Section-III
Predictive Simulation

III-1 Basic Concept

According to the financial indicators of water source development obtaining from Water Remind in terms of "Life-cycle Cost" and "Benefit by Cost Ratio", development priority can be given in due order of groundwater, surface water and seawater. Groundwater should be developed as much as possible at the first. On this basic concept, the Cebu-GWM-09 was built in this study.

Managerial issue of the predictive simulation is to secure the consent of social acceptance. Essentially, ownership of groundwater resources has been fallen on local society and economy including environmental influences. Compliance of regulation is most important criterion, but it is required to handle very sensitively. Therefore, review of administrative order shall include the hearing from public, regulator and developer.

On the other hand, technical issue of that is saltwater intrusion. Groundwater potential was studied on the particular occasion of "without artificial protection from saltwater intrusion" in this study. It means that measures using under ground fence or well injection (see Figure B.III-01) were not considered in this predictive simulation.

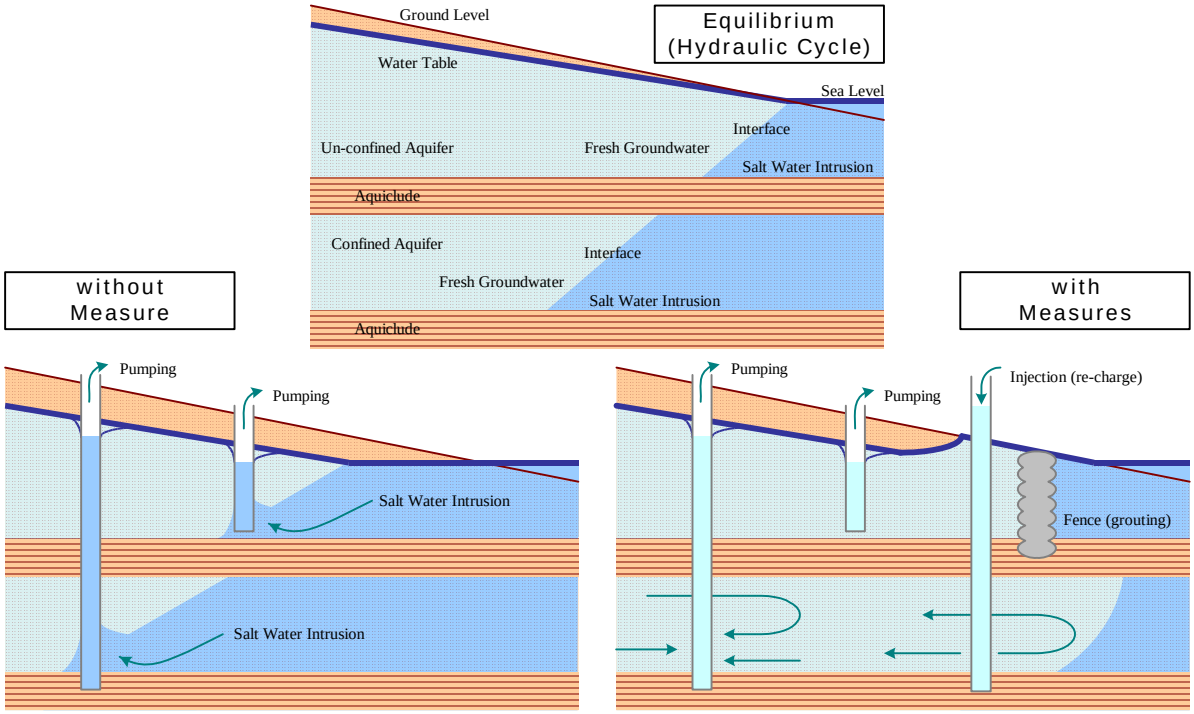


Figure B.III-01 Image of Groundwater Potential Study

III-1.1 Objectives

The aim of predictive simulation using the Cebu-GWM-09 is to estimate the groundwater potential. Estimated groundwater potential was input information of following studies.

- Gross potential was used for water balance study between demand and supply, and
- Well field potential was used for water allocation balance study between the distribution blocks.

III-1.2 Evaluation Method

Following items were considered to evaluate the predictive simulation of saltwater intrusion using the calibrated model.

(1) Compliance of Administrative Order

There are two orders related to saltwater intrusion in Metropolitan Cebu; (1) Philippines National Standard for Drinking Water 2007 by DOH and (2) Groundwater Regulation 2007 by NWRB.

< PNSDW-2007 >

Maximum desirable concentration of chloride ion shall not exceed 250 mg/L. MCWD did not remove the chloride ion from the raw groundwater. This value of Cl 250 mg/L was adopted.

< Groundwater Regulation 2007 >

NWRB designated Metropolitan Cebu in 2006 as water crisis area in terms of saltwater intrusion. Guideline of this regulation was established in 2007 as listed below. In this regard, Cl 200 mg/L was used for evaluation criterion of the predictive simulation.

- Critical area was restricted by topographical conditions (below 70 masl).
- Applicants of water permit shall report the groundwater quality with parameters of Cl and NO_3.
- Water sources with salinity level 210 mg/L shall be required to reduce their volume of extraction, and shall be subject to strict monitoring.
- Reduction rate of groundwater abstraction was mentioned clearly according to the said report.
- If the salinity level exceeds 250 mg/L, the well shall be closed immediately.
- MCWD shall inform NWRB his service area using map for correspondence to new applicants.

(2) Hydrogeologic Standpoint

Position and intensity of hydrologic stresses were examined as following.

< Position >

Although groundwater availability in alluvial aquifers along the coastal area is still applicable, groundwater potential was studied with target aquifer of limestone in hilly area and fluvial aquifer along the river. It was reflected that many MCWD wells in alluvial area had been abandoned due to groundwater quality of chloride because of aggravated saltwater intrusion.

MCWD well abstraction was pinpointed at exact well site or optimum new well fields. In the case study of optimum new well field, following forms of production well arrangement (see Figure B.III-02) were applied.

