N	Longitude	74° 01'47.7"W	Elevation	2558

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph



Local Situation

Note

Meadow nearby the gate of toll road

Name	Y-16	Reagion	Yerba Buena	Chia City	
Latitude	4° 50'27.2"N	Longitude	74° 01'36.2"W	Elevation	2564

Surface Geology

K2t, west limb of anticline

Aerial Photograph

Local Situation

Note

Meadow nearby the soccer ground

Name	Y-17	Reagion	Yerba Buena	Chia City	
Latitude	4° 50'55.6"N	Longitude	74° 01'35.4"W	Elevation	2556

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph

Local Situation

Note

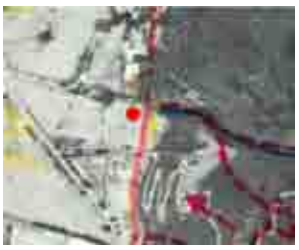
Grassland nearby the outcrop of Labor-Tierna formation

Name	Y-18	Reagion	Yerba Buena	Chia City	
Latitude	4° 51'15.1"N	Longitude	74° 01'25.6"W	Elevation	2571

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph



Local Situation

Note

Grassland alow the outcrop of Labor-Tierna formation

Name	Y-19	Reagion	Yerba Buena	Chia City	
Latitude	4° 51'21.4"N	Longitude	74° 01'17.6"W	Elevation	2617

Surface Geology

K2t, west limb of anticline

Aerial Photograph

Local Situation

Note

In the experimental farm of Lasayi Univesity

Name	Y-20	Reagion	Yerba Buena	Chia City	
Latitude	4° 51'38.8"N	Longitude	74° 01'28.8"W	Elevation	2577

Surface Geology

K2E1g

Aerial Photograph

Local Situation

Note

Meadow in the backside of CATOLICA university campus

Name	Y-21	Reagion	Yerba Buena	Chia City	
Latitude	4° 52'29.5"N	Longitude	74° 00'53.8"W	Elevation	2570

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph

Local Situation

Note

Residential land

Name	Y-22	Reagion	Yerba Buena	Sopo City	
Latitude	4° 52'43.5"N	Longitude	74° 00'48.4"W	Elevation	2566

surface geology

K2t, west limb of anticline, along the lineament

aerial photograph

Local Situation

Note

Grassland in the backside of INSTITUTO CARO Y CUERVO soccer ground

Name	Y-23	Reagion	Yerba Buena	Sopo City	
Latitude	4° 52'52.3"N	Longitude	74° 00'45.6"W	Elevation	2563

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph

Local Situation

Note

Grassland neighboring of COLEGIO school

Name	Y-24	Reagion	Yerba Buena	Sopo City	
Latitude	4° 53'21.3"N	Longitude	74° 00'34.8"W	Elevation	2557

Surface Geology

Q1sa(K2t)

Aerial Photograph

Local Situation

Note

Meadow on the west of CASAS road

Name	Y-25	Reagion	Yerba Buena	Sopo City	
Latitude	4° 53'35.2"N	Longitude	74° 00'26.9"W	Elevation	2559

Surface Geology

Q1sa(K2t)

Aerial Photograph

Local Situation

Note

Meadow

Name	Y-26	Reagion	Yerba Buena	Sopo City	
Latitude	4° 53'46.8"N	Longitude	74° 00'22.6"W	Elevation	2559

Surface Geology

Q1sa(K2t)

Aerial Photograph

Local Situation

Note

Glebe

Name	Y-27	Reagion	Yerba Buena	Sopo City	
Latitude	4° 54'49.5"N	Longitude	73° 59'50.3"W	Elevation	2558

Surface Geology

Q1sa(K2d), west limb of anticline

Aerial Photograph

Local Situation

Note

Nearby the jumping well

Name	Y-28	Reagion	Yerba Buena	Sopo City	
Latitude	4° 55'08.5"N	Longitude	73° 59'51.1"W	Elevation	2554

Surface Geology

Q1sa(K2d), west limb of anticline

Aerial Photograph

Local Situation

Note

Grassland

Name	Y-29	**Reagion**	Yerba Buena	Sopo City	
Latitude	4° 55'21.2"N	**Longitude**	73° 59'47.8"W	**Elevation**	2561

Surface Geology

K2d, west limb of anticline

Aerial Photograph

Local Situation

Note

Meadow

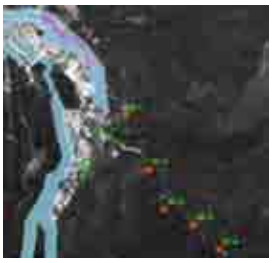
CHAPTER 4. PROPOSED WELL SITE WITHIN FOREST PROTECTION AREA

Name	VI-1	Reagion	Bogota	San Cristbal	Vitelma
Latitude	4°33'33.5"N	Longitude	74°03'48.0"	Elevation	2881

Surface Geology

Q2c(K2t)

Aerial Photograph



Local Situation

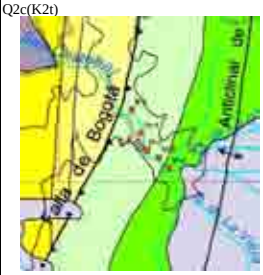
Note

Grassland in the factory of AMERICAN PIPE

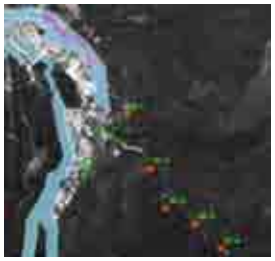
Name	VI-2	Reagion	Bogota	San Cristbal	Vitelma
Latitude	4°33'23.3"N	Longitude	74°03'44.2"W	Elevation	2911

Surface Geology

Q2c(K2t)



Aerial Photograph



Local Situation

Note

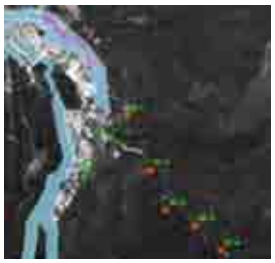
Meadow

Name	VI-3	Reagion	Bogota	San Cristbal	Vitelma
Latitude	4°33'19.1"N	Longitude	74°03'37.3"W	Elevation	2918

Surface Geology

Q2c(K2t)

Aerial Photograph



Local Situation

Note

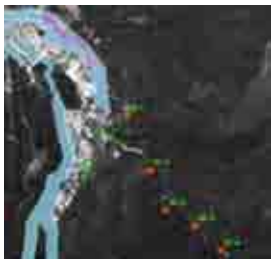
Meadow by the side of substation

Name	VI-4	Reagion	Bogota	San Cristbal	Vitelma
Latitude	4°33'12.8"N	Longitude	74°03'31.2"	Elevation	2921

Surface Geology

Q2c(K2p)

Aerial Photograph



Local Situation

Note

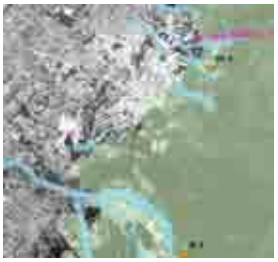
Game place

Name	SI-1	Reagion	Bogota	Santa Fe	Sant Isabel
Latitude		Longitude		Elevation	

Surface Geology

Q2c(K2p)

Aerial Photograph



Local Situation

Note

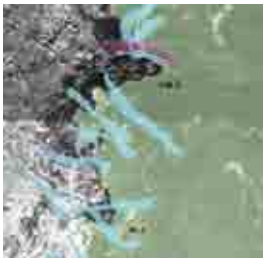
Meadow

Name	CM-1	Reagion	Bogota	Santa Fe	Casa Molino
Latitude	4°36'04.5"N	Longitude	74°03'33.0"W	Elevation	2715

Surface Geology

Q2c(K2p)

Aerial photograph



Local Situation

Note

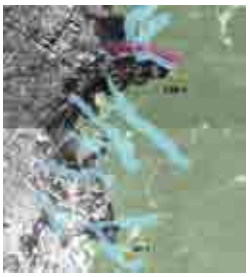
Meadow

Name	CM-2	Reagion	Bogota	Santa Fe	Casa Molino
Latitude	4°36'01.6"N	Longitude	74°03'31.5"	Elevation	2728

Surface Geology

Q2c(K2p)

Aerial Photograph



Local Situation

Note

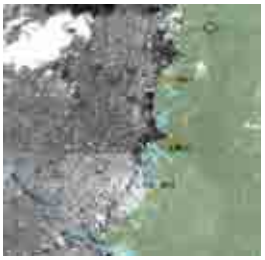
Meadow

Name	TS-1	Reagion	Bogota	Santa Fe	Tank Silencio
Latitude	4°37'06.2"N	Longitude	74°03'28.4"W	Elevation	2,790

Surface Geology

Q2c(K2t)

Aerial Photograph



Local Situation

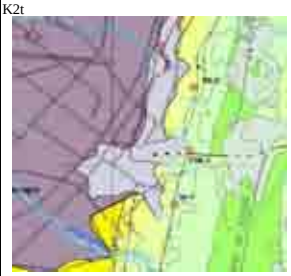
Note

Meadow

Name	TS-2	Reagion	Bogota	Santa Fe	Tank Silencio
Latitude	4°37'10.8"N	Longitude	74°03'25.8"	Elevation	2,771

Surface Geology

K2t



Aerial Photograph

Local Situation

Note

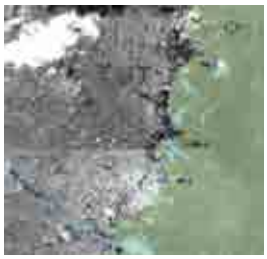
Grassland of ivent place

Name	TS-3	Reagion	Bogota	Santa Fe	Tank Silencio
Latitude	4°36'53.35"N	Longitude	74°03'32.05"W	Elevation	2,774

Surface Geology

Q2c,Q2ch

Aerial Photograph



Local Situation

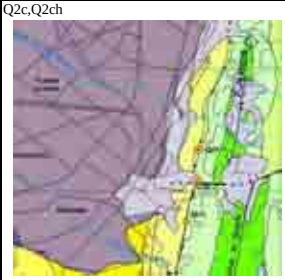
Note

Grassland

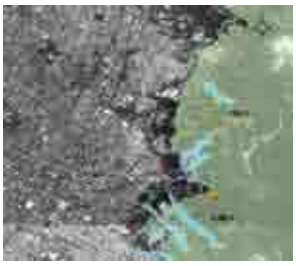
Name	OH-1	Reagion	Bogota	Santa Fe	Olaya Herrera
Latitude	4°36'42.16"N	Longitude	74°03'31.64W	Elevation	2,800

Surface Geology

Q2c,Q2ch



Aerial Photograph



Local Situation

Note

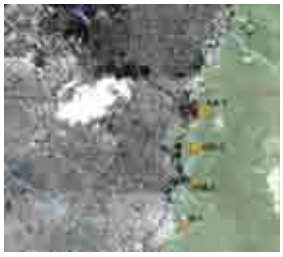
Grassland

Name	RA-1	Reagion	Bogota	Santa Fe	Rio Arzobispo
Latitude	4°37'24.3"N	Longitude	74°03'22.9"W	Elevation	2721

Surface Geology

K2t, west limb of anticline

Aerial Photograph



Local Situation

Note

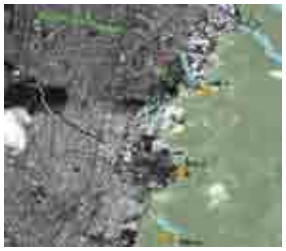
Meadow near the remain of factory

Name	UP-1	Reagion	Bogota	Chapinero	Unv. Poli-Technology
Latitude	4°38'16.0"N	Longitude	74°03'10.0"W	Elevation	2725

Surface Geology

K2t, west limb of anticline

Aerial Photograph



Local Situation

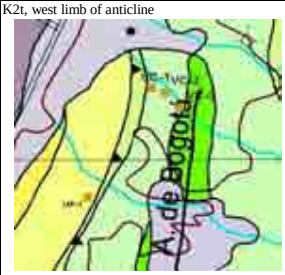
Note

Meadow

Name	VC-1	Reagion	Bogota	Chapinero	La Vieja Creek
Latitude	4°38'57.6"N	Longitude	74°02'48.9"	Elevation	2733

Surface Geology

K2t, west limb of anticline



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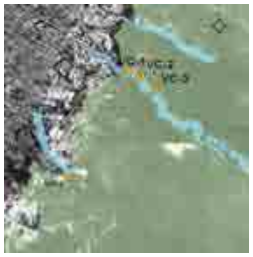


Local Situation

Note

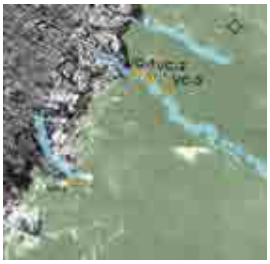
Grassland

Name	VC-2	Reagion	Bogota	Chapinero	La Vieja Creek
Latitude	4°38'55.7"N	Longitude	74°02'44.4"W	Elevation	2757

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph



Local Situation

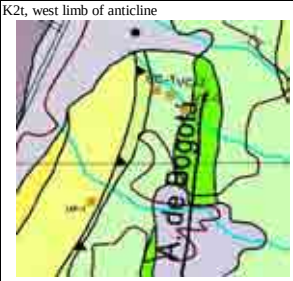
Note

Meadow nearby the gate of toll road

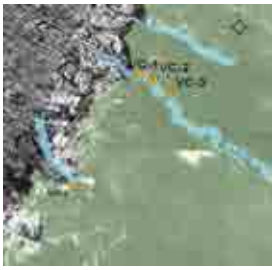
Name	VC-3	Reagion	Bogota	Chapinero	La Vieja Creek
Latitude	4°38'50.1"N	Longitude	74°02'38.9"W	Elevation	2777

Surface Geology

K2t, west limb of anticline



Aerial Photograph



Local Situation

Note

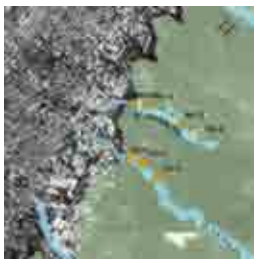
Meadow nearby the soccer ground

Name	RC-1	Reagion	Bogota	Chapinero	Rosales Creek
Latitude	4°39'18.6"N	Longitude	74°02'48.0"W	Elevation	2722

Surface Geology

K2t, west limb of anticline, along the l

Aerial Photograph



Local Situation

Note

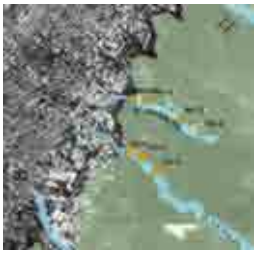
Grassland nearby the outcrop of Labor-Tierna formation

Name	RC-2	Reagion	Bogota	Chapinero	Rosales Creek
Latitude	4°39'17.8"N	Longitude	74°02'41.9"W	Elevation	2774

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph



Local Situation

Note

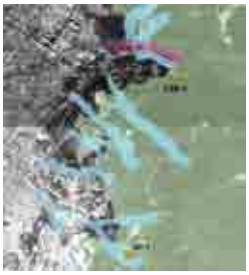
Grassland alow the outcrop of Labor-Tierna formation

Name	CM-2	Reagion	Bogota	Santa Fe	Casa Molino
Latitude	4°36'01.6"N	Longitude	74°03'31.5"	Elevation	2728

Surface Geology

Q2c(K2p)

Aerial Photograph



Local Situation

Note

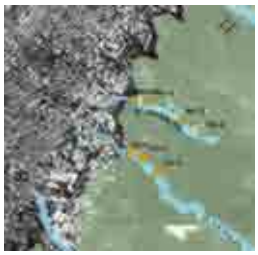
Meadow

Name	RC-3	Reagion	Bogota	Chapinero	Rosales Creek
Latitude	4°39'10.6"N	Longitude	74°02'30.3"W	Elevation	2827

Surface Geology

K2t, west limb of anticline

Aerial Photograph



Local Situation

Note

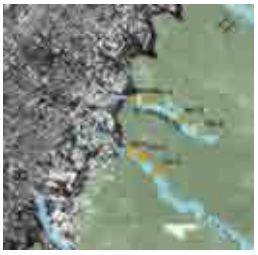
In the experimental farm of Lasayi Univesity

Name	RC-4	**Reagion**	Bogota	Chapinero	Rosales Creek
Latitude	4°39'05.2"N	**Longitude**	74°02'22.8"W	**Elevation**	2857

Surface Geology

K2E1g

Aerial Photograph



Local Situation

Note

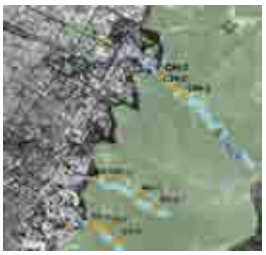
Meadow in the backside of CATOLICA university campus

Name	CH-1	**Reagion**	Bogota	Chapinero	Chico
Latitude	4°40'05.0"N	**Longitude**	74°02'20.5"W	**Elevation**	2709

Surface Geology

K2t, west limb of anticline, along the lineament

Aerial Photograph



Local Situation

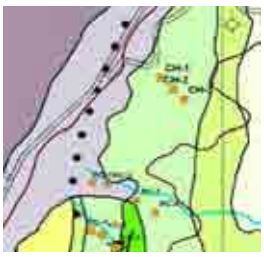
Note

Residential land

Name	CH-2	**Reagion**	Bogota	Chapinero	Chico
Latitude	4°39'59.7"N	**Longitude**	74°02'15.6"	**Elevation**	2748

Surface Geology

K2t, west limb of anticline, along the lineament



Aerial Photograph

Local Situation

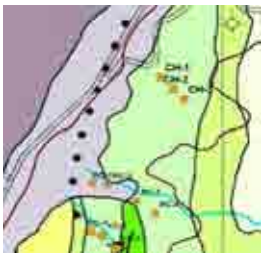
Note

Grassland in the backside of INSTITUTO CARO Y CUERVO soccer ground

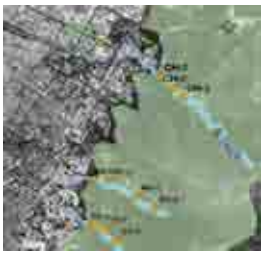
Name	CH-3	**Reagion**	Bogota	Chapinero	Chico
Latitude	4°39'55.3"N	**Longitude**	74°02'11.3"W	**Elevation**	2757

Surface Geology

K2t, west limb of anticline, along the lineament



Aerial Photograph



Local Situation

Note

Grassland neighboring of COLEGIO school

Name	EC-1	**Reagion**	Bogota	Usaquen	Escuela de Caballeria
Latitude	4°40'49.8"N	**Longitude**	74°02'14.4"W	**Elevation**	2600

Surface Geology

Q1sa(K2t)

Aerial Photograph

Local Situation

Name	EC-2	**Reagion**	Bogota	Usaquen	Escuela de Caballeria
Latitude	4°40'53.3"N	**Longitude**	74°02'06.5"W	**Elevation**	2613

Surface Geology

Q1sa(K2t)

Aerial Photograph

Local Situation

Note

Meadow

Name	EC-3	**Reagion**	Bogota	Usaquen	Escuela de Caballeria
Latitude	4°40'55.9"N	**Longitude**	74°02'01.6"W	**Elevation**	2618

Surface Geology

Q1sa(K2t)

Aerial Photograph

Local Situation

Note

Glebe

PART 2

GROUNDWATER MONITORING

Final Report

(Supporting Report)

PART 2 GROUNDWATER MONITORING

Table of Contents

List of Tables and Figures

Page

PART 2. GROUND WATER MONITORING

CHAPTER 1. GROUND WATER MONITORING

Acueducto is continuing groundwater level monitoring by automatic groundwater Level Recorder at 10 sites in Bogotá Plain. Observation begun in 2001 during the JICA Study of Sustainable Groundwater development in Bogotá Plain. Result of Monitoring data is listed below:

Table-2. 1 Site of Monitoring Wells with Automatic Recorder

	Well. No	Coordinate		Depth of Well(m)	Aquifer
		E	N		
No.1	Gibraltar (Soacha)	988,439	1,005,845	198	Quaternary
No.2	Tisquesusa (Facatativa)	976,639	1,022,020	192	
No.3	Siberia (Tabio)	991,462	1,017,974	173	
No.4	Sopo (Sopo)	1,011,020	1,037,638	150	
No.5	Diana	1,013,170	1,038,429	188	
No.6	Choconta	1,049,874	1,067,343	123	
No.7	Suba	999,911	1,017,839	389	Cretaceous
No.8	Guadarrama	1,014,772	1,053,702	Unknown	Quaternary
No.9	Grasco	996,772	1,001,948	Unknown	
No.10	Santa Monica Flowers	977,203	1,014,760	Unknown	

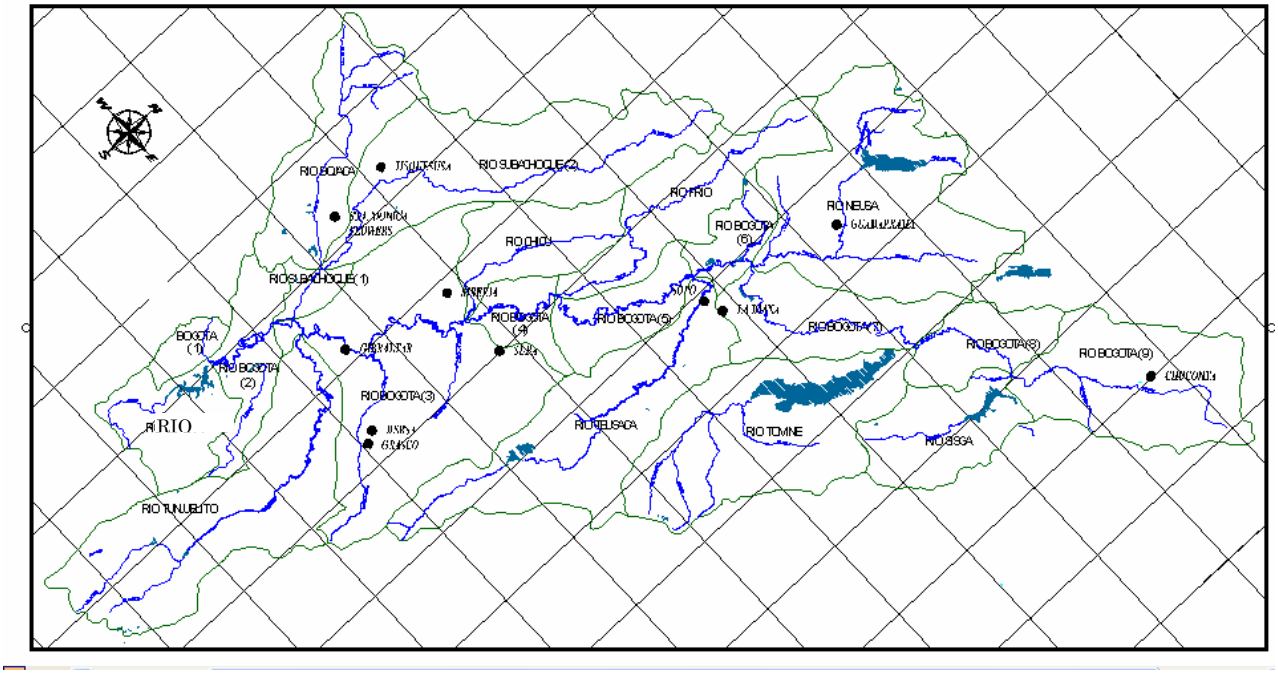
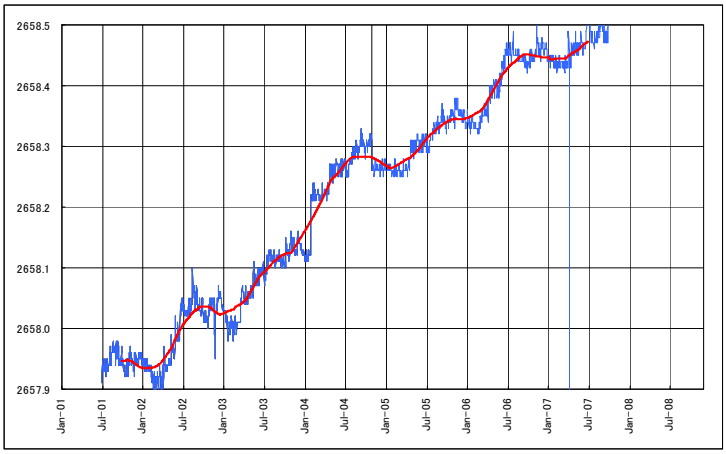
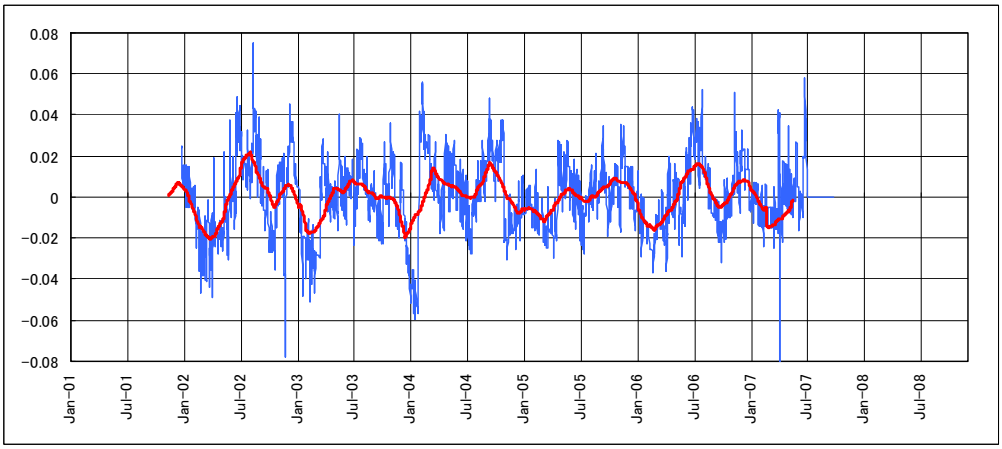


Figure-2. 1 Monitoring Site

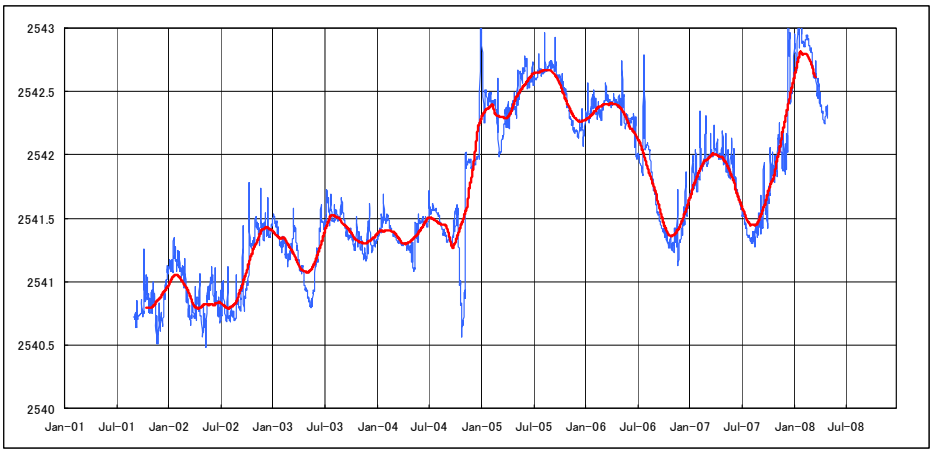


(a) Groundwater Level and Long-term Trend (Moving average)

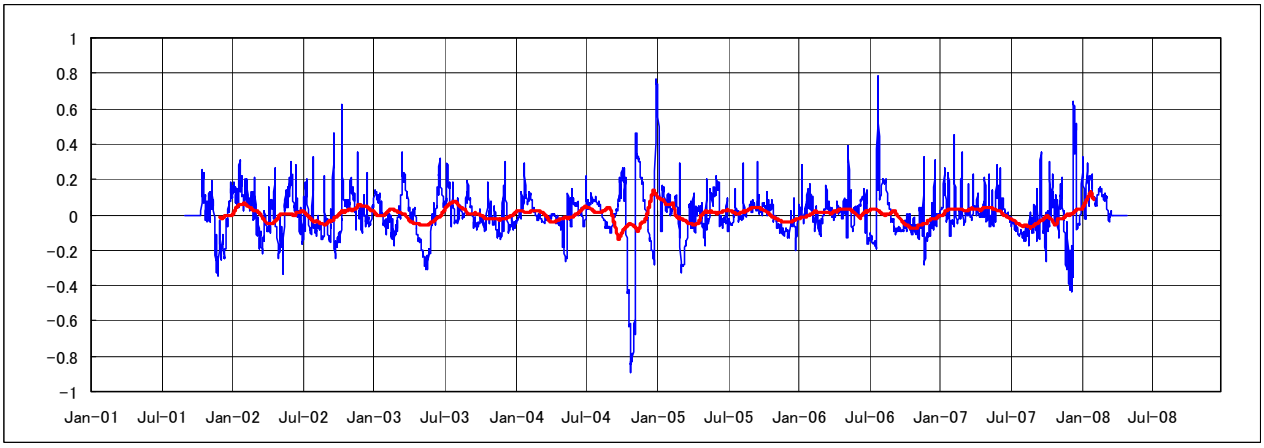


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 2 CHOCONTA

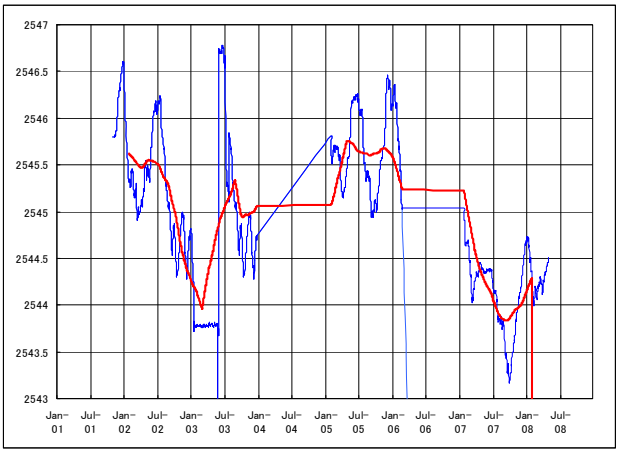


(a) Groundwater Level and Long-term Trend (Moving average)

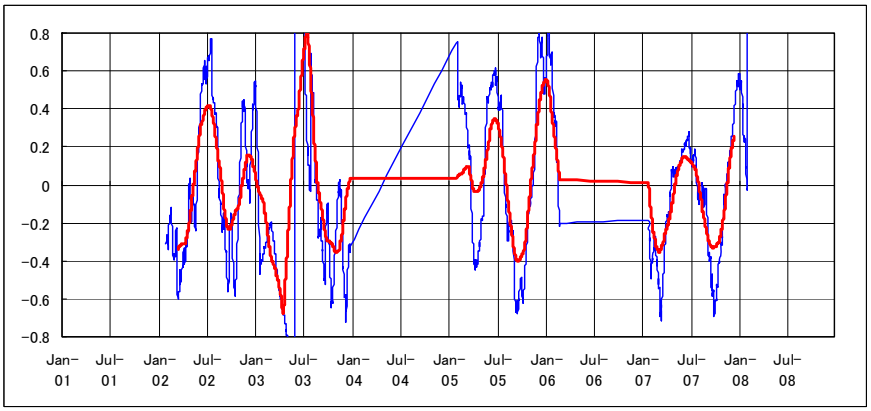


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 3Dersa

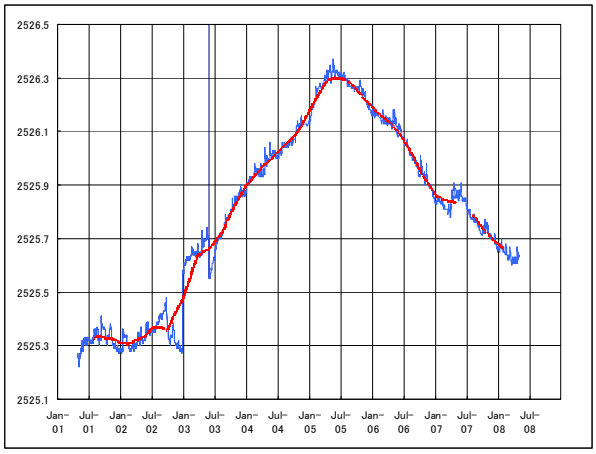


(a) Groundwater Level and Long-term Trend (Moving average)

