**THE STUDY**
**ON SUSTAINABLE GROUNDWATER DEVELOPMENT**
**FOR BOGOTA PLAIN**
**IN THE REPUBLIC OF COLOMBIA**

**FINAL REPORT**
**SUPPORTING REPORT**

# PART 6

# WATER QUALITY TEST FOR WELL

# Final Report
# (Supporting Report)

## Part 6 Water Quality Test For Wells

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# PART - 6 WATER QUALITY TEST FOR WELLS

Water quality tests for wells were carried out in 3 phases aiming to evaluate the groundwater in Bogotá Plain both from the environmental and hydro-geological viewpoints. Phase 1 survey was done at 99 wells from February to March 2001 and Phase 2 survey at 104 wells from October to November 2001. Phase 3 survey was conducted at 70 wells from August to September 2002.

## CHAPTER 1 Water Sampling Points and Test Items

Sampling points for water quality test were selected from the wells around the rivers, in the agricultural areas, in the industrial areas, and for isotopic analysis and other wells as shown in Table-1.1 and Figure-1.3. Most of them were selected from 3,273 existing wells, on INGEOMINAS data base, available information at the beginning of this Study. Sampling points were typical aquifers, which were distributed all over the study area. 104 wells in total were surveyed in Phase 2, excluding 4 out of 99 wells tested in Phase 1, and adding one well in Tabio District and 8 wells newly drilled (6 by the Study Team and 2 by EAAB). The 4 wells were excluded because they indicated the values exceeding the standard parameters not related to human health only on less than 4 items, and they were not the wells for isotopic analysis and not in the Guadalupe aquifer. In the Phase 3 survey, water quality test of 70 wells were also executed to confirm the results on the Phase 1 and 2 studies.

Test items were selected to cover 6 categories (chemical parameters related to human health, parameters related to taste, odor and color, inorganic parameters, organic parameters, agrochemicals, and bacteria). However, organic parameters were surveyed at the wells in the industrial areas and agrochemicals in the agricultural areas.

The specifications of sampling wells are shown in Table-1.2. Those wells having no information on aquifers were estimated using a geological map, marked with a circle O and categorized into the Quaternary, Tertiary, and Cretaceous aquifers.

On the other hand, in Phase 3 study, new efforts were made to analyze the river water quality in order to earn basic data regarding water quality of environmental inventory and artificial recharge. Sampling of superficial water was carried out at 18 points of the major rivers. Test items were same as that for well water quality test.

4 samples of sediments of riverbeds were also taken and tested in items of Cu, Pb, Cd, Se, As, Cr, Hg, Cn, *Coliform bacillus* and *Coliform bacilli* group.

## Table-1.1 Sampling Points for Well Water Quality Test and Items

| Items | Phase 1 | Phase 2 | Phase 3 |
|---|---|---|---|
| 1. Sampling Points (Total) | 99 | 104 | 70 |
| - Wells around Rivers | 33 | 33 | 18 |
| - Wells in Agricultural Areas | 5 | 5 | 5 |
| - Wells in Industrial Areas | 5 | 5 | 5 |
| - Wells for Isotopic Analysis | 20 | 20 | 9 |
| - Wells in Other Areas | 36 | 42 | 33 |

| 2. Analysis Items | Around Rivers | Agricultural Area | Industrial Area | Isotopic Analysis | Other Areas |
|---|---|---|---|---|---|
| Chemical parameters related to human health | ○ | ○ | ○ | ○ | ○ |
| | Arsenic, Boron, Cadmium, Chromium, Cyanide, Fluorine, Lead, Total mercury, Nickel, Nitrates, Nitrites, Selenium, Antimony, Barium, Beryllium, Copper, Manganese, Molybdenum, Cupper | | | | |
| Physical & chemical parameters related to taste/odor/color | ○ | ○ | ○ | ○ | ○ |
| | Color, Odor, Turbidly, Temperature, Langelier index, Conductivity | | | | |
| Inorganic parameters | ○ | ○ | ○ | ○ | ○ |
| | Aluminum, Ammonia, Chloride, Hardness, Hydrogen sulfide, Iron, Dissolved oxygen (Phase 2 only), pH, Sodium, Sulfates, Dissolved total solid, Zinc, Magnesium, Potassium, Bicarbonate Ion, Carbonate, Calcium, Alkalinity, Acidity | | | | |
| Organic parameters | -- | -- | ○ | -- | -- |
| | Toluene, Xylems, Benzene | | | | |
| Agrochemicals | -- | ○ | -- | -- | -- |
| | Aldicarb, Carbofuran, Aldrin, Endrin, Dieldrin, Chlordane, Linuron, P, p-DDT, o-p ′ DDT, p-p ′ DDT, Permetrina, 2-Clorofenol, 2, 4, 6-Triclorofenol, Endosulfan I, Endosulfan II, Endosulfan S042-, Heptachlor, Heptachlorepoxide, Lindane, Metolachlor, Atrazine, Bentazone, Profenofos, Clorpirifos, Triclorfos, 2, 4-D, Methoxychlor, Simazine, Trifluralin, 2, 4-DB, Dichlorprop, Malation, Etil Paration, Metil Paration, 2, 4, 5-T, PCP, Diazinon, Permethrin, 2, 4, 5-TP | | | | |
| Bacteria | ○ | ○ | ○ | ○ | ○ |
| | Escherichia coli, *Coliform* bacteria | | | | |