	Cebu Island	Mactan Island
∗ Topography:	approximately 70 masl	approximately 10 masl
∗ Groundwater Level:	estimated at 30 to 35 masl	estimated at 3 to 5 masl
∗ Arrangement:	2 lines	MCWD plan
∗ Distance:	200 m	about 200 to 500 m

Development concepts in Cebu and Mactan Islands are quite different. Well structures and abstraction rate will be designed in later section.

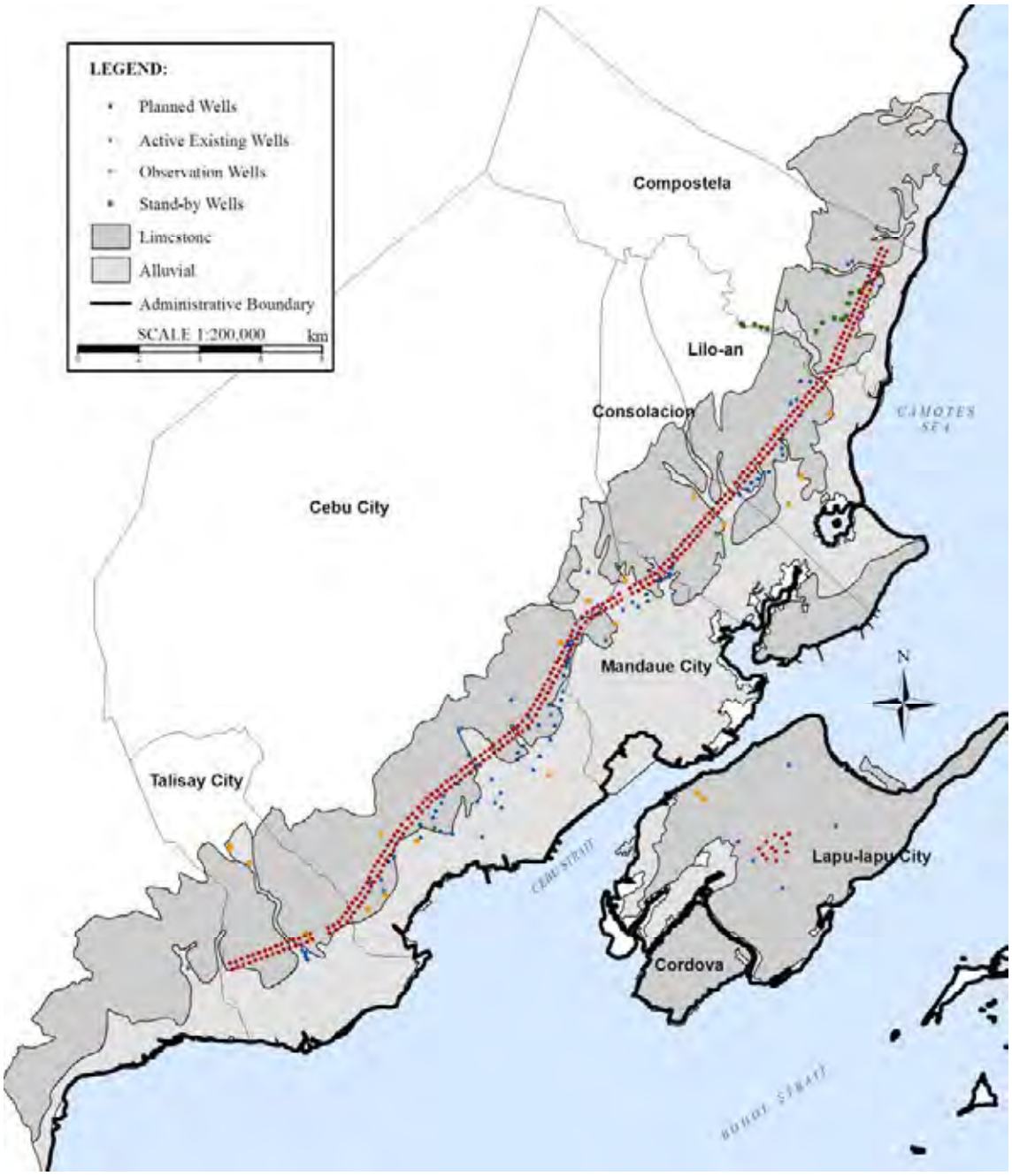


Figure B.III-02 Location Map of New Well Fields for Predictive Simulation

< Intensity >

Artificial hydrologic stresses of groundwater abstraction were predicted by case study. Natural hydrologic stresses of natural recharge and return flow were examined by statistical analysis of past weather. Un-desirable weather condition of long drought period was considered at the end period of predictive term for the worst case (climate change).

III-1.3 Predictive Simulation Term

Groundwater potential was predicted by following simulation term that was connected to and almost similar period of the calibration term (Jan-1980 until Dec-2004: 25 years or 300 months). Normally, same terms of calibration and predictive simulation are advisable.

- Jan-2005 until Dec-2030: 26 years or 312 months

III-2 Applied Hydrologic Stresses

Cebu-GWM-09 in the calibration term from Jan-1980 until Dec-2004 has hydrologic stresses of following that was obtained from the Water Remind.

- Natural Recharge: Direct recharge and In-direct Recharge
- Lateral Flow: Underground Balance between WRMUs
- Return Flow: Human Waste Water and Pipeline Leakage
- Abstraction: MCWD Wells and Non-MCWD Wells

The same hydraulic stresses of the calibration term were given to the model in the predictive simulation term. Among these hydraulic stresses, only lateral flow rate was adopted as constant. Other stresses were examined by the analysis results statistically. Following are process of examination.

III-2.1 Natural Recharge

Natural recharge obtaining from the Water Remind Project was fully utilized. Since the hydraulic stresses of Water Remind were estimated monthly basis, monthly rainfall patterns were assumed using past record of Jan-1975 until Dec-2005. In this study groundwater conservation was not considered as safety side.

As a basic assumption, standard deviations of natural recharge and rainfall were supposed to be correlated closely. Monthly rainfall patterns were examined statistically as following procedures.