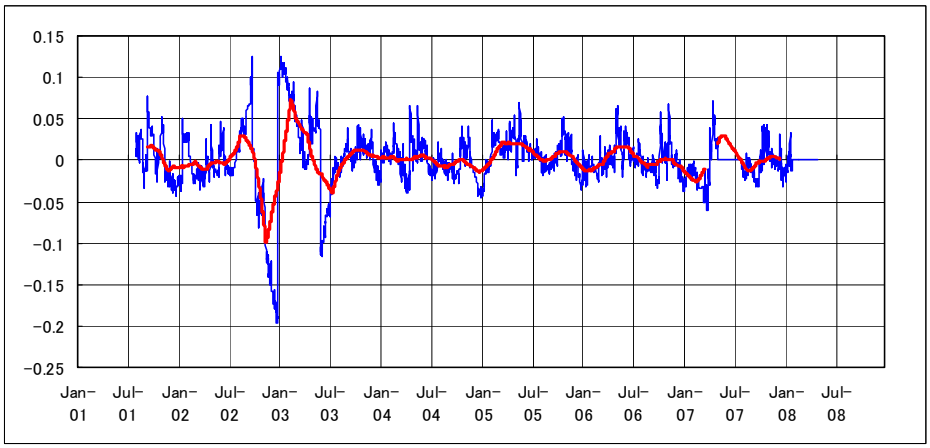


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 4Suba Cota

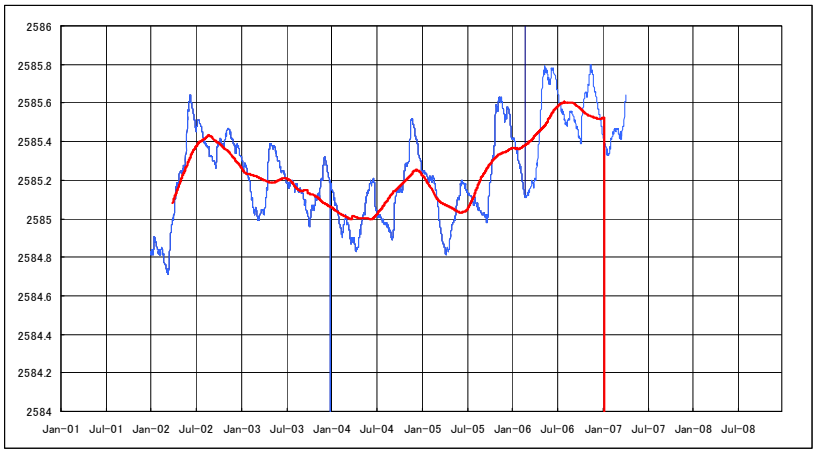


(a) Groundwater Level and Long-term Trend (Moving average)

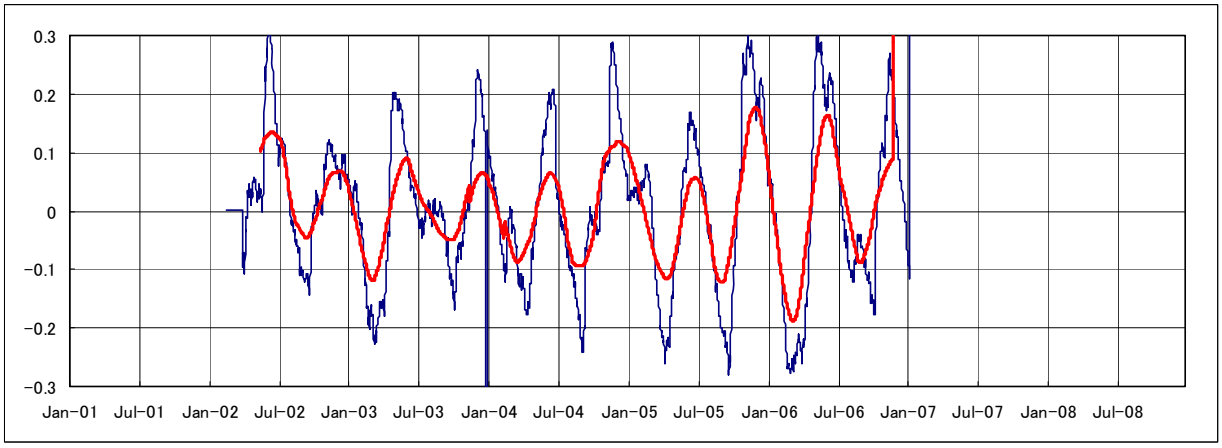


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 5 Gibraltar

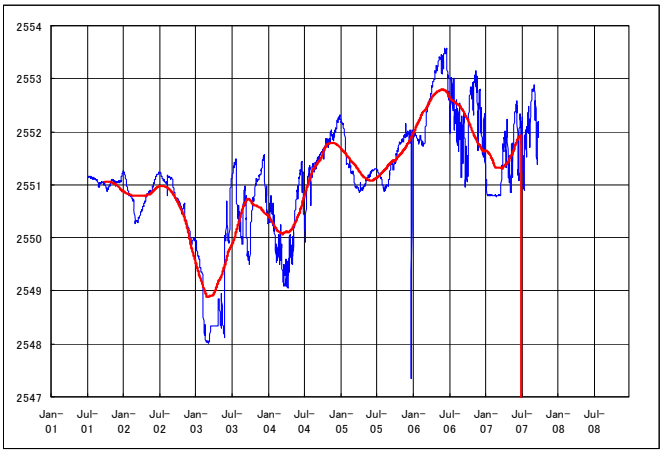


(a) Groundwater Level and Long-term Trend (Moving average)

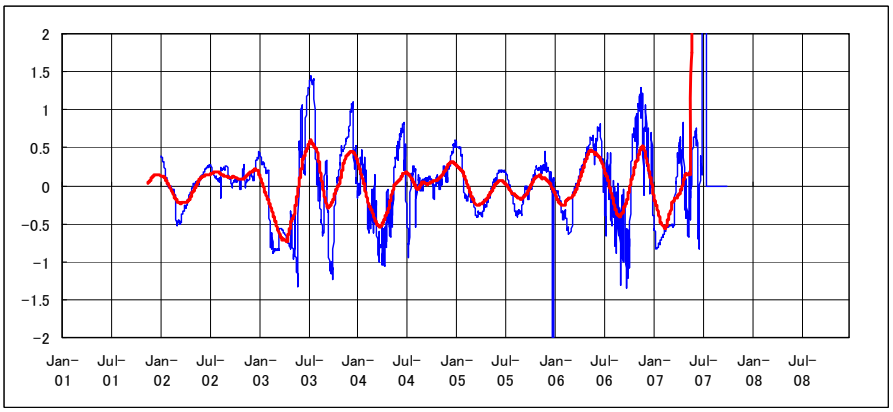


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 6 GUADARRAMA

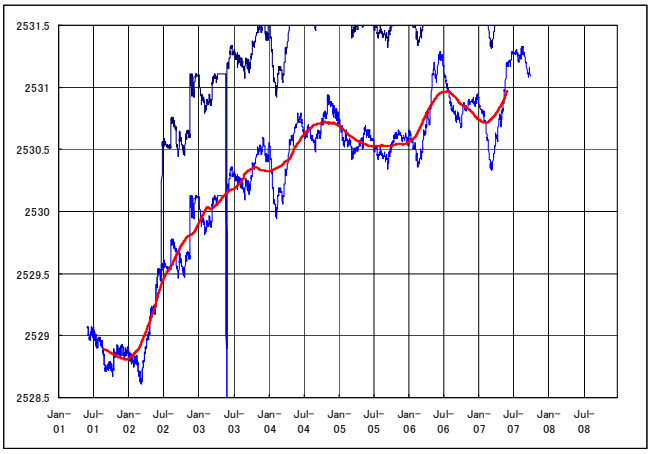


(a) Groundwater Level and Long-term Trend (Moving average)

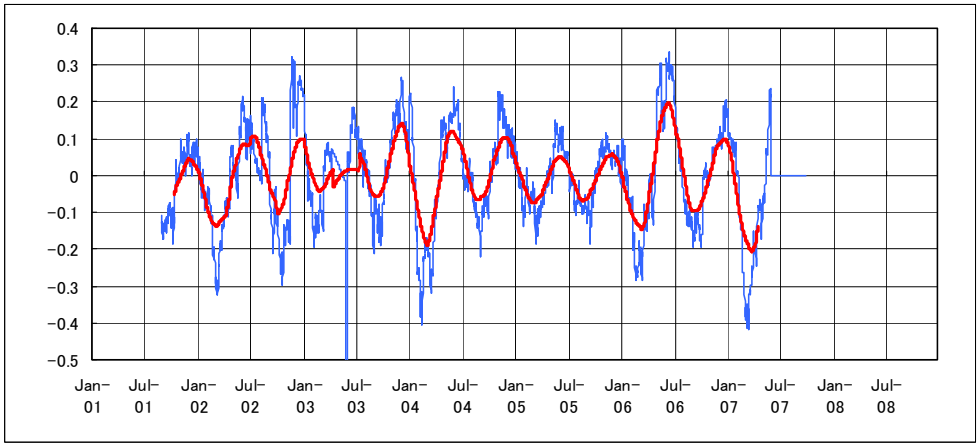


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 7 LA DIANA

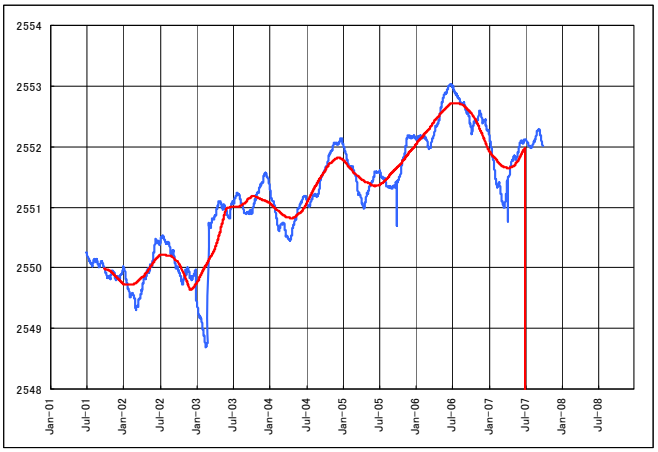


(a) Groundwater Level and Long-term Trend (Moving average)

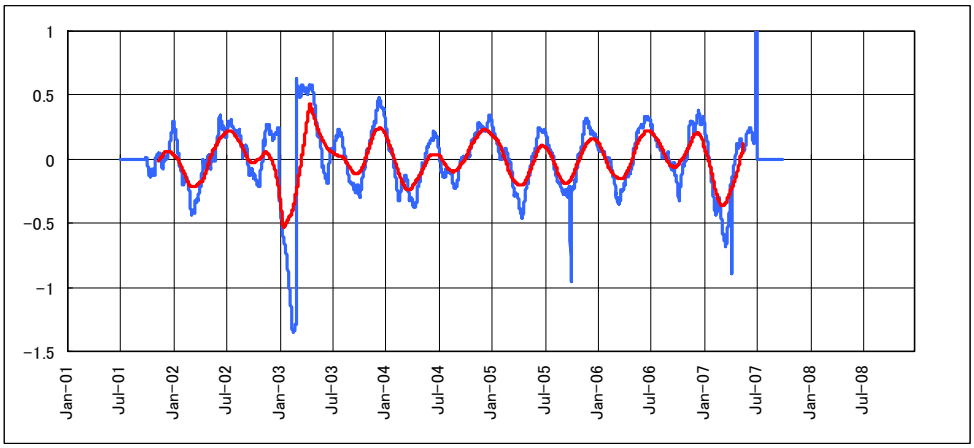


(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 8 SIBERIA



(a) Groundwater Level and Long-term Trend (Moving average)



(b) Seasonal Fluctuation of Groundwater Level and its Trend (Moving average)

Figure-2. 9 SOPO

PART 3

GEOPHYSICAL SURVEY

Final Report

(Supporting Report)

PART 3 GEOPHYSICAL SURVEY

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List of Tables and Figures

PART 3 GEOPHYSICAL SURVEY

CHAPTER 1. THE TECHNIQUE OF GEOPHYSICAL SURVEY

(a) Theory

The TEM method was applied as geophysical survey for this study.

The TEM method is one of the electromagnetic techniques which induce an electric current to the earth using an electromagnetic-phenomenon.

Electromagnetic (EM) geophysical techniques induce electrical currents in the earth using electromagnetic induction. A time varying magnetic field is created using a loop of wire on the earth surface. Faraday's law of induction tells us that a changing magnetic field will produce an electric field, which in turn will create an electric current. Thus, the primary magnetic field from the transmitter loop will create a secondary electric current in the earth.

Finally, we measure the secondary magnetic field produced by those secondary electric currents in the earth.

This technique is often called a transient electromagnetic method (TEM) or a time-domain electromagnetic method (TDEM). In this study, this technique is called the TEM method.

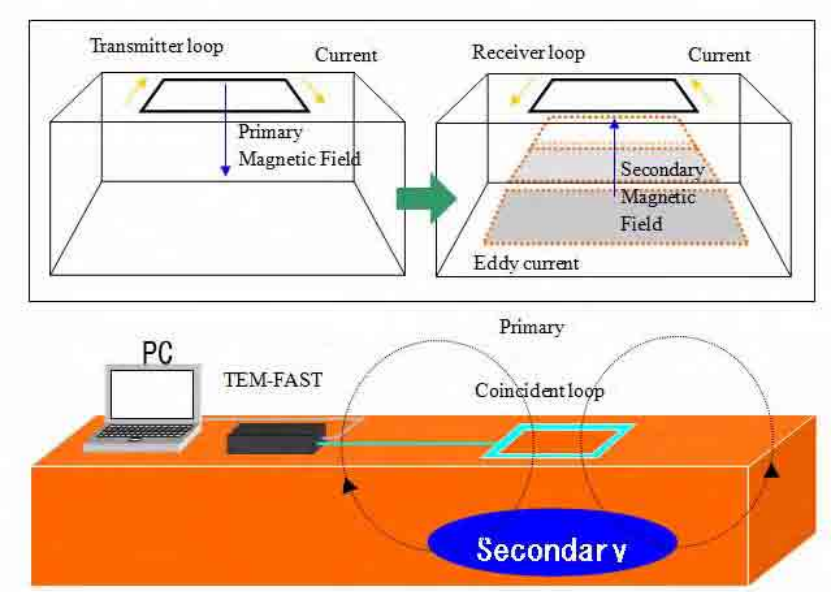


Figure-3. 1 Rowland B. French, Ph.D., R.G.: Time-Domain Electromagnetic Exploration

1) TEM

The benefit of TEM

The TDEM technique has several advantages over the more traditional DC resistivity technique. TDEM does not require large electrode arrays and so is less sensitive to lateral changes in the soils. DC resistivity requires long electrode spreads with lengths that are typically three to five times the depth of exploration.

Thus, the investigation to depths of three hundred meters requires an area of uniform horizontally stratified soils with a lateral extent in excess of nine hundred meters. Controlled Sourced Audio-frequency Magneto-telluric or CSAMT requires putting 10 ampere current using an earthed dipole longer than 1,000 meters far 4,000 to 8,000 meters from survey area and Engine-powered generator-transmitter. In contrast, TDEM techniques can obtain depths of exploration of several hundred meters with a 50 meters transmitter loop.

2) Field survey

The TEM survey was carried out in following three areas, the Southern Hills, the Eastern Hills, and the

South Eastern Hills. TEM Survey stations are shown in a figure. As power lines, metallic material, power generators, cars, buried pipelines, cellular phones, and wireless equipment affect signals of TEM, TEM survey stations were selected carefully.

TEM-FAST uses coincident Loop which means that the same square loop is used as a receiver loop and a transmitter loop. 25 meter, 50 meter, and 200 meter square loops, were basically used in this study.

CHAPTER 2. SURVEY RESULT OF EASTERN HILLS

a) The Eastern Hills

The TEM survey was carried out in the Eastern Hills. Most of western slope of the Eastern Hills are covered by broad-leaved forest. Among them rich condominium for high-income bracket, pasture land, farm land, quarry. Most of western slope of the Eastern Hills are occupied private land, being surrounded with fences, barbed wires, where strictly limited. Especially the residential section is patrolled with trained guards and dogs due to poor security in Bogota. We took almost one month to get the entry permission from reconnaissance through application with documents.

The TEM surveys were mainly carried out in pasture land, farm land, quarry sites or among thin woods. On field operations, 25 meters, 50 meters and 200 meters square loops on the surface were basically used there. Although the maximum loop sizes on most of stations were 170 meters or 200 meters, sizes of area limited the maximum size of loop as 65 meters, 100 meters and 50 meters in the BEH007, BEH015, and BEH021 respectively.

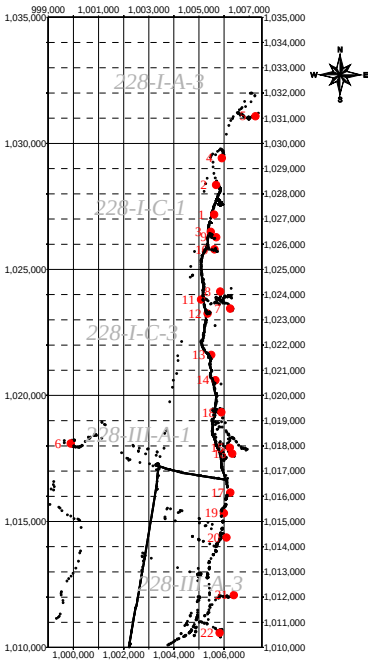


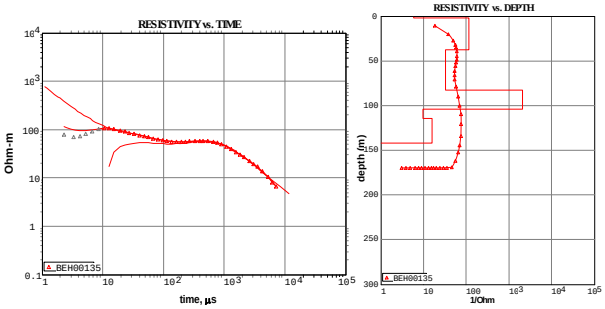
Figure-3. 2 TEM Survey Points Location In Eastern Hills

The diagrams of TEM data and 1D analyzed model on each TEM station are shown in figures.

Data and Graphic 1D Modeling for TEM in Eastern Hills

Eastern Hills

BEH001



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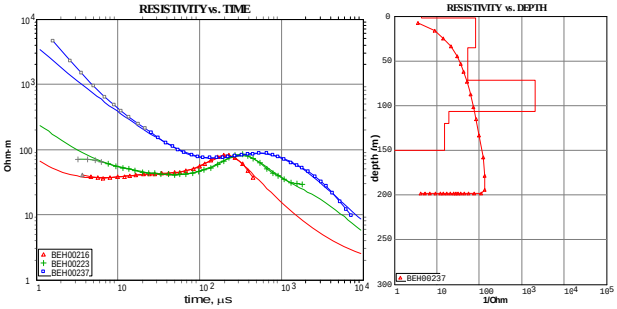

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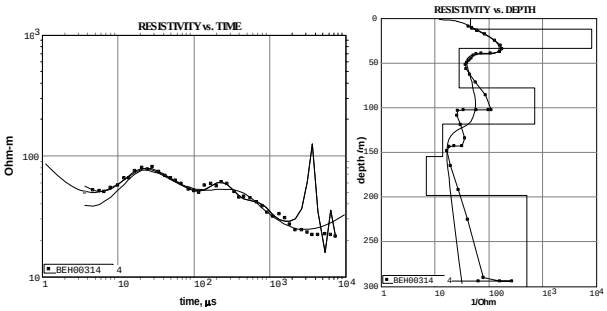

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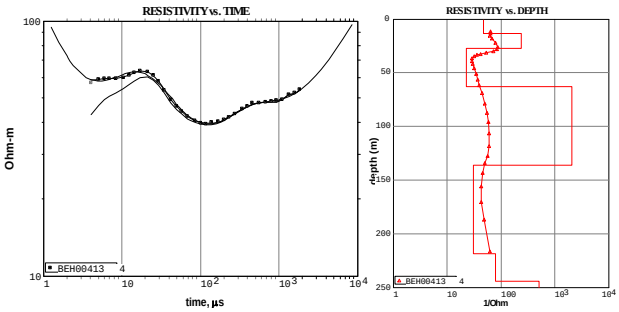

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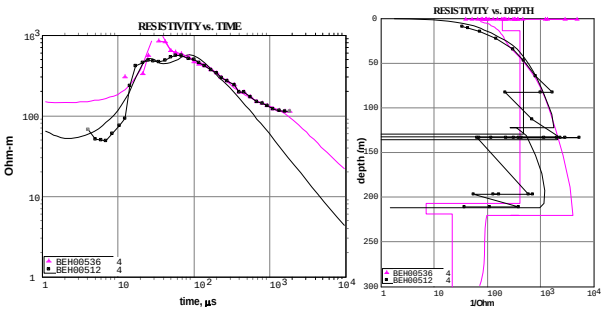

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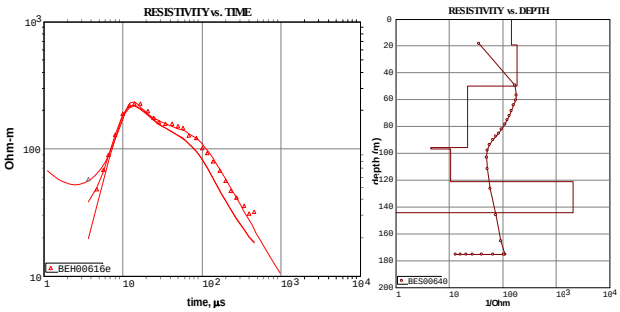

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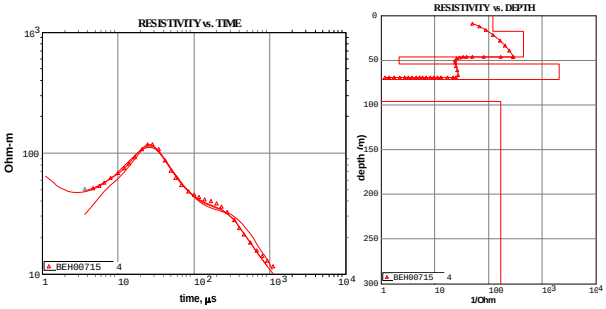

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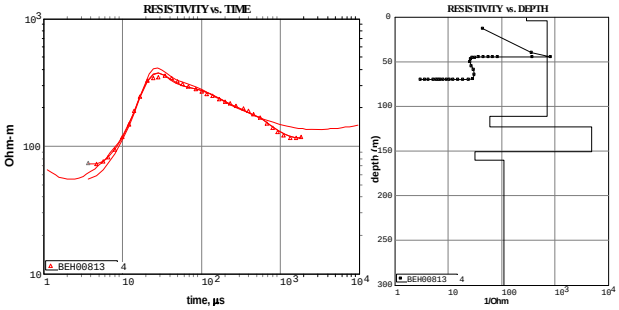

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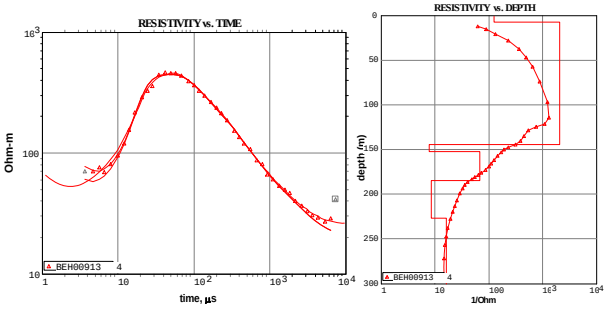

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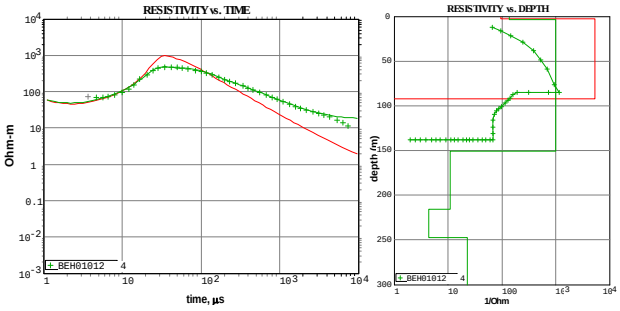

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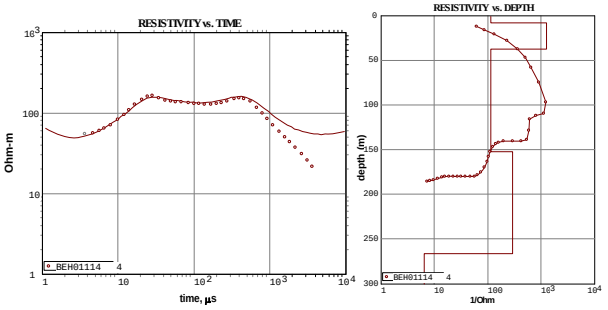

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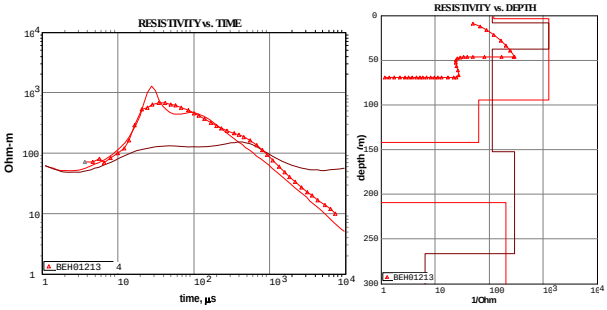

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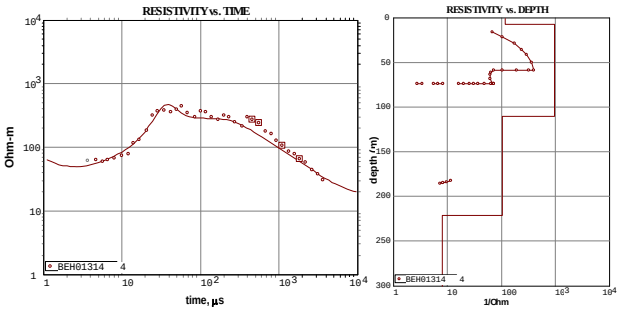

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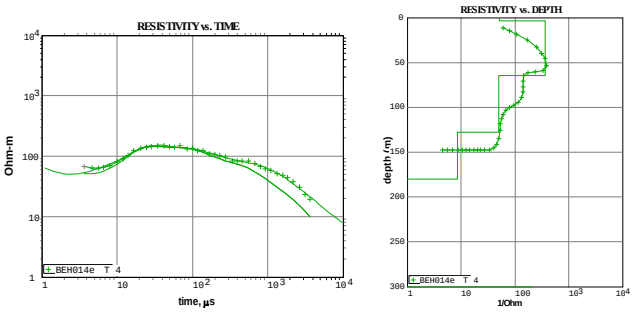

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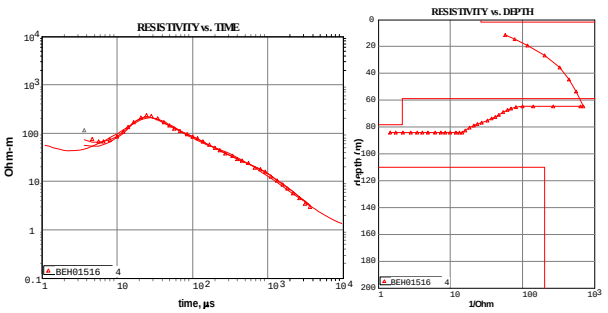

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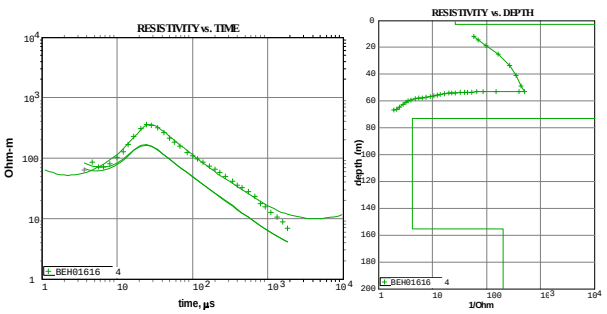

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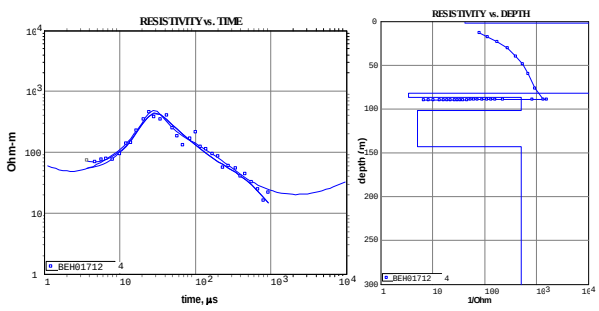

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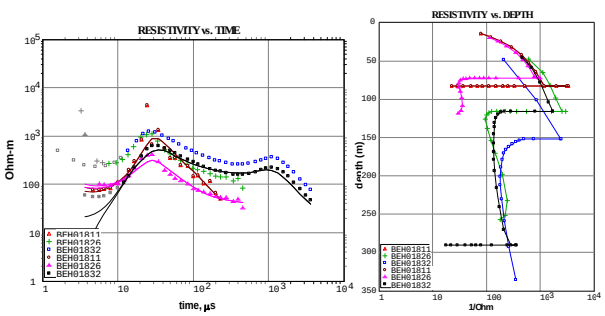

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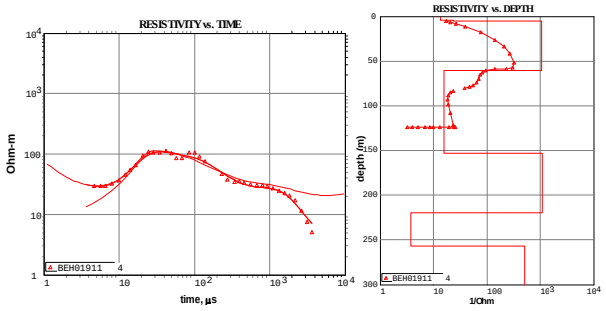

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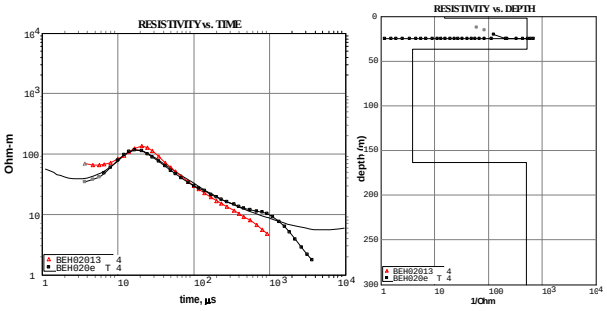

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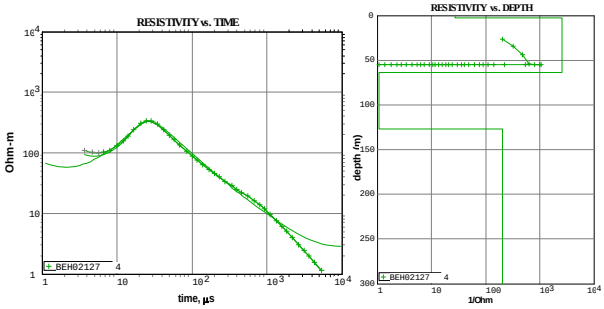

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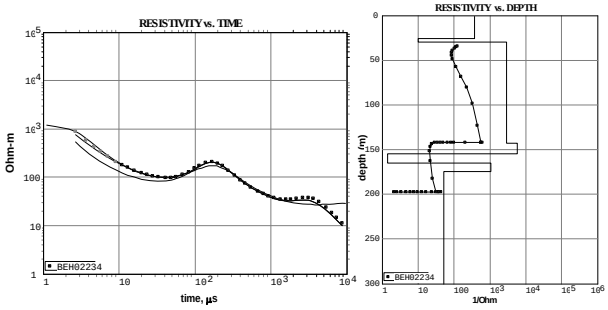


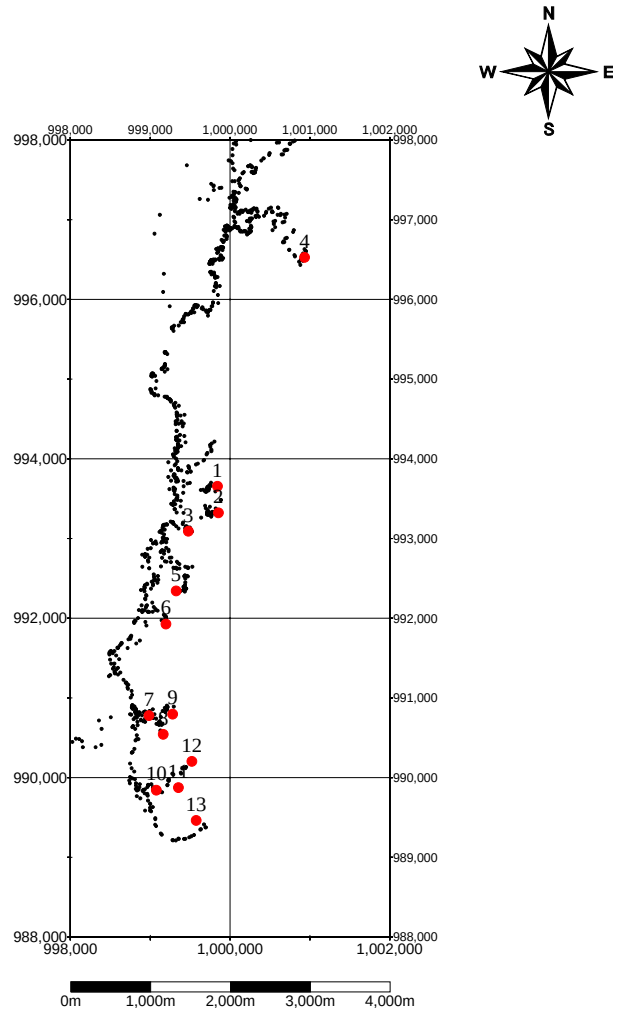
Figure-3. 3 Data and Graphic 1D Modeling for TEM in Eastern Hills

CHAPTER 3. RESULT OF SOUTHERN PART OF EASTERN HILL

The TEM surveys were carried out on 13 stations in the South Eastern Hills.