○ : tested -- : not tested

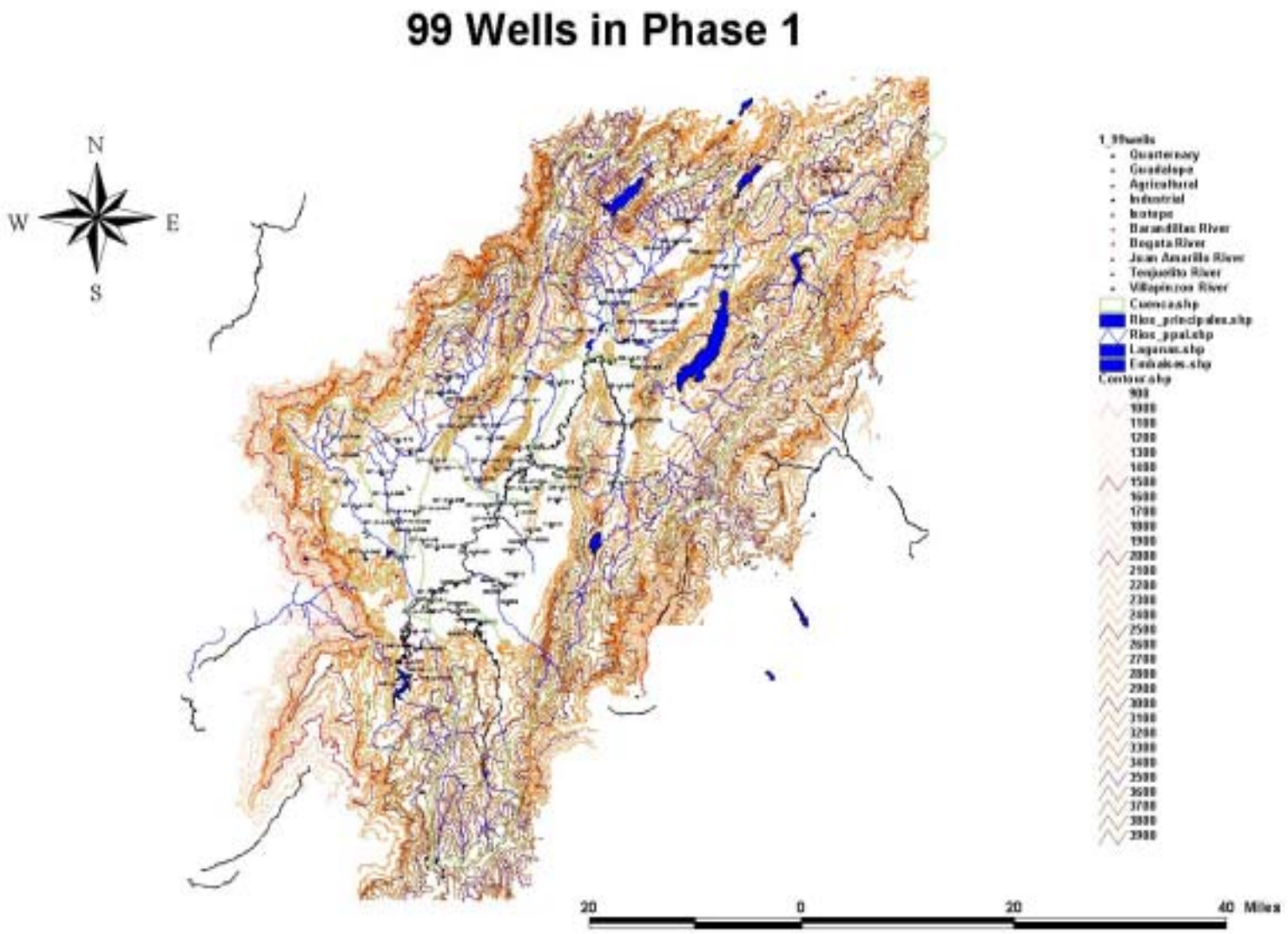


**Figure-1.1 Well distribution map (Phase 1)**

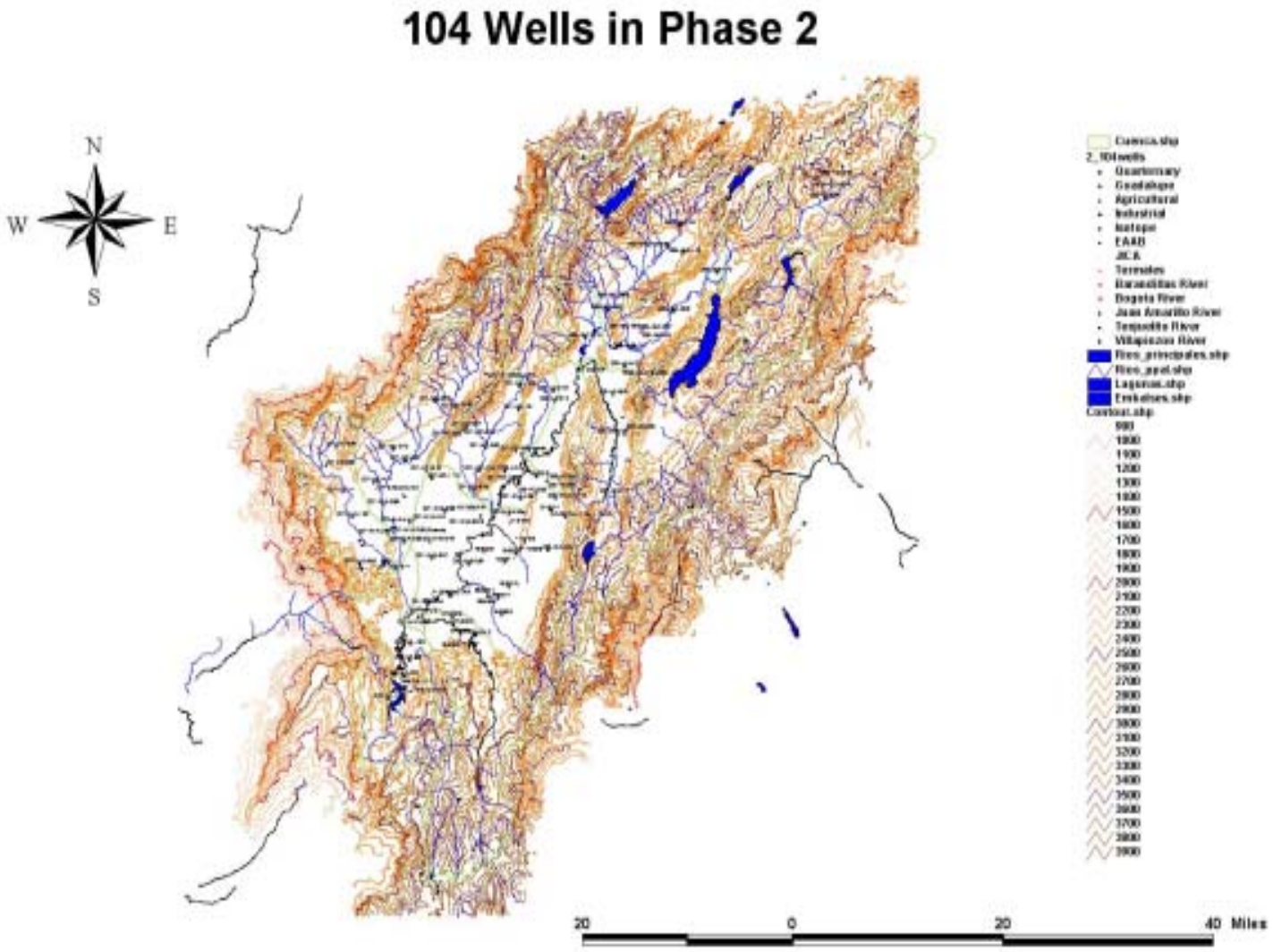


**Figure-1.2 Well distribution map (Phase 2) (continued)**

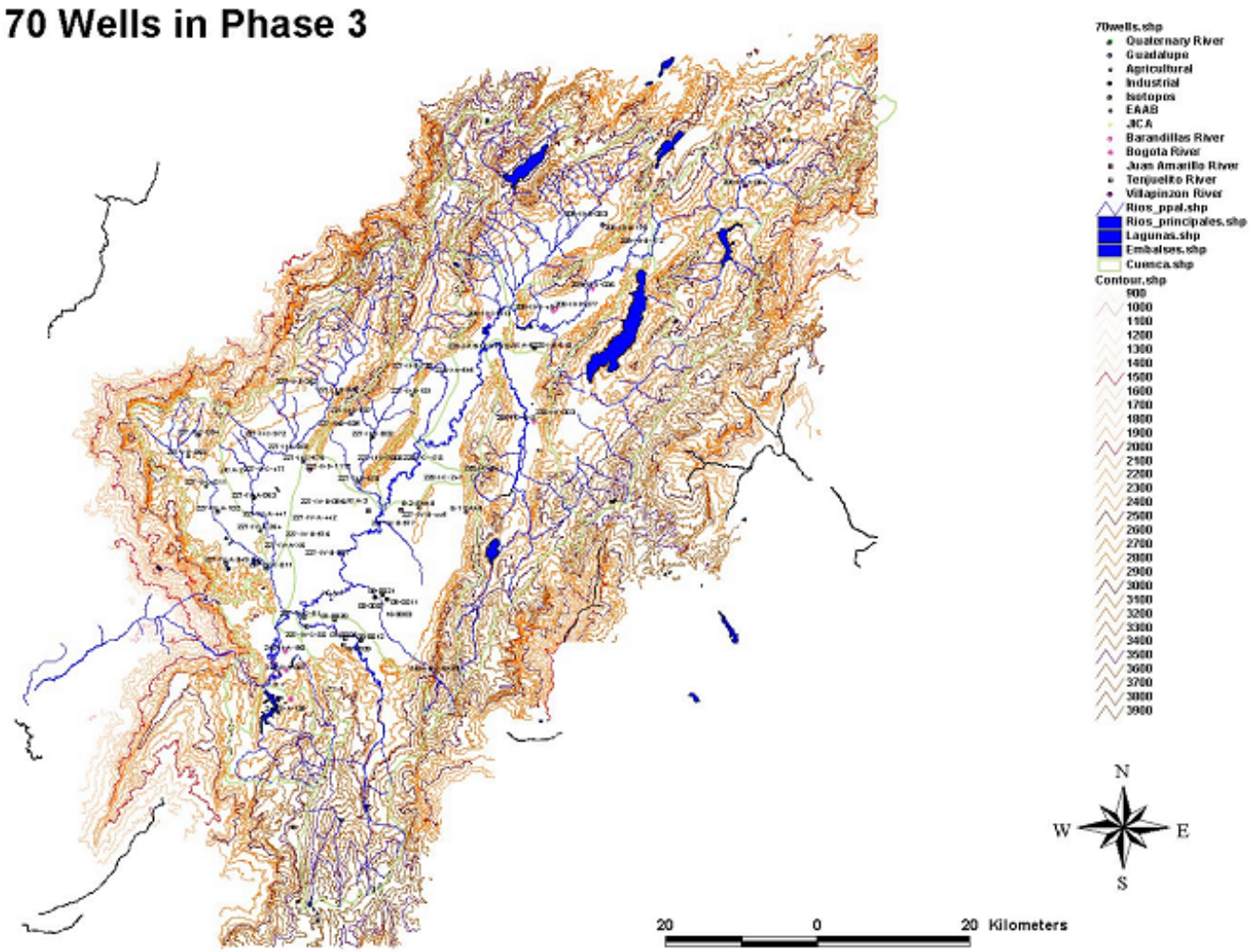


**Figure-1.3 Well distribution map (Phase 3) (continued)**

# Table-1.2 Specifications of sampling wells

| | No. | No. | Well No. | Basin | NAME | TOWN | COORDINATES EAST | COORDINATES NORTH | AQUIFER SYSTEM | estimated aquifer Quaternary | estimated aquifer Tertiary | estimated aquifer Cretaceous | USE | DEPTH m | Ph-1 | Ph-2 | Ph-3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VILLAPINZON | 0a | VI-0a | 209-IV-A-004 | 20 | EL ESPARTILLAL | CHOCONTA | 1,042,680 | 1,059,900 | F. Sabana | ○ | | | HUMAN | ? | o | x | o |
| | 1 | VI-1 | 10-0015 | 8 | COMPENSAR 1 | BOGOTA | 997,324 | 1,007,141 | | ○ | | | | 201 | o | o | x |
| | 2 | VI-2 | 209-II-D-054 | 20 | EL TABLON | CHOCONTA | 1,045,760 | 1,062,640 | F. Sabana | ○ | | | HUMAN | 160 | o | o | o |
| | 3 | VI-3 | 209-II-D-093 | 20 | LA ESPERANZA | CHOCONTA | 1,048,400 | 1,067,200 | Guad-Gudlupe | | ○ | ○ | IRRIGATION | 100 | o | o | o |
| BARANDILLAS | 4 | BA-1 | 209-III-C-032 | 15 | BALSORA | ZIPAQUIRA | 1,012,340 | 1,046,670 | F. Sabana | ○ | | | IRRIGATION | 70 | o | o | x |
| | 4a | BA-1a | 209-III-B-077 | 15 | LA RAMADA | | 1,020,780 | 1,054,660 | F. Sabana | ○ | | | IRRIGATION | 97 | o | x | x |
| | 5 | BA-2 | 209-III-C-013 | 14 | HIDA. SUSASUCA | ZIPAQUIRA | 1,009,040 | 1,042,630 | F. Sabana | ○ | | | IRRIGATION | 60 | o | o | o |
| | 6 | BA-3 | 209-III-C-095 | 16 | ZIPATOCA | TOCANCIPA | 1,015,000 | 1,044,000 | F. Sabana | ○ | | | IRRIGATION | 70 | o | o | x |
| | 7 | BA-4 | 209-III-C-069 | 15 | SAN MIGUEL | ZIPAQUIRA | 1,013,370 | 1,048,430 | F. Sabana | ○ | | | HUMAN | 120 | o | o | x |
| | 8 | BA-5 | 209-III-D-077 | 16 | ESC. PORVENIR | TOCANCIPA | 1,017,880 | 1,043,860 | F. Sabana | ○ | | | HUMAN | | o | o | o |
| | 9 | BA-6 | 209-III-D-49 | 16 | BGTA GOLF 1 | TOCANCIPA | 1,017,555 | 1,043,482 | F. Sabana | ○ | | | HUMAN | | o | o | o |
| JUAN AMARILLO | 10 | JU-1 | 227-IV-B-445 | 8 | Flores Colombianas | BOGOTA | 997,348 | 1,017,280 | F. Sabana | ○ | | | FLOWERS | | o | o | o |
| | 11 | JU-2 | 10-0020 | 8 | SERVICENTRO EL RADAR | BOGOTA | 993,495 | 1,012,038 | F. Sabana | ○ | | | | 80 | o | o | x |
| | 12 | JU-3 | 11-0106 | 8 | TEXACO TIBABUYES | BOGOTA | 997,600 | 1,016,150 | F. Sabana | ○ | | | | 200 | o | o | x |
| | 13 | JU-4 | 227-IV-B-361 | 8 | ROSAS COTA | COTA | 993,120 | 1,017,170 | F. Sabana | ○ | | | FLOWERS | 123 | o | o | x |
| | 14 | JU-5 | 11-0138 | 8 | INVERSIONES BELLO MONTE | BOGOTA | 999,850 | 1,013,500 | F. Sabana | ○ | | | | 143 | o | o | x |
| | 15 | JU-6 | 11-0026 | 8 | LOS LAGARTOS 2 | BOGOTA | 999,290 | 1,012,690 | F. Sabana | ○ | | | | 60 | o | o | x |
| | 16 | JU-7 | 10-0026 | 8 | LUBRICENTRO EL MORISCO | BOGOTA | 998,396 | 1,011,775 | F. Sabana | ○ | | | | 85 | o | o | x |
| TUNJUELITO RIVER | 17 | TU-1 | 227-IV-C-044 | 8 | ISLA LA VUELTA | | 984,930 | 1,004,550 | | ○ | | | | | o | o | x |
| | 18 | TU-2 | 227-IV-C-51 | 8 | LAS MERCEDES | | 984,660 | 1,003,250 | | ○ | | | | | o | o | o |
| | 19 | TU-3 | 227-IV-C-56 | 8 | BOSATAMA | | 983,495 | 1,002,795 | | ○ | | | | | o | o | x |
| | 20 | TU-4 | 227-IV-C-80 | 7 | RCN | | 984,995 | 1,001,940 | | ○ | | | | | o | o | o |
| | 21 | TU-5 | 07-0022 | 7 | CLARETIANO | BOGOTA | 988,721 | 1,001,657 | | ○ | | | | 63 | o | o | x |
| | 22 | TU-6 | 07-0020 | 7 | CONSULTECNICA | BOGOTA | 988,701 | 1,002,829 | | ○ | | | | | o | o | o |
| | 23 | TU-7 | 17-0001 | 7 | COTERPIEL | BOGOTA | 991,350 | 998,460 | | ○ | ○ | | | | o | o | x |
| | 24 | TU-8 | 07-0005 | 7 | CARBOQUIMICA 2 | BOGOTA | 989,990 | 1,000,375 | QUATERNARY | ○ | | | | | o | o | o |
| | 25 | TU-9 | 19-0009 | 7 | INMACU 4 | BOGOTA | 989,842 | 999,552 | | ○ | ○ | | | | o | o | o |
| BOGOYA RIVER | 26 | BO-1 | 246-II-A-104 | 3 | Proteicol – 2 | SIBATE | 981,445 | 994,280 | F. Sabana | ○ | | | INDUSTRY | 95 | o | o | x |
| | 27 | BO-2 | 246-II-A-143 | 2 | Indumil | SOACHA | 978,970 | 991,025 | F. Sabana | ○ | | | INDUSTRY | 65 | o | o | x |
| | 28 | BO-3 | 246-II-A-177 | 2 | Eternit de Colombia – 2 | | 980,815 | 993,645 | Guad-Gdlupe | | ○ | ○ | INDUSTRY | 450 | o | o | x |
| | 29 | BO-4 | 246-II-A-135 | 2 | Acción Comunal Chacua ISS | SIBATE | 982,940 | 992,460 | F. Sabana | ○ | | | HUMAN | 64 | o | o | o |
| | 29a | BO-4a | 246-II-A-087 | 3 | TORINO | SOACHA | 982,370 | 996,170 | F. Cuaternario | ○ | | | INDUSTRY | 92 | o | x | o |
| | 30 | BO-5 | 246-II-A-190 | 3 | INDUMIL 3 | SOACHA | 982,180 | 998,700 | F. Cuaternario | ○ | | | INDUSTRY | 101 | o | o | o |
| AGRICULTURAL AREA | 31 | AG-1 | 227-II-D-605 | 9 | HATO BLANCO | TENJO | 989,275 | 1,028,640 | F. Sabana | ○ | | | IRRIGATION | 159 | o | o | o |