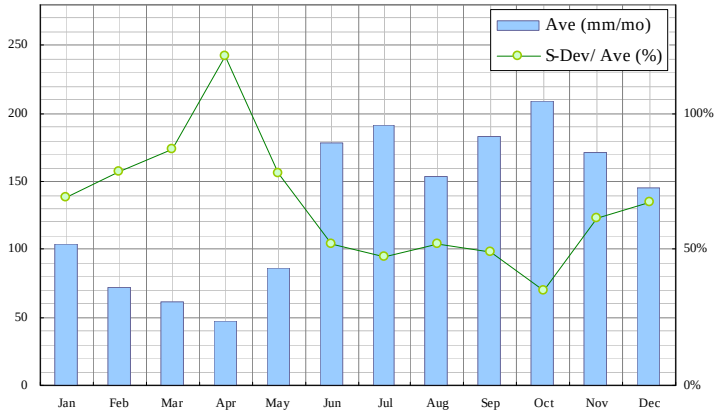
- Annual rainfall pattern was predicted.
- Then predicted annual patterns were broken into monthly rainfall patterns.
- Longer drought period was given to the end of predictive simulation term with due consideration of climate change.

(1) Selection of Rainfall Record

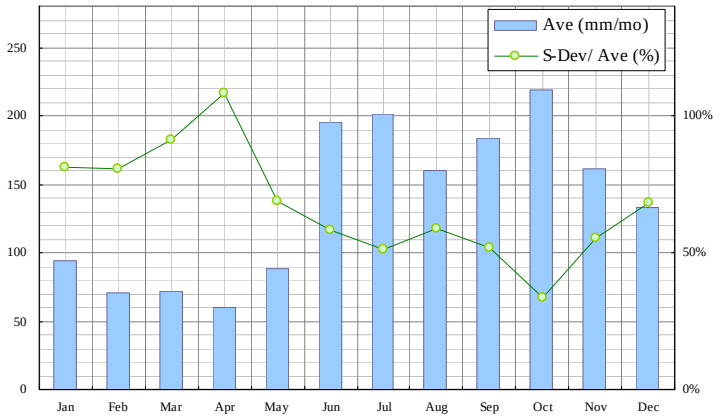
There are 21 synoptic stations in the model domain. Among these, following typical stations were selected to compare its characteristics.

- Mac-01 21 masl (plain)
- But-08 70 masl (hilly)
- Man-12 715 masl (mountainous)

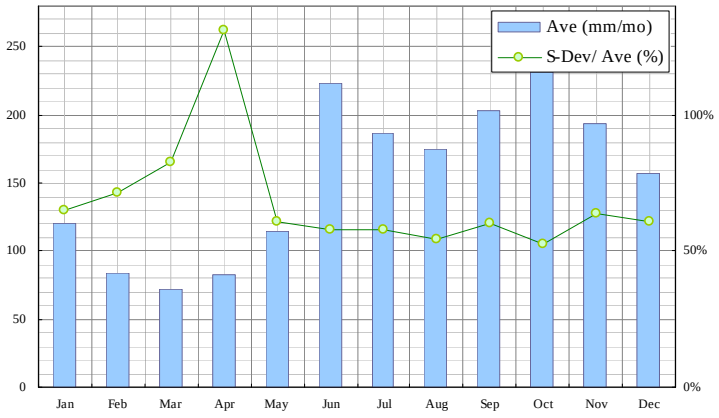
Figure III-03 shows the monthly rainfall patterns and coefficient of variation (standard deviation per average in %) at each station.



Mac-01 (plain)



But-08 (hilly)



Man-12 (mountainous)

Figure B.III-03 Average Monthly Rainfall and Coefficient of Variation

Same variation can be observed in Figure B.III-03. Development target in the model simulation is mainly groundwater contained in limestone aquifer. In this regard, rainfall record of "But-08" station was adopted for analysis.

(2) Annual Rainfall Analysis

Figure B.III-04 indicates annual rainfall at But-08 station. Statistic parameters of this record are calculated below. Figure B.III-04 indicates the rank correlation of annual rainfall deviation. Thus, the constant cycle can be applied for high probable prediction.

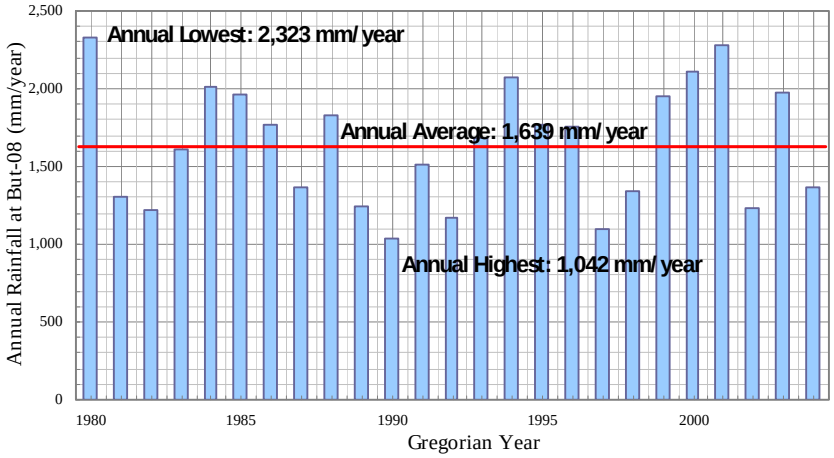


Figure B.III-04 Annual Rainfall at But-08 Station (1980 until 2004)

- Average: 1,639 mm/year
- Maximum: 2,323 mm/year (1980)
- Minimum: 1,042 mm/year (1990)
- Standard Deviation: 385 mm/year
- Deviation Rang: ±162 %
- Rank Correlation 0.993 none
- Correlation Cycle: 7 year/cycle
- Correlation Coefficient: 0.501 none