The broadleaf forest or scrub thicket spreads on western foot of the Southern Eastern Hills a slope spreads, and pasture land, farm land, residents for medium to low-income bracket dotted among them. Although most of them are private lands, there is rarely surrounded with fences to prohibiting to entry. It is only several points that needed the document for the entry permissions. As we had some troubles there such as snatchers for loop cables during the survey, we took care about for our security.

The TEM survey was mainly conducted in the pasture land, farm land or scrubs near mountain foot far from residential area. On field operations, 25 meters, 50 meters and 200 meters square loops on the surface were basically used there. The maximum loop size on every station was 200m.



South-Eastern Hills, near USME

Figure-3. 4 South-Eastern Hills, near USME

The diagrams of TEM data and 1D analyzed model on each TEM station are shown in figures.

South Eastern Hills

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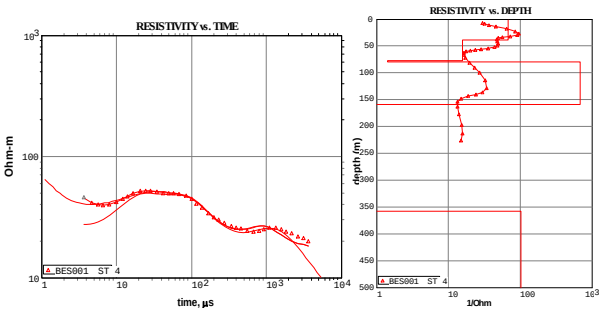

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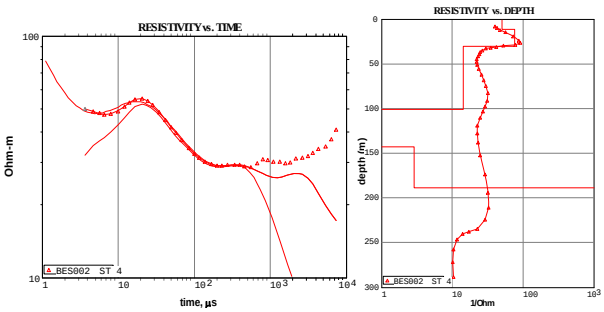

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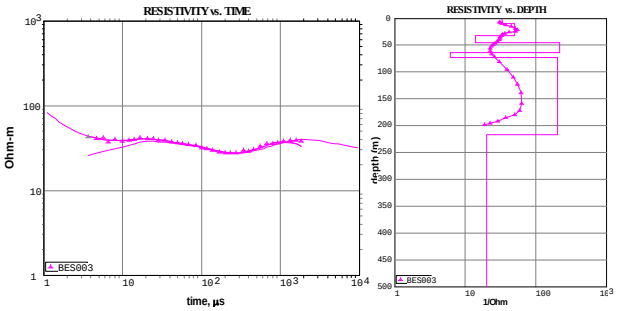

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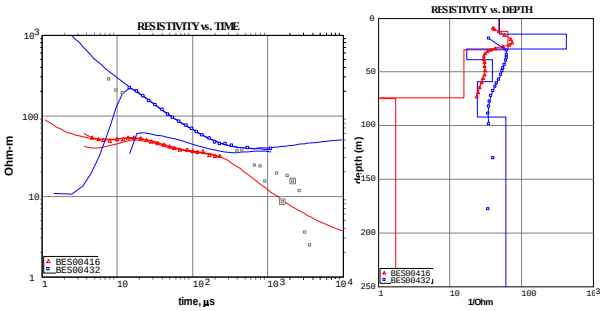

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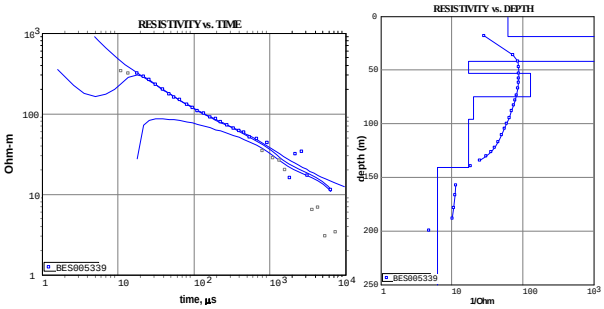

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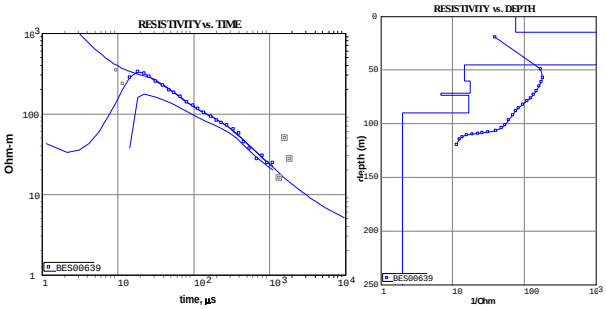

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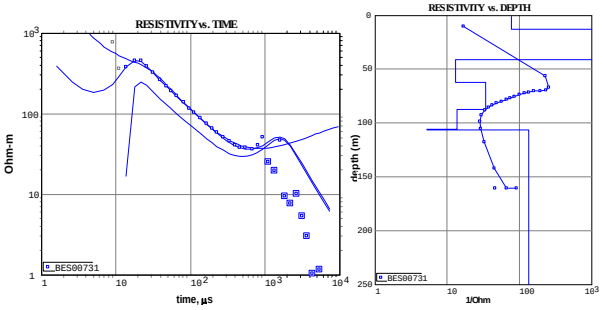

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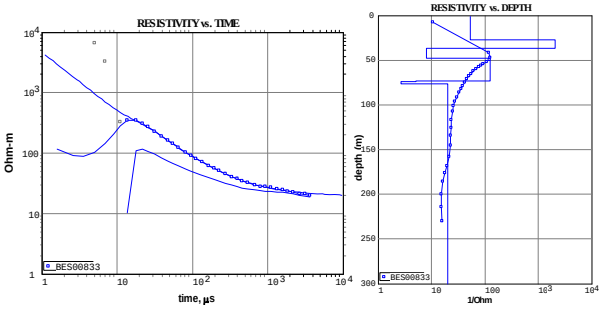

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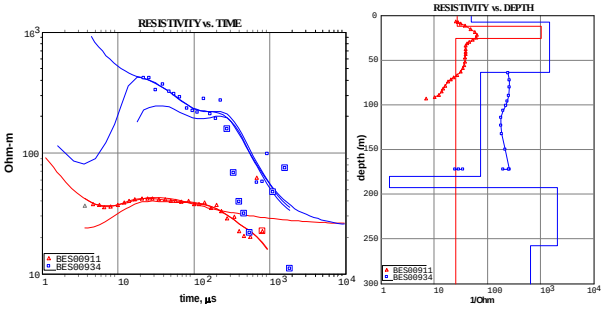

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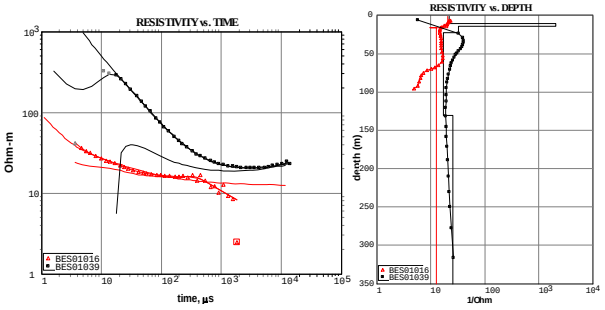

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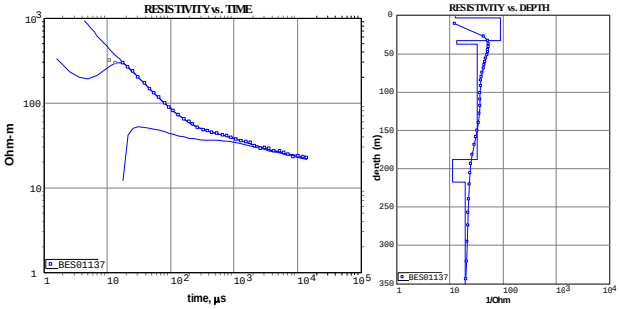

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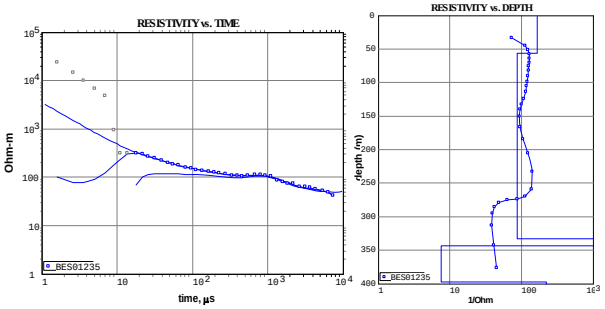

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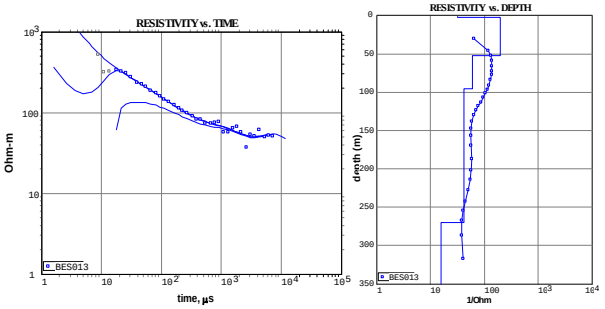


Figure-3. 5 Data and Graphic 1D Modeling for TEM in South Eastern Hills.

CHAPTER 4. SOUTHERN HILL

The TEM surveys were carried out on 29 stations in the Southern Hills.

Most of the Southern Hills is specified as the dangerous area strictly prohibited entering where antigovernment guerrillas might appear. All field surveys were accompanied by armed official uniformed police. The lookout posts or garrisons of an army are located on the Southern Hills where once fights took place between antigovernment guerrillas and National Army. We had visitors the landowner accompanied with militia during survey.

The Southern Hills is roughly classified into two categories. The north slope of the Southern Hills is occupied by residential of the illegal refugee, and the land of higher altitude is used as a pasture. The TEM survey was carried out in the pasture area.

On field operations, 25 meters, 50 meters and 200 meters square loops on the surface were basically used there. 150 meters, 200meters or 250 meters square loop was used as the maximum loop size on some stations. 100 meter square loop was supposed to be used at initial plan. The resistivity in the area was extremely high and the rapid decay of signal intensity caused poor data in the planned sounding depth. The size of square loop gradually turned into bigger to get quality data.

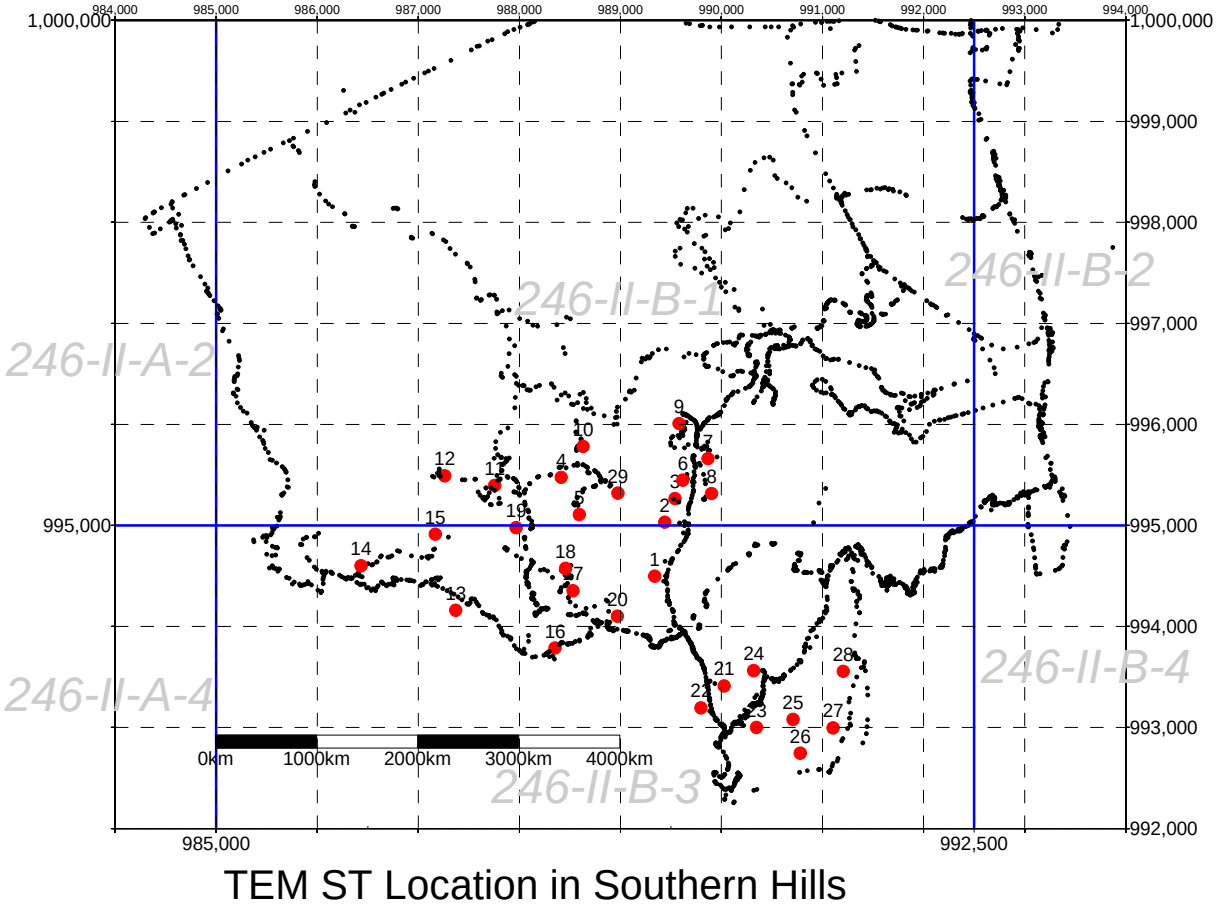
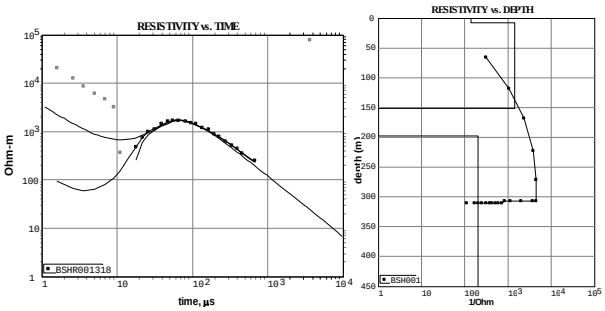


Figure-3. 6 TEM ST Location in Southem Hills

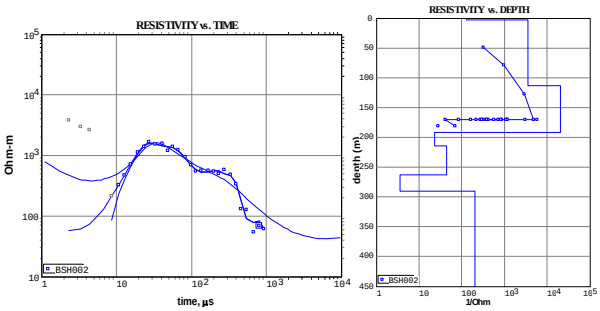
The diagrams of TEM data and 1D analyzed model on each TEM station are shown in figures.

Southern Hills

BSH001



BSH002



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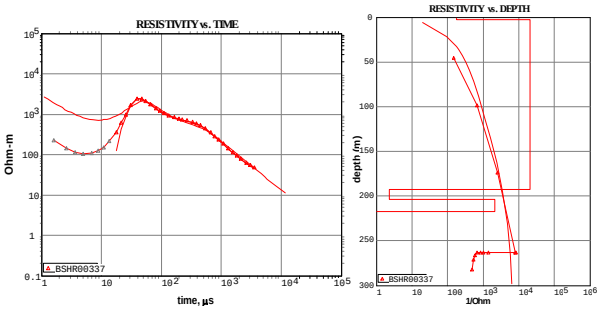

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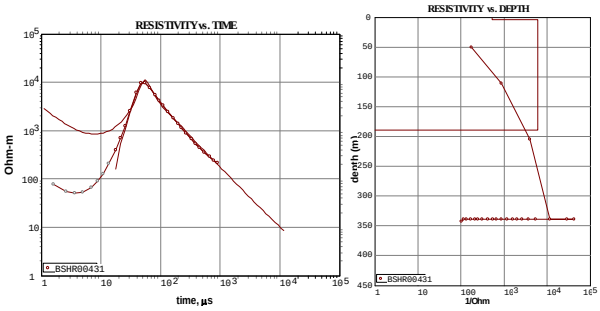

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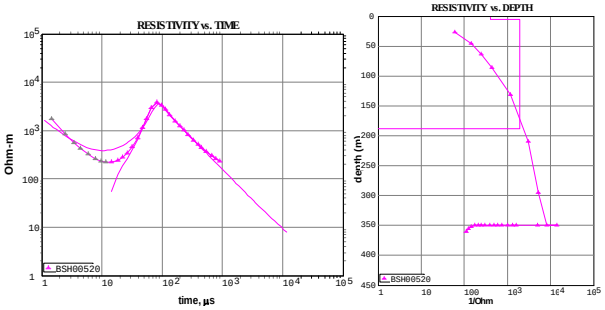

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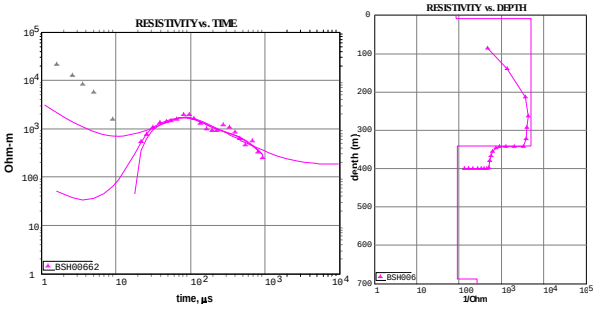

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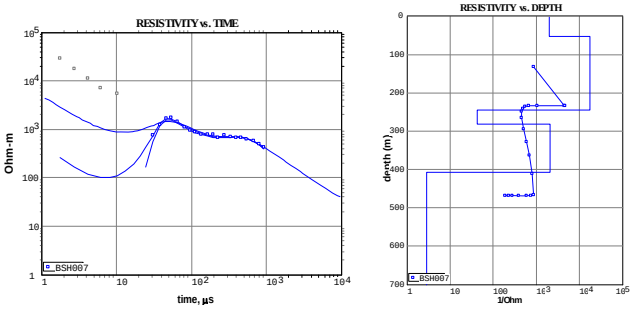

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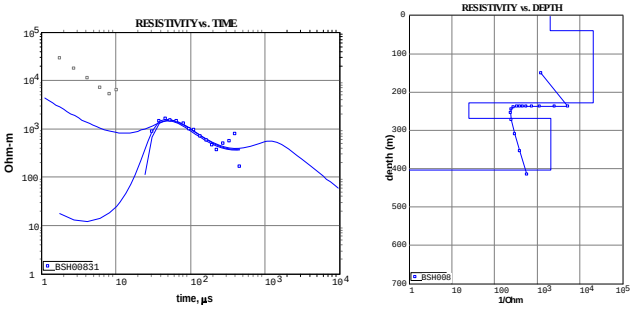

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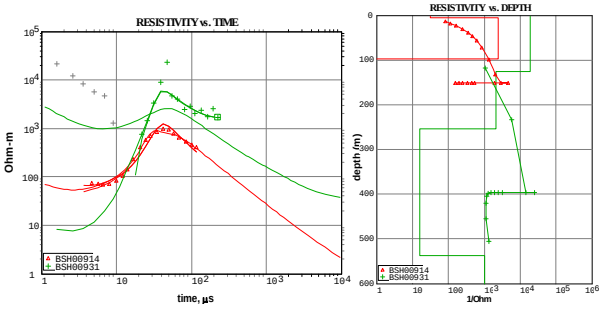

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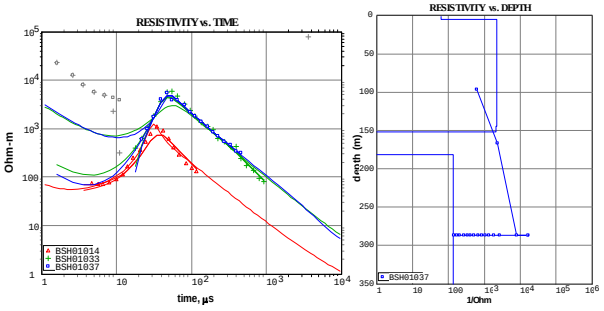

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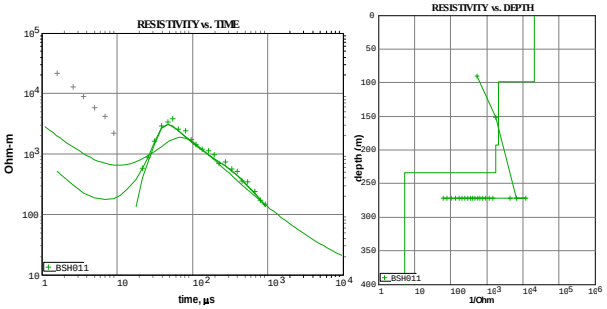

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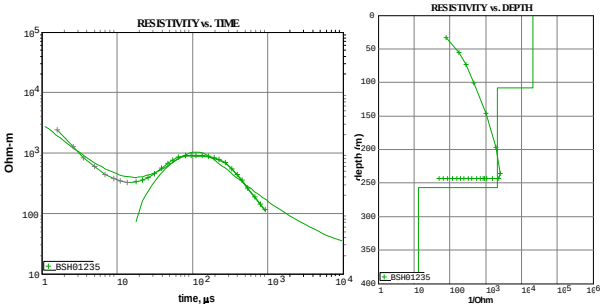

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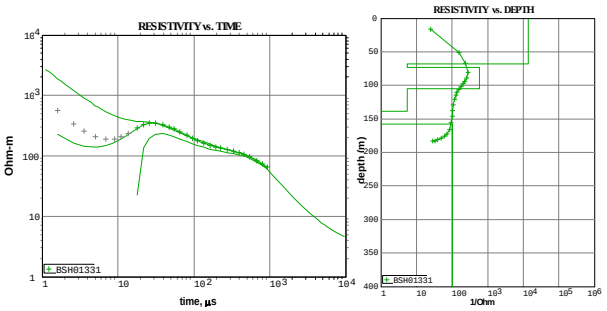

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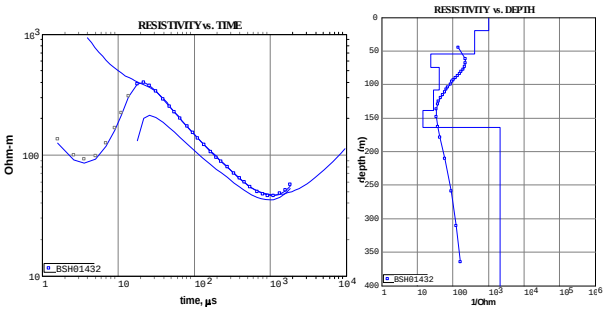

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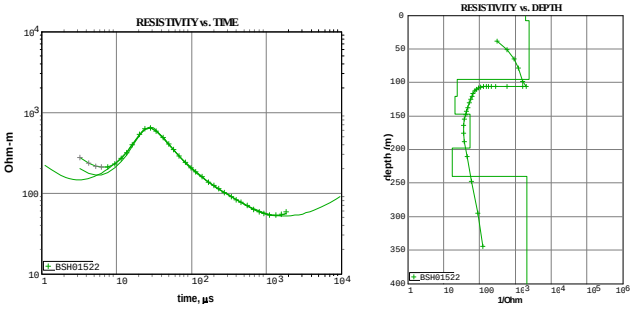

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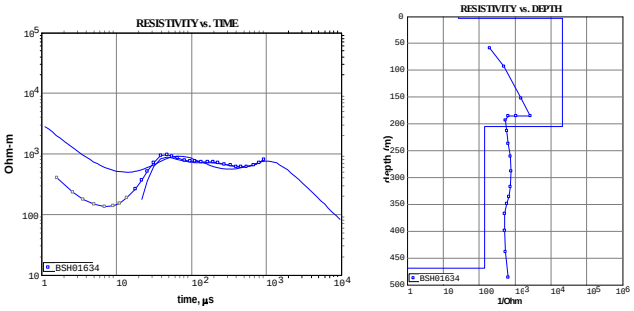

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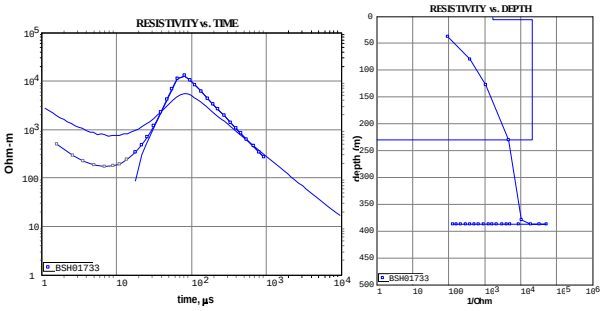

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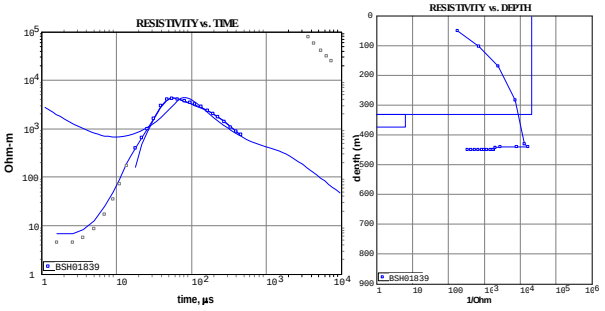

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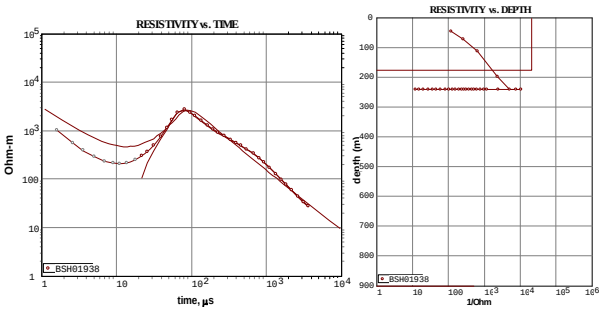

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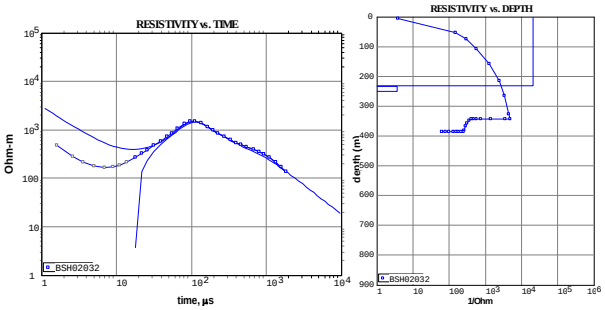

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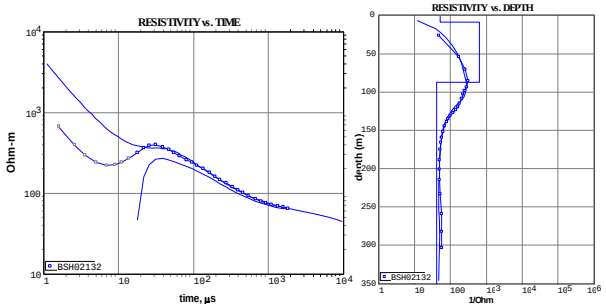

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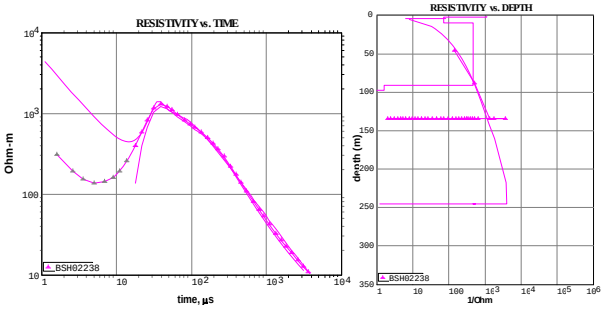

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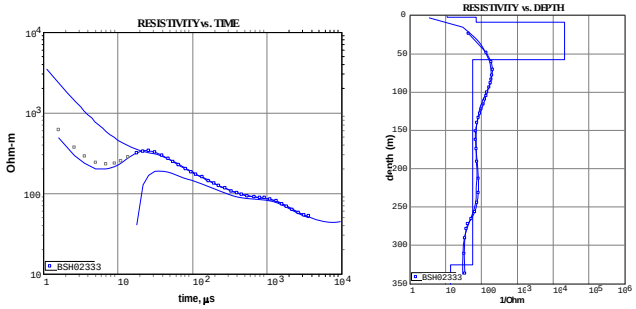

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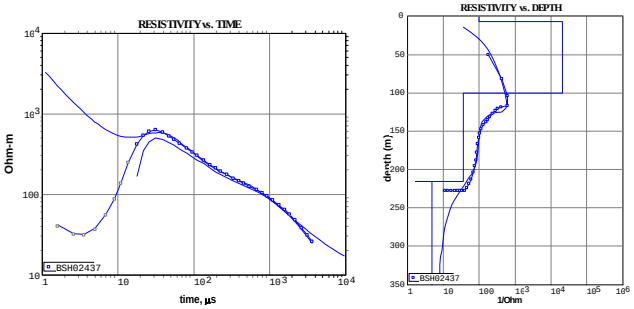

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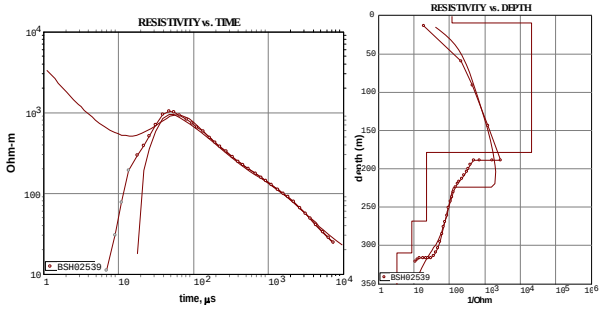

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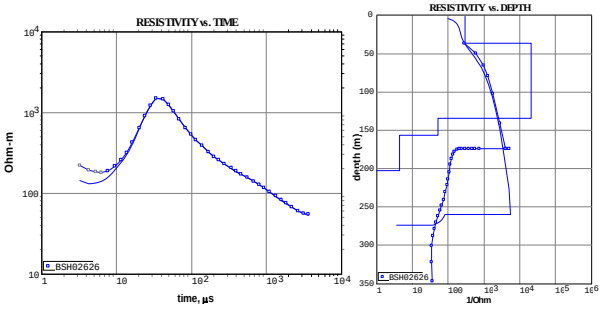

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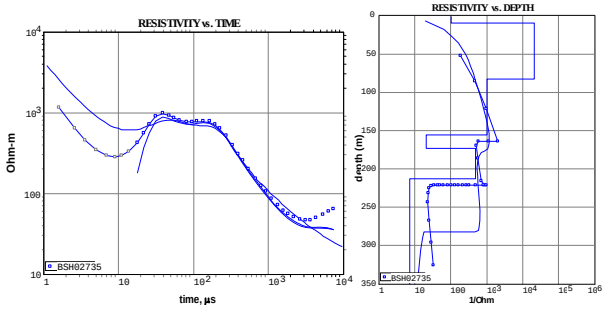

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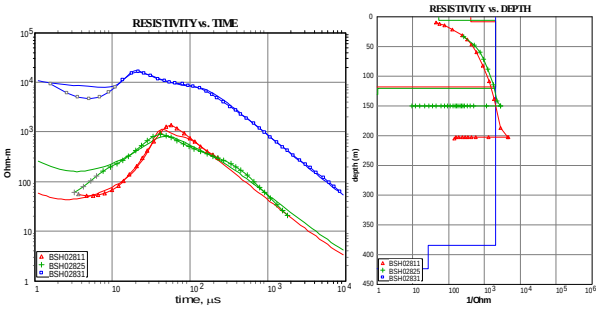

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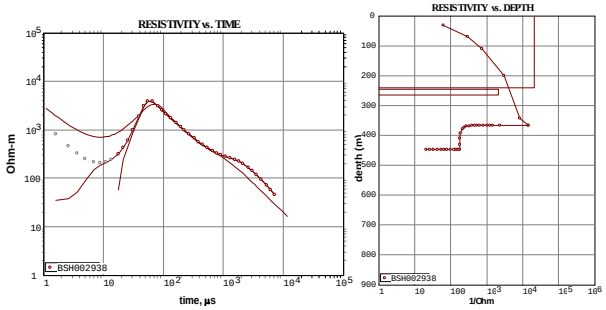

Figure-3. 7 Data and Graphic 1D Modeling for TEM in Southern Hills

CHAPTER 5. THE RESULTS AND CONSIDERATIONS OF TEM SURVEY

a) The Comparison between the TEM model and the electric well logging in the existing well

TEM survey was carried out in Suba where the test well was bored in the previous study for ground-water development. The electric well logging result of the well in Suba proves that aquifer structure can be considered from the model made by TEM method. The next figure shows the comparison with TEM 1D modeling structure and the electric well logging chart.