| | 32 | AG-2 | 227-II-C-011(11) | 5 | E.A.A. FACATATIVA | FACATATIVA | 971,790 | 1,020,500 | G. Guadalupe | | | ○ | HUMAN | 197 | o | o | o |
| | 33 | AG-3 | 227-I-D-068 | 5 | E.A.A. FACATATIVA | FACATATIVA | 969,400 | 1,024,410 | G. Guadalupe | | | ○ | HUMAN | 396 | o | o | o |
| | 34 | AG-4 | 227-IV-A-264 | 5 | E.A.A. MADRID | MADRID | 978,860 | 1,014,560 | G. Guadalupe | | | ○ | HUMAN | 394 | o | o | o |
| | 35 | AG-5 | 227-II-B-181 | 9 | CUCHARO 3 | TENJO | 998,825 | 1,032,430 | F. Sabana | ○ | | | IRRIGATION | 120 | o | o | o |
| INDUSTRY AREA | 36 | IN-1 | 09-0011 | 8 | Estación Esso avenida Boyacá | BOGOTA | 995,706 | 1,005,505 | | ○ | | | | 190 | o | o | o |
| | 37 | IN-2 | 09-0021 | 8 | Hilacol No.2 | BOGOTA | 995,042 | 1,006,166 | | ○ | | | | 161 | o | o | o |
| | 38 | IN-3 | 01-0011 | 8 | PARMALAT | BOGOTA | 1,003,747 | 1,017,976 | | ○ | | | | 80 | o | o | x |
| | 39 | IN-4 | 08-0012 | 7 | GASEOSAS COLOMBIANA 2 | BOGOTA | 992,233 | 1,000,120 | | ○ | | | | 165 | o | o | o |
| | 40 | IN-5 | 228-I-A-510 | 13 | LEONA | TOCANCIPA | 1,015,040 | 1,038,530 | F. Sabana | ○ | | | INDUSTRY | 258 | o | o | o |
| GUADALUPE | 41 | GU-1 | 227-IV-A-349 | 5 | AGRICOLA LA MONTAÑA | MADRID | 974,520 | 1,010,360 | G. Guadalupe | | | ○ | IRRIGATION | 387 | o | o | o |
| | 42 | GU-2 | 227-IV-C-011 | 5 | ACUED.VEREDAL LOS PUENTES | MOSQUERA | 979,800 | 1,009,550 | G. Guadalupe | | | ○ | HUMAN | 200 | o | o | o |
| | 43 | GU-3 | 227-II-D-1112 | 8 | Acueducto La Punta | TENJO | 985,450 | 1,022,565 | Saban-Gdlupe | ○ | ○ | ○ | HUMAN | 115 | o | o | o |
| | 44 | GU-4 | 227-II-D-016 | 9 | ALTAMIRA 1 | TENJO | 990,420 | 1,029,510 | G. Guadalupe | | | ○ | FLOWERS | 249 | o | o | x |
| | 45 | GU-5 | 227-II-D-670 | 9 | FLORES LA GAITANA | TENJO | 991,908 | 1,020,934 | G. Guadalupe | | | ○ | IRRIGATION | 178 | o | o | o |
| | 46 | GU-6 | 227-II-C-576 | 6 | E.A.A. PUENTE PIEDRA | MADRID | 984,641 | 1,023,670 | G. Guadalupe | | | ○ | HUMAN | 150 | o | o | o |
| | 47 | GU-7 | 227-II-B-028 | 6 | PROPAGAR PLANTAS S.A. | SUBACHOQUE | 989,160 | 1,032,630 | G. Guadalupe | | | ○ | IRRIGATION | 70 | o | o | o |
| | 48 | GU-8 | 227-IV-A-063 | 6 | FLOREX S.A. | MADRID | 978,150 | 1,018,820 | G. Guadalupe | | | ○ | FLOWERS | 448 | o | o | o |
| | 49 | GU-9 | 227-II-C-094 | 5 | ECOPETR. TERMINAL MANCILLA | FACATATIVA | 970,818 | 1,027,100 | G. Guadalupe | | | ○ | INDUSTRY | 84 | o | o | o |
| | 50 | GU-10 | 227-IV-A-102 | 5 | HACIENDA ARGEL | BOJACA | 973,400 | 1,017,000 | G. Guadalupe | | | ○ | IRRIGATION | 392 | o | o | o |
| QUATERNARY | 51 | QU-1 | 227-IV-B-307 | 8 | SOLLA S.A | MOSQUERA | 985,535 | 1,011,140 | F.CUATERNARIO | ○ | | | INDUSTRY | 119 | o | o | o |
| | 52 | QU-2 | 227-IV-A-441 | 6 | FLORAMERICA 4 | FUNZA | 982,150 | 1,016,290 | F. Subachoque | ○ | | | FLOWERS | 370 | o | o | o |
| | 53 | QU-3 | 227-IV-B-066 | 8 | Flores de Funza | FUNZA | 987,500 | 1,017,870 | F. Sabana | ○ | | | FLOWERS | 470 | o | o | o |
| | 54 | QU-4 | 227-IV-B-456 | 10 | Liceo Juan Ramón Jiménez | BOGOTA | 999,170 | 1,019,540 | F. Sabana | ○ | | | HUMAN | 121 | o | o | x |
| | 55 | QU-5 | 228-I-A-518 | 8 | Polo Club de Bogotá | BOGOTA | 1,004,510 | 1,019,700 | F. Sabana | ○ | | | HUMAN | 122 | o | o | x |
| | 56 | QU-6 | 227-II-C-477 | 6 | VIVERO TISQUESUSA CAR | SUBACHOQUE | 977,100 | 1,022,060 | F. Subachoque | ○ | | | IRRIGATION | 293 | o | o | o |
| | 57 | QU-7 | 228-I-C-247 | 10 | Colegio Andino | BOGOTA | 1,003,110 | 1,022,120 | F. Sabana | ○ | | | HUMAN | 60 | o | o | o |
| | 58 | QU-8 | 228-I-C-041 | 10 | Club Fontanar | CHIA | 1,005,040 | 1,022,480 | F. Sabana | ○ | | | HUMAN | 118 | o | o | o |
| | 59 | QU-9 | 227-II-D-749 | 9 | EL AMOLADERO | TENJO | 992,850 | 1,023,680 | F. Sabana | ○ | | | IRRIGATION | 147 | o | o | x |
| | 60 | QU-10 | 228-I-C-018 | 13 | San Prudencio | | 1,014,950 | 1,028,960 | F. Sabana | ○ | | | IRRIGATION | 68 | o | o | o |
| | 61 | QU-11 | 227-II-D-802 | 9 | LETICIA | TENJO | 993,680 | 1,026,860 | F. Sabana | ○ | | | IRRIGATION | 100 | o | o | o |
| | 62 | QU-12 | 228-I-D-003 | 13 | Hacienda Ingruma | SOPO | 1,015,440 | 1,029,620 | F. Sabana | ○ | | | IRRIGATION | 110 | o | o | o |
| | 63 | QU-13 | 227-II-C-972 | 6 | FLORES CONDOR -LA CONSTANCIA | SUBACHOQUE | 979,630 | 1,026,770 | F. Subachoque | ○ | | | FLOWERS | 172 | o | o | o |
| | 64 | QU-14 | 227-II-B-252 | 6 | HIDA. TIBAGOTA | SUBACHOQUE | 986,000 | 1,033,600 | F. Subachoque | ○ | | | IRRIGATION | 172 | o | o | o |
| | 65 | QU-15 | 227-II-C-007 | 6 | FLORES MOCARI S.A. | SUBACHOQUE | 981,500 | 1,025,100 | F. Subachoque | ○ | | | FLOWERS | 243 | o | o | o |
| | 66 | QU-16 | 227-II-B-720 | 9 | HACIENDA LOS SAUCES | TABIO | 998,990 | 1,035,720 | F. Sabana | ○ | | | IRRIGATION | 80 | o | o | o |
| | 66a | QU-16a | 227-II-B-255 | 6 | CONDOMINIO EL VERDE | SUBACHOQUE | 987,410 | 1,035,840 | F. Subachoque | ○ | | | IRRIGATION | 127 | o | x | x |