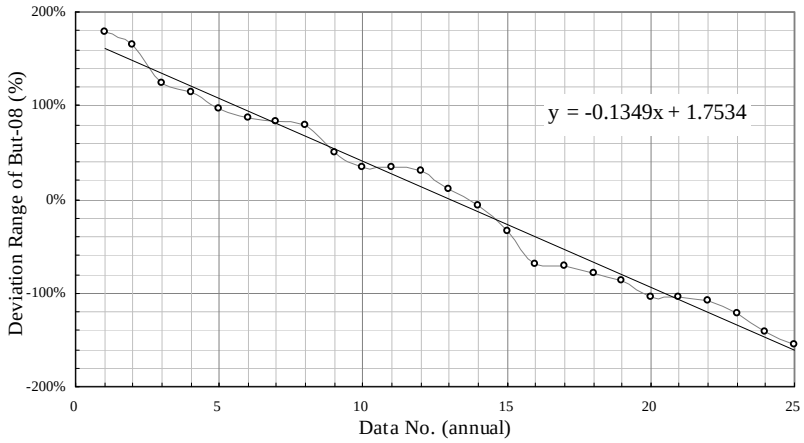


Figure B.III-05 Rank Correlation of Annual Rainfall Deviation (1980 until 2004)

Predictive formula of annual rainfall pattern is concluded below. Figure B.III-06 indicates the records and predicted values for comparison.

- Predicted Annual Rainfall Deviation = Max-Dev. × sin{(year-C)/(2π/Cycle)}
  Where; C is constant and estimated at 4.

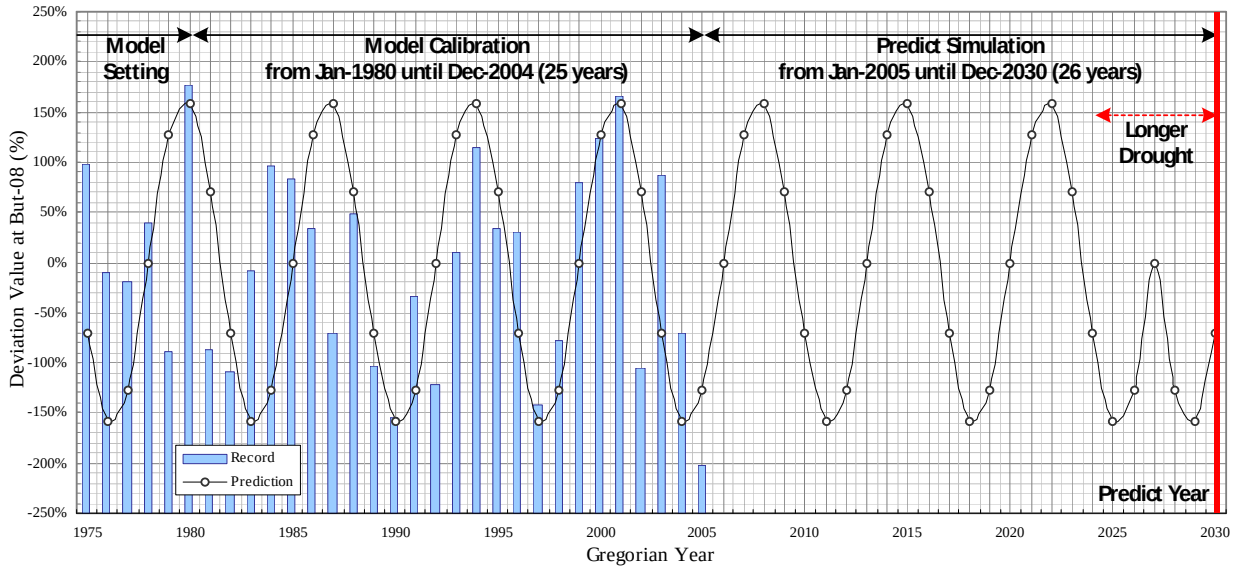


Figure B.III-06 Comparison Graph on Rainfall Record and Predicted Values

(3) Monthly Rainfall Analysis

Monthly rainfall patterns in high-water and drought year were analyzed. Typical high-water year was 1980, while drought year was 1990, respectively (see Figure B.III-07).

Following are characteristics of monthly rainfall during the statistic period.

- High-water: average in dry season and increased in wet season
- Drought: decreased both in dry and wet seasons

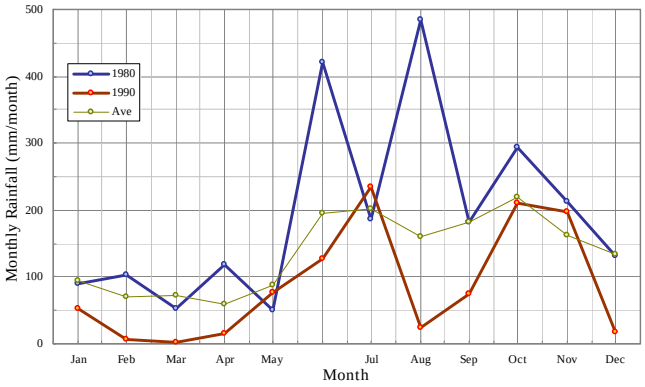


Figure B.III-07 Average Monthly with Actual Record in High-water and Drought

Based on the range of annual rainfall deviation (±162**%**), monthly occupation ratios within annual rainfall were estimated as shown in Table B.III-01 and shown in Figure B.III-08.

Table B.III-01 Predicted Rainfall Occupation Rate of Monthly within Annual

Annual Data		Monthly Allotment (% of Annual Value)												Annual
Dev.%	Code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Values
+162		6.0	4.5	4.0	4.0	6.0	16.5	19.0	17.0	17.5	19.5	13.5	9.5	137%
+125		6.0	4.5	4.0	4.0	5.9	15.5	17.5	15.4	16.1	17.9	12.7	9.0	129%
+100		6.0	4.5	4.0	4.0	5.8	14.8	16.5	14.3	15.2	16.8	12.2	8.7	123%
+75	High-water	6.0	4.5	4.0	4.0	5.7	14.1	15.5	13.2	14.3	15.7	11.6	8.4	117%
+50		6.0	4.5	4.0	4.0	5.7	13.4	14.5	12.2	13.4	14.7	11.1	8.1	111%
+25		6.0	4.5	4.0	4.0	5.6	12.7	13.5	11.1	12.4	13.6	10.5	7.8	106%
±0	Av.	6.0	4.5	4.0	4.0	5.5	12.0	12.5	10.0	11.5	12.5	10.0	7.5	100%
-25		5.7	4.2	3.8	3.8	5.2	11.1	11.7	9.5	11.0	11.9	9.5	7.1	94%
-50		5.3	4.0	3.5	3.5	4.9	10.1	11.0	8.9	10.4	11.3	8.9	6.7	89%
-75	Drought	5.0	3.7	3.3	3.3	4.6	9.2	10.2	8.4	9.9	10.6	8.4	6.3	83%
-100		4.6	3.5	3.1	3.1	4.3	8.3	9.4	7.8	9.3	10.0	7.8	5.9	77%
-125		4.3	3.2	2.8	2.8	4.0	7.4	8.6	7.3	8.8	9.4	7.3	5.5	71%
-162		3.8	2.8	2.5	2.5	3.5	6.0	7.5	6.5	8.0	8.5	6.5	4.9	63%