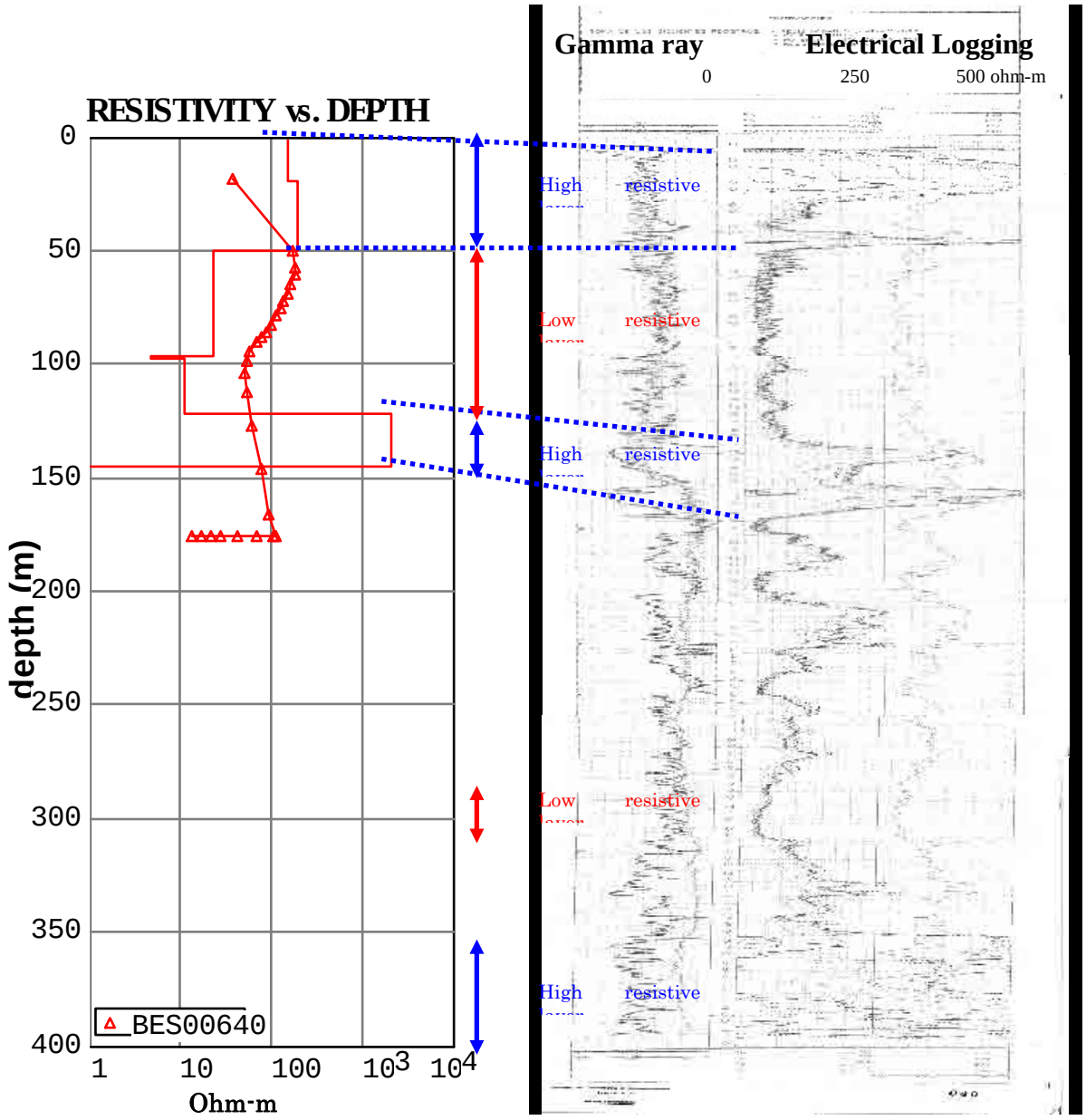

Figure-3. 8 Resistivity Vs Depth

High resistivity sections play a role of the main aquifer of the study area. Sandstone-rich layer of the Cretaceous Guadalupe Group shows high resistivity in the electric well logging chart on the figure above. Moreover, low resistivity sections play a role of the main shielding layer of the study area.

Mudstone-rich sections of the Cretaceous Guadalupe Group show low resistivity.

The TEM result could not detail resistivity structure in the deeper level of the BEH006.

This was caused by noise from high voltage power lines surrounding the TEM survey point near the existing

well.

The resistivity structure to the depth of 150m as the TEM result roughly agrees with the electric well logging result.

In the case of the same geological structure, the sandstone-rich sections and the mudstone-rich sections of the Cretaceous Guadalupe Group are considered to be identified from the TEM method as a high resistivity aquifer and low resistivity shielding layer, respectively.

a) Eastern Hills

i) Resistivity structure

The resistivity structure of the western slope in the Eastern Hills is characterized below. Here, the layers thinner than 10 meters thick were omitted from discussion. The resistivity structures in each station were modeled as horizontally layered model from 4 layers to 8 layers in the modeling diagram. The deeper the layer exists, the less their resistivity and thickness turn accurate. Because signal intensity decreases with depth.

TEM survey stations exist on the both sides of Fault running in the N-S direction in the western slope of the Eastern Hills.

On the east side of this Fault, Cretaceous formation is laid over the surface, dipping nearly vertical.

In the west of Fault, the Quaternary Formation lies over the surface horizontally over the Cretaceous Formation.

The resistivity structure on each station was roughly characterized as a two-layer model which consists of the high resistivity layer over low resistivity layer.

Group I : EH001, BEH002

Near surface low resistivity layer is thick. The thicknesses of the Quaternary layer are 81m and 69m at the flat pasture along a road, respectively. The high resistivity layer lies below them with thick of 36m and 21m respectively. The low resistivity layers of 20 ohm-m or less exist below them, and signal intensity declines rapidly below them.

Group II : BEH004, BEH005, BEH007, BEH008, BEH009, BEH010, BEH013, BEH014, BEH018

TEM stations exist on the steep western slope, where the Cretaceous Formation lies on the surface. They present a 2 layered model as a high resistivity layer over low resistivity layer. Near surface high resistivity layer lies thick of 100m or more, a low resistivity layer lies under it, and signal intensity declines rapidly below them.

Group III : BEH003, BEH006, BEH011, BEH012

TEM stations exist in flat area or gently sloping hill, where the Cretaceous Formation lies on the surface. They present a 4 layered model as a high resistivity layer over low resistivity layer over high resistivity layer over low resistivity layer. They present less decay of signal intensity toward depth and were modeled precisely.

Group IV : BEH015, BEH016, BEH017, BEH019, BEH020, BEH021, BEH022

TEM stations exist in the quarry among steep Western slope, where the Cretaceous Formation lies on a surface. They present a 3 layered model as a high resistivity layer over low resistivity layer over high resistivity layer. Near surface high resistivity layer lies thick of 100m or more, a low resistivity layer lies under them, and signal intensity declines rapidly below them.

ii) Aquifer structure

The Cretaceous Formation in the Group II and IV dips almost vertical and are not suitable for 1D model assuming horizontally layered model. But the result of modeling reflects near surface resistivity.

Group I : EH001, BEH002

On the stations belonging to Group I, aquifer is highly expected to exist near the boundary between near surface low resistivity layer reflecting Quaternary Formation and high resistivity layer reflecting Cretaceous Formation. But its water quality might not be possibly suitable to drink because contamination of surface water. Aquifer is highly expected to exist in the deeper part of Cretaceous Formation. But resistivity structure is identified in the deeper part because of decay of signal intensity.

Group II : BEH004, BEH005, BEH007, BEH008, BEH009, BEH010, BEH013, BEH014, BEH018

The analyzed high resistivity layer on the TEM stations belonging to Group II is considered to reflect the Cretaceous Formation. The Cretaceous Formation dips nearly vertical and continues downward. But the low resistivity layer was modeled under it. It is considered that TEM receives lower level information in wider area where the Cretaceous Formation and the Quaternary layer exist on the same level along the fault, or shows decay of signal intensity.

Group III : BEH003, BEH006, BEH011, BEH012

The Cretaceous Formation lie nearly horizontally a surface layer on the stations belonging to Group III. They are modeled through to relatively deeper part with out decay of signal intensity. The high resistivity layer at the depth may turn into an aquifer from the compare with the logging result of the well near TEM BEH006.

Group IV : BEH015, BEH016, BEH017, BEH019, BEH020, BEH021, BEH022

The analyzed high resistivity layer on the TEM stations belonging to Group IV is considered to reflect the Cretaceous Formation. The Cretaceous Formation exists from the surface and dips nearly vertical and continues downward. But the low resistivity layer was modeled under it. It is considered that TEM receives lower level information in wider area where the Cretaceous Formation and the Quaternary layer exist on the same level along the fault. The high resistivity layer at the bottom reflects the Cretaceous Formation on lower level where the Cretaceous Formation exists on the both side of the fault. An aquifer possibly exists in the Cretaceous Formation which continues from the surface to the depth.

b) The Southern Eastern Hills

i) Resistivity structure

The resistivity structure of the western slope in the South Eastern Hills is characterized as below. Here, as for the thin resistivity layers of less than 10m of thicknesses were omitted. The resistivity structures in each station were modeled as horizontally layered model from 4 layers to 8 layers in the modeling diagram. The deeper structures consisting of resistivity and thickness were modeled, the less accurate, because signal level goes down to the noise level.

The resistivity structure on each station was roughly characterized as a two-layer model which consists of the high resistivity layer over low resistivity layer.

Group I : BES004, BES005, BES006, BES008, BES010, BES011, BES012, BES013

TEM stations exist on the western slope in the South Eastern Hills, where the Cretaceous Formation lies on the surface. They present a 2 layered model as a high resistivity layer over low resistivity layer. The resistivity of surface high resistivity layers are several hundreds ohm-m, lower than those of the Eastern Hills. The thickness of surface high resistivity layers are several tens meters, thinner than those of the Eastern Hills. Layers below them are modeled as low resistivity from several ohm-m to tens ohm-m.

Group II : BES007, BES009

TEM stations exist in the pasture on the western slope in the South Eastern Hills, where the Cretaceous Formation lies on the surface. They are located on the west side of the N-S oriented fault, and the Cretaceous Formation is considered to lie nearly horizontal. They present a 4 layered model as a high resistivity layer over low resistivity layer over a high resistivity layer over low resistivity. They present less decay of signal intensity toward depth and were modeled precisely.

Group III : BES001, BES002

TEM stations exist in the pasture on the western slope in the South Eastern Hills, where the Cretaceous Formation lies on the surface. They present a 3 layered model as a high resistivity layer over low resistivity layer over high resistivity layer. They present less decay of signal intensity toward depth and were modeled precisely.

Group IV : BES 003

BES 003 exists in the pasture on the western slope of the South Eastern Hills, where the Cretaceous Formation lies on the surface. BES 003 is not similar in its resistivity structure to other TEM stations in the South Eastern Hills.

A low resistivity layer dominates on the BES 003 except the resistivity layer of about 200 ohm-m existing near surface with 13 meters thick.

ii) Aquifer structure

Group I : BES004, BES005, BES006, BES008, BES010, BES011, BES012, BES013

The Cretaceous Formation lies on the surface almost horizontally on the TEM stations belonging to Group I. It is considered that near surface high resistivity layer reflects the section where sandstone of Cretaceous formation dominates, and low resistivity layer reflects the section where mudstone of Cretaceous formation dominates. An aquifer possibly exists in the boundary between a high resistivity layer and a low resistivity layer.

Group II : BES007, BES009

The Cretaceous Formation lie nearly horizontally a surface layer on the stations belonging to Group II. They are modeled through to relatively deeper part with out decay of signal intensity. The high resistivity layer of the depths may turn into an aquifer.

Group III : BES001, BES002

The Cretaceous Formation lie nearly horizontally a surface layer on the stations belonging to Group III. Near surface high resistivity layer considerably reflects sandstone rich section of Cretaceous Formation. A low resistivity layer under it considerably reflects mudstone rich section of Cretaceous Formation. The high resistivity layer near surface possibly turns into an aquifer.

Group IV : BES 003

A low resistivity layer dominates on the BES003. This may have gathered noises caused by the conductive structure which could not be identified on the surface. 10/24

c) Southern Hills

i) Resistivity structure

The resistivity structure of the western slope in the Southern Hills is characterized as below. Here, as for the thin resistivity layers of less than 10m of thicknesses were omitted. The resistivity structures in each station were modeled as horizontally layered model from 4 layers to 8 layers in the modeling diagram. The resistivity and thickness of layers modeled naturally come less accurate in the deeper part, because signal intensity goes simultaneously .

The resistivity structure on each station was roughly characterized as a two-layer model which consists of the high resistivity layer over low resistivity layer.

Group I : From BSH001 to BSH012 consecutively, BSH016, BSH020, BSH028 and BSH029

Group I exists on the Northern slope in the Southern Hills, where the Cretaceous Formation lies on the surface. They present a 2 layered model as a high resistivity layer over low resistivity layer. High resistivity layers of 1,000 ohm-m or more lie thicker than 100 meter from the surface. Low resistivity layers lie below them and signal intensity decay gradually bellow them.

Group II : BSH013, BSH013 and BSH015

Group II exists on the Western part of the Southern Hills, where the Cretaceous Formation lies on the surface. Group II presents a 2 layered model as a high resistivity layer over low resistivity layer. The resistivity values of first layer are higher than those of Group I. Low resistivity layers lie below them and signal intensity decay gradually bellow them.

Group III : From BSH021 to BSH027 consecutively

It is in the sloping ground of a southeastern southern part hill, where the Cretaceous Formation lies on the surface. Group II present a 2 layered model as a high resistivity layer over low resistivity layer.

The resistivity values of high resistivity layer are higher than 2,000 ohm-m and the maximum thickness of them is 170 meter and most of them are less than 100 meters. Low resistivity layers exist below them and signal intensity decay gradually bellow them.

ii) Aquifer structure

Group I : From BSH001 to BSH012 consecutively, BSH016, BSH020, BSH028 and BSH029

The Cretaceous Formation lies on the surface almost horizontally around the Group I. Near surface high resistivity layer reflects considerably the sandstone-rich section of the Cretaceous Formation. Low resistivity layer under it reflects considerably the mudstone-rich section of the Cretaceous Formation. An aquifer is highly expected to exit in the boundary between a high resistivity layer and a low resistivity layer.

Group II : BSH013, BSH013 and BSH015

The Cretaceous Formation lies horizontally near surface around Group II. Since the resistivity value of a high resistivity layer is not so high and the thickness of it is thin, geological condition is considered to be much different from Group I. The aquifer is not considered to exist around Group II.

Group III : From BSH021 to BSH027 consecutively

The Cretaceous Formation lies from the surface horizontally near Group III. It is considered that near surface high resistivity layer reflects the sandstone-rich Cretaceous formation. Whether low resistivity layer below it reflects the mudstone-rich section or shows the decay of signal intensity are not identified. An aquifer is expected to exist in the boundary between a high resistivity layer and a low resistivity layer.

Table-3. 1 Eastern Hill

Name	X	Y	Z	Max.Loop Size	
BEH01	X=1005605	y=1027175	z=2584	Max. loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	109.7	35.4	0	- 35.4	2584 - 2548.6
2	31.8	45.5	35.4	- 80.9	2548.6 - 2503.1
3	2000	21	80.9	- 101.9	2503.1 - 2482.1
4	9.17	10.7	101.9	- 112.6	2482.1 - 2471.4
5	15.4	27.5	112.6	- 140.1	2471.4 - 2443.9
6	0.93	19.3	140.1	- 159.4	2443.9 - 2424.6
7	0.175	10000000000	159.4	- 1.00E+10	2424.6 - -9999997575

Data Name	X	Y	Z	Max.Loop Size	
BEH02	X=1005684	y=1028352	z=2581		
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	78	32.6	0	- 32.6	z=2581 - 2548.4
2	51	36.3	32.6	- 68.9	2548.4 - 2512.1
3	2000	35.6	68.9	- 104.5	2512.1 - 2476.5
4	18.6	12.7	104.5	- 117.2	2476.5 - 2463.8
5	14.7	30.4	117.2	- 147.6	2463.8 - 2433.4
6	0.929	20.5	147.6	- 168.1	2433.4 - 2412.9
7	0.1	10000000000	168.1	- 1.00E+10	2412.9 - -9999997587

Data Name	X	Y	Z	Max.Loop Size	
BEH03	X=1005473	y=1026491	z=2594		
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	131.0143	45.79	0	- 45.79	2594 - 2548.21
2	58.3846	36.55	45.79	- 82.34	2548.21 - 2511.66
3	2000.0002	63.92	82.34	- 146.26	2511.66 - 2447.74
4	12.142	42.08	146.3	- 188.34	2447.74 - 2405.66
5	15.6122	75.9	188.3	- 264.24	2405.66 - 2329.76
6	1.9654	70.04	264.2	- 334.28	2329.76 - 2259.72
7	0.1	10000000000	334.3	- 1.00E+10	2259.72 - -9999997740

Data Name	X	Y	Z	Max.Loop Size	
BEH04	X=1005914	y=1029415	z=2610	Max. oop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	270.793	32.09	0	- 32.09	2610 - 2577.91
2	38.943	42.56	32.09	- 74.65	2577.91 - 2535.35
3	546.4254	77.08	74.65	- 151.73	2535.35 - 2458.27
4	15.5772	35.89	151.7	- 187.62	2458.27 - 2422.38
5	35.0804	102.58	187.6	- 290.2	2422.38 - 2319.8
6	1.4737	30.62	290.2	- 320.82	2319.8 - 2289.18
7	0.1	10000000000	320.8	- 1.00E+10	2289.18 - -9999997711

Data Name	X	Y	Z	Max.Loop Size	
BEH05	X=1007251	y=1031074	z=2598	Max. oop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	26.0163	0.36	0	- 0.36	2598 - 2597.64
2	2213.1313	85.4	0.36	- 85.76	2597.64 - 2512.24
3	2000.0002	59.65	85.76	- 145.41	2512.24 - 2452.59
4	2000.0002	52.07	145.4	- 197.48	2452.59 - 2400.52
5	2.6146	1.94	197.5	- 199.42	2400.52 - 2398.58
6	1095.9358	22.97	199.4	- 222.39	2398.58 - 2375.61
7	80.2025	10000000000	222.4	- 1.00E+10	2375.61 - -9999997624

Data Name	X	Y	Z	Max.Loop Size	
BEH06	x=999892	y=1018093	z=2572	Max. loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	143.429	18.53	0	- 18.53	2572 - 2553.47
2	181.2523	30.25	18.53	- 48.78	2553.47 - 2523.22
3	21.5713	46.05	48.78	- 94.83	2523.22 - 2477.17
4	4.3641	1.01	94.83	- 95.84	2477.17 - 2476.16
5	10.1544	24.31	95.84	- 120.15	2476.16 - 2451.85
6	2000.0002	23.38	120.2	- 143.53	2451.85 - 2428.47
7	0.1737	10000000000	143.5	- 1.00E+10	2428.47 - -9999997572

Data Name	X	Y	Z	Max.Loop Size	
BEH07	X=1006248	y=1023446	z=2725	Max. Loop=65	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	246.8198	17.04	0	- 17.04	2725 - 2707.96
2	2000.0002	45.02	17.04	- 62.06	2707.96 - 2662.94
3	5.3439	13.69	62.06	- 75.75	2662.94 - 2649.25
4	2000.0002	4.17	75.75	- 79.92	2649.25 - 2645.08
5	2000.0002	14.36	79.92	- 94.28	2645.08 - 2630.72
6	0.3896	13.87	94.28	- 108.15	2630.72 - 2616.85
7	0.1	10000000000	108.2	- 1.00E+10	2616.85 - -9999997383

Data Name	X	Y	Z	Max.Loop Size	
BEH08	X=1005849	y=1024121	z=2671	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	19999.9922	105.1	0	- 105.1	2671 - 2565.9
2	120.6348	142.44	105.1	- 247.54	2565.9 - 2423.46
3	4.942	5.43	247.5	- 252.97	2423.46 - 2418.03
4	93.9224	34.81	253	- 287.78	2418.03 - 2383.22
5	3.9197	57.78	287.8	- 345.56	2383.22 - 2325.44
6	0.1	10000000000	345.6	- 1E+10	2325.44 - -9999997675

Data Name	X	Y	Z	Max.Loop Size	
BEH09	X=1005691	y=1026273	z=2635	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	137.6386	9	0	- 9	2635 - 2626
2	4466.4209	63.25	9	- 72.25	2626 - 2562.75
3	2000.0002	39.15	72.25	- 111.4	2562.75 - 2523.6
4	360.5795	84.12	111.4	- 195.52	2523.6 - 2439.48
5	18.1179	61.61	195.5	- 257.13	2439.48 - 2377.87
6	6.4641	122.17	257.1	- 379.3	2377.87 - 2255.7
7	0.4716	10000000000	379.3	-	2255.7 - -9999997744

Data Name	X	Y	Z	Max.Loop Size	
BEH10	X=1005620	y=1025795	z=2642	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	182.0487	6.7	0	- 6.7	2642 - 2635.3
2	19999.9922	80.2	6.7	- 86.9	2635.3 - 2555.1
3	2000.0002	57.18	86.9	- 144.08	2555.1 - 2497.92
4	2000.0002	90.85	144.1	- 234.93	2497.92 - 2407.07
5	34.4478	68.36	234.9	- 303.29	2407.07 - 2338.71
6	5.1581	90.28	303.3	- 393.57	2338.71 - 2248.43
7	0.5828	10000000000	393.6	- 1E+10	2248.43 - -9999997752

Data Name	X	Y	Z	Max.Loop Size	
BEH11	X=1005087	y=1023806	z=2583	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	174.8701	61.48	0	- 61.48	2583 - 2521.52
2	322.3637	37.1	61.48	- 98.58	2521.52 - 2484.42
3	805.2426	30.46	98.58	- 129.04	2484.42 - 2453.96
4	28.5269	17.26	129	- 146.3	2453.96 - 2436.7
5	2000.0002	98.36	146.3	- 244.66	2436.7 - 2338.34
6	4.3227	63.45	244.7	- 308.11	2338.34 - 2274.89
7	6.6203	10000000000	308.1	- 1E+10	2274.89 - -9999997725

Data Name	X	Y	Z	Max.Loop Size	
BEH13	X=1005490	y=1021608	z=2633	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	295.7727	36.8	0	- 36.8	2633 - 2596.2
2	1747.7749	70.81	36.8	- 107.61	2596.2 - 2525.39
3	1986.4753	58.86	107.6	- 166.47	2525.39 - 2466.53
4	30.0918	17.87	166.5	- 184.34	2466.53 - 2448.66
5	647.7433	110.29	184.3	- 294.63	2448.66 - 2338.37
6	9.043	129.9	294.6	- 424.53	2338.37 - 2208.47
7	20.0893	10000000000	424.5	- 1E+10	2208.47 - -9999997792

Data Name	X	Y	Z	Max.Loop Size	
BEH15	X=1006231	y=1017926	z=2713	Max.Loop=100	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	465.1275	18.39	0	- 18.39	2713 - 2694.61
2	2000.0002	48.54	18.39	- 66.93	2694.61 - 2646.07
3	13.7095	26	66.93	- 92.93	2646.07 - 2620.07
4	0.2619	0.25	92.93	- 93.18	2620.07 - 2619.82
5	2000.0002	17.48	93.18	- 110.66	2619.82 - 2602.34
6	2000.0002	8.55	110.7	- 119.21	2602.34 - 2593.79
7	0.1	10000000000	119.2	- 1E+10	2593.79 - -9999997406

Data Name	X	Y	Z	Max.Loop Size	
BEH17	X=1006253	y=1016146	z=2625	Max.Loop=170	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	199.9111	5.79	0	- 5.79	2625 - 2619.21
2	2000.0002	75.96	5.79	- 81.75	2619.21 - 2543.25
3	2000.0002	58.75	81.75	- 140.5	2543.25 - 2484.5
4	1.5117	4.87	140.5	- 145.37	2484.5 - 2479.63
5	2000.0002	2.86	145.4	- 148.23	2479.63 - 2476.77
6	2000.0002	5.25	148.2	- 153.48	2476.77 - 2471.52
7	0.1	10000000000	153.5	- 1E+10	2471.52 - -9999997528

Data Name	X	Y	Z	Max.Loop Size	
BEH19	X=1005995	y=1015329	z=2607	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	1911.7971	11.05	0	- 11.05	2607 - 2595.95
2	527.3831	51.08	11.05	- 62.13	2595.95 - 2544.87
3	76.8564	50.93	62.13	- 113.06	2544.87 - 2493.94
4	10.1007	35.15	113.1	- 148.21	2493.94 - 2458.79
5	19999.9922	61	148.2	- 209.21	2458.79 - 2397.79
6	1.1379	49.01	209.2	- 258.22	2397.79 - 2348.78
7	200	10000000000	258.2	- 1E+10	2348.78 - -9999997651

Data Name	X	Y	Z	Max.Loop Size	
BEH12	X=1005346	y=1023246	z=2609	Max.Loop=170	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	5.5221	0.29	0	- 0.29	2609 - 2608.71
2	259.7185	9.88	0.29	- 10.17	2608.71 - 2598.83
3	2000.0002	71.61	10.17	- 81.78	2598.83 - 2527.22
4	503.1398	15.13	81.78	- 96.91	2527.22 - 2512.09
5	644.8283	28.57	96.91	- 125.48	2512.09 - 2483.52
6	7.4186	33.56	125.5	- 159.04	2483.52 - 2449.96
7	0.5619	6.34	159	- 165.38	2449.96 - 2443.62
8	0.2314	10000000000	165.4	- 1E+10	2443.62 - -9999997556

Data Name	X	Y	Z	Max.Loop Size	
BEH14	X=1005655	y=1020599	z=2594	Max.Loop=170	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	291.7779	38.48	0	- 38.48	2594 - 2555.52
2	1201.7776	67.9	38.48	- 106.38	2555.52 - 2487.62
3	663.9973	56.65	106.4	- 163.03	2487.62 - 2430.97
4	33.8878	15.93	163	- 178.96	2430.97 - 2415.04
5	224.5063	101.91	179	- 280.87	2415.04 - 2313.13
6	23.4914	263.23	280.9	- 544.1	2313.13 - 2049.9
7	2000.0002	10000000000	544.1	- 1E+10	2049.9 - -9999997950

Data Name	X	Y	Z	Max.Loop Size	
BEH16	X=1006326	y=1017690	z=2714	Max. loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	164.0694	7.22	0	- 7.22	2714 - 2706.78
2	2235.5671	74.21	7.22	- 81.43	2706.78 - 2632.57
3	19999.9922	43.5	81.43	- 124.93	2632.57 - 2589.07
4	1.9058	4.19	124.9	- 129.12	2589.07 - 2584.88
5	1.2485	1.61	129.1	- 130.73	2584.88 - 2583.27
6	10117.4717	3.2	130.7	- 133.93	2583.27 - 2580.07
7	0.1	10000000000	133.9	- 1E+10	2580.07 - -9999997420

Data Name	X	Y	Z	Max.Loop Size	
BEH18	X=1005891	y=1019330	z=2694	Max. loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	2000.0002	11.74	0	- 11.74	2694 - 2682.26
2	19999.9922	81.7	11.74	- 93.44	2682.26 - 2600.56
3	19999.9922	55.9	93.44	- 149.34	2600.56 - 2544.66
4	14.4677	14.44	149.3	- 163.78	2544.66 - 2530.22
5	554.6165	58.05	163.8	- 221.83	2530.22 - 2472.17
6	23.2945	85.02	221.8	- 306.85	2472.17 - 2387.15
7	0.1	10000000000	306.9	- 1E+10	2387.15 - -9999997613

Data Name	X	Y	Z	Max.Loop Size	
BEH20	X=1006098	y=1014361	z=2625	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m) - (m)
1	24.5	0.42	0	- 0.42	258.22 - 257.8
2	2000.0002	119.8	0.42	- 120.22	257.8 - 138
3	36.7	88.8	120.2	- 209.02	138 - 49.2
4	4.28	21.3	209	- 230.32	49.2 - 27.9
5	13	22.2	230.3	- 252.52	27.9 - 5.7
6	11.5	24.9	252.5	- 277.42	5.7 - -19.2
7	0.1	10000000000	277.4	- 1E+10	-19.2 - -10000000019

Data Name	X	Y	Z	Max.Loop Size
BEH21	X=1006389	y=1012079	z=2698	Max. Loop=50

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary - (m) (m)
1	33.6	0.35	0 - 0.35	277.42 - 277.07
2	3650.9983	104.6	0.35 - 104.95	277.07 - 172.47
3	5.72	42.2	105 - 147.15	172.47 - 130.27
4	0.221	4.03	147.2 - 151.18	130.27 - 126.24
5	0.219	3.47	151.2 - 154.65	126.24 - 122.77
6	7.36	1.01	154.7 - 155.66	122.77 - 121.76
7	2000.0002	10000000000	155.7 - 1E+10	121.76 - -9999999878

Data Name	X	Y	Z	Max.Loop Size
BEH22	X=1005820	y=1010576	z=2668	Max.Loop=170

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary - (m) (m)
1	32	4.53	0 - 4.53	2668 - 2663.47
2	2000.0002	100.7	4.53 - 105.23	2663.47 - 2562.77
3	2000.0002	33.3	105.2 - 138.53	2562.77 - 2529.47
4	0.694	12.2	138.5 - 150.73	2529.47 - 2517.27
5	857.6002	10000000000	150.7 - 1E+10	2517.27 - -9999997483

Table-3. 2 Southern Part of Eastern Hills

Data Name	X	Y	Z	Max.Loop Size
BES01	x=999842	y=993654	z=3046	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	1.6113	0.25	0 - 0.25	3046 - 3045.75
2	6.9784	0.48	0.25 - 0.73	3045.75 - 3045.27
3	2000.0002	20.72	0.73 - 21.45	3045.27 - 3024.55
4	39.5601	90.12	21.45 - 111.57	3024.55 - 2934.43
5	0.4607	0.25	111.57 - 111.82	2934.43 - 2934.18
6	176.5577	38.63	111.82 - 150.45	2934.18 - 2895.55
7	42.2218	126.25	150.45 - 2.77E+02	2895.55 - 2769.3
8	4.7194	10000000000	276.7 - 1.00E+10	2769.3 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES02	x=999855	y=993322	z=3057	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	2.28	0.28	0 - 0.28	3057 - 3056.72
2	96.1	37	0.28 - 37.28	3056.72 - 3019.72
3	50.9	255.4	37.28 - 292.68	3019.72 - 2764.32
4	3.75	86.7	292.68 - 379.38	2764.32 - 2677.62
5	7.92	16.2	379.38 - 395.58	2677.62 - 2661.42
6	0.299	300	395.58 - 695.58	2661.42 - 2361.42
7	2000.0002	10000000000	695.58 - 1.00E+10	2361.42 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES03	x=999479	y=993090	z=3005	Max. loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	1.49	0.42	0 - 0.42	3005 - 3004.58
2	206.3	12.9	0.42 - 13.32	3004.58 - 2991.68
3	22	122	13.32 - 135.32	2991.68 - 2869.68
4	0.923	2.5	135.32 - 137.82	2869.68 - 2867.18
5	0.952	25	137.82 - 162.82	2867.18 - 2842.18
6	4.62	50	162.82 - 212.82	2842.18 - 2792.18
7	0.1	10000000000	212.82 - 1.00E+10	2792.18 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES04	x=1000933	y=996527	z=2818	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	1.49	0.43	0 - 0.43	2818 - 2817.57
2	56.4	0.43	0.43 - 0.86	2817.57 - 2817.14
3	1764	19.6	0.86 - 20.46	2817.14 - 2797.54
4	13.4	37.2	20.46 - 57.66	2797.54 - 2760.34
5	0.221	0.34	57.66 - 58	2760.34 - 2760
6	3.85	11.6	58 - 69.6	2760 - 2748.4
7	0.452	15.8	69.6 - 8.54E+01	2748.4 - 2732.6
8	0.145	10000000000	85.4 - 1.00E+10	2732.6 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES05	x=999326	y=992342	z=3078	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	2.7387	0.54	0 - 0.54	3078 - 3077.46
2	949.4294	2.08	0.54 - 2.62	3077.46 - 3075.38
3	212.6347	31.01	2.62 - 33.63	3075.38 - 3044.37
4	26.5267	55.39	33.63 - 89.02	3044.37 - 2988.98
5	5.6741	26.15	89.02 - 115.17	2988.98 - 2962.83
6	1.8496	58.64	115.17 - 173.81	2962.83 - 2904.19
7	3.4659	10000000000	173.81 - 1.00E+10	2904.19 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES06	x=999197	y=991926	z=3113	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	3.1133	0.47	0 - 0.47	3113 - 3112.53
2	1978.4194	7.68	0.47 - 8.15	3112.53 - 3104.85
3	433.9	34.24	8.15 - 42.39	3104.85 - 3070.61
4	22.1456	46.6	42.39 - 88.99	3070.61 - 3024.01
5	4.7049	54.84	88.99 - 143.83	3024.01 - 2969.17
6	6.2839	113.76	143.83 - 257.59	2969.17 - 2855.41
7	2.6242	10000000000	257.59 - 1.00E+10	2855.41 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES07	x=998985	y=990778	z=3121	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	1.9083	0.32	0 - 0.32	3121 - 3120.68
2	2000.0002	5.96	0.32 - 6.28	3120.68 - 3114.72
3	2000.0002	28.65	6.28 - 34.93	3114.72 - 3086.07
4	13.2135	50.5	34.93 - 85.43	3086.07 - 3035.57
5	0.3685	0.39	85.43 - 85.82	3035.57 - 3035.18
6	21.9957	48.39	85.82 - 134.21	3035.18 - 2986.79
7	0.4428	7.52	134.21 - 1.42E+02	2986.79 - 2979.27
8	0.9788	10000000000	141.73 - 1.00E+10	2979.27 - -10000000000