| | 67 | QU-17 | 228-I-B-069 | 13 | ALEJANDRIA | TOCANCIPA | 1,015,040 | 1,037,815 | Sab-Guaduas | ○ | ○ | | | | o | o | x |
| | 68 | QU-18 | 209- 11-B-172 | 16 | DANDY | SUESCA | 1,029,150 | 1,052,100 | F. Sabana | ○ | | | FLOWERS | 100 | o | o | o |
| | 69 | QU-19 | 228-I-A-512 | 11 | JARDINES DEL ROSAL | CAJICA | 1,004,350 | 1,033,600 | Saban-Gdlupe | ○ | | ○ | IRRIGATION | | o | o | x |
| | 70 | QU-20 | 228-I-A-512-APOS | 13 | APOS | SOPO | 1,011,750 | 1,038,250 | | ○ | | ○ | | | x | o | o |
| | 71 | QU-21 | 228-I-A-515 | 11 | VILLA SANT | CAJICA | 1,004,130 | 1,035,120 | F. Sabana | ○ | | | IRRIGATION | 120 | o | o | o |
| | 72 | QU-22 | 209-III-B-083 | 15 | PACAYAL | NEMOCON | 1,019,830 | 1,055,970 | F. Sabana | ○ | | | FLOWERS | 107 | o | o | o |
| | 73 | QU-23 | 228-I-C-178 | 10 | FLORES ASTRO | BOGOTA | 1,000,370 | 1,023,600 | F.CUATERNARIO | ○ | | | FLOWERS | 118 | o | o | o |
| | 74 | QU-24 | 227-II-D-1008 | 10 | EL TESORO | COTA | 996,640 | 1,023,530 | F.CUATERNARIO | ○ | | | IRRIGATION | 145 | o | o | o |
| | 75 | QU-25 | 209-III-B-145 | 15 | HIDA. SUSASUCA | NEMOCON | 1,023,500 | 1,058,800 | F.CUATERNARIO | ○ | | | IRRIGATION | 110 | o | o | x |
| ISOTOPE | 78 | IS-3 | 227-IV-A-233 (Nuevo) | 6 | E.A.A. MADRID | MADRID | 979,426 | 1,015,408 | | ○ | | | | | x | o | x |
| | 79 | IS-4 | 227-IV-A-299 | 6 | Ponque Ramo 1 | MOSQUERA | 981,300 | 1,013,550 | Sap-Subacho | ○ | | | | 500 | o | o | x |
| | 80 | IS-5 | 228-I-C-252 | 10 | MADRIGAL SUBA | BOGOTA | 1,001,340 | 1,020,545 | | ○ | | | FLOWERS | | o | o | x |
| | 81 | IS-6 | 08-0007 | 8 | AUTOBOYACA | BOGOTA | 994,111 | 1,005,719 | Guadalupe | | | ○ | | 450 | o | o | o |
| | 82 | IS-7 | 227-IV-B-561 | 8 | BOMBA DE GASOLINA | BOGOTA | 991,190 | 1,010,320 | Sabana | ○ | | | INDUSTRY | 115 | o | o | x |
| | 82a | IS-7a | 11-0010 | 8 | MAZUREN CAR WASH | BOGOTA | 1,002,950 | 1,014,345 | | ○ | | | | 251.8 | o | x | x |
| | 83 | IS-8 | 228-III-A-051 | 8 | Armitage | BOGOTA | 1,003,300 | 1,012,400 | | ○ | | | | | x | o | x |
| | 84 | IS-9 | 22-0078 | 10 | GIMNASIO FONTANA 1 | GUAYMARAL | 1,001,600 | 1,022,900 | | ○ | | | | 252 | o | o | x |
| | 85 | IS-10 | 228-I-C-019 | 13 | La Gavia | | 1,013,480 | 1,020,460 | F. Sabana | ○ | | | IRRIGATION | 135 | o | o | x |
| | 86 | IS-11 | 209-III-D-172 | 16 | LEONA | TOCANCIPA | 1,015,800 | 1,041,100 | F. Sabana | ○ | | | | 253 | o | o | x |
| | 87 | IS-12 | 228-I-A-509 | 13 | SAN MARTIN | BOGOTA | 1,013,250 | 1,034,560 | | ○ | | | | 112 | o | o | x |
| | 88 | IS-13 | 209-III-D-036 | 16 | AGROMONTE | GACHANCIPA | 1,022,600 | 1,046,450 | F. Sabana | ○ | | | IRRIGATION | 82 | o | o | o |
| | 89 | IS-14 | 209-III-B-170 | 15 | CASUPA 2 | NEMOCON | 1,023,930 | 1,054,700 | F. Cacho | | ○ | | | | o | o | o |
| | 89a | IS-14a | 227-II-D-1115 | 10 | La Palma | COTA | 998,100 | 1,025,500 | Guadalupe | | | ○ | | | o | x | x |
| | 90 | IS-15 | 227-II-D-Noviciado | 10 | Noviciado | COTA | 998,405 | 1,026,470 | | ○ | | ○ | | | x | o | x |
| | 91 | IS-16 | 227-IV-A-442 | 6 | San Francisco | MADRID | 982,800 | 1,016,630 | Sap-Subacho | ○ | | | IRRIGATION | 353 | o | o | o |
| | 92 | IS-17 | 227-IV-B-577 | 8 | Uniabastos | COTA | 993,310 | 1,016,350 | F. Sabana | ○ | | | HUMAN | 526 | o | o | o |
| | 92a | IS-17a | 227-IV-A-X6 | 8 | Mosquera 1 - EAMOS | | 983,480 | 1,012,100 | Tilatá | ○ | | | HUMAN | 581 | o | x | o |
| | 93 | IS-18 | 227-IV-B-576 | 8 | Empresa A. | Funza | 985,210 | 1,013,525 | | ○ | | | | | x | o | o |
| | 94 | IS-19 | 16-0003 | 8 | GASEOSAS LUX 1 | | 996,280 | 1,003,018 | F. Sabana | ○ | | | INDUSTRY | 192 | o | o | o |
| | 95 | IS-20 | 10-0011 | 8 | LAVAUNTOS UNO A | BOGOTA | 996,735 | 1,010,576 | F.Sabana | ○ | | | | 120 | o | o | x |
| EAAB | 96 | EAAB-1 | EAAB-1 LA SALLE | 8 | EAAB-1 | LA SALLE | 1,006,000 | 1,017,000 | Guadalupe | | | ○ | Test | 270 | x | o | o |
| | 97 | EAAB-2 | EAAB-2 SUBA | 8 | EAAB-2 | SUBA | 999,700 | 1,017,700 | Guadalupe | | | ○ | Test | 389 | x | o | o |
| | 98 | | Vitelma 1-EAAB | | | | 996,000 | 1,001,850 | | | | | | | x | x | o |
| JICA | 99 | JICA-1 | GIBRALTAR | 8 | JICA-1 | GIBRALTAR | 1,005,845 | 988,439 | Sabana | ○ | | | Test | 196 | o | o | o |
| | 100 | JICA-2 | J-2 TISQUESUSA | 6 | JICA-2 | TISQUESUSA | 1,022,020 | 976,639 | Sabana | ○ | | | Test | 192 | x | o | o |
| | 101 | JICA-3 | J-3 SIBERIA | 8 | JICA-3 | SIBERIA | 1,017,974 | 991,462 | Sabana | ○ | | | Test | 173 | x | o | o |
| | 102 | JICA-4 | J-4 SOPO | 13 | JICA-4 | SOPO | 1,011,020 | 1,037,638 | Sabana | ○ | | | Test | 150 | x | o | x |
| | 103 | JICA-5 | J-5 LA DIANA | 16 | JICA-5 | LA DIANA | 1,038,429 | 1,013,170 | Sabana | ○ | | | Test | 188 | x | o | o |
| | 104 | JICA-6 | J-6 CHOCONTA | 20 | JICA-6 | CHOCONTA | 1,067,343 | 1,049,874 | Tilata | ○ | | | Test | 123 | x | o | o |
| TERMALES | 105 | TE-1 | Pozo Termales Tabio | 9 | Pozo Termales Tabio | Tabio | 997,600 | 1,037,000 | | | | ○ | Recreation | | x | o | x |