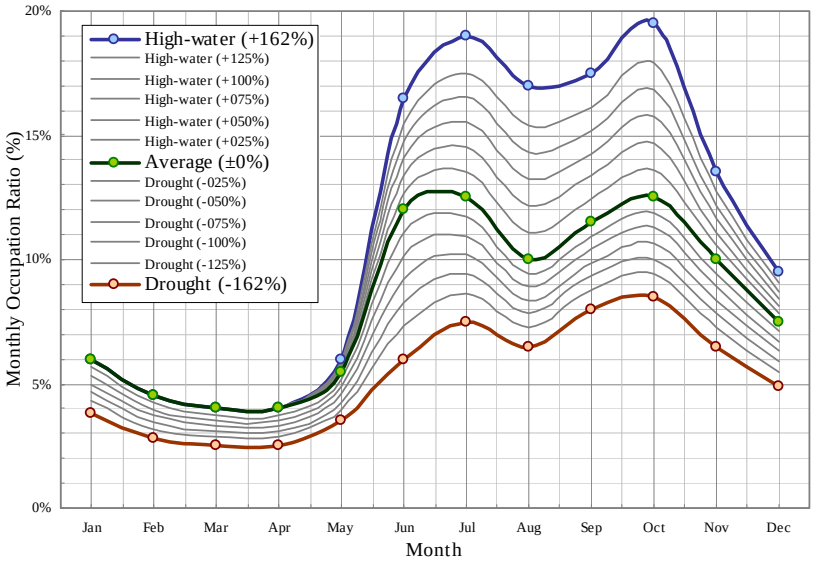


Figure B.III-08 Predicted Monthly Rainfall Patterns

(4) Monthly Recharge Rate

Monthly rainfall allotment rates (see Table B.III-01) were applied for monthly recharge rate using average monthly recharge in Water Remind (Jan-1980 until Dec-2004) according to annual rainfall patterns.

III-2.2 Return Flow

Return flow was classified into two categories showing below.

(1) Human Waste Water

Constant human living level was adopted. It means that amount of human waste water was assumed according to the projected population growth rate as shown in Figure B.III-09.

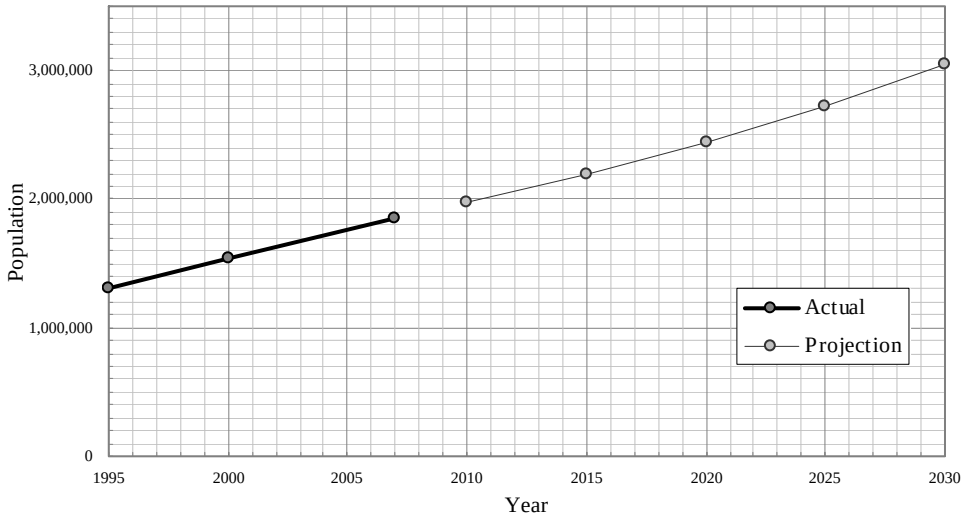


Figure B.III-09 Population Projection of Metropolitan Cebu

(2) Leakage from Water Supply Pipeline

NRW reduction program is on-going. Water supply volume until 2015 was estimated by the population growth rate, while leakage volume was assumed NRW % as shown in Table B.III-02.

Table B.III-02 NRW Reduction Plan

2011		2012		2013		2014		2015	
Jan	Jul	Jan	Jul	Jan	Jul	Jan	Jul	Jan	Jul
25.0 %	23.6 %	22.5 %	21.8 %	21.2 %	20.7 %	20.4 %	20.1 %	19.9 %	19.8 %

Source: JICA Study Expert of NRW Reduction

III-2.3 Abstraction

Abstractions from MCWD wells and Non-MCWD wells were predicted. However, combinations of abstraction patterns were examined in case simulation. In this part, applied well structures and the said abstraction patterns are described below.

(1) Well Structures

Position of abstraction influences the different impact to aquifer environmental system depending on well screen depth with permissibility in each portion. Structures of MCWD wells are recorded, but almost all Non-MCWD wells have no record. Additionally, structures of optimal wells were designed with due consideration of both saltwater intrusion and NO_3 contamination.

< MCWD Wells >

- by Population Growth: Actual well structures were adopted.
- for Potential Simulation: Screen length of 50 m from 0 mbsl until 50 mbsl in Cebu Is., Screen length of 3 m from 0 mbsl until 3 mbsl in Mactan Is.