Data Name	X	Y	Z	Max.Loop Size
BES08	x=999163	y=990542	z=3166	Max.Loop=200

Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)	Alutitude Boundary (m)
1	2.85	0.41	0 - 0.41	3166 - 3165.59
2	16.1	1.34	0.41 - 1.75	3165.59 - 3164.25
3	2000	21.8	1.75 - 23.55	3164.25 - 3142.45
4	16.5	44.5	23.55 - 68.05	3142.45 - 3097.95
5	10.3	25	68.05 - 93.05	3097.95 - 3072.95
6	7.45	50	93.05 - 143.05	3072.95 - 3022.95
7	0.81	10000000000	143.05 - 1.00E+10	3022.95 - -10000000000

Data Name	X	Y	Z	Max.Loop Size	
BES09	x=999283	y=990795	z=3155	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.9026	0.3	0 - 0.3		3155 - 3154.7
2	29.0777	1.92	0.3 - 2.22		3154.7 - 3152.78
3	2000.0002	67.99	2.22 - 70.21		3152.78 - 3084.79
4	54.0905	56.04	70.21 - 126.25		3084.79 - 3028.75
5	19999.9922	42.9	126.25 - 169.15		3028.75 - 2985.85
6	3.45	50	169.15 - 219.15		2985.85 - 2935.85
7	2000.0002	10000000000	219.15 - 1.00E+10		2935.85 - -10000000000

Data Name	X	Y	Z	Max.Loop Size	
BES10	999078	989842	3120	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	2.97	0.6	0 - 0.6		3120 - 3119.4
2	48.9	16.9	0.6 - 17.5		3119.4 - 3102.5
3	24.1	2.32	17.5 - 19.82		3102.5 - 3100.18
4	15.8	101.3	19.82 - 121.12		3100.18 - 2998.88
5	0.36	0.25	121.12 - 121.37		2998.88 - 2998.63
6	119.3	21	121.37 - 142.37		2998.63 - 2977.63
7	10	111.6	142.37 - 2.54E+02		2977.63 - 2866.03
8	1.1	10000000000	253.97 - 1.00E+10		2866.03 - -10000000000

Data Name	X	Y	Z	Max.Loop Size	
BES11	999354	989874	3169	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	36.4892	2.96	0 - 2.96		3169 - 3166.04
2	42.5747	60.23	2.96 - 63.19		3166.04 - 3105.81
3	1.3308	1.3	63.19 - 64.49		3105.81 - 3104.51
4	146.9641	49.84	64.49 - 114.33		3104.51 - 3054.67
5	19.8444	205.77	114.33 - 320.1		3054.67 - 2848.9
6	11.5529	466.22	320.1 - 786.32		2848.9 - 2382.68
7	0.1	10000000000	786.32 - 1.00E+10		2382.68 - -10000000000

Data Name	X	Y	Z	Max.Loop Size	
BES12	999523	990204	3246	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	114.9207	3.23	0 - 3.23		3246 - 3242.77
2	114.4051	131.69	3.23 - 134.92		3242.77 - 3111.08
3	1.4107	1.24	134.92 - 136.16		3111.08 - 3109.84
4	443.853	97.28	136.16 - 233.44		3109.84 - 3012.56
5	8.6632	194.38	233.44 - 427.82		3012.56 - 2818.18
6	14.082	95.9	427.82 - 523.72		2818.18 - 2722.28
7	2000.0002	10000000000	523.72 - 1.00E+10		2722.28 - -10000000000

Data Name	X	Y	Z	Max.Loop Size	
BES13	999576	989462	3146	Max.Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	2000.0002	1.55	0 - 1.55		3146 - 3144.45
2	106.4731	107.05	1.55 - 108.6		3144.45 - 3037.4
3	1.5377	1.2	108.6 - 109.8		3037.4 - 3036.2
4	57.6734	14.89	109.8 - 124.69		3036.2 - 3021.31
5	65.5321	89.85	124.69 - 214.54		3021.31 - 2931.46
6	35.9736	214.29	214.54 - 428.83		2931.46 - 2717.17
7	2000.0002	10000000000	428.83 - 1.00E+10		2717.17 - -10000000000

Table-3. 3 Southern Hills

BSH01	x=989340	y=994498	z=2960	Max. Loop=150	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.88	0.28	0 - 0.28		2960 - 2959.72
2	124.5	1.26	0.28 - 1.54		2959.72 - 2958.46
3	3481	110.5	1.54 - 112.04		2958.46 - 2847.96
4	20000	78.6	112.04 - 190.64		2847.96 - 2769.36
5	22.2	22.5	190.64 - 213.14		2769.36 - 2746.86
6	42.7	48.9	213.14 - 262.04		2746.86 - 2697.96
7	3.47	27	262.04 - 289.04		2697.96 - 2670.96
8	200	27	289.04 - 316.04		2670.96 - 2643.96

BSH02	x=989439	y=995032	z=2904	Max. Loop=150	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.88	0.28	0 - 0.28		2904 - 2903.72
2	124.5	1.26	0.28 - 1.54		2903.72 - 2902.46
3	3481	110.5	1.54 - 112.04		2902.46 - 2791.96
4	2000	78.6	112.04 - 190.64		2791.96 - 2713.36
5	22.2	22.5	190.64 - 213.14		2713.36 - 2690.86
6	42.7	48.9	213.14 - 262.04		2690.86 - 2641.96
7	3.47	27	262.04 - 289.04		2641.96 - 2614.96
8	200	27	289.04 - 316.04		2614.96 - 2587.96

BSH03	x=989541	y=995266	z=2920	Max. Loop=150	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.8756	0.25	0 - 0.25		2920 - 2919.75
2	170.4965	1.71	0.25 - 1.96		2919.75 - 2918.04
3	19999.9922	190.07	1.96 - 192.03		2918.04 - 2727.97
4	2.2663	11.27	192.03 - 203.3		2727.97 - 2716.7
5	2000.0002	13.48	203.3 - 216.78		2716.7 - 2703.22
6	0.1	0.5	216.78 - 217.28		2703.22 - 2702.72

BSH04	x=988415	y=995475	z=2832	Max. Loop=150	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.96	0.27	0 - 0.27		2832 - 2831.73
2	513	2.53	0.27 - 2.8		2831.73 - 2829.2
3	5783	184.8	2.8 - 187.6		2829.2 - 2644.4
4	0.1	10	187.6 - 197.6		2644.4 - 2634.4

BSH05	x=988593	y=995107	z=2850	Max. Loop=150	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.83	0.41	0 - 0.41		2850 - 2849.59
2	384.7	3.54	0.41 - 3.95		2849.59 - 2846.05
3	1881	182.9	3.95 - 186.85		2846.05 - 2663.15
4	0.1	10	186.85 - 196.85		2663.15 - 2653.15

BSH07	x=989868	y=995661	z=2873	Max. Loop=250	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	5.73	0.36	0 - 0.36		2873 - 2872.64
2	1914	50.8	0.36 - 51.16		2872.64 - 2821.84
3	16696	192.1	51.16 - 243.26		2821.84 - 2629.74
4	41.1	36.2	243.26 - 279.46		2629.74 - 2593.54
5	2000	125.7	279.46 - 405.16		2593.54 - 2467.84
6	2.74	0.25	405.16 - 405.41		2467.84 - 2467.59

BSH09	x=989582	y=996008	z=2886	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.78	0.25	0 - 0.25		2886 - 2885.75
2	482.2	0.44	0.25 - 0.69		2885.75 - 2885.31
3	17978	123.6	0.69 - 124.29		2885.31 - 2761.71
4	2000	128.9	124.29 - 253.19		2761.71 - 2632.81
5	15.1	282.3	253.19 - 535.49		2632.81 - 2350.51
6	1000	3.95	535.49 - 539.44		2350.51 - 2346.56

BSH11	x=987757	y=995396	z=2850	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.02	0.25	0 - 0.25		2850 - 2849.75
2	1586	0.47	0.25 - 0.72		2849.75 - 2849.28
3	20000	96.9	0.72 - 97.62		2849.28 - 2752.38
4	2000	93.7	97.62 - 191.32		2752.38 - 2658.68
5	1660	41.4	191.32 - 232.72		2658.68 - 2617.28
6	5	1000	232.72 - 1232.72		2617.28 - 1617.28
7	5	200.5	1232.72 - 1433.22		1617.28 - 1416.78
8	100	200.5	1433.22 - 1633.72		1416.78 - 1216.28

BSH13	x=987371	y=994160	z=2728	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	1.79	0.29	0 - 0.29		2728 - 2727.71
2	51.8	0.34	0.29 - 0.63		2727.71 - 2727.37
3	13497	66.3	0.63 - 66.93		2727.37 - 2661.07
4	5.3	4.85	66.93 - 71.78		2661.07 - 2656.22
5	553	32	71.78 - 103.78		2656.22 - 2624.22
6	5.3	33.6	103.78 - 137.38		2624.22 - 2590.62
7	0.316	19.1	137.38 - 156.48		2590.62 - 2571.52
8	100	19.1	156.48 - 175.58		2571.52 - 2552.42

BSH15	x=987168	y=994913	z=2858	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.74	0.36	0 - 0.36		2858 - 2857.64
2	1893	6.91	0.36 - 7.27		2857.64 - 2850.73
3	2364	87.2	7.27 - 94.47		2850.73 - 2763.53
4	22.6	25.8	94.47 - 120.27		2763.53 - 2737.73
5	20.2	26	120.27 - 146.27		2737.73 - 2711.73
6	52.5	50.3	146.27 - 196.57		2711.73 - 2661.43
7	16.7	42.9	196.57 - 239.47		2661.43 - 2618.53
8	2000	42.9	239.47 - 282.37		2618.53 - 2575.63

BSH06	x=989619	y=995448	z=2916	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	28.2	0.29	0 - 0.29		2916 - 2915.71
2	82.3	5.26	0.29 - 5.55		2915.71 - 2910.45
3	4745	332.6	5.55 - 338.15		2910.45 - 2577.85
4	87.4	348.8	338.15 - 686.95		2577.85 - 2229.05
5	258.9	200.3	686.95 - 887.25		2229.05 - 2028.75

BSH08	x=989903	y=995316	z=2894	Max. Loop=250	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	5.31	0.38	0 - 0.38		2894 - 2893.62
2	1954	37.9	0.38 - 38.28		2893.62 - 2855.72
3	20000	187.1	38.28 - 225.38		2855.72 - 2668.62
4	23.9	40.6	225.38 - 265.98		2668.62 - 2628.02
5	2000	135.2	265.98 - 401.18		2628.02 - 2492.82
6	0.1	0.25	401.18 - 401.43		2492.82 - 2492.57

BSH10	x=988632	y=995781	z=2801	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	19.7	0.28	0 - 0.28		2801 - 2800.72
2	60.9	3.58	0.28 - 3.86		2800.72 - 2797.14
3	2095	139.7	3.86 - 143.56		2797.14 - 2657.44
4	2000	7.18	143.56 - 150.74		2657.44 - 2650.26
5	0.128	10	150.74 - 160.74		2650.26 - 2640.26
6	0.128	10	160.74 - 170.74		2640.26 - 2630.26
7	0.128	10	170.74 - 180.74		2630.26 - 2620.26
8	128	10	180.74 - 190.74		2620.26 - 2610.26

BSH12	x=987262	y=995491	z=2798	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	2.03	0.26	0 - 0.26		2798 - 2797.74
2	41.1	0.38	0.26 - 0.64		2797.74 - 2797.36
3	20000	106.9	0.64 - 107.54		2797.36 - 2690.46
4	2000	148.5	107.54 - 256.04		2690.46 - 2541.96
5	12.4	10	256.04 - 266.04		2541.96 - 2531.96

BSH14	x=986433	y=994600	z=2746	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.46	0.48	0 - 0.48		2746 - 2745.52
2	989.5	18	0.48 - 18.48		2745.52 - 2727.52
3	397.2	35	18.48 - 53.48		2727.52 - 2692.52
4	22.9	19.5	53.48 - 72.98		2692.52 - 2673.02
5	40.4	34.3	72.98 - 107.28		2673.02 - 2638.72
6	27.4	30.5	107.28 - 137.78		2638.72 - 2608.22
7	13.6	25.5	137.78 - 163.28		2608.22 - 2582.72
8	2000	25.5	163.28 - 188.78		2582.72 - 2557.22

BSH16	x=988354	y=993786	z=3014	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.82	0.25	0 - 0.25		3014 - 3013.75
2	24.7	1.47	0.25 - 1.72		3013.75 - 3012.28
3	20000	201.8	1.72 - 203.52		3012.28 - 2810.48
4	136.4	264.6	203.52 - 468.12		2810.48 - 2545.88
5	0.826	15.1	468.12 - 483.22		2545.88 - 2530.78
6	0.28	1.12	483.22 - 484.34		2530.78 - 2529.66
7	0.14	18.7	484.34 - 503.04		2529.66 - 2510.96

BSH17	x=988531	y=994353	z=2935	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	4.25	0.3	0 - 0.3		2935 - 2934.7
2	1587	4.65	0.3 - 4.95		2934.7 - 2930.05
3	20000	224.6	4.95 - 229.55		2930.05 - 2705.45
4	0.1	10	229.55 - 239.55		2705.45 - 2695.45

BSH19	x=987969	y=994977	z=2911	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.1	0.25	0 - 0.25		2911 - 2910.75
2	49.8	1.86	0.25 - 2.11		2910.75 - 2908.89
3	20000	172	2.11 - 174.11		2908.89 - 2736.89
4	0.1	1000	174.11 - 1174.11		2736.89 - 1736.89
5	500	703.4	1174.11 - 1877.51		1736.89 - 1033.49
6	2000	1.07	1877.51 - 1878.58		1033.49 - 1032.42

BSH21	X=990028	y=993411	z=2933	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	104.1	0.25	0 - 0.25		2933 - 2932.75
2	50.3	7.3	0.25 - 7.55		2932.75 - 2925.45
3	624.8	78.9	7.55 - 86.45		2925.45 - 2846.55
4	39.1	399.8	86.45 - 486.25		2846.55 - 2446.75
5	16.6	0.5	486.25 - 486.75		2446.75 - 2446.25

BSH23	x=990348	y=993000	z=2943	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	10.5	0.98	0 - 0.98		2943 - 2942.02
2	68.9	7.15	0.98 - 8.13		2942.02 - 2934.87
3	20000	49	8.13 - 57.13		2934.87 - 2885.87
4	55.4	267.3	57.13 - 324.43		2885.87 - 2618.57
5	13.2	116.8	324.43 - 441.23		2618.57 - 2501.77
6	2000	644.6	441.23 - 1085.83		2501.77 - 1857.17

BSH25	x=990709	y=993079	z=2941	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	12.5	0.66	0 - 0.66		2941 - 2940.34
2	114.7	7.76	0.66 - 8.42		2940.34 - 2932.58
3	20000	169.1	8.42 - 177.52		2932.58 - 2763.48
4	22.1	89.6	177.52 - 267.12		2763.48 - 2673.88
5	8.35	42.1	267.12 - 309.22		2673.88 - 2631.78
6	3.2	644.6	309.22 - 953.82		2631.78 - 1987.18

BSH27	x=991105	y=992995	z=2939	Max.Loop=200	
Layer	resisivity(ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	98.5	8.9	0 - 8.9		2939 - 2930.1
2	1491	0.25	8.9 - 9.15		2930.1 - 2929.85
3	20000	72.7	9.15 - 81.85		2929.85 - 2857.15
4	1000	73	81.85 - 154.85		2857.15 - 2784.15
5	19.8	17.2	154.85 - 172.05		2784.15 - 2766.95
6	464.4	40.2	172.05 - 212.25		2766.95 - 2726.75
7	7.07	0.5	212.25 - 212.75		2726.75 - 2726.25

BSH29	x=988976	y=995319	z=2819	Max.Loop=200	
Layer	resisivity(ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.72	0.25	0 - 0.25		2819 - 2818.75
2	111.5	0.89	0.25 - 1.14		2818.75 - 2817.86
3	20000	238.4	1.14 - 239.54		2817.86 - 2579.46
4	0.405	4.58	239.54 - 244.12		2579.46 - 2574.88
5	2000	17.2	244.12 - 261.32		2574.88 - 2557.68
6	0.1	1.07	261.32 - 262.39		2557.68 - 2556.61

BSH18	x=988458	y=994575	z=2988	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	3.71	0.25	0 - 0.25		2988 - 2987.75
2	43.9	0.42	0.25 - 0.67		2987.75 - 2987.33
3	20000	327.4	0.67 - 328.07		2987.33 - 2659.93
4	2000	0.25	328.07 - 328.32		2659.93 - 2659.68
5	0.1	0.48	328.32 - 328.8		2659.68 - 2659.2
6	6.21	43.3	328.8 - 372.1		2659.2 - 2615.9
7	0.1	0.5	372.1 - 372.6		2615.9 - 2615.4

BSH20	x=988971	y=994101	z=2954	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	2.84	0.26	0 - 0.26		2954 - 2953.74
2	43.3	2.06	0.26 - 2.32		2953.74 - 2951.68
3	20000	225.7	2.32 - 228.02		2951.68 - 2725.98
4	0.483	3.77	228.02 - 231.79		2725.98 - 2722.21
5	3.51	16.5	231.79 - 248.29		2722.21 - 2705.71
6	0.1	1.07	248.29 - 249.36		2705.71 - 2704.64

BSH22	x=989798	y=993193	z=2981	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	1090	1.51	0 - 1.51		2981 - 2979.49
2	69.5	6.81	1.51 - 8.32		2979.49 - 2972.68
3	448.4	81.3	8.32 - 89.62		2972.68 - 2891.38
4	1.52	6.99	89.62 - 96.61		2891.38 - 2884.39
5	0.1	0.5	96.61 - 97.11		2884.39 - 2883.89

BSH24	x=990320	y=993563	z=2898	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	11.7	0.78	0 - 0.78		2898 - 2897.22
2	93	5.65	0.78 - 6.43		2897.22 - 2891.57
3	20000	93.3	6.43 - 99.73		2891.57 - 2798.27
4	34	114.9	99.73 - 214.63		2798.27 - 2683.37
5	1.64	0.25	214.63 - 214.88		2683.37 - 2683.12
6	4.61	644.6	214.88 - 859.48		2683.12 - 2038.52

BSH26	x=990780	y=992745	z=2985	Max. Loop=200	
Layer	Resisivity (ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	34.2	0.58	0 - 0.58		2985 - 2984.42
2	284	35.2	0.58 - 35.78		2984.42 - 2949.22
3	20000	97.9	35.78 - 133.68		2949.22 - 2851.32
4	50.3	21.7	133.68 - 155.38		2851.32 - 2829.62
5	4.31	46.6	155.38 - 201.98		2829.62 - 2783.02
6	0.1	0.5	201.98 - 202.48		2783.02 - 2782.52

BSH28	x=991206	y=993555	z=2956	Max. Loop=200	
Layer	resisivity(ohm-m)	Thickness(m)	Depth Boundary (m)		Alutitude Boundary (m)
1	7784	255.3	0 - 255.3		2956 - 2700.7
2	5876	128.8	255.3 - 384.1		2700.7 - 2571.9
3	25.8	38.6	384.1 - 422.7		2571.9 - 2533.3
4	0.268	0.25	422.7 - 422.95		2533.3 - 2533.05

PART 4

DRILLING EXPLORATION

Final Report

(Supporting Report)

PART 4 DRILLING EXPLORATION

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PART 4 DRILLING EXPLORATION

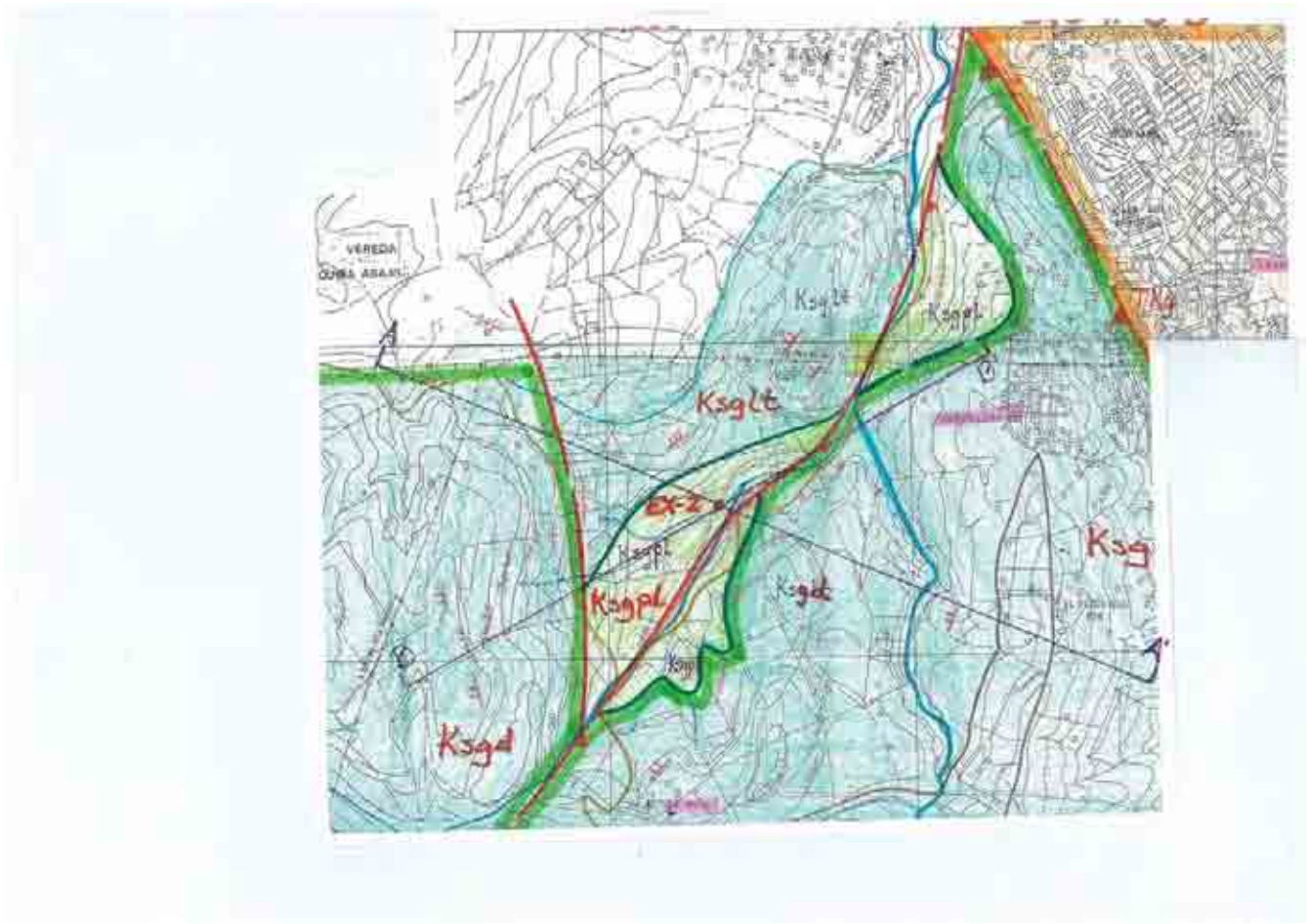

Figure-4. 1 Geological Plain and Section around EX-2

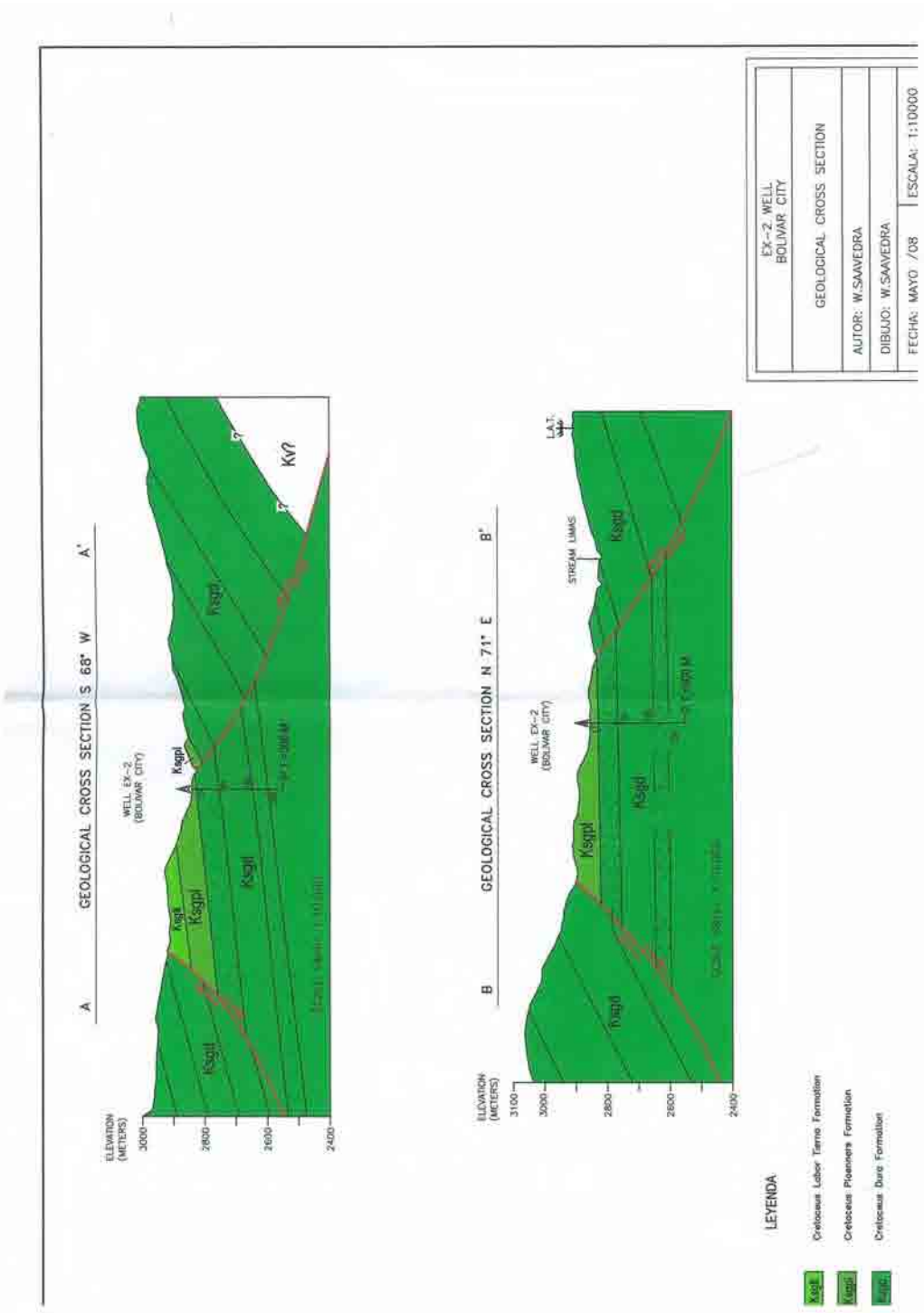

Figure-4.1(b)Geological Plain and Section around EX-2

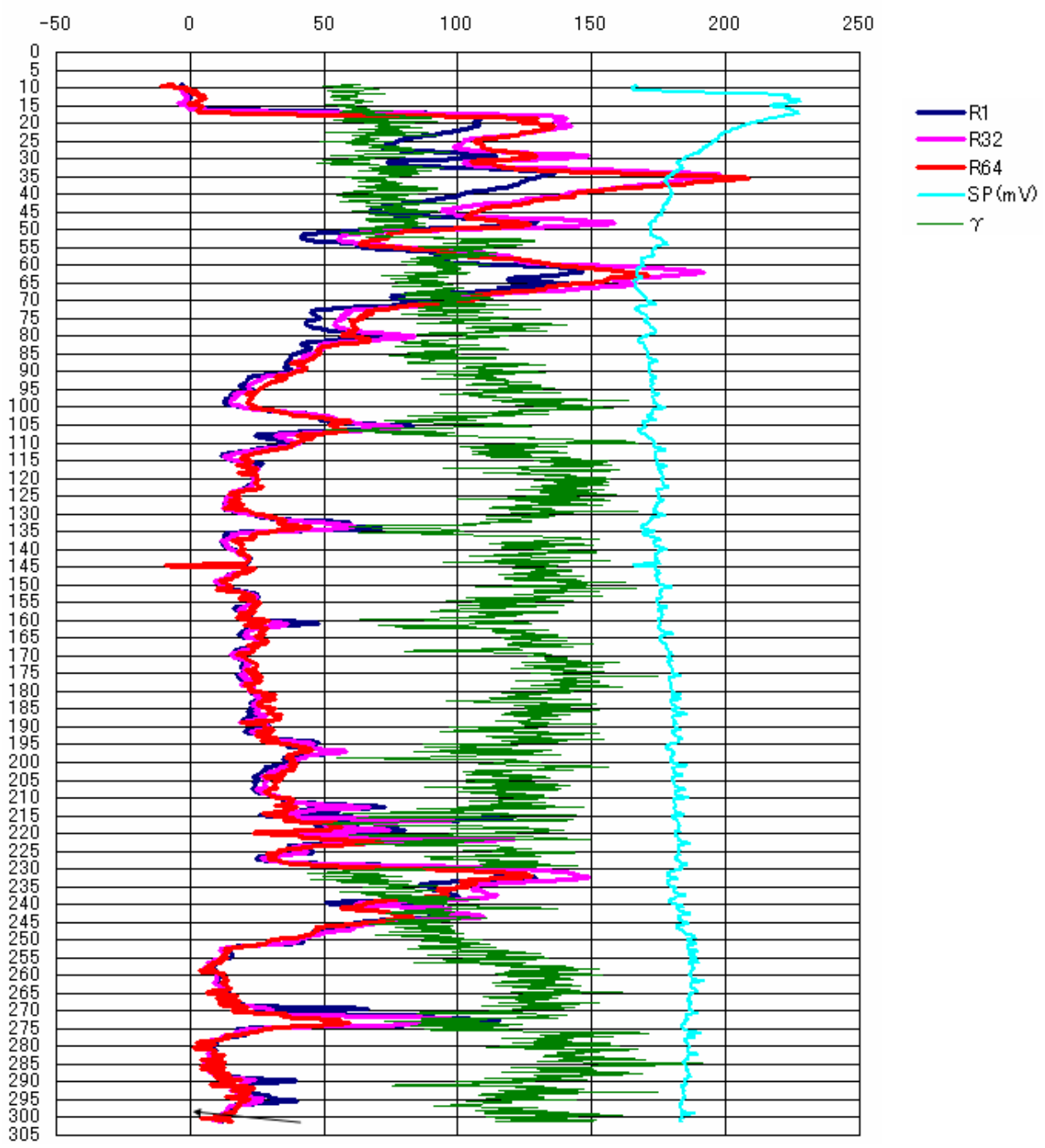

Figure-4. 2 Result of Electrical Logging of Ciudad Bolivar (EX-2)