■ Auifer of the well is estimated from gepgraphic map and other data.

# CHAPTER 2 Results of Water Quality Tests

All the tests result are listed on Table 4.13 through Table 4.15 in the Main Report.

## 2.1 Comparison of Potable water standard

### (1) Potable water standard values and wells exceeding those value

Table-2.1 shows the standard values of water quality (Colombian standard, WHO guideline and Japanese standard) usable for potable water without any treatment and the number of wells exceeding the standard value in each item.

**Table-2.1 Standard values of water quality for potable water, and number of wells exceeding the standard value**

| Test Items | Potable Water Standards | | | Number exceeded Standards | | |
|---|---|---|---|---|---|---|
| | Colombian Standard | WHO Guideline | Japanese Standard | Phase 1 | Phase 2 | Phase 3 |
| Parameters related to Human Health | | | | | | |
| ・Arsenic | 0.01mg/l | 0.01mg/l | 0.01mg/l | 0 | 0 | 0 |
| ・Boron(B) | 0.3mg/l | 0.5mg/l | 0.2mg/l | 0 | 3(0) | 1(0) |
| ・Cadmium(Cd) | 0.003mg/l | 0.003mg/l | 0.01mg/l | 3(1) | 1(0) | 0 |
| ・Chromium | 0.01mg/l | 0.05mg/l | 0.05mg/l | 0 | 2(0) | 0 |
| ・Cyanide | 0.1mg/l | 0.07mg/l | 0.01mg/l | 1(0) | 1(0) | 0 |
| ・Fluoride | 12mg/l | 1.5mg/l | 0.8mg/l | 0 | 0 | 0 |
| ・Lead(Pb) | 0.01mg/l | 0.01mg/l | 0.05mg/l | 3(0) | 0 | 0 |
| ・Mercury(Hg) | 0.001mg/l | 0.001mg/l | 0.0005mg/l | 0 | 0 | 0 |
| ・Nickel(NL) | 0.02mg/l | 0.02mg/l | 0.01mg/l | 1(0) | 1(0) | 0 |
| ・Nitrate | 10mg/l | 50mg/l | 10mg/l | 1(0) | 4(0) | 0 |
| ・Nitrite | 0.1mg/l | 0.2mg/l | 10mg/l | 1(0) | 0 | 0 |
| ・Selenium | 0.01mg/l | 0.01mg/l | 0.01mg/l | 0 | 0 | 0 |
| ・Antimony | 0.005mg/l | 0.005mg/l | 0.002mg/l | 0 | 0 | 0 |
| ・Barium(Ba) | 0.5mg/l | 0.7mg/l | - | 15(2) | 18(2) | 2(0) |
| ・Beryllium(Be) | - | NAD | - | 0 | 0 | 0 |
| ・Cupper(Cu) | 1.0mg/l | 2mg/l | 1.0mg/l | 0 | 0 | 0 |
| ・Manganese | 0.1mg/l | 0.5mg/l | 0.05mg/l | 30(6) | 38(10) | 23(5) |
| ・Molybdnum | 0.07mg/l | 0.07mg/l | 0.07mg/l | 0 | 0 | 0 |
| Parameters related to Taste, Odor and Color | | | | | | |
| ・Color | <=15 | 15TCU | 5° | 89(19) | 58(6) | 58(10) |
| ・Turbity | <=5 | 5NTU | 2° | 66(17) | 18(2) | 45(8) |
| ・Langelier Inde | - | - | -1<、 0 | 89(18) | 104(18) | 63(13) |
| ・Conductivity | 50-1000μS/cm | - | - | 13(3) | 10(2) | 12(3) |
| Inorganic Parameters | | | | | | |
| ・Aluminum | 0.2mg/l | 0.2mg/l | 0.2mg/l | 8(1) | 0 | 0 |
| ・Ammonia | - | 1.5mg/l | - | 53(9) | 60(7) | 23(3) |
| ・Chloride | 250mg/l | 250mg/l | 200mg/l | 1(0) | 2(0) | 1(0) |
| ・Hardness | 160mg/l | - | 300mg/l | 1(0) | 1(0) | 3(0) |
| ・Hydrogen sulfi | - | 0.05mg/l | - | 89(17) | 98(15) | 67(13) |
| ・Iron(Fe) | 0.3mg/l | 0.3mg/l | 0.3mg/l | 87(19) | 70(11) | 48(8) |
| ・Dissolved Oxy | - | - | - | - | - | - |
| ・pH | - | - | 5.8-8.6 | 9(3) | 7(3) | 5(1) |
| ・Sodium | - | 200mg/l | 200mg/l | 0 | 4(0) | 3(0) |
| ・Sulfate(SO4) | - | 250mg/l | - | 16(2) | 0 | 0 |
| ・Total Dissolve | <=500mg/l | 1000mg/l | 500mg/l | 6(1) | 7(0) | 5(0) |
| ・Zinc(Zn) | 5mg/l | 3mg/l | 1.0mg/l | 1(0) | 0 | 0 |
| ・Magnesium | 36mg/l | - | - | 0 | 0 | 0 |
| ・Potassium | - | - | - | - | - | - |
| ・Bicarbonate | - | - | - | - | - | - |
| ・Carbonate | - | - | - | - | - | - |
| ・Calcium | 60mg/l | - | - | 1(0) | 0 | 0 |
| ・Alkalinity | 100mg/l | - | - | 58(8) | 62(4) | 41(3) |
| ・Acidity | - | - | - | - | - | - |
| Bacteria | | | | | | |
| ・E.coli | Not detected | Not detected | - | 9(2) | 5(1) | 4(1) |
| ・Total coliform | Not detected | Not detected | Not detected | 51(11) | 55(9) | 32(5) |

( ) denotes the number of wells for potable water exceeding the standard value among the walls in actual use for drinking.

denotes the number of wells for potable water exceeding WHO guideline

denotes the number of wells for potable water exceeding Japanese standard

## (2) Items exceeding the potable water standard values

The Study team have prepared a reference map that indicates the positions and values on the items exceeding the standard values. Those items exceeding the standard values will be described below.

### (a) Chemical substances affecting health

On 8 items of arsenic, fluorine, total mercury, selenium, antimony, beryllium, copper, and molybdenum, there was no well that exceeded the Colombian standard or WHO guideline values in all three Phases. But on other items, there were some wells that exceeded the standard values in three phases. The items exceeding or nearly reaching the standard values will be described below.

**Boron** (Colombian potable water quality standard: 0.3mg/l, WHO guideline: 0.5mg/l)

The water of 3 wells in phase 2 and 1 well in phase 3 exceeded the standard value. Baron creates various chemical compounds, but in the natural condition, it exists as borax, particularly in hot spring water or seawater (and ocean sediments) in a relatively high concentration. The wells exceeding the standards are all in the Quaternary aquifer and have no relation with ocean sediments, so that hot springs and mineral springs are assumed as their sources of natural pollution. The land around these wells is used mainly for farming, but boron is also used in gilding factories, glass/chinaware manufacturing and silicon semiconductor plants. It is necessary to survey if there is such a plant in the vicinity of these wells.

**Cadmium** (Colombian potable water quality standard: 0.003mg/l, WHO guideline: 0.003mg/l)

In Phase 1 study, 3 wells exceeded the standard values, and one of the 3 wells exceeded the standards in Phase 2, but there was no exceeding well in Phase 3. Cadmium often exists in the earth crust with zinc, containing 1/100 – 1/200 of zinc, and it flowed out of a mine, but its distribution is not equal to the zinc distribution as described later. The wells that exceeded the standards in both phases are located in the Cretaceous aquifer along Bojaca River. Around those there are mainly bare lands or grasslands or cultivated lands. Other 2 wells are located near Muna Lake and are near the city area. Cadmium is widely used for metal processing, gilding, paints, rubber, or as a photo material and pottery material. Therefore, cadmium pollution is assumed due to drainages from these factories.

**Chromium** (Colombian potable water quality standard: 0.01mg/l, WHO guideline: 0.05mg/l)

In Phase 2 test, 2 wells exceeded the standards, but there was no exceeding well in Phase 1 and 3. A chromium pollution source is thought to be the drainages from chromium and other mines and gilding, stainless steel, paints and tanning factories. One of the wells exceeding the standards is located near Tabio hot spring and there is a lot of tanning factories. The potential pollution source to the well 227-II-D-802 near Chicu River is assumed as these tanning factories.

**Total Cyanide** (Colombian potable water quality standard: 0.1mg/l, WHO guideline

0.07mg/l)

In Phase 1 and Phase 2 each, one well exceeded the Colombian potable water quality standard. Also 3 wells exceeded WHO guideline in Phase 1 and one of the same wells tested in Phase 1 exceeded the WHO standard in Phase 2.But there was no exceeding well in Phase 3.All the wells except the 227-II-D-587 well along a branch of Chicu River are in the Quaternary aquifer. Since cyanide is little contained in natural water, the pollution source is thought to be drainages from factories of gilding, metal refinery and photo industry. Cyanide compounds have a high toxicity in general and even a tiny quantity of those is impedimental to aquatic animals and plants as well as microorganisms for drainage purification.

**Fluorine** (Colombian potable water quality standard: 12mg/l, WHO guideline: 1.5mg/l)

There was no well that exceeded the standards, but only the 227-IV-A-264 well showed an exceptionally high value of 1.46mg/l in comparison with the other wells. Fluorine is not alienated in the natural condition but exists as fluorite. It exists in hot spring water or seawater in a relatively high concentration. It is thought that there was geological factor, because this well is in the Cretaceous aquifer that was the origin of ocean. It is used for metal grinding and stainless steel washing.

**Lead** (Colombian potable water quality standard: 0.01mg/l, WHO guideline: 0.01mg/l)

In Phase 1 test, 3 wells exceeded the standards, but there was no exceeding well in Phase 2 and 3. The geological factor of water pollution by lead is thought to be draining from a mine or a terrain including lead deposit, but lead is used variously and pollution is generally thought to be due to drainages from factories of scouring, storage batteries, paints, and agricultural chemicals. Also if lead pipes are used, lead can be dissolved and flow out.

**Nickel** (Colombian potable water quality standard: 0.02mg/l, WHO guideline: 0.02mg/l)

There was one well that exceeded the standards in Phase 1 and Phase 2 respectively. There was no exceeding well in Phase 3.Nickel is used in various ways for the materials of batteries, machines, furniture and money, as well as alloying and gilding of stainless steel. The well tested in Phase 2 is located near a Tabio hot spring, but the well tested in Phase 1 is located in the Quaternary aquifer of a cultivated land which means that there is a low possibility of containing drainages from alloy and gilding factories.

**Nitrate nitrogen** (Colombian potable water quality standard: 10mg/l, WHO guideline: 50mg/l)

One well in Phase 1 and 4 wells in Phase 2 exceeded the standards, but there was no exceeding well in Phase 3. Nitrate nitrogen and nitrite nitrogen are caused by the pollution of fertilizers in agricultural areas and of excreta and sewerage in city areas. So they should be

seen in the shallow layer in the Quaternary aquifer, but in Phase 1, they were seen in the well 227-II-D-016 in the Cretaceous aquifer that was used for flower cultivation. There may be problems with water sampling and the well structure causing mixture of water from the shallow layer.