< Non-MCWD Wells >

- Balance of MCWD Wells: Deduct of abstraction value from natural recharge
- Additional Dummy Wells: - ditto -

(2) Abstraction Rate

Two cases of abstraction from each MCWD and Non-MCWD well were adopted.

< MCWD Wells >

- Case-I: Actual record was used for Jan-2005 until Dec-2008, and then assumed abstraction rate until Dec-2030 was estimated using population growth rate.
- Case-II: Actual record was used for Jan-2005 until Dec-2008, and then assumed abstraction rate until Dec-2010 was estimated using population growth rate. Optimal well with constant rate of potential abstraction as a result from trial and error was applied from Jan-2011 until Dec-2015

< Non-MCWD Wells >

- Case-I: Based on the abstraction rate on Dec-2004 (at the end of calibration term), assumed rate from Jan-2005 until Dec2030 was estimated using population growth rate.
- Case-II: The same assumption was given to the period from Jan-2005 until Dec-2010. After that, constant rate of Dec-2010 was applied until Dec-2030.

III-3 Case Simulation

A population explosion including centralization will induce resident's scramble for basic human needs. Such situation accelerates the negative spirals continuously. Social services are most critical issue and residents have to pay monetary compensation for environmental damages such as groundwater contamination, atmospheric pollution and so on. Groundwater environment in Metropolitan Cebu has a serious problem of saltwater intrusion when it is considered as main source for the water supply services.

The Cebu-GWM-09 was simulated up to the year 2030 using predicted input cases for estimation of groundwater potential. Many wells without permit have been infringing the registered wells including vested water rights. According to water permits issued as of Dec-2007, groundwater of 577,140 m^3/day (MCWD: 173,005 m^3/day and Non-MCWD: 404,125 m^3/day) within Metropolitan Cebu was registered in NWRB. Probably, this granted amount will be a limit of groundwater potential.

III-3.1 Applied Scenario

Subject of groundwater control would be abstraction from the wells under operation of MCWD and Non-MCWD. Combinations of case study will be candidates of applied scenario. As mentioned above, natural recharge and return flow were studied as prone case on condition that Water Remind provided conscientious outputs.

Following scenarios were examined in this study, stresses in which were illustrated in Figure B.III-10.

- Scenario-1: MCWD wells and Non-MCWD wells will extract groundwater amount according to population growth rate continuously until year 2030.
- Scenario-2: MCWD wells will extract groundwater amount according to population growth rate continuously until year 2030. However, Non-MCWD wells will be regulated after 2011 with constant extraction rate.
- Scenario-3: Non-MCWD wells will be regulated after 2011 with constant extraction rate. Optimal MCWD wells will extract the expected potential amount starting from Jan-2011 until Dec-2030.

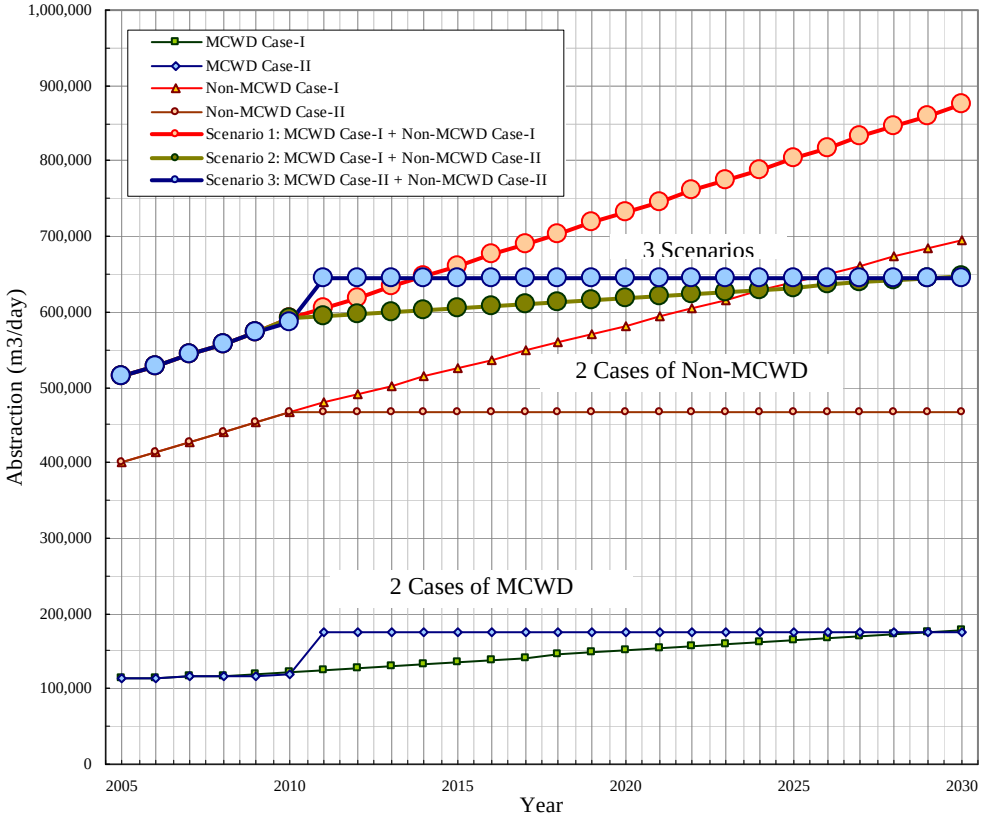


Figure B.III-10 Predicted Abstraction Stresses by Cases and Scenarios

III-3.2 Predictive Simulation Results

The results of groundwater potential study were evaluated by water quality using chloride concentration not exceeding 200 mg/L at Dec-2030. Brief results of predictive simulations are described below.

< Scenario-1: Liner MCWD and Chaotic Non-MCWD >

Abstraction from Non-MCWD will strongly influence the situation of saltwater intrusion.

- Northern District: Production capacity is over limitation especially at well field of San Vicente. Conduit flow analysis may be required for future improvement.
- Central District: Most of MCWD wells in the central district are concentrated at well fields of Guadalupe, Lahug and Talamban. More than half of MCWD wells at elevation about 30 to 40 masl may have chloride exceeding 200 mg/L.
- Southern District: This district still has a surplus potential.
- Mactan District: Thin fresh water aquifer will be disappeared due to over exploitation.