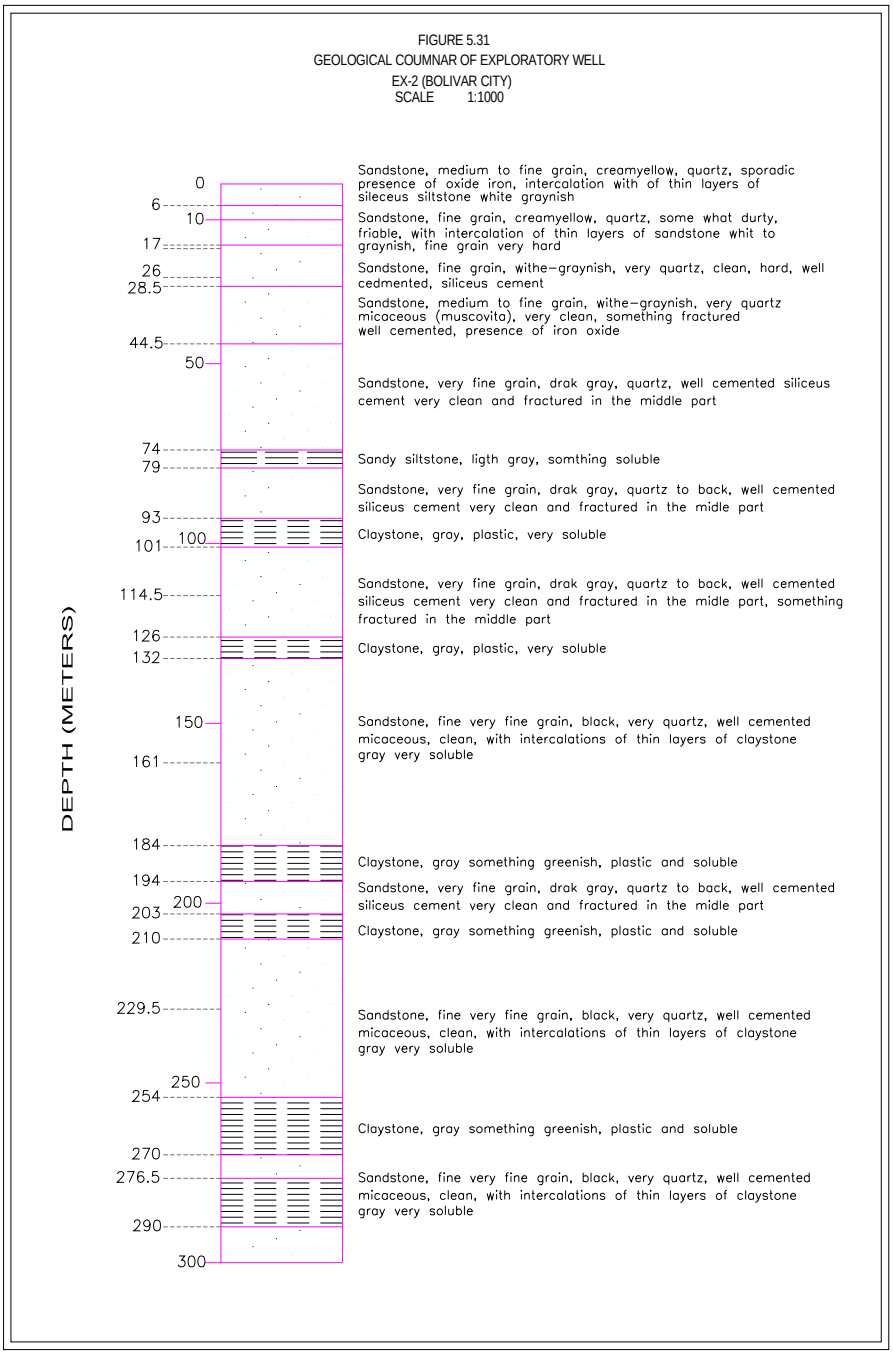

Figure-4. 3 Result of Geological Logging of Ciudad Bolivar (EX-2)

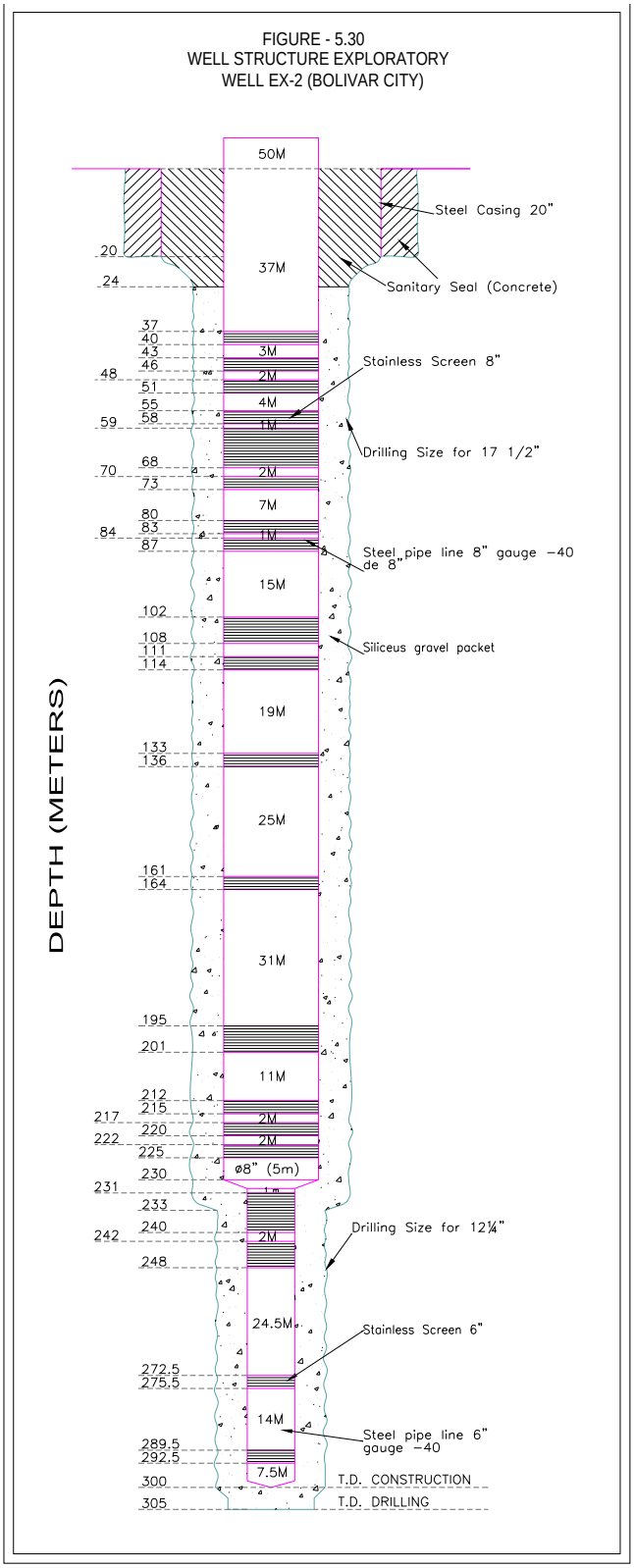

Figure-4. 4 Result of Well Structure of Ciudad Bolivar (EX-2)

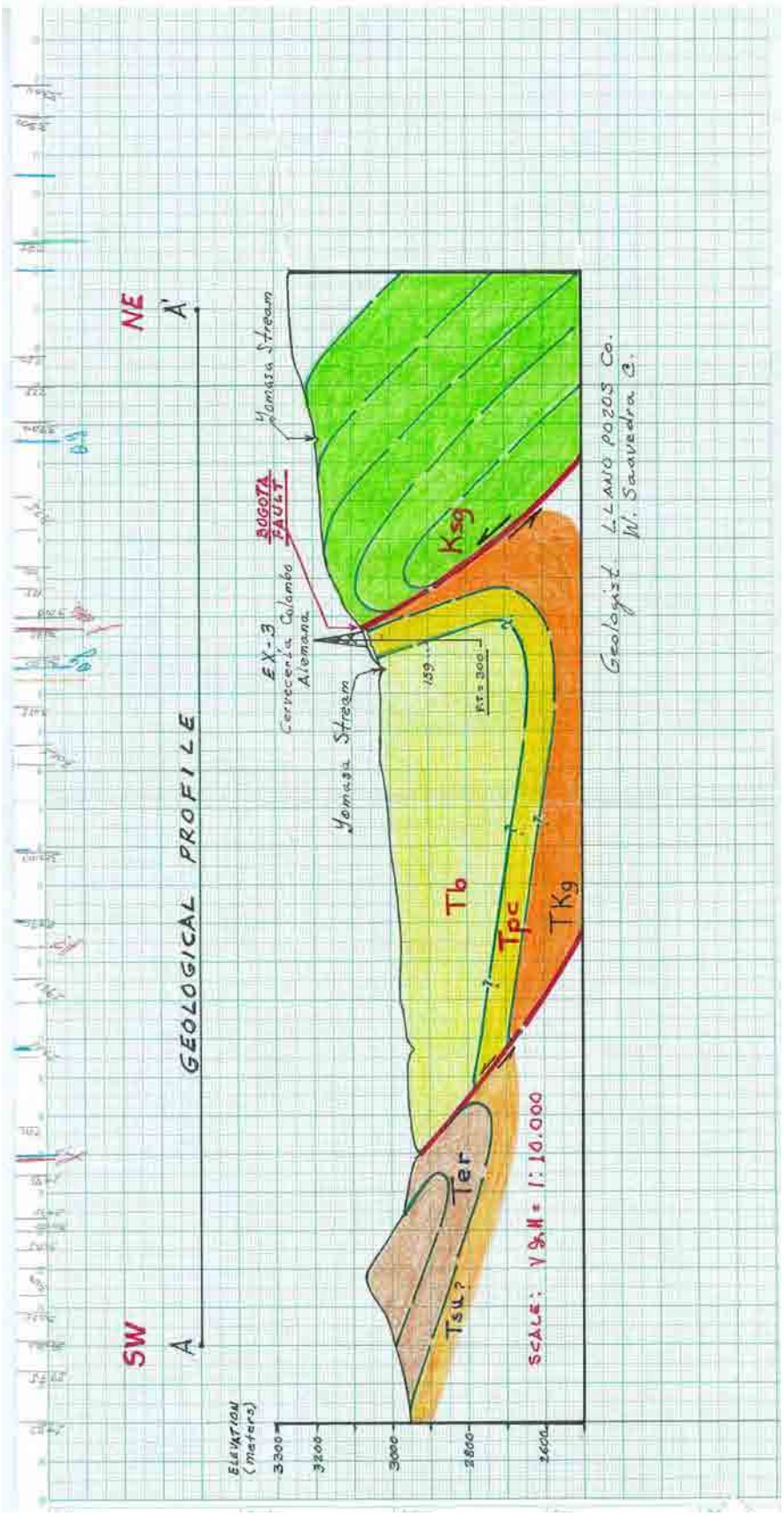

Figure-4. 5 Geological Section around EX-3

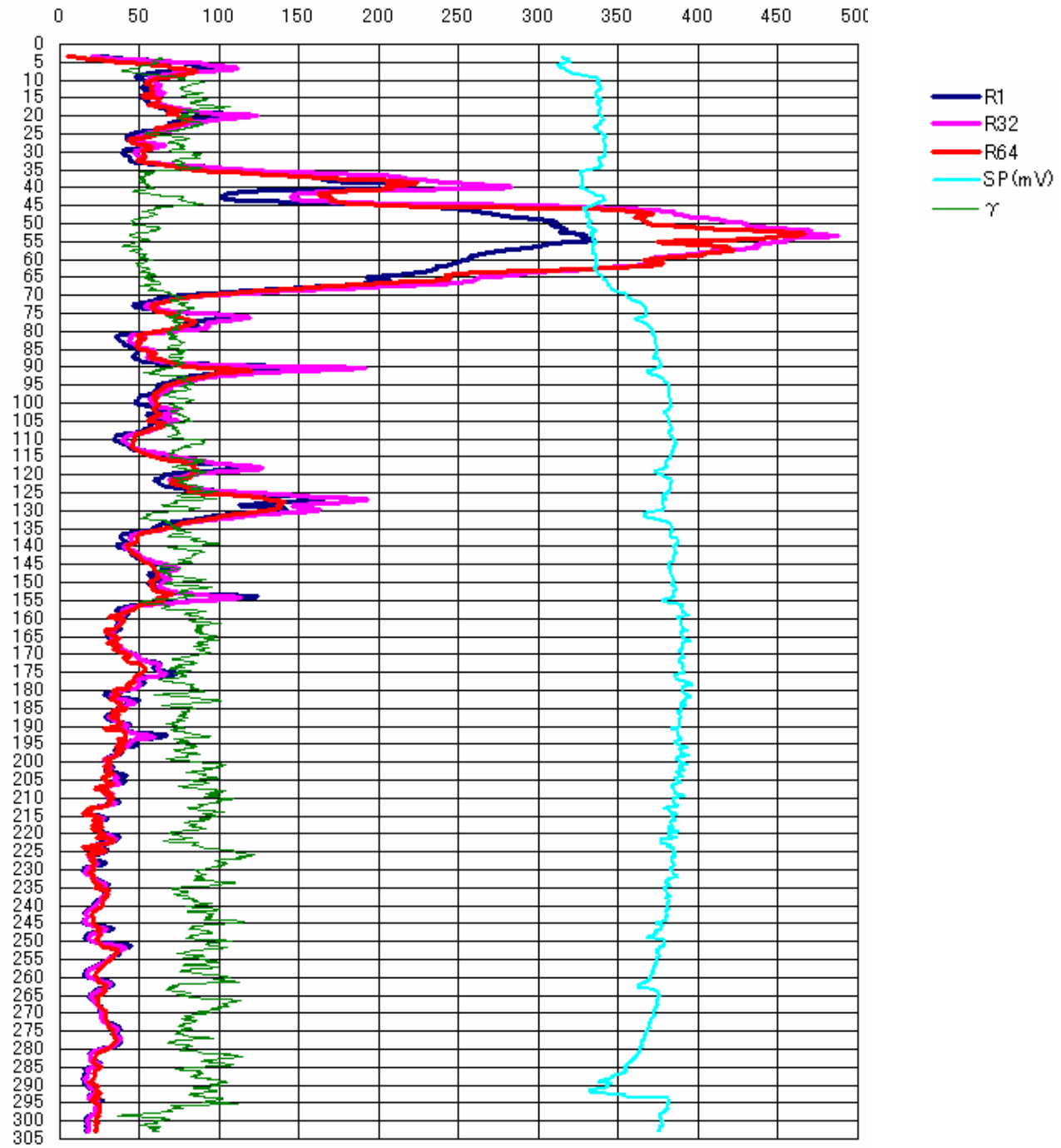

Figure-4. 6 Result of Electrical Logging of Usme (EX-3)

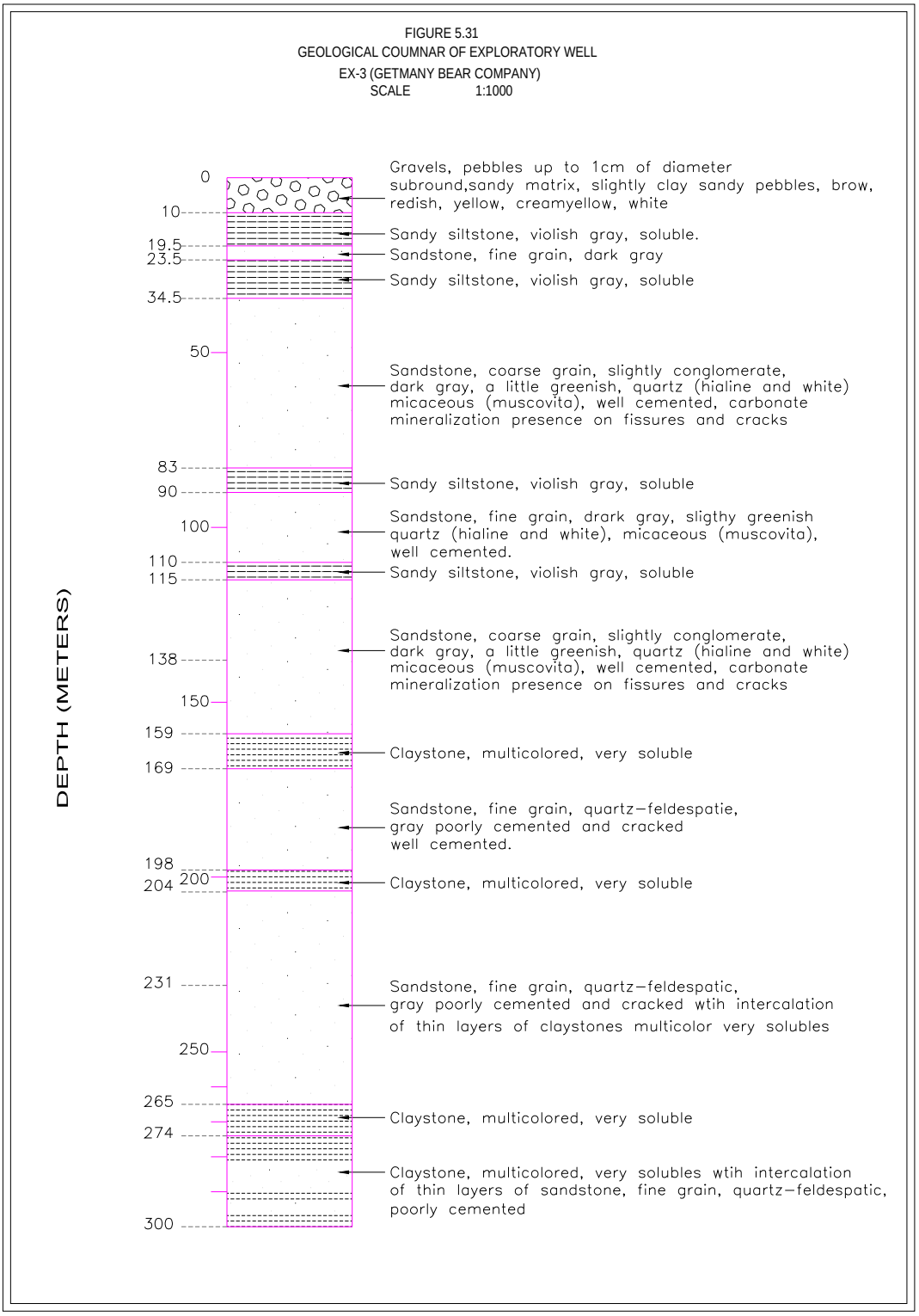

Figure-4. 7 Result of Geological Logging of Usme (EX-3)

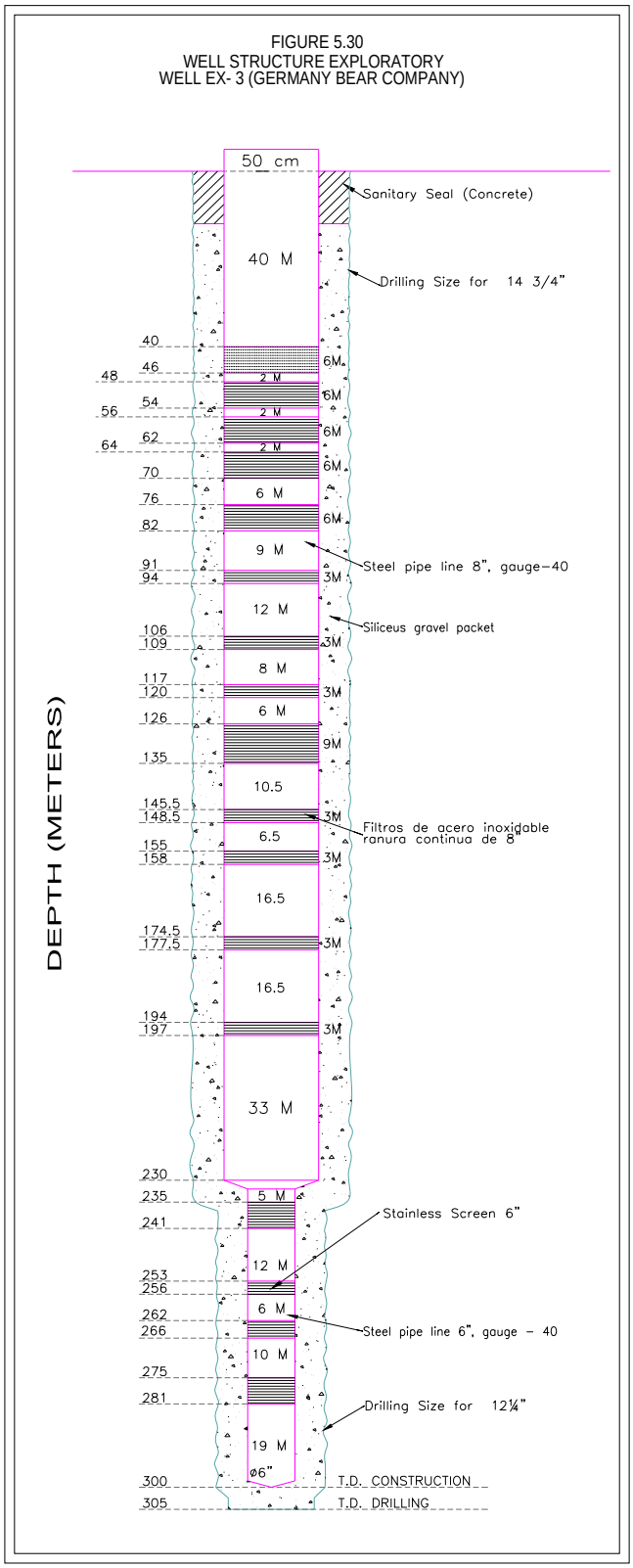

Figure-4. 8 Result of Well Structure of Usme (EX-3)

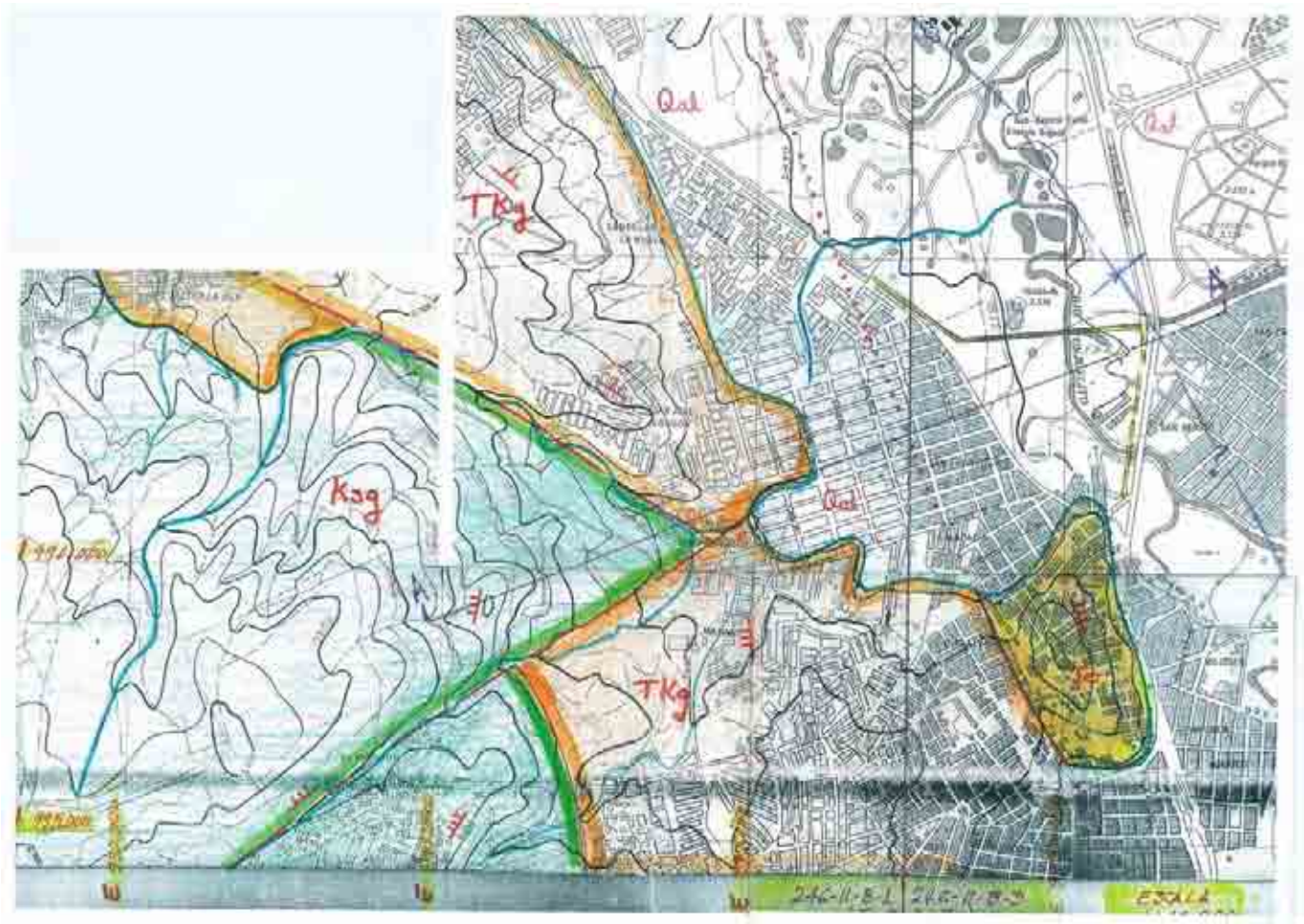

Figure-4. 9 Geological Plain and Section around EX-4

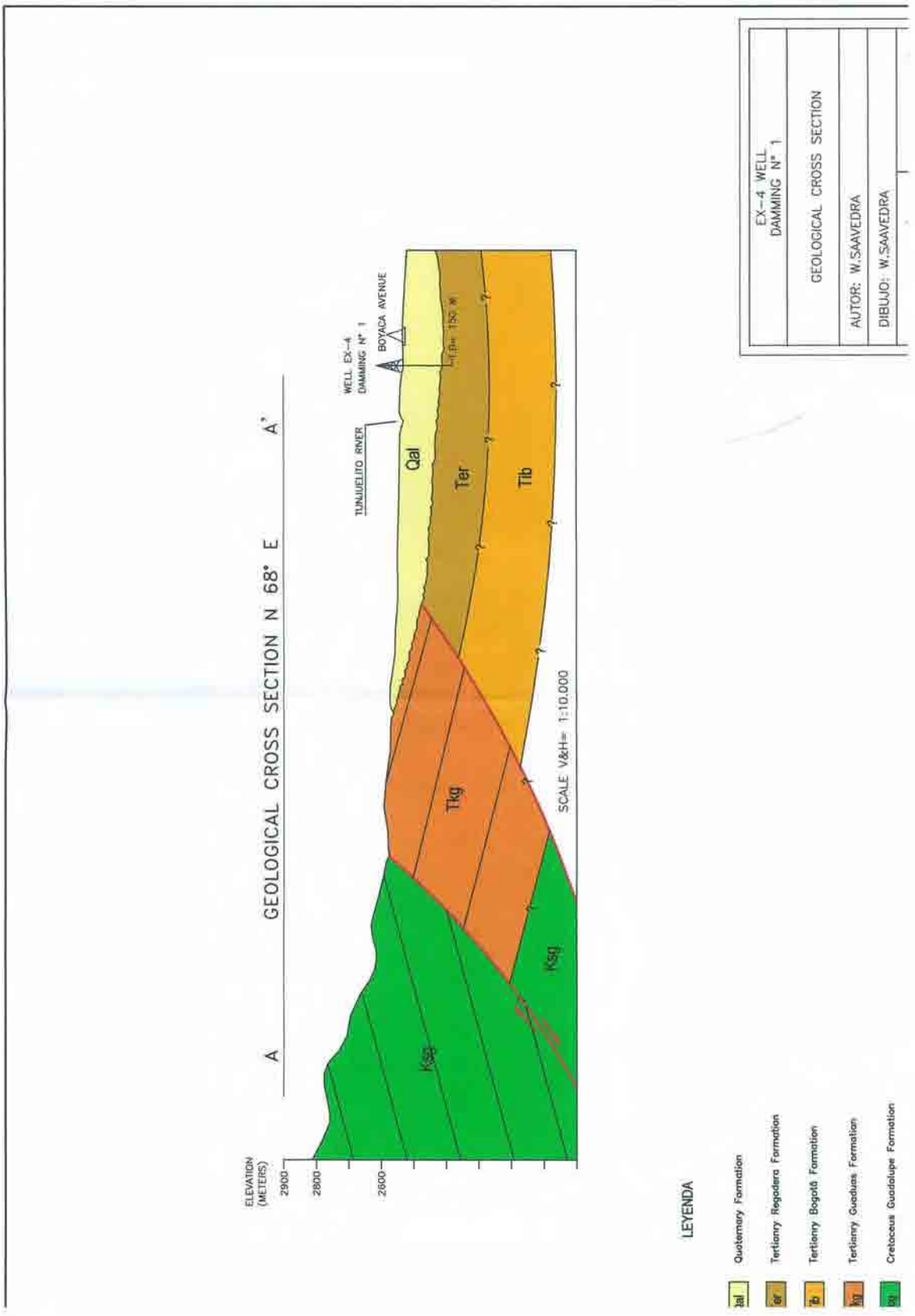

Figure-4.9 (b) Geological Plain and Section around EX-4

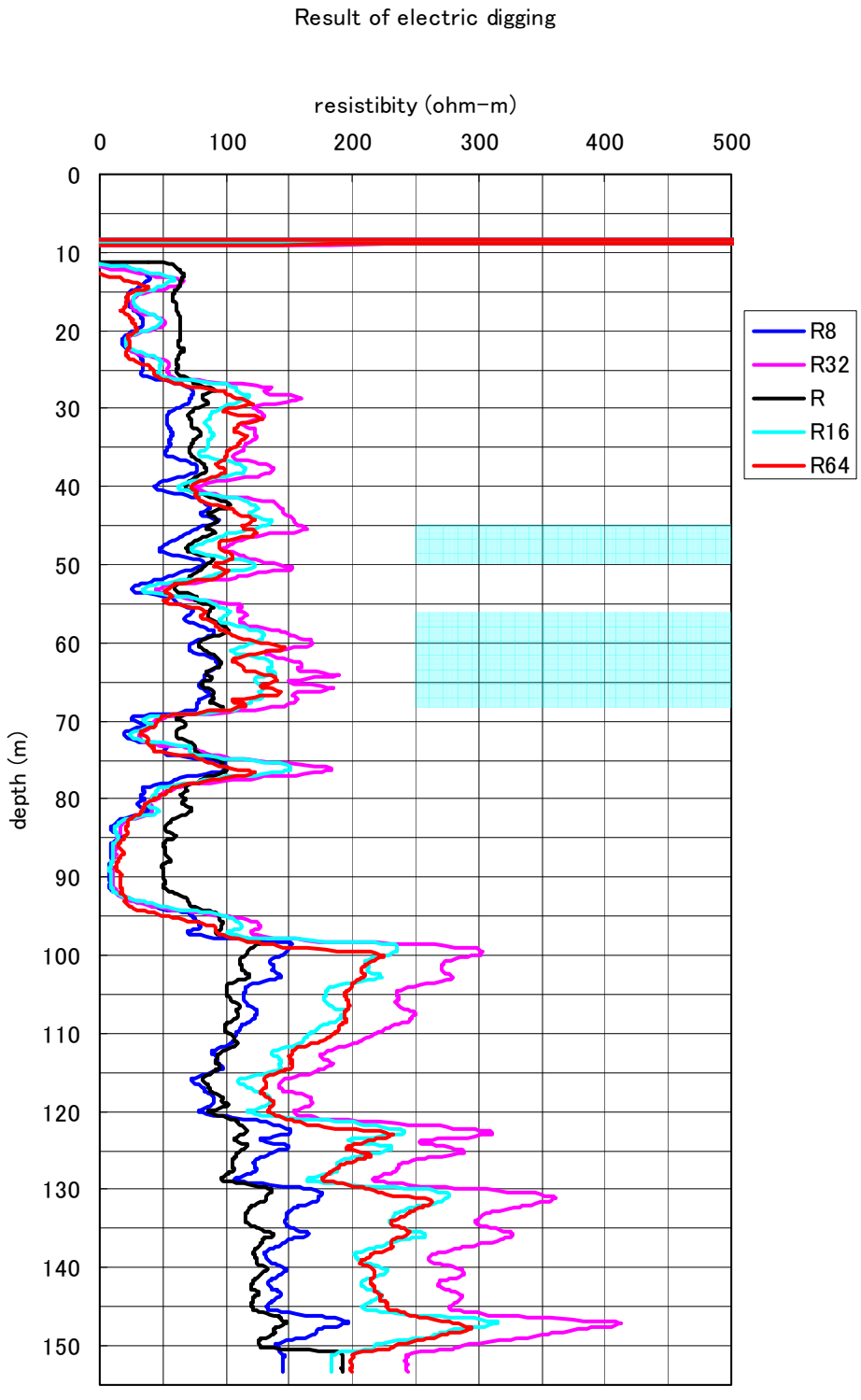

Figure-4. 10 Result of Electrical Logging of Quaternary Well (EX-4)