**Nitrite nitrogen** (Colombian potable water quality standard: 0.1mg/l, WHO guideline: 0.2mg/l)

It was detected in Phase 1 that the well 227-II-D-016 exceeded the nitrate nitrogen standards. There was no well that exceeded the nitrite nitrogen standards in Phase 2 and 3.

**Barium** (Colombian potable water quality standard: 0.5mg/l, WHO guideline: 0.7mg/l)

There were 15 wells in the west area that exceeded the standards in Phase 1, and 18 wells in Phase 2. Also 2 wells exceeded the standards in Phase 3. Barium exists extensively in the earth crust, and a lot of it is contained in barite and witherite. It is used for metal deoxidizing agents, alloy, and insecticide. Most of the wells exceeding the standards are densely distributed in the farming zone, so that some barium compounds may be contained in agrochemicals. There are several aquifers distributed in the Quaternary, Tertiary and Cretaceous aquifers.

**Manganese** (Colombian potable water quality standard: 0.1mg/l, WHO guideline: 0.5mg/l)

In Phase 1, there were 30 wells exceeded the standards and 35 wells exceeded in Phase 2, and

23 wells exceeded in Phase 3. Such wells were distributed over the whole study area, but there are a relatively small number of such wells in the plain areas around cities. The cause of the exceeded standards can be the mixture of drainages from mines and factories, but considering that the manganese content exceeded the standards in the entire study area, the geological factor is thought to be large.

### (b) Physical & chemical parameters related to taste, odor and color

Concerning chromaticity and turbidity, most of the wells exceeded the standard values in Phase 1, 2 and 3. For conductivity, Colombian standard values have the upper and lower limits. In Colombian standards and WHO guideline, there is no standard such as Langelier index. In applying the Japanese potable water quality standards instead of Colombian standard and WHO guideline, there were only 11 wells in Phase 1 and 7 wells in Phase 3 that passed the standards. Langelier index denotes the value of water erosion and if it is less than –1.0, a metal like steel pipe and a concrete building may be eroded and melt down. To prevent this, it is required to increase the pH-value by adding an alkaline agent such as slaked lime or using aeration.

**Chromaticity** (Colombian potable water quality standard: 15TCU, WHO guideline: 15TCU)

Almost all the wells exceeded the standards in Phase 1, 2 and 3. The chromaticity in natural water is mainly attributed to the huminate substance that is produced in oxidation of cellulose and lignin oxide, which is included in the cellulose of plants in soil and trees. Therefore, the river water passing a dense planting zone and the undercurrent water penetrated through a peat moss area are colored in pale yellow or yellowish brown. Other substances than the huminate substance may be derived from the drainages from pulp and paper industries and textile plants. Beside these factors, in this area, there is a high possibility of geological factor that a lot of iron and manganese compounds may color the water. The countermeasure against this coloring is to filter the well water using a water purifier.

**Turbidity** (Colombian potable water quality standard: 5 NTU, WHO guideline: 5NTU)

Almost all the wells in the whole area in Phase 1,18 wells in Phase 2, and 45 wells in Phase 3 exceeded the standards. Normally, the high turbidity is caused by the mixture of sewerage and soil, or the mixture of medicines, or melting from zinc-plated pipe coating and faults in the water supply facility. There was a tendency to have less exceeding wells in Phase 2 that was tested in rainy season.

**Conductivity** (Colombian potable water quality standard: 50～1000 μS/cm)

Conductivity is an index to show the water's capability of conducting electricity and to presume the electrolytic concentration in water as a whole, which has a correlation between an electrolytic substance and voltage. No standard value is prescribed in WHO guideline or in Japan, but the average conductivity of water in rivers in Japan is about 110 μS/cm, and that of seawater is about 45,000 μS/cm. The wells of less than the lower limit lie in the Cretaceous aquifer and the wells exceeding the upper limit are seen in the city areas and in rock salt areas.

**(c) Inorganic substances**

Concerning items except potassium, bicarbonate ion and carbonate having no standard, not including magnesium the wells exceeded the standard.

**Aluminum** (Colombian potable water quality standard: 0.2mg/l, WHO guideline: 0.2mg/l)

In Phase 1 test, 8 wells exceeded the standards. But there was no exceeding well in Phase 2 and 3. Aluminum is contained in soil in the highest quantity as a metal. All the wells exceeding the standards have the water in the Quaternary aquifer. The source of pollution exclusive of the natural conditions was supposed by aluminum used as a condensation agent in water purification and disposal of wastewater or drainage from aluminum-product factories.

**Ammonia** ( WHO guideline: 1.5mg/l)

There is no standard for ammonia in Colombia, but according to the WHO guideline, in Phase

1, 2 and 3, all the wells in the study area excluding the most upstream part of the northwest region exceeded the standard. Pollution can be derived from stock-raising yards and excreta processing plants. Therefore, pollution is mostly detected in the Quaternary aquifer, but 6 wells in the Cretaceous aquifer exceeded the standard in Phase 1, 3 wells in Phase 2, and 6 wells in Phase 3.

**Chloride** (Colombian potable water quality standard: 250mg/l, WHO guideline: 250mg/l)

One well in Phase 1 and 3, 2 wells in Phase 2 are exceeded the standards. Generally, the chlorine concentration is used as the index to show the mixture of excreta, sewerage and drainages from factories or houses. The wells that exceeded the standards in Phase 2 are located near the Tabio hot spring and the well exceeded the standards in all three Phases was 209-III-C-013. It is supposed that the pollution is from rack salt, which has been recognized in this area.

**Hardness** (Colombian potable water quality standard: 160mg/l)

In both Phase 1 and 2, one well each exceeded the standard. In Phase 3, 3 wells exceeded the standard. Hardness is the amount of calcium carbonate mainly equivalent to the amounts of calcium ion and magnesium ion. The origin of calcium ion and magnesium ion in water is mainly geological, but the mixture of seawater, drainage from factories and sewerage can be considered. In three phases, different wells exceeded the standard, but they are located near Chicu River and along its branch, so that the factories and sewerage can be the sources of such components.

**Hydrogen sulfide** (WHO guideline: 0.05mg/l)

There is no standard for hydrogen sulfide in Colombia, but based on the WHO guideline, almost all the wells exceeded the standard in three Phases. Generally, hydrogen sulfide is seen in the mixture of sewerage and excreta or drainages from stock raising businesses or pulp factories.

**Iron** (Colombian potable water quality standard: 0.3mg/l, WHO guideline: 0.3mg/l)

Almost all the wells exceeded the standards in three Phases. Iron is contained extensively in the earth crust, but it may exist in the drainages from mines and factories or be dissolved from pipes. In this study area, the iron contained in water can be attributed to the geological factor. According to geological data, there are layers containing a lot of iron in part of the Cretaceous aquifer and the Tertiary aquifer. A high concentration of iron in water may cause red water and metallic odor.

**Sodium** (WHO guideline: 200mg/l)

There is no standard for sodium in Colombia, but in applying the WHO guideline, 4 wells exceeded the standard in Phase 2 and 3 wells in Phase 3. Sodium ion is the main element of

fresh water and mainly attributed to the dissolution from rocks and soil, and about 1～10mg/l is contained in ordinary river water. As sodium ion has a low absorbability into soil, it is liable to be discharged through the ion exchange between groundwater and soil grains, so that it tends to increase as the groundwater flows. The wells that exceeded the standard as made clear in the tests in this study are located in hot spring and rock salt areas and in the downstream areas. The geological factor can surely be considered, but the sodium component increases through the mixture of drainages from factories and houses.

**Sulfate** (WHO guideline: 250mg/l)

There is no standard for sulfate in Colombia, but in applying the WHO guideline, 15 wells exceeded the standard in Phase 1. There was no exceeding well in Phase 2 and 3. Sulfate is seen in most natural water, but if a high concentration of it is detected, the mixture of drainages from mines, hot springs, factories, chemical fertilizers, sewerage and excreta can be considered as the source of it. However, the test results in Phase 1 showed an abnormal ion balance, which was improved by the removal of sulfate components. Thus, these analysis results are doubtful.

**Total Dissolved Solids** (Colombian potable water quality standard: 500mg/l, WHO guideline: 1000mg/l)

In Phase 1 test, 6 wells exceeded the standards. 7 wells in Phase 2 test and 5 wells in Phase 3 test exceeded the standards. Total dissolved solids show the total value of soluble substances in water. The wells that exceeded the standards were distributed in rock salt and hot spring areas and in the downstream basin of Bogotá River.

**Zinc** (Colombian potable water quality standard: 5mg/l, WHO guideline: 3mg/l)

In Phase 1, one well exceeded the standard. There was no exceeding well in Phase 2 and 3. Zinc is a metal distributed in a relatively high quantity in the natural world and is one of the indispensable elements for living things. If it lacks, various impediments will occur to them. There are few problems against human health that may be caused by water pollution. However, zinc has toxicity to plants, microorganisms and fish. As an artificial mixture, there may be drainages from mines and metal factories, and dissolutions from zinc-plated pipes.

**Calcium** (Colombian potable water quality standard: 60mg/l)

In Phase 1, one well exceeded the standard. There was no exceeding well in Phase 2 and 3. The largest factor dominating calcium ion is geology. Calcium is contained in the stratum with limestone or in the water from stalactite caves while a little of it is contained in the water from the igneous rock areas. Generally, the existence of carbonate and the mixture of water from hot springs and mineral springs can be presumed as pollution sources of calcium. As an artificial factor, it is considered that lime may be used for water treatment materials or

agrochemical.

**Total alkalinity** (Colombian potable water quality standard: 100mg/l)

Many wells exceeded the standard in all three Phases, mainly in plain areas. Alkalinity is an acid amount to neutralize water to a prescribed pH-value. Normally, the geological factor is large, but sewerage and industrial wastewater affect the increase or decrease of alkalinity.

**(d) Organic Substances**

The influence of organic matter (BTX) used in the industrial areas was not identified in groundwater. Similarly, the influence of agricultural chemicals was not in groundwater.

**(e) Agricultural chemicals**

The tests were carried out in the agricultural region, one well in Madrid, 2 wells in Facataiva and 2 wells in Tenjo, 5 wells in total. No chemicals were detected in Phase 1 and Phase 3, but heptachlorepoxide was found in 2 wells each in Facatativa and Tenjo in Phase 2.