< Scenario-2: Liner MCWD and Control Non-MCWD >

Location of MCWD well should be scattered more widely.

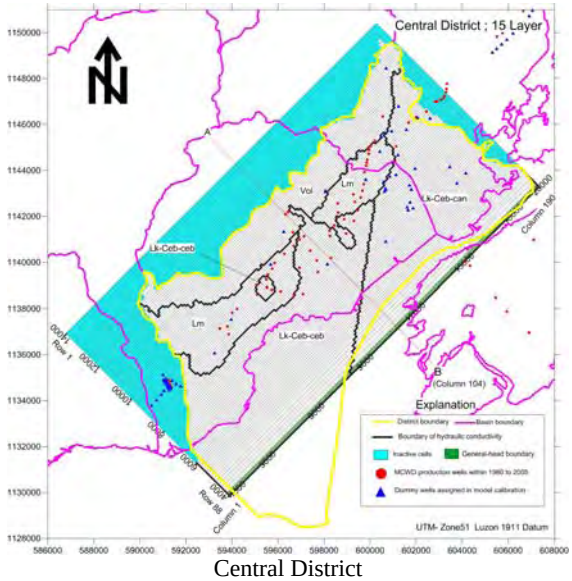
- Northern District: Production capacity is still over limitation especially at San Vicente.
- Central District: Saltwater intrusion in Butuanon basin becomes serious. Many MCWD wells at elevation about 30 to 40 masl may have chloride exceeding 200 mg/L.
- Southern District: This district still has a surplus potential.
- Mactan District: Thin fresh water aquifer in the planned well field will be affected by saltwater.

< Scenario-3: Optimal MCWD and Control Non-MCWD >

Abstraction from MCWD was simulated according to the criterion.

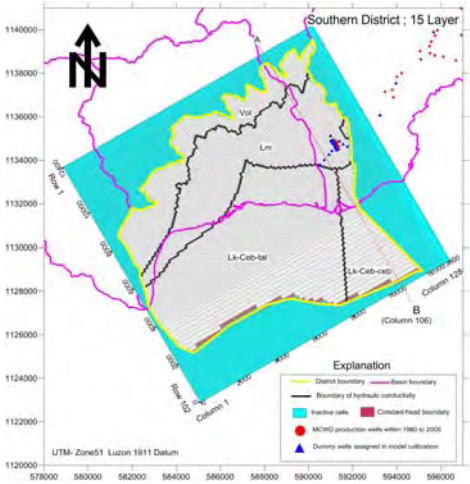
- Northern District: Production capacity was reduced at well field of San Vicente.
- Central District: Well fields are arranged at 70 masl by 2-liner. Because of smaller permeability in this district, overall productivity becomes larger.
- Southern District: Surplus potential was estimated by optimal wells.
- Mactan District: Thin fresh water aquifer will become stable.

Three scenarios are presented visually by cross section images in each sub-regional model.

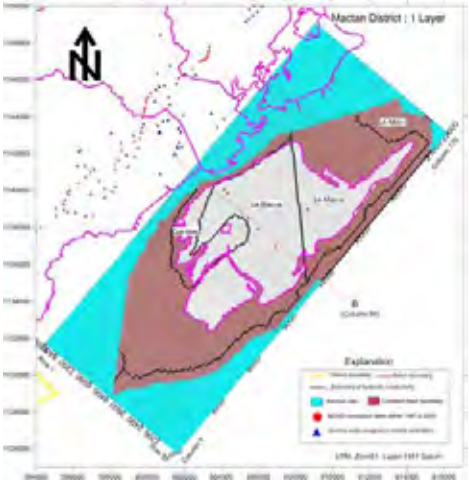


Central District

Northern District



Southern District

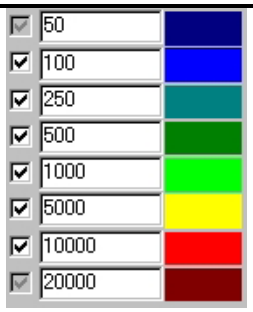


Mactan District

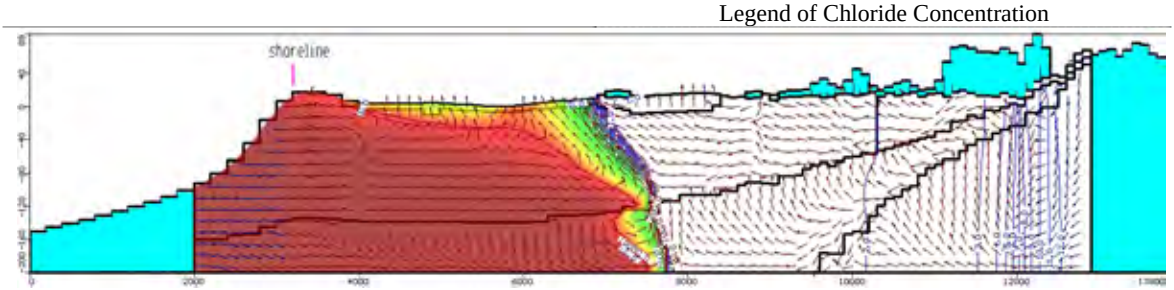
Figure B.III-11 Location Map of Cross Section Images

(1) Northern District

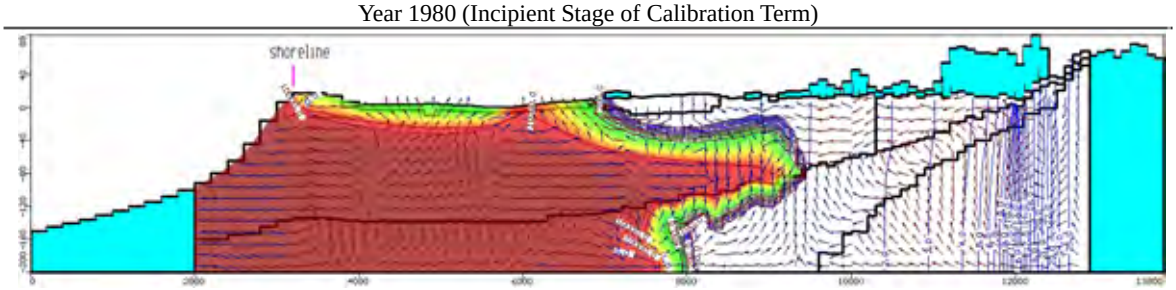
Model Domain: within white portion.
Aquifer Boundary: internal border
Vector can be read as follows:
Arrow: direction
Length: velocity
Blue: toward this side
Red: toward the other side