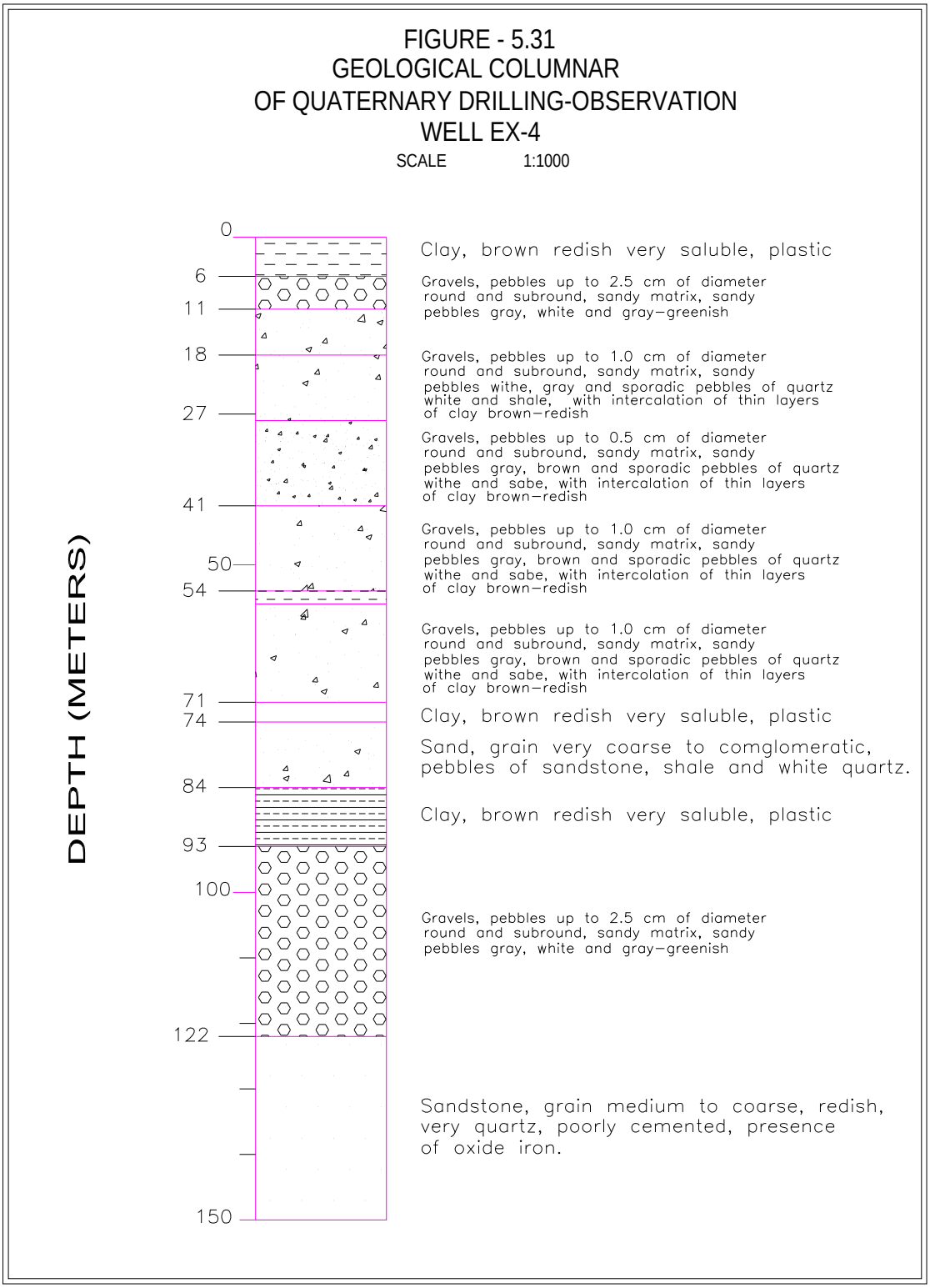

Figure-4. 11 Result of Geological Logging of Quaternary Well (EX-4)

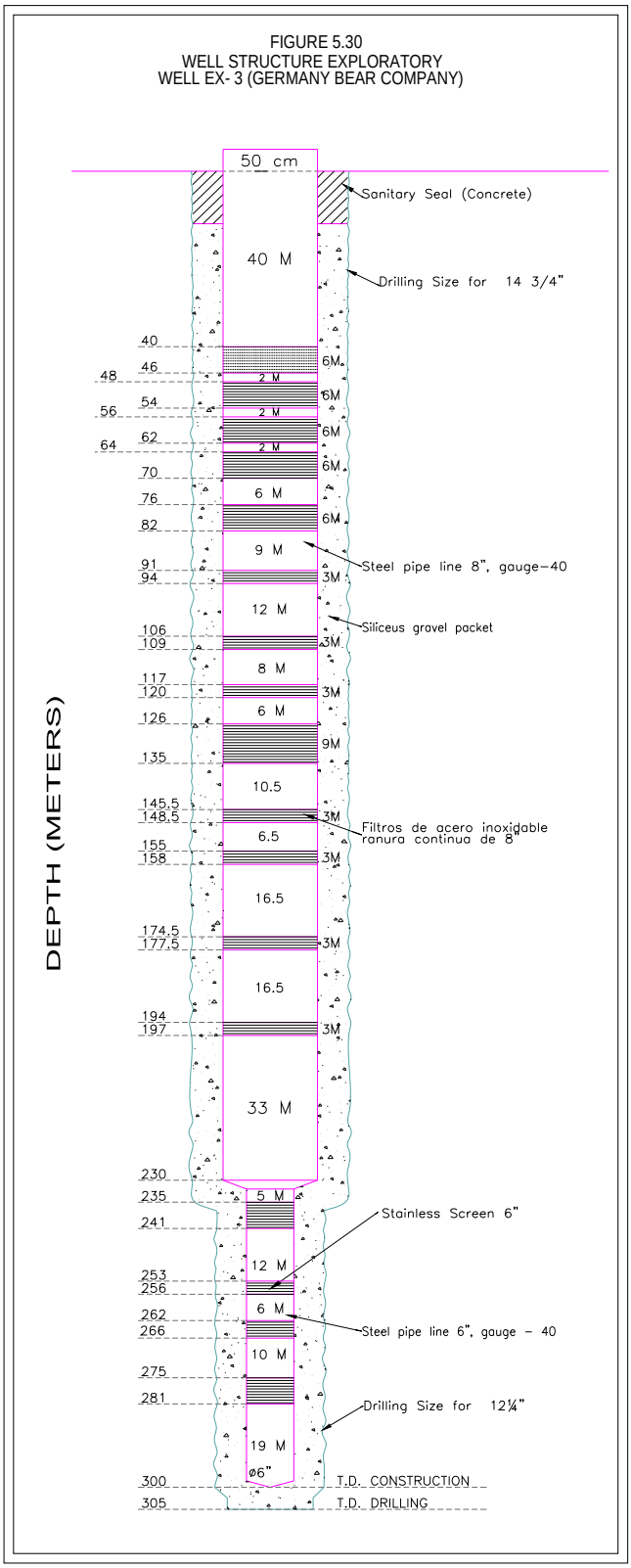

Figure-4. 12 Result of Well Structure of Quaternary Well (EX-4)

PART 5

WATER BALANCE ANALYSIS

Final Report

(Supporting Report)

PART 5 WATER BALANCE ANALYSIS

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PART 5 WATER BALANCE ANALYSIS

CHAPTER 1. PRECIPITATION DATA COLLECTION AND CHECKING

1.1. Data Collection

Data used in Meteorological analysis are mainly obtained from EAAB, some data also obtained from other agencies, such as CAR、EAAB and IDEAM.

Table-5. 1 Data Collected for Precipitation Analysis

Code	Location	Elev.	Duration	D_Year	Entity
2120008	San Francisco-Salitre K9	3228	1933-2006	74	EAAB
2120011	San Rafael	2753	1933-2006	74	EAAB
2120013	El Delirio	3019	1933-2006	74	EAAB
2120019	Bocagrande - Salitre	3583	1941-2006	62	EAAB
2120020	El Hato	3116	1928-2006	70	EAAB
2120031	Cerro De Suba	2669	1946-1973	27	EAAB
2120032	El Granizo	3108	1947-2006	58	EAAB
2120044	La Pradera	2741	1951-2006	53	CAR
2120051	Apostolica	2582	1956-2006	49	CAR
2120074	Zipaquira	2660	1970-2006	25	CAR
2120075	Bojaca	2583	1970-2006	28	CAR
2120085	El Bosque	3149	1966-2006	32	CAR
2120096	El Consuelo	2975	1967-2006	31	CAR
2120112	La Casita	3181	1973-2006	22	CAR
2120113	Almaviva	2552	1973-1997	20	CAR
2120115	Edificio M Mejia	2623	1981-2003	22	CAR
2120141	Acandi	2574	1977-2006	30	CAR
2120154	Bosa Barreno	2556	1942-2006	52	EAAB
2120156	La Picota	2562	1980-2006	27	CAR
2120159	Alco	2567	1980-2006	24	CAR
2120162	Suesca	2575	1987-2007	21	IDEAM
2120166	El Fute	2584	1959-2006	47	CAR
2120168	Alto De Aire	2938	1987-2006	18	CAR
2120171	Represa Sisga	2775	1939-1994	53	CAR
2120173	Campobello	2557	1987-2006	18	CAR
2120174	Nanjui	3186	1970-2006	28	CAR
2120183	Dario Valencia	792	1988-2006	16	CAR
2120186	La Maria	2926	1993-2006	9	CAR
2120187	Bombas Sesquile	2611	1987-2006	15	CAR
2120194	El Choche	2732	1996-2006	11	CAR
2120195	Montecillos	2897	1996-2006	11	CAR
2120196	Casa De Bombas Salitre	2546	1975-2006	30	EAAB
2120197	Casablanca	2706	1976-2006	31	EAAB
2120198	Guadalupe	3201	1987-2006	20	EAAB
2120202	Serrezuela	2831	1990-2006	17	EAAB
2120203	Cabrera La Meseta	2658	1990-1996	7	EAAB
2120204	Juan Rey	3114	1990-2006	17	EAAB
2120205	Quiba	2987	1990-2006	17	EAAB
2120207	Saucedal Ii	2544	1990-2006	17	EAAB
2120208	La Conejera	2556	1990-2006	17	EAAB
2120209	La Isla	2541	1991-1996	6	EAAB
2120210	Los Tunjos	3643	1989-2006	18	EAAB
2120211	Las Huertas	2571	1990-2006	17	EAAB
2120516	La Ramada	2543	1938-2006	59	CAR
2120531	La Caro	2576	1990-2006	17	EAAB
2120538	Techo	2543	1957-1996	39	EAAB
2120540	Checua	2579	1953-2006	54	CAR
2120541	Represa Del Neusa	3036	1954-2003	49	CAR
2120545	Tibitoc	2560	1980-2006	26	EAAB
2120548	La Iberia	2789	1953-2006	54	CAR

Code	Location	Elev.	Duration	D_Year	Entity
2120559	Apto. Guaymaral	2557	1965-2006	41	CAR
2120561	Muña	2561	1966-2003	37	CAR
2120569	Camavieja	2558	1979-2006	28	EAAB
2120585	Colombiano	2567	1987-2006	19	IDEAM
2120596	Tachi	2650	1987-2006	13	IDEAM
2120603	San Cayetano	2650	1978	1	IDEAM
2120632	La Fortuna	2852	1963-2006	43	CAR
2120633	Barrancas	2729	1966-2006	41	CAR
2401110	Isla Del Santuario	2565	1957-2005	46	CAR
3502506	Bolsala	3195	1988-2006	19	IDEAM

Elev.: Elevation, values are read from 90m mesh DEM of SRTM (USNASA)
Duration: First and last Years of observation.
D_Year : Total years of observation.
Entity : Entities for observation stations management.

1.2. Data Checking and Revising

The collected precipitation data includes error values because of problems of observation equipments, miss input and others. It is impossible to find all error data but some of them can be found by logic analysis and experience. The followings are several examples of data checking:

- Station 120113 (El Delirio)
  All precipitation in January ,1993 have the same value of 99.9mm, and all of them was exchanged as null (no data).
- Station 2120085 (El Bosque):
  Precipitation on August 26th 2003 was as big as 189.5mm. but the precipitation for all other station were within the range of 0 -18.8 mm. about 200mm/day is very usual phenomena and only the heavy rain concentrated in one station is almost unbelievable. So, the data was exchanged to 18.9mm.
- Station2120633 （Barrancas）
  All precipitation in February 1995 have the same value as 1×10^34. This is obviously wrong. So the data were exchanged to null.

1.3. Data Complement

Because of various kinds of problems, data could not the obtained for some days.

Table-5. 2 Results of Missing Day Checking

Code	M_Days	T_Days	Pcntg		Code	M_Days	T_Days	Pcntg
2120008	990	26,663	3.7		2120195	712	4,018	17.7
2120011	1,213	27,028	4.5		2120196	816	10,958	7.4
2120013	771	27,028	2.9		2120197	463	11,323	4.1
2120019	1,971	22,645	8.7		2120198	1,037	7,305	14.2
2120020	1,040	25,567	4.1		2120202	253	6,209	4.1
2120031	406	9,862	4.1		2120203	507	2,557	19.8
2120032	1,538	21,550	7.1		2120204	724	6,209	11.7
2120044	1,163	9,863	11.8		2120205	274	6,209	4.4
2120051	441	10,228	4.3		2120207	376	6,209	6.1
2120074	599	9,131	6.6		2120208	422	6,209	6.8
2120075	1,100	10,228	10.8		2120209	536	2,192	24.5
2120085	834	11,689	7.1		2120210	466	6,574	7.1
2120096	225	11,324	2		2120211	249	6,209	4
2120112	441	8,401	5.2		2120516	1,330	21,914	6.1
2120113	2,410	8,035	30		2120531	521	6,209	8.4
2120115	1,805	5,479	32.9		2120538	730	14,245	5.1
2120141	727	10,957	6.6		2120540	633	15,705	4
2120154	1,206	18,993	6.3		2120541	937	13,879	6.8
2120156	1,255	6,941	18.1		2120545	879	9,862	8.9
2120159	1,857	9,131	20.3		2120548	647	14,610	4.4
2120162	930	7,670	12.1		2120559	884	14,610	6.1
2120166	841	9,863	8.5		2120561	609	12,784	4.8
2120168	41	6,575	0.6		2120569	324	10,227	3.2
2120171	37	7,306	0.5		2120585	1,073	7,305	14.7
2120173	482	6,575	7.3		2120596	1,363	5,114	26.7
2120174	407	10,228	4		2120603	2	365	0.5
2120183	491	6,210	7.9		2120632	31	12,054	0.3
2120186	1,800	4,382	41.1		2120633	587	12,054	4.9
2120187	1,278	5,844	21.9		2401110	760	11,324	6.7
2120194	132	4,018	3.3		3502506	429	6,940	6.2

M-days: Missed observation days
T-days: Total observation days (including missed days). **Pcntg**: Percentage of M-days to T-days

Autocorrelation technique was used for completion of the missed data. The first step is to calculate the average form January to 31december for each data serials. Then the second is to use the average value as the precipitation for a corresponding missing day. The method can be expressed by the equation as follows:

$$\mathbf{Ri = \Sigma Rj / N}$$

Here

Ri is the value used for for complementing a missing day
Rj is the value on the same day but in other years of the same data serials.
N is the number of the years which have observation value for the day.

Table-5. 3 Result of Missing day's Completion

Code	Location	Before	After	Pctg
2120008	San Francisco-Salitre K9	82,921	86,291	4.1
2120011	San Rafael	57,508	60,149	4.6
2120013	El Delirio	88,885	91,168	2.6
2120019	Bocagrande - Salitre	82,670	90,490	9.5
2120020	El Hato	51,676	53,938	4.4
2120031	Cerro De Suba	23,530	24,530	4.2
2120032	El Granizo	64,611	68,341	5.8
2120044	La Pradera	19,617	21,925	11.8
2120051	Apostolica	17,947	18,723	4.3
2120074	Zipaquira	21,182	22,743	7.4

Code	Location	Before	After	Pctg
2120075	Bojaca	15,209	16,344	7.5
2120085	El Bosque	37,952	40,931	7.8
2120096	El Consuelo	26,564	26,962	1.5
2120112	La Casita	22,680	23,858	5.2
2120113	Almaviva	10,089	13,780	36.6
2120115	Edificio M Mejia	8,102	11,223	38.5
2120141	Acandi	22,464	24,044	7.0
2120154	Bosa Barreno No. 2	29,461	31,341	6.4
2120156	La Picota	9,143	11,104	21.4
2120159	Alco	14,133	17,098	21.0
2120162	Suesca	11,074	12,644	14.2
2120166	El Fute	14,060	15,311	8.9
2120168	Alto De Aire	12,382	12,478	0.8
2120171	Represa Sisga	17,376	17,475	0.6
2120173	Campobello	10,106	10,822	7.1
2120174	Nanjui	20,831	21,613	3.8
2120183	Dario Valencia	18,928	19,385	2.4
2120186	La Maria	6,166	8,192	32.9
2120187	Bombas Sesquile	7,346	8,840	20.3
2120194	El Choche	8,449	8,688	2.8
2120195	Montecillos	5,640	6,915	22.6
2120196	Casa De Bombas Salitre	26,097	28,156	7.9
2120197	Casablanca	18,148	18,897	4.1
2120198	Guadalupe	20,406	23,851	16.9
2120202	Serrezuela	16,313	16,970	4.0
2120203	Cabrera La Meseta	3,337	4,133	23.9
2120204	Juan Rey	17,902	20,251	13.1
2120205	Quiba	11,136	11,627	4.4
2120207	Saucedal Ii	10,917	11,597	6.2
2120208	La Conejera	13,256	14,199	7.1
2120209	La Isla	2,515	3,324	32.2
2120210	Los Tunjos	21,244	22,952	8.0
2120211	Las Huertas	8,596	8,914	3.7
2120516	La Ramada	41,129	43,170	5.0
2120531	La Caro	11,932	12,959	8.6
2120538	Techo	21,527	22,729	5.6
2120540	Checua	26,477	27,527	4.0
2120541	Represa Del Neusa	32,865	33,535	2.0
2120545	Tibitoc	20,709	21,937	5.9
2120548	La Iberia	32,022	33,422	4.4
2120559	Apto. Guaymaral	29,866	30,915	3.5
2120561	Muna	19,201	19,600	2.1
2120569	Camavieja	23,876	24,720	3.5
2120585	Colombiano	13,456	15,065	12.0
2120596	Tachi	8,537	10,810	26.6
2120603	San Cayetano	1,425	1,425	0.0
2120632	La Fortuna	25,218	25,270	0.2
2120633	Barrancas	21,871	22,983	5.1
2401110	Isla Del Santuario	31,126	31,462	1.1
3502506	Bolsala	22,224	23,735	6.8
Total		1,392,026	1,483,479	6.6

Before : Total precipitation in mm before the data complement. **After** : Total precipitation in mm after the data complement.
Pcntg : Percentage of change as the result of complement.

CHAPTER 2. AVERAGE PRECIPITATION

2.1. Yearly Precipitation

Some results of the statistics for precipitation analysis have been calculated by using the data after checking and completion.

Table-5. 4 Statistics of Precipitation

Code	Location	D_Year	Avrg	Max	Max_Y	Min	Min_Y	Code	Location	D_Year	Avrg	Max	Max_Y	Min	Min_Y
2120008	San Francisco-Salitre K9	74	1185	1620	2005	677	1948	2120194	El Choche	11	790	1007	2004	605	1997
2120011	San Rafael	74	814	1155	1938	465	1968	2120195	Montecillos	11	623	742	2000	427	1998
2120013	El Delirio	74	1233	1643	1986	725	1949	2120196	Casa De Bombas Salitre	30	951	1878	2006	660	1995
2120019	Bocagrande - Salitre	62	1464	2362	2004	993	1958	2120197	Casablanca	31	616	1039	2006	376	1992
2120020	El Hato	70	771	1173	2006	476	1958	2120198	Guadalupe	20	1199	1756	2006	667	1992
2120031	Cerro De Suba	27	902	1354	1950	585	1973	2120202	Serrezuela	17	1008	1360	2006	755	2001
2120032	El Granizo	58	1171	1865	1950	712	1947	2120203	Cabrera La Meseta	7	615	779	1996	354	1992
2120044	La Pradera	53	869	1600	1988	393	1997	2120204	Juan Rey	17	1196	1586	2004	984	1993
2120050	La Caba%A	32	869	1416	1979	438	1977	2120205	Quiba	17	690	889	2006	469	1992
2120051	Apostolica	49	664	950	1971	378	1997	2120207	Saucedal Ii	17	691	972	2006	396	1992
2120074	Zipaquira	25	899	1365	2006	179	1980	2120208	La Conejera	17	844	1179	2006	531	1992
2120075	Bojaca	28	588	929	2001	280	1992	2120209	La Isla	6	547	648	1993	386	1992
2120085	El Bosque	32	1261	2383	1976	499	1988	2120210	Los Tunjos	18	1283	1586	2004	743	1989
2120096	El Consuelo	31	870	1212	1999	570	1992	2120211	Las Huertas	17	532	773	2006	327	1997
2120112	La Casita	22	997	1319	2006	714	1977	2120516	La Ramada	59	725	957	1950	458	1992
2120113	Almaviva	20	659	1282	1988	276	1993	2120531	La Caro	17	769	1208	2006	535	2001
2120115	Edificio M Mejia	22	772	1013	1981	464	1989	2120538	Techo	39	584	834	1971	411	1995
2120141	Acandi	30	801	1201	1979	333	1983	2120540	Checua	54	644	1769	2004	263	1957
2120154	Bosa Barreno	52	603	1164	2006	319	1992	2120541	Represa Del Neusa	49	956	1377	1955	403	1998
2120156	La Picota	27	612	994	2005	223	1992	2120545	Tibitoc	26	853	1273	2006	339	1991
2120159	Alco	24	706	990	1999	441	2003	2120548	La Iberia	54	847	1951	2005	542	2001
2120162	Suesca	21	591	782	1990	344	2006	2120559	Apto. Guaymaral	41	789	1073	1995	433	1980
2120166	El Fute	47	585	1099	1981	340	1997	2120561	Muña	37	560	865	1979	248	1987
2120168	Alto De Aire	18	693	847	1996	523	1992	2120569	Camavieja	28	883	1202	2006	620	1985
2120171	Represa Sisga	53	861	1244	1994	582	1947	2120585	Colombiano	19	781	1101	2000	321	1996
2120173	Campobello	18	595	1459	1998	343	1997	2120596	Tachi	13	848	1061	1988	567	1997
2120174	Nanjui	28	762	1444	2006	265	1996	2120632	La Fortuna	43	755	1187	1999	486	1980
2120183	Dario Valencia	16	1204	1983	1994	889	1993	2120633	Barrancas	41	709	1270	2004	436	2001
2120186	La Maria	9	882	1488	2000	509	1993	2401110	Isla Del Santuario	46	1051	1556	1999	772	1992
2120187	Bombas Sesquile	15	574	896	1999	211	1998	3502506	Bolsala	19	1240	1555	1999	579	1994

D_Year : Total years of observation. **Avrg** : Yearly average precipitation. **Max** : Maximum yearly precipitation (mm) in the observation duration. **Max_Y** : The year of maximum yearly precipitation occurring. **Min** : Minimum yearly precipitation (mm) in the observation duration. **Min_Y** : The year of minimum yearly precipitation occurring.

2.2. Monthly Change of the Precipitation

Monthly precipitation of Bogota basin are calculated together with the monthly precipitation for the whole Colombia.

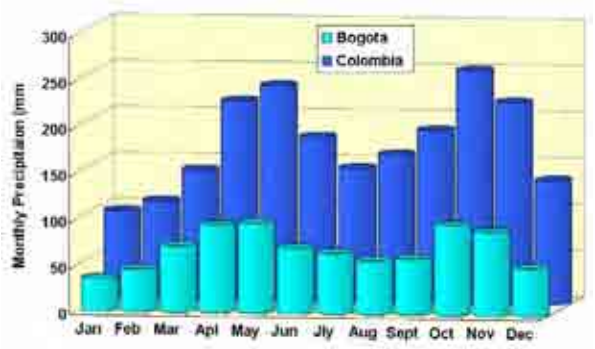


Figure-5. 1 Monthly Precipitation in Bogota Basin and the Whole Columbia

CHAPTER 3. TREND OF PRECIPITATION CHANGING

The trend analysis was conducted by using the data of National Meteorological Station from the data base of WMO (World Meteorological Organization).

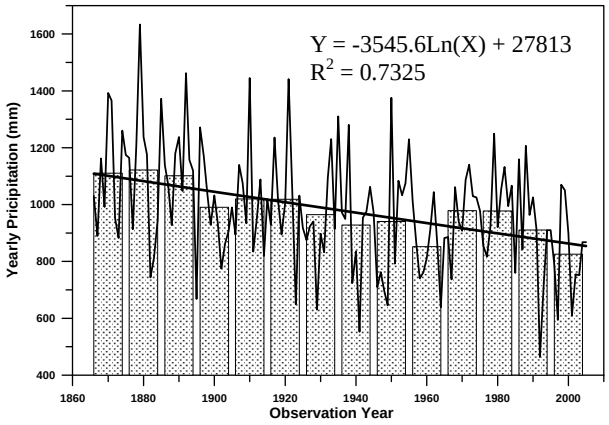


Figure-5. 2 Change of Precipitation in Bogotá Basin

(Data source: National meteorological station)

The sequential line graph in the figure shows the yearly change of the precipitation, and the bar chart shows the 10 – year average. The curve shows the correlation type with the correlation equation and correlation coefficient. Obviously the precipitation in Bogota basin has been in the downward trend.

Table-5. 5 – Year Average precipitation in Bogota Basin

Period	$Rain_{Average}$	Period	$Rain_{Average}$
1866-1875	1,110	1936-1945	928
1876-1885	1,121	1946-1955	940
1886-1895	1,101	1956-1965	852
1896-1905	991	1966-1975	979
1906-1915	1,020	1976-1985	977
1916-1925	1,019	1986-1995	911
1926-1935	965	1996-2005	825
70year average	**1,047**	**70year average**	**916**

Table5 shows the 10-year average of precipitation corresponding to the bar chart in Figure-5.2. when the total observation duration of 140 was divided into the two parts, the former 70 years and the later 70 years, the average of precipitation in the former one is over 1000mm/year corresponding by an average of 916mm for the later one. Another characteristics can be found in from the table is that in the former 70 years, the decrease was in relative high speed, but in the later 70 years the speed of decrees has been getting low and seems going to the equilibrium.

CHAPTER 4. CYCLE OF FLUCTUATION

Cycle of fluctuation can be calculated by the standard method using coefficient of variation as shown in the following equation.

$$\sum (Ki / Kmean)$$

Here, Ki is the precipitation in year of i, Kmean is the average of the precipitation of the whole observation serials.

However, this standard method can only be used to get proper result when the precipitation fluctuates around the average value. In Bogota basin, the precipitation is obviously in the decrease trend in the last 140 years. If the standard method is used for cycle analysis in Bogota basin, the precipitation in the former part of the observation duration would be over evaluated as rainy year, and the later part would be undervalued as dry year. Therefore, the method was modified by exchange the Kmean with the value calculated from the correlation equation shown in the Figure-5.3.

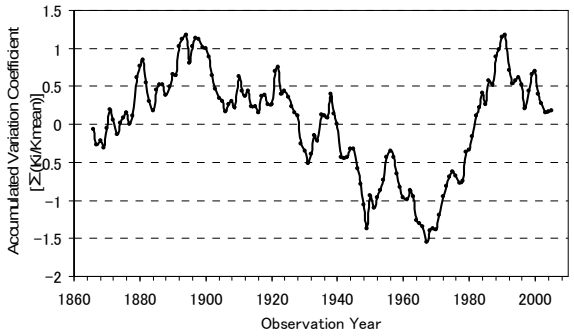


Figure-5. 3 Accumulated Variation Coefficient of the Precipitation

Table-5. 6 Result of Cycle Analysis

Sequence	Periodicity			Drought Year		Wet Year	
	Duration	$K_{average}$	$R_{average}$	Duration	$K_{average}$	Duration	$K_{average}$
1	-1881	1.05	1,153	-1867	--	1868-1881	1.08
2	1882-1894	1.03	1,093	1882-1884	0.77	1889-1894	1.13
3	1895-1910	0.97	1,004	1895-1906	0.92	1907-1910	1.12
4	1911-1922	1.01	1,025	1911-1916	0.92	1920-1922	1.16
5	1923-1938	0.98	966	1923-1931	0.86	1932-1938	1.13
6	1939-1956	0.96	916	1939-1949	0.85	1950-1956	1.15
7	1957-1991	1.04	948	1957-1967	0.89	1967-1991	1.1
8	1992-	0.93	804	1992-1997	0.84	1998-	--

Kaverage : Average of Ki/Kmean for each corresponding duration. **Raverage :** Average of precipitation for each corresponding duration.

In the last 140 years from 1866 to 2005, precipitation in Bogota basin can be divided into eight (8) circulation cycles. In each cycle, precipitation can be divided into rainy season and drought season. In rainy season the precipitation was larger than the average value, and then the Kaverage was larger than 1, in a range of 1.08 to 1.16. In contrast, the Kaverage in drought season was less than 1, changing in a range of 0.77 to 0.92. for one of the cycle the Kaverage had a value near 1, in a range of 0.97 to 1.04.

According to this result, it has been revealed that the length of the precipitation fluctuation cycle changes from 11 years to 33 years in Bogota basin. Therefore at least more than 11 years data should be used for the hydrological analysis in Bogota basin. otherwise possibility would increase to incline to rainy or drought season.

CHAPTER 5. PROBABILITY

Many methods have been developed for probability calculation. 4 of them were used in this analysis:

1) Normal distribution
2) Log normal distribution
3) Plotting Position (Hazen Method)
4) Log-Pearson Type III distribution

Table-5.7 shows the result of the probability calculation by using the above mentioned 4 methods, and Figure4 shows the curve of probability calculated by Log-Pearson Type III distribution method together with the plotting following the Plotting Position (Hazen Method).

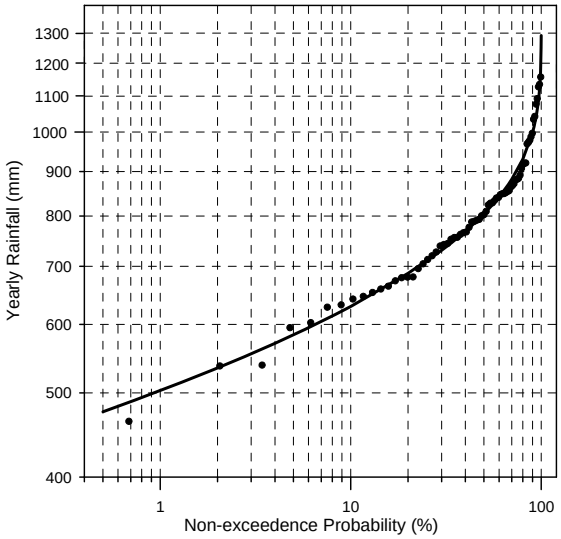


Figure-5. 4 Result of Probability Calculation

Table-5. 7 Result of Probability Calculation

Non-Ex.(%)	Normal[1)]	Log_Nor[2)]	P.P[3)]	Log_PIII[4)]	Mean[5)]	RPIY[6)]
1	499	589	552	544	546	100
2	560	625	594	598	594	50
4	638	659	645	631	643	25
10	725	734	726	742	732	10
25	847	837	837	854	844	4
50	980	951	973	949	963	2
75	1,113	1,113	1,115	1,080	1,105	4
90	1,236	1,258	1,245	1,237	1,244	10
96	1,342	1,373	1,373	1,348	1,359	25
98	1,391	1,490	1,414	1,442	1,434	50
99	1,446	1,593	1,474	1,479	1,498	100

Non-Ex : Non exceedence probability. **Normal** : Normal Distribution. **Log_Nor**. : Log-normal Distribution
P.P. : Plotting Position (Hazen Method). **Log_PIII** : log-Pearson Type III distribution
Mean : Average of the result obtained from the above 4 methods. **RPIY** : Return period in years

CHAPTER 6. RELATION BETWEEN PRECIPITATION AND ELEVATION

Precipitation in Bogota basin changes from 532mm to 1,464mm. the most important factor for precipitation control is identified as elevation. To make clear the relation of precipitation and elevation, all collected precipitation data were divided into 7 groups according to the range of elevation.

Table-5. 8 Relation between Precipitation and Elevation

Elevation_calss	Avrg	Stdev	No_Sttn
2500-2600	697	124	25
2600-2700	768	154	6
2700-2800	787	93	7
2800-2900	795	196	3
2900-3000	784	107	4
3000-3200	1084	181	7
>3200	1283	128	4

Elevation_calss: Class of station grouping. **Avrg :** Average of the precipitation in the group. **Stdev :** Standard deviation of the precipitation in the group. **No_Sttn :** Number of the stations within the group.