**(f) Bacteria**

***Coliform* bacillus/*Coliform* bacilli group** (Colombian potable water quality standard: not to be detected, WHO guideline: not to be detected)

*Coliform bacilli* were detected in 9 wells in Phase 1,in 5 wells in Phase 2, and in 4 wells in Phase 3. The wells and areas in which *coliform bacilli* were detected are different in Phase 1, Phase 2, and Phase 3.

The *coliform bacilli* group was detected in more than half of the wells in all three phases. The results of analysis showed that the *coliform bacilli* group was detected not only in the Quaternary aquifer but also in the Tertiary and Cretaceous aquifers.

**(3) Characteristics of pollution on underground water derived by considerations on the exceeding well of Potable water standard**

**(a) Items of pollution in the entire area**

The items that exceeded the Potable water standards (Colombian standard and WHO guideline) in more than 10% of the test wells in the study area in all Phases were barium, manganese, chromaticity, turbidity, ammonia, hydrogen sulfide, iron, total alkalinity and *coliform bacilli* group. Also, sulfate was detected in Phase 1. The pollution sources of these items are thought as follows:

Manganese and iron are contained in the strata in Bogotá Plain, so the geological factor may be large.

① Barium was concentrated in the agricultural areas.
② Ammonia, hydrogen sulfide and total alkalinity as well as *coliform bacilli* group are thought to be the mixtures of sewerage and excreta.
③ For the chromaticity, the Bogotá Plain was a marshland zone, which was rich in huminate substances, and it was also considered that a lot of manganese (black colored water) and iron (red colored water) was contained in the zone.
④ For turbidity, generally the mixture of soil and sand (soil grains) can be considered.

**(b) Items of local pollution**

The items of pollution that exceeded the standard locally will be described below.

① Geological factor: The influence of soil in the rock salt area is characteristic of chloride and sodium. Several other metals can be presumed as the sources of pollution from mines.
② Industrial factor: The pollution items from metal, refinery and gilding factories may be cadmium, nickel, lead, zinc, cyanide and aluminum. Boron and cadmium may be derived from ceramic industry and chloride, sulfide and chromium are from tanning industry.
③ Living factor: The pollution items from living drainages, sewerage and mixture of excreta may be chloride, sulfide, nitrate nitrogen and nitrite nitrogen. Aluminum and calcium are used for water purifying treatment.
④ Agricultural factor: The pollution items from fertilization in farming activity and stock raising may be nitrate nitrogen and nitrite nitrogen.

It is necessary to execute more detail study if these pollution factors directly affected the groundwater. Additionally, the groundwater flow is very slow that normally it is difficult to improve the pollution conditions once it was polluted. However, the detected items in the wells were different in the all three Phases. The analysis result of the Phase 1 has a low degree of reliability, due to the bad ion balance. Therefore, the items that exceeded the standard values in Phase 1 such as lead, nickel, aluminum, zinc, calcium and sulfate, remain uncertainty.

**(c) Wells with many items of pollution**

The wells that exceeded the standards for many items, except the aforesaid items of pollution, which were detected in the entire area, are 209-III-C-013 in Zipaquira district, 227-II-D-016 in Tenjo district and Pozo Termales Tabio in Tabio district.

① 209-III-C-013 contained chloride, sodium and aluminum. This well is located in a rock salt area and may be affected by this.
② 227-II-D-016 contained nitrate nitrogen, nitrite nitrogen and calcium. This well exceeded the standard values in the items having a close relation with agriculture.
③ Pozo Termales Tabio exceeded the standard values for several items, but it is a hot-spring

well.

## 2.2 Comparison with the Quality Standards for Raw Water

In addition to the drinking water standard, the "water quality standards for raw water" are specified in Colombia according to the Law No. 1594 (June 26, 1984, Ministry of Public Health), which are "the water quality standard for raw water usable for drinking and living if treated", "the allowable water quality standard for raw water usable for agriculture", "the allowable water quality standard for raw water usable for stock-raising" and "the allowable water quality standard for raw water usable for recreation". The number of wells for which the water quality exceeds the standard value of each item is also indicated.

### (1) Water quality standards for raw water usable for drinking and living if treated

The comparisons of the water quality test results at each well with the standard values are indicated in Table 4.13 through Table 4.15 of the Main Report. The water quality standards for raw water usable for drinking and living if treated and the number of wells exceeding these standard values are indicated in Table-2.2 of this supporting report.

As shown in Table-2.2, a large number of wells exceeded the standard values for the items of chromaticity, turbidity, ammonia and pH, in accordance with "the water quality standards for raw water usable as drinking and living water if chlorinated". These wells could not clear the standard value for ammonia in accordance with "the water quality standard for raw water usable for drinking and living if treated by the traditional method". This means that the severity of standard is higher than the one of the WHO guideline value for ammonia.

Also regarding the items of hydrogen sulfide and iron, most wells exceeded "the drinking water standard values in Colombia", but "the water quality standards for raw water usable for drinking and living if treated" include these items. Therefore, the water of the wells exceeding the standard values on these items is not deemed adequate for drinking and living even if it is treated.

In Phase 1 test, 21 wells were used for drinking water. In Phase 2 and Phase 3 test, 18 wells and 16 wells respectively were used for drinking. The number of wells exceeding the standard among the wells in actual use for drinking is indicated in ( ).

These test results by aquifer are shown in Table-2.3. (In this case, the number of wells exceeding the standard on each item among the wells in actual use for drinking is also available.)

As shown in Table-2.3, even some wells in the Cretaceous aquifer exceeded the standard values on the living water pollution items such as ammonia, hydrogen sulfide and *coliform bacilli*. The underground water of shallow aquifer may have penetrated into these wells.

## Table-2.2 The quality standard for raw water usable for drinking and living if treated, and the number of wells exceeded the standard

| Items | Allowable raw water quality | | Number of wells exceeding the standard | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Traditional treatment | Chlorination | Traditional treatment | | | Chlorination | | |
| | | | Phase1 | Phase2 | Phase3 | Phase1 | Phase2 | Phase3 |
| Chemical parameters related ot Human Health | | | | | | | | |
| ･Arsenic | 0.05mg/l | 0.05mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Cadmium | 0.01mg/l | 0.01mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Chromium | 0.05mg/l | 0.05mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Cyanide | 0.2mg/l | 0.2mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Lead | 0.05mg/l | 0.05mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Mercury | 0.002mg/l | 0.002mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Nitrate | 10.0mg/l | 10.0mg/l | 1 (0) | 4 (0) | 0 | 1 (0) | 4 (0) | 0 |
| ･Nitrite | 1.0mg/l | 1.0mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Selenium | 0.01mg/l | 0.01mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| ･Barium | 1.0mg/l | 1.0mg/l | 2 (0) | 7 (1) | 1 (0) | 2 (0) | 7 (1) | 1 (0) |
| ･Cupper | 1.0mg/l | 1.0mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| Parameters related to Taste, Odor, and Color | | | | | | | | |
| Color | 75unit, Scale of Platinium Cobalt | 20unit, Scale of Platinium Cobalt | 44 (4) | 3 (0) | 32 (4) | 80 (15) | 51 (6) | 54 (9) |
| Turbity | | 10unit(Jack rule) | | | | 52 (9) | 10(1) | 37(6) |
| Inorganic Parameters | | | | | | | | |
| Ammonia | 1.0mg/l | 1.0mg/l | 64 (9) | 68 (7) | 27 (3) | 64 (9) | 68 (7) | 27 (3) |
| Chloride | 250.0mg/l | 250.0mg/l | 1 (0) | 2 (0) | 1 (0) | 1 (0) | 2 (0) | 1 (0) |
| pH | 5.0-9.0 | 6.5-8.5 | 3 (0) | 1 (0) | 0 | 32 (8) | 37 (9) | 11 (3) |
| Sulfate | 400.0mg/l | 400.0mg/l | 7 (0) | 0 | 0 | 7 (0) | 0 | 0 |
| Zinc | 15.0mg/l | 15.0mg/l | 0 | 0 | 0 | 0 | 0 | 0 |
| Bacteria | | | | | | | | |
| Ecoli | 2,000/100ml | | 1 (0) | 0 | 0 | | | |
| Total coliform bacter | 20,000/100ml | 1,000/100ml | 1 (0) | 0 | 2(1) | 5 (1) | 9 (1) | 5 (1) |

※ ( )indicates the number of wells exceeding the standard among the wells in actual use for drinking

## Table-2.3 Number of wells in each aquifer, which exceeded the quality standard for raw water usable for drinking and living if treated