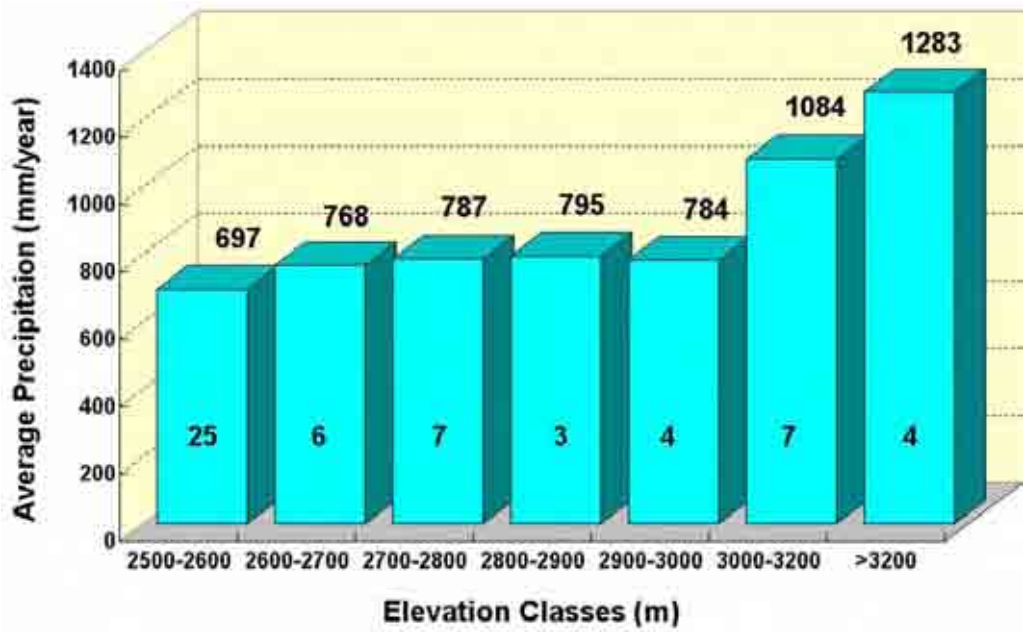


Figure-5. 5 Relation between Yearly Precipitation and Elevation

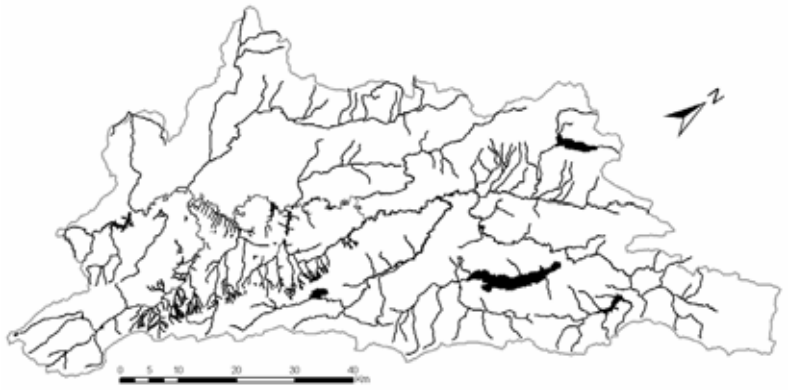
(The value over the bar chart is the average yearly precipitation. The figure within the bar chart is the number of samples of the group)

In case that the elevation is lower than 3,000m over average sea level, yearly precipitation changes in a small range from about 700mm to 800mm. in places where the elevation is larger than 3,000m, the precipitation increases larger with the elevation.

CHAPTER 7. RIVER DATA IN BOGOTA BASIN

7.1. River's Distribution

Bogota River is the main river in Bogota basin, having many tributaries. Within the GISDB of Acueducto there are 31 relatively big rivers with river names and 217 creeks and channels without names. All rivers and creeks included in Acueducto GISDB are shown in Figure-5.6.



(Data source: Acueducto GISDB)

Figure-5. 6 Rivers and Creeks in Bogota Basin

7.2. River Data Collection

River data of 37 discharge observation stations were collected from EAAB and CAR. Table9 shows the name of rivers, tributary basin, agencies of data source, area of catchment, star year and end year of the data serials, and total observation years within the whole data serials.

Table-5. 9 River Data Collected for River Discharge Analysis

Code	Location	Entity	C_Area	Duration	D_A_Y
2120701	Puente Bosa_Tunjuelo	EAAB	380.9	1970-2005	28
2120705	El Delirio - Rio San Cristobal (Tunjuelo)	EAAB	23.8	1927-2006	57
2120706	Regadera - Rio Tunjuelo (Tunjuelo)	EAAB	162.9	1989-2005	18
2120725	Puente Australia - Rio Curubita (Tunjuelo)	EAAB	56.5	1946-2007	53
2120726	El Tambor_Teusaca	EAAB	67.7	1946-1991	46
2120729	La Cabaña - Rio Teusaca	EAAB	160.9	1959-2007	49
2120746	La Toma - Rio Chisaca (Tunjuelo)	EAAB	52.1	1991-2007	17
2120747	El Herradero - Rio Mugroso (Tunjuelo)	EAAB	33.5	1953-2007	42
2120750	Cantarrana - Rio Tunjuelo	EAAB	2.8	1958-1997	27
2120752	Puente Galindo_Rio_Bojaca	CAR	165.1	1970-1980	11
2120756	El Recreo_Rio_Bojaca	CAR	93.5	1966-1980	14
2120759	Canaleta Parshall - Rio Chisaca (Tunjuelo)	EAAB	90.2	1960-2006	23
2120798	San Isidro_Rio_Tomine	CAR	67.3	1970-1979	10
2120799	Santo Domingo_Rio_Tomine	CAR	27.4	1971-1980	9
2120802	La Isla - Rio Bogota (NE Bogota Area 10)	EAAB	2,903	1972-2005	33
2120806	Las Huertas (last station in Bogota basin)	EAAB	4,257	1973-2007	35
2120810	Vuelta Grande (NE Bogota Area 10)	EAAB	2486.8	1973-2005	31
2120811	Puente La Virgen (NE Bogota Area 10)	EAAB	2108	1971-2005	35
2120836	Avenida Boyaca - Rio Tunjuelo	EAAB	326.5	1989-2006	17
2120845	El Bosque_Rio_Subachoque	CAR	214.4	1975-2006	19
2120849	El Faro_Rio_Teusaca	EAAB	9	1969-1981	13
2120864	El Volador_Rio_Neusa	CAR	68.5	1993-2005	4
2120888	El Cortijo (NE Bogota Area 10)	EAAB	2618.6	1999-2005	7
2120889	Chicu (NE Bogota Area 10)	EAAB	2486.8	1999-2005	7
2120892	El Toro - Qda Yomasa (Tunjuelo)	EAAB	18.4	1998-2003	6
2120918	El Volador_Rio_Neusa	CAR	65.8	1996-2007	12
2120925	Puente Calamar_Rio_Chicu	CAR	142.9	1995-2006	12
2120942	Usaquen - Garita - Qda. Molinos_Bogota(L)	EAAB	5.9	1990-2006	17
2120946	Puente Francis - Rio Teusaca	EAAB	53.1	1988-2007	18
2120949	Ventana - Captacion - Qda. La V_Bogota(L)	EAAB	1.5	1990-2006	17
2120951	Parque Nacional - Rio Arzobispo_Bogota(L)	EAAB	13.6	1991-2006	15
3502725	Simaya - Canaleta Parshall_Rio_Teusaca	EAAB	10.5	1983-2007	25
3506711	Sueva - Rio Balcones_Chuza	EAAB	112.3	1971-1998	27
3506716	Cota 3020 - Rio Tunjo_Chuza	EAAB	7.4	1987-1990	4
3506717	Cantabria - Rio Barandillas_Chuza	EAAB	13	1987-1989	3
3506722	Canaleta Leticia - Canal Letici_Chuza	EAAB	27.1	1988-1990	3
3506730	El Penono Rio Juiquin_Chuza	EAAB	12.3	1987-1990	4

C_Area: Catchment area (km^2). **Duration** : First and last Years of observation.
D_A_Y : Data available years.

7.3. River Data Checking and Complement

The same method used for precipitation data checking and complement was used for river data processing. Table10 shows the result of missing day's checking.

Table-5. 10 Result of Missing day Checking for River Discharge Data

Code	M_Days	T_Days	Pcntg	Code	M_Days	T_Days	Pcntg
2120701	654	10613	6.2	2120845	890	6971	12.8
2120705	934	20820	4.5	2120849	307	4748	6.5
2120706	337	6574	5.1	2120864	442	1826	24.2
2120725	757	19723	3.8	2120888	555	2922	19
2120726	235	16801	1.4	2120889	422	2922	14.4
2120729	869	17897	4.9	2120892	260	2191	11.9
2120746	287	6209	4.6	2120918	679	4383	15.5
2120747	1005	15340	6.6	2120925	93	4442	2.1
2120750	735	9892	7.4	2120942	1424	6209	22.9
2120752	351	4018	8.7	2120946	605	6606	9.2
2120756	98	5114	1.9	2120949	1520	6209	24.5
2120759	465	8401	5.5	2120951	1243	5478	22.7
2120798	39	3652	1.1	3502725	1539	9131	16.9
2120799	14	3287	0.4	3506711	958	9862	9.7
2120802	606	12473	4.9	3506716	303	1461	20.7
2120806	1330	12418	10.7	3506717	107	1127	9.5
2120810	763	11322	6.7	3506722	79	1145	6.9
2120811	945	12784	7.4	3506730	303	1461	20.7
2120836	1217	6234	19.5	**Total**	23,370	282,666	8.3

M-days: Missed observation days. **T-days**: Total observation days (including missed days)
Pcntg: Percentage of M-days to T-days

Table-5.11 shows the complement result by using the same method for precipitation data complement.

Table-5. 11 Result of Discharge Data Complement

Unit:10^6m^3

Code	Location	Before	After	Pcntg
2120701	Puente Bosa_Tunjuelo	4,519.4	4,819.4	6.6
2120705	El Delirio - Rio San Cristobal (Tunjuelo)	1,128.8	1,171.7	3.8
2120706	Regadera - Rio Tunjuelo (Tunjuelo)	927.5	971.7	4.8
2120725	Puente Australia - Rio Curubita (Tunjuelo)	2,318.0	2,407.0	3.8
2120726	El Tambor_Teusaca	2,067.7	2,093.1	1.2
2120729	La Cabaña - Rio Teusaca	3,854.7	4,040.0	4.8
2120746	La Toma - Rio Chisaca (Tunjuelo)	341.6	360.4	5.5
2120747	El Herradero - Rio Mugroso (Tunjuelo)	711.4	761.7	7.1
2120750	Cantarrana - Rio Tunjuelo	2,352.5	2,516.1	7.0
2120752	Puente Galindo_Rio_Bojaca	172.4	188.8	9.5
2120756	El Recreo_Rio_Bojaca	332.7	336.1	1.0
2120759	Canaleta Parshall - Rio Chisaca (Tunjuelo)	281.1	295.7	5.2
2120798	San Isidro_Rio_Tomine	421.6	423.3	0.4
2120799	Santo Domingo_Rio_Tomine	302.9	303.1	0.1
2120802	La Isla - Rio Bogota (NE Bogota Area 10)	23,567.7	24,796.7	5.2
2120806	Las Huertas (last station in Bogota basin)	30,682.1	34,295.1	11.8
2120810	Vuelta Grande (NE Bogota Area 10)	9,065.6	9,707.5	7.1
2120811	Puente La Virgen (NE Bogota Area 10)	13,425.3	14,433.9	7.5
2120836	Avenida Boyaca - Rio Tunjuelo	2,203.6	2,719.8	23.4
2120845	El Bosque_Rio_Subachoque	347.1	398.1	14.7
2120849	El Faro_Rio_Teusaca	79.7	84.4	5.9
2120864	El Volador_Rio_Neusa	80.7	108.8	34.8
2120888	El Cortijo (NE Bogota Area 10)	3,976.6	4,894.4	23.1
2120889	Chicu (NE Bogota Area 10)	2,552.6	2,968.7	16.3
2120892	El Toro - Qda Yomasa (Tunjuelo)	113.9	127.2	11.7
2120918	El Volador_Rio_Neusa	202.7	242.4	19.6
2120925	Puente Calamar_Rio_Chicu	423.0	430.6	1.8
2120942	Usaquen - Garita - Qda. Molinos_Bogota(L)	30.2	39.3	30.1
2120946	Puente Francis - Rio Teusaca	404.1	443.9	9.8
2120949	Ventana - Captacion - Qda. La V_Bogota(L)	6.8	8.8	29.4
2120951	Parque Nacional - Rio Arzobispo_Bogota(L)	18.8	24.8	31.9
3502725	Simaya - Canaleta Parshall_Rio_Teusaca	6,151.1	7,395.2	20.2
3506711	Sueva - Rio Balcones_Chuza	3,344.9	3,724.6	11.4
3506716	Cota 3020 - Rio Tunjo_Chuza	31.0	37.0	19.4
3506717	Cantabria - Rio Barandillas_Chuza	29.0	31.6	9.0
3506722	Canaleta Leticia - Canal Letici_Chuza	84.6	90.7	7.2
3506730	El Penono Rio Juiquin_Chuza	31.0	37.0	19.4
Total		116,584.4	127,728.6	9.6

Before : Total precipitation in mm before the data complement.. **After** : Total precipitation in mm after the data complement.
Pcntg : Percentage of change as the result of complement.

CHAPTER 8. STATISTICS OF DISCHARGE DATA

8.1. Average Yearly Discharge

Table-5.12 shows the average yearly discharge for each river using the complement result.

Table-5. 12 Average Discharge and Standard Deviation

Unit:$10^6 m^3$

Code	Location	Avrg	Stdev
2120701	Puente Bosa_Tunjuelo	163.8	38.6
2120705	El Delirio - Rio San Cristobal (Tunjuelo)	20.6	5.3
2120706	Regadera - Rio Tunjuelo (Tunjuelo)	52.4	20.9
2120725	Puente Australia - Rio Curubita (Tunjuelo)	44.6	8.5
2120726	El Tambor_Teusaca	45.5	32.4
2120729	La Cabaña - Rio Teusaca	82.5	33.4
2120746	La Toma - Rio Chisaca (Tunjuelo)	21.2	6.6
2120747	El Herradero - Rio Mugroso (Tunjuelo)	17.7	5.5
2120750	Cantarrana - Rio Tunjuelo	92.9	26.8
2120752	Puente Galindo_Rio_Bojaca	17.4	7.7
2120756	El Recreo_Rio_Bojaca	24.0	8.5
2120759	Canaleta Parshall - Rio Chisaca (Tunjuelo)	16.0	18.7
2120798	San Isidro_Rio_Tomine	42.3	7.0
2120799	Santo Domingo_Rio_Tomine	33.7	14.6
2120802	La Isla - Rio Bogota (NE Bogota Area 10)	719.5	127.1
2120806	Las Huertas (last station in Bogota basin)	967.2	199.0
2120810	Vuelta Grande (NE Bogota Area 10)	313.4	86.0
2120811	Puente La Virgen (NE Bogota Area 10)	412.3	156.5
2120836	Avenida Boyaca - Rio Tunjuelo	158.7	42.9
2120845	El Bosque_Rio_Subachoque	20.3	10.6
2120849	El Faro_Rio_Teusaca	6.5	1.8
2120864	El Volador_Rio_Neusa	23.3	10.3
2120888	El Cortijo (NE Bogota Area 10)	655.8	224.3
2120889	Chicu (NE Bogota Area 10)	409.6	199.9
2120892	El Toro - Qda Yomasa (Tunjuelo)	21.2	3.1
2120918	El Volador_Rio_Neusa	19.1	7.8
2120925	Puente Calamar_Rio_Chicu	35.8	13.3
2120942	Usaquen - Garita - Qda. Molinos_Bogota(L)	2.3	0.8
2120946	Puente Francis - Rio Teusaca	25.0	7.5
2120949	Ventana - Captacion - Qda. La V_Bogota(L)	0.5	0.2
2120951	Parque Nacional - Rio Arzobispo_Bogota(L)	1.8	1.9
3502725	Simaya - Canaleta Parshall_Rio_Teusaca	298.0	66.1
3506711	Sueva - Rio Balcones_Chuza	136.2	84.7
3506716	Cota 3020 - Rio Tunjo_Chuza	9.2	0.9
3506717	Cantabria - Rio Barandillas_Chuza	10.1	4.0
3506722	Canaleta Leticia - Canal Letici_Chuza	29.3	4.6
3506730	El Penono Rio Juiquin_Chuza	9.2	0.9

Avrg: Average of discharge for a station in its analysis series. **STDEV:** Standard deviation of discharge.

8.2. Maximum and Minimum Yearly Discharge

Using the complement result the maximum and minimum yearly discharge for each river were calculated as shown in Table-5.13.

Table-5. 13 Maximum and Minimum Yearly Discharge

Unit:10^6m^3

Code	Location	Max	Max_Y	Min	Min_Y
2120701	Puente Bosa_Tunjuelo	234.8	1996	108.9	1973
2120705	El Delirio - Rio San Cristobal (Tunjuelo)	33.5	1986	10.6	1978
2120706	Regadera - Rio Tunjuelo (Tunjuelo)	107	2004	24.9	1989
2120725	Puente Australia - Rio Curubita (Tunjuelo)	64.1	1972	29.6	1960
2120726	El Tambor_Teusaca	166	1986	17.3	1958
2120729	La Cabaña - Rio Teusaca	199.6	1985	42.1	1995
2120746	La Toma - Rio Chisaca (Tunjuelo)	33.6	2004	11.6	1992
2120747	El Herradero - Rio Mugroso (Tunjuelo)	34.9	1976	6.1	1977
2120750	Cantarrana - Rio Tunjuelo	151.4	1976	35.3	1958
2120752	Puente Galindo_Rio_Bojaca	31.8	1971	5.3	1978
2120756	El Recreo_Rio_Bojaca	38.2	1968	9.2	1980
2120759	Canaleta Parshall - Rio Chisaca (Tunjuelo)	94.5	2003	1.7	2004
2120798	San Isidro_Rio_Tomine	56.9	1976	30.9	1971
2120799	Santo Domingo_Rio_Tomine	68.1	1976	17.4	1973
2120802	La Isla - Rio Bogota (NE Bogota Area 10)	1,032	1986	469.6	2001
2120806	Las Huertas (last station in Bogota basin)	1,386	2006	613.6	1978
2120810	Vuelta Grande (NE Bogota Area 10)	482.9	1976	170.6	2001
2120811	Puente La Virgen (NE Bogota Area 10)	737.6	1988	164.3	1997
2120836	Avenida Boyaca - Rio Tunjuelo	243.3	2004	106.3	1992
2120845	El Bosque_Rio_Subachoque	48	1999	4.9	2001
2120849	El Faro_Rio_Teusaca	10.1	1972	3.3	1977
2120864	El Volador_Rio_Neusa	40.5	2006	14	1996
2120888	El Cortijo (NE Bogota Area 10)	1,056	2006	355.9	2001
2120889	Chicu (NE Bogota Area 10)	818.3	2006	154.3	2001
2120892	El Toro - Qda Yomasa (Tunjuelo)	23.9	2002	16.9	1999
2120918	El Volador_Rio_Neusa	30.9	1999	5	2007
2120925	Puente Calamar_Rio_Chicu	60	1999	17.2	1997
2120942	Usaquen - Garita - Qda. Molinos_Bogota(L)	4	2004	1.2	1993
2120946	Puente Francis - Rio Teusaca	41.6	2002	14.5	1990
2120949	Ventana - Captacion - Qda. La V_Bogota(L)	0.9	1999	0.3	2003
2120951	Parque Nacional - Rio Arzobispo_Bogota(L)	7.8	1991	0.7	1992
3502725	Simaya - Canaleta Parshall_Rio_Teusaca	365.3	1991	90.6	1984
3506711	Sueva - Rio Balcones_Chuza	457.7	1987	56.6	1992
3506716	Cota 3020 - Rio Tunjo_Chuza	10.2	1988	8.1	1989
3506717	Cantabria - Rio Barandillas_Chuza	14.7	1989	7.4	1987
3506722	Canaleta Leticia - Canal Letici_Chuza	32.5	1990	24	1988
3506730	El Penono Rio Juiquin_Chuza	10.2	1988	8.1	1989

Max : Maximum discharge. **Max_Y :** Yea of the maximum discharge. **Min** : Minimum discharge
Min_Y : Yea of the minimum discharge.

CHAPTER 9. RIVER´S STABILITY ANALYSIS

9.1. Cv and CORR

Coefficient of Variation (Cv) and Coefficient Of River Regime (CORR) were used for stability analysis. Cv is given by the following equation, and CORR is the ratio of the maximum discharge to the minimum discharge.

$$CV = \frac{\sqrt{\frac{1}{n-1}\Sigma(x-\bar{x})^2}}{\bar{x}} \times 100\% \quad = \quad \sqrt{\sum_{i=1}^{n}\frac{(K_i-1)^2}{n-1}}$$

Here: $Ki = \frac{Xi}{\overline{X}}$

Xi is the discharge for a year

$\overline{X}$ is the average of the whole observation serials.

According to result of meteorological analysis, the hydro cycle in Bogota basin is in the range of 11 to 33 years. Therefore, the stability analysis was conducted for those rivers having observation years more than 11 years. The result is shown in Table-5.14.

Table-5. 14 Result of Stability Analysis for the Main Rivers in Bogota Basin

Code	Location	Area	Avrg	Max	Min	CORR	Cv
2120701	Puente Bosa	380.9	163.8	234.8	108.9	2.16	0.24
2120705	El Delirio - Rio San Cristobal	23.8	20.6	33.5	10.6	3.17	0.26
2120725	Puente Australia - Rio Curubita	56.5	44.6	64.1	29.6	2.17	0.19
2120729	La Cabaña - Rio Teusaca	160.9	82.5	199.6	42.1	4.75	0.4
2120746	La Toma - Rio Chisaca	52.1	21.2	33.6	11.6	2.89	0.31
2120747	El Herradero - Rio Mugroso	33.5	17.7	34.9	6.1	5.77	0.31
2120756	El Recreo_Rio_Bojaca	93.5	24	38.2	9.2	4.17	0.36
2120806	Las Huertas	4,257	967.2	1,386	613.6	2.26	0.21
2120836	Avenida Boyaca - Rio Tunjuelo	326.5	158.7	243.3	106.3	2.29	0.27
2120845	El Bosque	214.4	20.3	48	4.9	9.88	0.52
2120918	El Volador	65.8	19.1	30.9	5	6.21	0.52
2120925	Puente Calamar	142.9	35.8	60	17.2	3.48	0.37
2120942	Usaquen - Garita - Qda. Molinos	5.9	2.3	4	1.2	3.33	0.36
2120946	Puente Francis - Rio Teusaca	53.1	25	41.6	14.5	2.86	0.3
2120949	Ventana - Captacion - Qda. La V	1.5	0.5	0.9	0.3	2.56	0.31
2120951	Parque Nacional - Rio Arzobispo	13.6	1.8	7.8	0.7	11.85	1.04

Except Arzobispo river, Cv for all rivers in Bogota basin changes from 0.19 to 0.52, indicating the relatively small variation in rives discharge. And the CORR shows the same kind of analysis result.

9.2. Monthly Discharge

Figure-5.7 shows monthly discharge by using the average of all rivers.

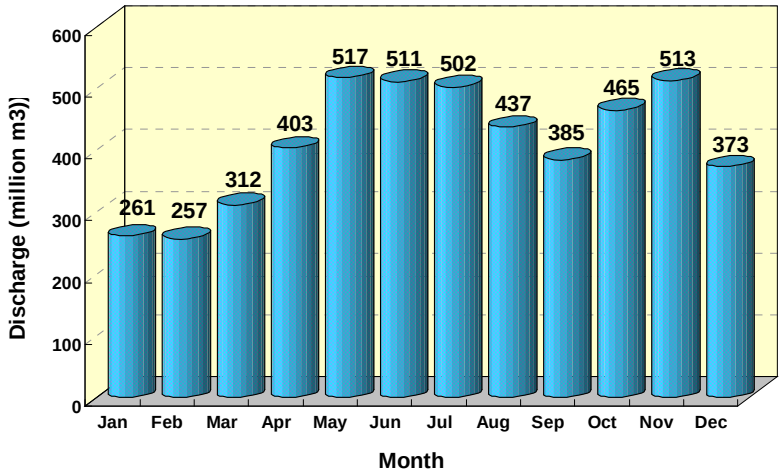


Figure-5. 7 Average Monthly River Discharge in Bogota Basin

Maximum monthly discharge appears in May, to be 517×106m^3. While the minimum monthly discharge appears in February is 257×106m^3. The ratio of maximum monthly discharge to minimum monthly discharge is 2.01, a little smaller than the same kind of ratio of monthly precipitation, which is 2.47.

CHAPTER 10. SPECIFIC DISCHARGE

10.1. Calculation

Different from precipitation data, river discharge data can not be used for interpolation directly, because the discharge is in a observation station is controlled by its catchment with no relation to its downstream side. Therefore, Specific discharge was use as a index to express the capacity of runoff in the catchment. Table-5.15 shows the result of specific discharge calculation.

Table-5. 15 Result of Specific Discharge Calculation

Code	Area	S_Dschg	D_A_Y	Avrg	Max	Min	A_Ele	A_Slope	A_Rain
2120701	380.9	13.6	28	163.8	234.8	108.9	3,149	9.03	996
2120705	23.8	27.4	57	20.6	33.5	10.6	3,279	13.34	1,259
2120725	56.5	25.0	53	44.6	64.1	29.6	3,455	9.79	1,360
2120729	160.9	16.3	49	82.5	199.6	42.1	3,011	10.17	1,033
2120746	52.1	12.9	17	21.2	33.6	11.6	3,556	10.51	1,091
2120747	33.5	16.8	42	17.7	34.9	6.1	3,551	10.08	1,286
2120756	93.5	8.1	14	24.0	38.2	9.2	2,735	8	737
2120798	67.3	19.9	10	42.3	56.9	30.9	3,136	9.76	990
2120802	2,903	7.9	33	719.5	1,032	469.6	2,809	7.26	839
2120806	4,257	7.2	35	967.2	1,386	613.6	2,829	7.22	828
2120811	2,108	6.2	35	412.3	737.6	164.3	2,849	8.22	852
2120836	326.5	15.4	17	158.7	243.3	106.3	3,225	9.91	1,055
2120845	214.4	3.0	19	20.3	48.0	4.9	2,899	8.78	824
2120864	68.5	10.8	4	23.3	40.5	14.0	3,399	10.5	1,056
2120888	2,619	7.9	7	655.8	1,056.5	355.9	2,820	7.73	841
2120889	2,487	5.2	7	409.6	818.3	154.3	2,828	7.9	840
2120892	18.4	36.5	6	21.2	23.9	16.9	3,016	9.82	1,103
2120918	65.8	9.2	12	19.1	30.9	5.0	3,408	10.26	1,058
2120925	142.9	7.9	12	35.8	60.0	17.2	3,038	9.87	880
2120942	5.9	12.6	17	2.3	4.0	1.2	2,956	12.11	969
2120946	53.1	15.0	18	25.0	41.6	14.5	3,145	10.64	1,108
2120949	1.5	11.3	17	0.5	0.9	0.3	3,074	17.32	1,026
2120951	13.6	4.2	15	1.8	7.8	0.7	3,041	15.01	1,092
3506711	112.3	38.5	27	136.2	457.7	56.6	3,025	14.4	1,083
3506716	7.4	39.8	4	9.2	10.2	8.1	3,371	14.3	1,087

Area: area of the catchment (km^2). S_Dschg: Specific Discharge ($l/sec/km^2$). D_A_Y: Duration of Available Years (year)
Avrg: Average Yearly Discharge (10^6m^3). Max: Maximum Yearly Discharge (10^6m^3). Min: Minimum Yearly Discharge (10^6m^3)
A_Ele: Average elevation in the catchment area (mams). A_Slope: Average slope in the catchment area (Degree)
A_Rain: Average precipitation in the catchment area (mm)

10.2. Specific Discharge Map

Based on the result shown in Table-5.15, a specific discharge distribution map was created as shown in Figure-5.8.

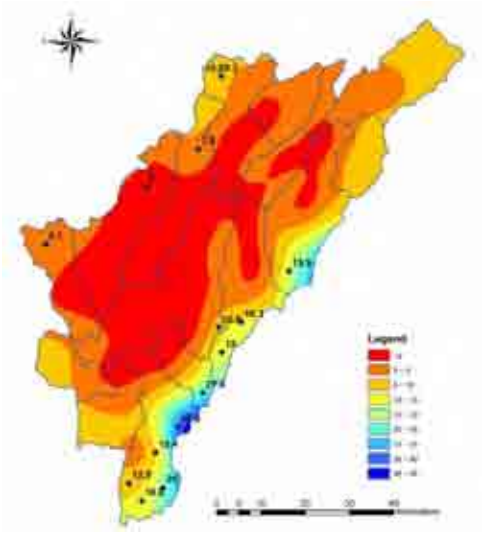


Figure-5. 8 Specific Discharge Distribution in Bogota Basin

10.3. Factors Relating to the Specific Discharge

The same as the distribution, the most important factor controlling the specific discharge is elevation. The relation between specific discharge and elevation is shown in Figure-5.9. Relation between specific discharge and other factors of slope and precipitation are shown in Figure-5.10 and Figure-5.11.

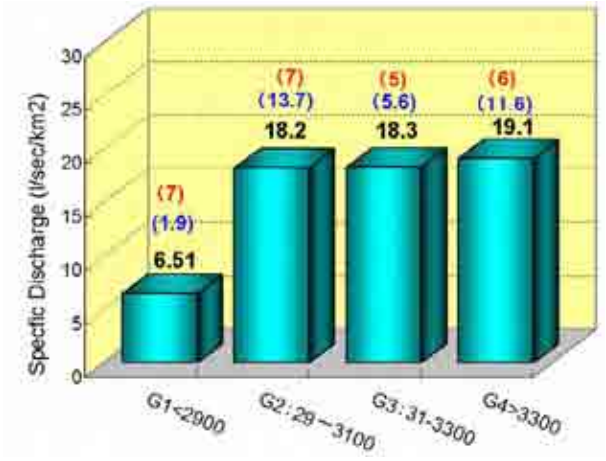


Figure-5. 9 Relation between Specific Discharge and Elevation

(Black colored figure: average specific discharge. Blue colored figure: Standard Deviation. Red colored figure: Number of Sample)

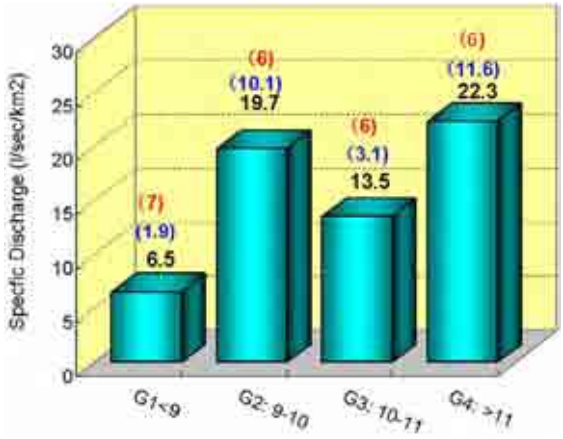


Figure-5. 10 Relation between Specific Discharge and Slope

(Meaning of figures with different colors is the same as Figure-5.9)

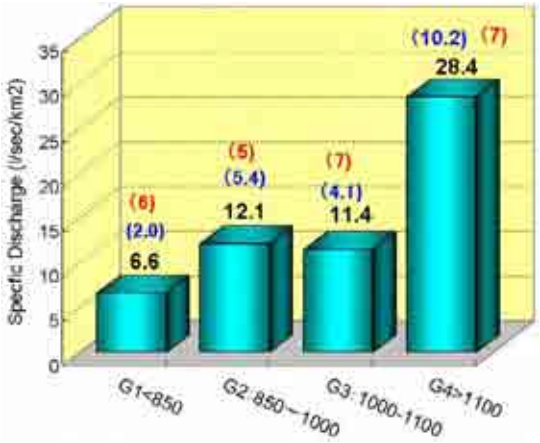


Figure-5. 11 Relation between Specific Discharge and Precipitation

(Meaning of figures with different colors is the same as Figure-5.9)

CHAPTER 11. PROBABILITIES

The same as precipitation analysis probability analysis was conducted for river discharge by using the data from the station of 2120806 (Las Huertas), because the station is located in the down most site of all the river discharge stations. The result was summarized in Table-5.16.

Table-5. 16 Result of Probability Calculation for Discharge Station 2020806 (Las Huertas)

Non-Ex.(%)	Normal[1)]	Log_Nor.[2)]	P.P.[3)]	Log_PIII[4)]	Mean[5)]	RPIY[6)]
1				563	563	100
2		617	615	601	611	50
4	622	647	621	646	634	25
10	723	735	726	720	726	10
25	838	833	812	824	827	4
50	970	952	971	954	962	2
75	1,108	1,108	1,083	1,098	1,099	4
90	1,239	1,272	1,222	1,234	1,242	10
96	1,353	1,383	1,385	1,349	1,368	25
98				1,427	1,427	50
99				1,499	1,499	100

1) Normal : Normal Distribution
2) Log_nor. : Log-normal Distribution
3) P.P. : Plotting Position (Hazen Method)
4) Log_PIII : log-Pearson Type III distribution
5) Mean : Average of the result obtained from the above 4 methods
6) RPIY : Return period in years

Probability calculation is not only used for comprehension of the basic characteristic of the river discharge in Bogota basin, but also useful of data checking. For the same very important discharge observation station Las Huertas, the maximum yearly discharge in 1986 is much big than the second largest discharge in 2006. the return period in year of that big discharge was revealed to be in a range of 2000 years to 100,000 years according to the resulted obtained from three probability calculation methods. This result suggests very high possibility that the data of discharge in 1986 in Las Huertas would include big error. Finally, this data was taken out of the processing after discussion with C/P.

Station 2120806
(Las Huertas)

Probability
1) Normal Distribution
Probability <0.0003
RPY>3,333 years
2) Log_Normal Distribution
Probability = 0.0005
RPY = 2000 years
3) Log-P_III Distribution
Probability < 0.00001
RPY > 100,000 years

Z	Discharge	Year
4.2354	2,261.7	1986
1.283679	1,386.1	2006
1.259744	1,379.0	1994
0.799928	1,242.6	1999
0.71228	1,216.6	1991
0.702167	1,213.6	2000
0.52923	1,162.3	1993
0.455404	1,140.4	1992
0.276062	1,087.2	1998
0.254824	1,080.9	2007
.....	.....	.....

Z = (Data-Mean) / Standard deviation
Unit : million m³

Figure-5. 12 Probability Calculation Result of Station Las Huertas