| Item | Phase 1 | | | | | | | | | Phase 2 | | | | | | | | | Phase 3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quaternary | | | Tertiary | | | Cretaceous | | | Quaternary | | | Tertiary | | | Cretaceous | | | Quaternary | | | Tertiary | | | Cretaceous | | |
| | DWS | TT | chlorin ation | DWS | TT | Chlorin ation | DWS | TT | Chlorin ation | DWS | TT | Chlorin ation | DWS | TT | Chlorin ation | DWS | TT | Chlorin ation | DWS | TT | chlorin ation | DWS | TT | Chlorin ation | DWS | TT | Chlorin ation |
| **Chemical parameters related to human health** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Arsenic As | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Boron B | 0 | | | 0 | | | 0 | | | 3 (0) | | | 0 | | | 0 | | | 0 | | | 0 | | | 1(0) | | |
| ・Cadmium Cd | 2 (1) | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Chromium Cr (T) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Cyanide CN (T) | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Fluoride F | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| ・Lead Pb | 2 (0) | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Mercury Hg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Nickel Ni | 1 (0) | | | 0 | | | 0 | | | 0 | | | 0 | | | 1 (0) | | | 0 | | | 0 | | | 0 | | |
| ・Nitrate NO3-N | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0) | 1 (0) | 1 (0) | 4 (0) | 4 (0) | 4 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Nitrite NO2-N | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Selenium Se | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Antimony Sb | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| ・Barium Ba | 11 (1) | 2 (0) | 2 (0) | 1 (0) | 0 | 0 | 3 (1) | 0 | 0 | 14 (2) | 5 (1) | 5 (1) | 1 (0) | 1 (0) | 1 (0) | 3 (0) | 1 (0) | 1 (0) | 2(0) | 1(0) | 1(0) | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Beryllium Be | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Cupper Cu | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Manganese Mn | 23 (4) | | | 2 (0) | | | 5 (2) | | | 28 (7) | | | 3 (0) | | | 7 (3) | | | 18(4) | | | 1(0) | | | 6(1) | | |
| ・Molybdenum Mo | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| **Parameters related to Taste, Odor and Color** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Color | 69 (11) | 37 (3) | 66 (10) | 3 (0) | 2 (0) | 2 (0) | 17 (8) | 5 (1) | 12 (5) | 52 (5) | 3 (0) | 45 (5) | 2 (0) | 0 | 2 (0) | 4 (1) | 0 | 4 (1) | 48(5) | 27(3) | 45(5) | 2(0) | 1(0) | 1(0) | 11(4) | 4(1) | 10(3) |
| ・Turbity | 50 (10) | | 41 (6) | 3 (0) | | 2 (0) | 13 (7) | | 9 (3) | 15 (2) | | 9(1) | 2 (0) | | 1(0) | 1(0) | | 0 | 0 | | 0 | 0 | | 0 | 0 | | 0 |
| ・Langelier Index | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Conductivity | 8 (2) | | | 0 | | | 5 (1) | | | 4 (0) | | | 0 | | | 5 (2) | | | 9(2) | | | 2(1) | | | 4(2) | | |
| **Inorganic parameters** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Aluminum | 8 (1) | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| ・Ammonia | 46 (7) | 55 (7) | 55 (7) | 1 (0) | 2 (0) | 2 (0) | 6 (2) | 7 (2) | 7 (2) | 56 (6) | 60 (6) | 60 (6) | 1 (0) | 2 (0) | 2 (0) | 3 (1) | 6 (1) | 6 (1) | 22(0) | 22(0) | 22(0) | 0 | 0 | 0 | 6(3) | 6(3) | 6(3) |
| ・Chloride | 1 (0) | 1 (0) | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0) | 1 (0) | 1 (0) | 0 | 0 | 0 | 1 (0) | 1 (0) | 1 (0) | 1 (0) | 1 (0) | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Hardness | 0 | | | 0 | | | 1 (0) | | | 1 (0) | | | 0 | | | 0 | | | 3(0) | | | 0 | | | 0 | | |
| ・Hydrogen sulfide | 68 (11) | | | 4 (0) | | | 17 (6) | | | 74 (9) | | | 4 (0) | | | 20 (6) | | | 51(7) | | | 4(1) | | | 17(7) | | |
| ・Iron | 66 (11) | | | 3 (0) | | | 18 (8) | | | 58 (7) | | | 3 (0) | | | 9 (4) | | | 41(5) | | | 1(0) | | | 7(3) | | |
| ・Dissolved Oxygen | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・pH | 6 (3) ＊ | 1 (0) | 24 (6) | 1 (0) ＊ | 0 | 2 (0) | 2 (0) ＊ | 2 (0) | 6 (2) | 2(1)＊ | 0 | 23(5) | 0＊ | 0 | 3(0) | 5(2)＊ | 1(0) | 11(4) | 6(2) | 0 | 6(2) | 3(1) | 0 | 3(1) | 5(2) | 0 | 5(2) |
| ・Sodium | 0 | | | 0 | | | 0 | | | 2(0) | | | 0 | | | 2(0) | | | 2(0) | | | 0 | | | 1(0) | | |
| ・Sulfate | 14 (2) | 7 (0) | 6 (0) | 2 (0) | 1(0) | 1(0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Total Dissolved Solids | 5 (1) | | | 0 | | | 1 (0) | | | 6(0) | | | 0 | | | 1(0) | | | 4(0) | | | 0 | | | 1 (0) | | |
| ・Zinc | 1 (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ・Magnesium | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| ・Potassium | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Bicarbonate | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Carbonate | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Calcium | 0 | | | 0 | | | 1 (0) | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | | 0 | | |
| ・Allcalinity | 48 (4) | | | 2 (0) | | | 8 (4) | | | 51(2) | | | 2(0) | | | 10(2) | | | 35(1) | | | 1(0) | | | 6(2) | | |
| ・Acidity | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Bacteria** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Ecoli | 6 (1) | 1(0) | | 0 | 0 | | 3 (1) | 0 | | 4(1) | 0 | | 0 | 0 | | 1(0) | 0 | | 2(0) | 0 | | 0 | 0 | | 1(0) | 0 | |
| ・Total coliform bacteria | 40 (6) | 1(0) | 4(1) | 2 (0) | 0 | 1(0) | 9 (5) | 0 | 0 | 45(6) | 0 | 9(1) | 1(0) | 0 | 0 | 10(3) | 0 | 1(0) | 25(4) | 1(1) | 4(1) | 1(0) | 0 | 0 | 6(1) | 1(0) | 1(0) |
| ・Total Bacteria | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Phenols | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・PCB | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Silver | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ・Methylen blue active substance | | | | | | | | | | | | | | | | | | | | | | | | | | | |

( ) Number of wells used for drinking water DWS : Drinking water standard TT : Traditional treatment

Non standard value in Colombia and WHO, or not tested

＊ Non standard value in Colonbia and WHO, but exceeding Japanese standard

### (2) Allowable water quality standards for raw water usable for agriculture

The water quality standard values for raw water usable for agriculture and the number of wells exceeding these values are indicated in Table-2.4. The number of wells exceeding the standard among the wells in actual use for agriculture is indicated in ( ). The number of wells exceeding the standard value on each item is among 38 wells in Phase 1 test. The number of those among 36 wells in Phase 2 test and 30 wells in Phase 3 test are indicated. On the items of cobalt, lithium and vanadium, no test was made in this study.

**Table-2.4 Allowable water quality standards for raw water usable for agriculture, and number of wells exceeded the standard**

| Item | Agriculture water standard | Number of wells exceeded the standards | | |
|---|---|---|---|---|
| | | Phase 1 | Phase 2 | Phase 3 |
| Chemical parameters related to human health | | | | |
| ･Arsenic | 0.1mg/l | 0 | 0 | 0 |
| ･Cadmium | 0.01mg/l | 0 | 0 | 0 |
| ･Chromium | 0.1mg/l | 0 | 0 | 0 |
| ･Fluoride | 1.0mg/l | 1(0) | 1(0) | 2(1) |
| ･Lead | 5.0mg/l | 0 | 0 | 0 |
| ･Nickel | 0.2mg/l | 0 | 0 | 0 |
| ･Selenium | 0.02mg/l | 0 | 0 | 0 |
| ･Beryllium | 0.1mg/l | 0 | 0 | 0 |
| ･Cupper | 0.2mg/l | 0 | 0 | 0 |
| ･Manganese | 0.2mg/l | 10(5) | 14(6) | 11(5) |
| ･Molybdenum | 0.01mg/l | 3(0) | 0 | 3(0) |
| Inorganic Parameters | | | | |
| ･Aluminum | 5.0mg/l | 0 | 0 | 0 |
| ･Iron | 5.0mg/l | 40(17) | 25(10) | 18(7) |
| ･pH | 4.5 - 9.0 | 1(0) | 0 | 0 |
| ･Zinc | 2.0mg/l | 1(1) | 0 | 0 |
| ･Cobalt | 0.05mg/l | ( )number of well used for agriculture | | |
| ･Lithium | 2.5mg/l | | | |
| ･Vanadium | 0.1mg/l | | | |

### (3) Allowable water quality standards for raw water usable for stock raising

The allowable water quality standard values for raw water usable for stock raising and the number of wells exceeding these standards are indicated in Table-2.5. There was no well exceeding the standards.

**Table-2.5 Allowable water quality standards for raw water usable for stock raising, and the number of wells exceeded the standards**

| Item | Stock-raising water standard | Number of wells exceeded the standards | | |
|---|---|---|---|---|
| | | Phase 1 | Phase 2 | Phase 3 |
| Chemical parameters related to human health | | | | |
| ・Arsenic | 0.3mg/l | 0 | 0 | 0 |
| ・Boron | 5.0mg/l | 0 | 0 | 0 |
| ・Cadmium | 0.05mg/l | 0 | 0 | 0 |
| ・Chromium | 1.0mg/l | 0 | 0 | 0 |
| ・Lead | 5.0mg/l | 0 | 0 | 0 |
| ・Mercury | 0.01mg/l | 0 | 0 | 0 |
| ・Nitrate | 100.0mg/l | 0 | 0 | 0 |
| ・Nitrite | 10.0mg/l | 0 | 0 | 0 |
| ・Cupper | 0.5mg/l | 0 | 0 | 0 |
| Inorganic Parameters | | | | |
| ・Aluminum | 5.0mg/l | 0 | 0 | 0 |
| ・Salinity | 3,000mg/l | 0 | 0 | 0 |
| ・Zinc | 25.0mg/l | 0 | 0 | 0 |

### (4) Allowable water quality standards for raw water usable for recreation

The allowable water quality standard values for raw water usable for recreation and the number of wells exceeding these standards are indicated in Table-2.6. In Phase 1 test, no test was conducted in the item of dissolved oxygen. Also in all three Phases, the items of phenol group and tensoactives were not tested. The Tabio hot spring well used for recreation actually did not exceed the standards.

**Table-2.6 Allowable water quality standards for raw water usable for recreation, and number of wells exceeded the standards**

| Item | Direct contact | Indirect contact | Number of wells exceeded the standards for direct contact recreation | | | Number of wells exceeded the standards for indirect contact recreation | | |
|---|---|---|---|---|---|---|---|---|
| | | | Phase 1 | Phase 2 | Phase 3 | Phase 1 | Phase 2 | Phase 3 |
| Inorganic parameters | | | | | | | | |
| Dissolved Oxygen | Saturate70% | Saturate70% | | 83 | 63 | | 83 | 65 |
| pH | 5.0～9.0 | 5.0～9.0 | 3 | 1 | 0 | 3 | 1 | 0 |
| Bacteria | | | | | | | | |
| Ecoli | 200/100ml | | 1 | 0 | 0 | | | |
| Total coliform bacteri | 1,000/100ml | 5,000/100ml | 5 | 9 | 5 | 2 | 3 | 4 |
| Others | | | | | | | | |
| Phenols | 0.002mg/l | | | | | | | |
| Methylen blue active substance | 0.5mg/l | 0.5mg/l | | | | | | |

## 2.3 The result of river water quality test

According to the result of river water quality test, all samples exceeded “Water quality standard of WHO Guideline” in Hydrogen sulfide. Also, most of the samples exceeded “Water quality standard usable if chlorinated” in total *coliform* bacteria, color, and turbidity. This fact shows that river water is not usable as potable water.