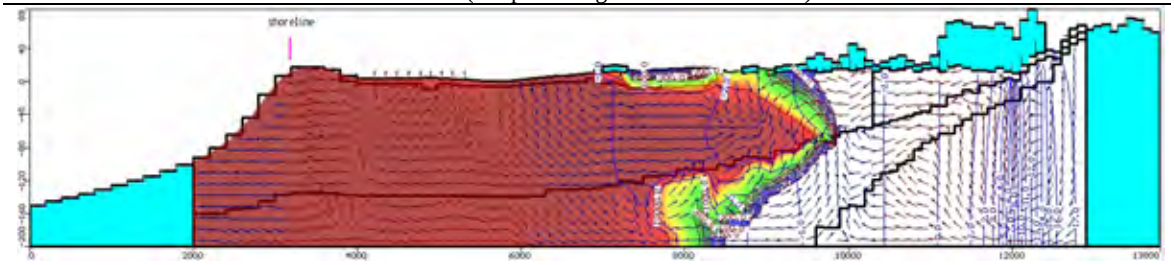
Legend of Chloride Concentration



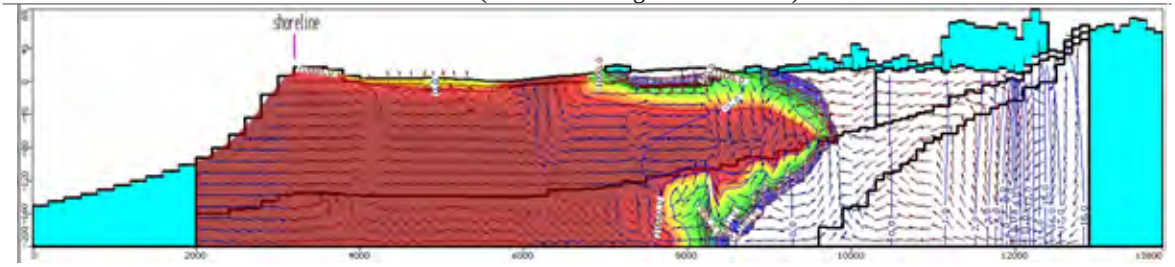
Year 1980 (Incipient Stage of Calibration Term)



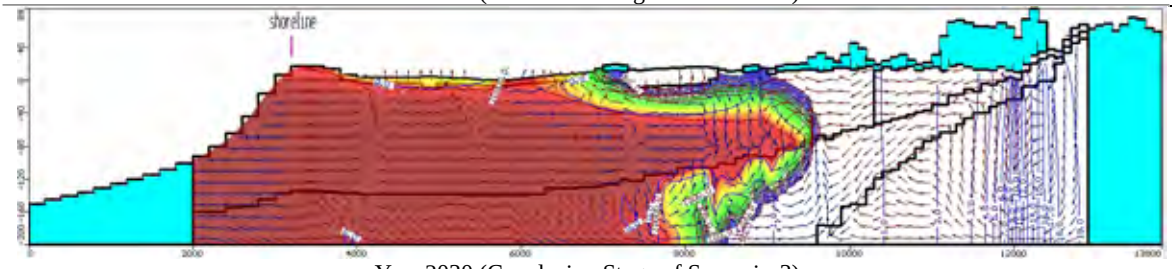
Year 2004 (Incipient Stage of Prediction Term)



Year 2030 (Conclusion Stage of Scenario-1)



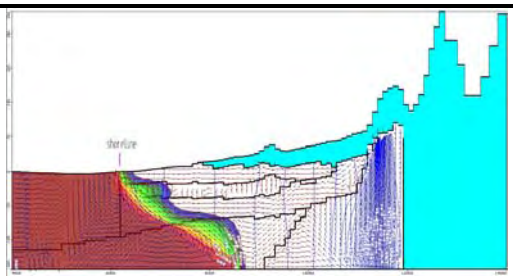
Year 2030 (Conclusion Stage of Scenario-2)



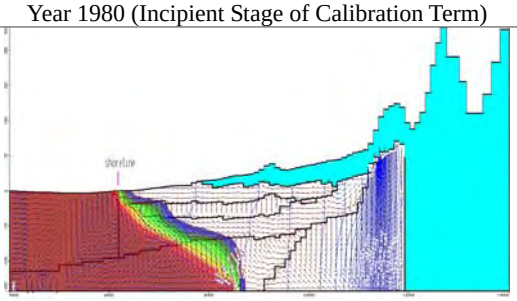
Year 2030 (Conclusion Stage of Scenario-3)

Figure B.III-12 Comparison of Scenarios in Northern District

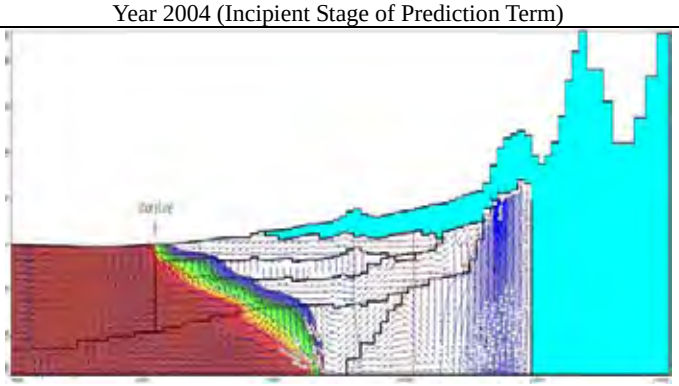
(2) Central District



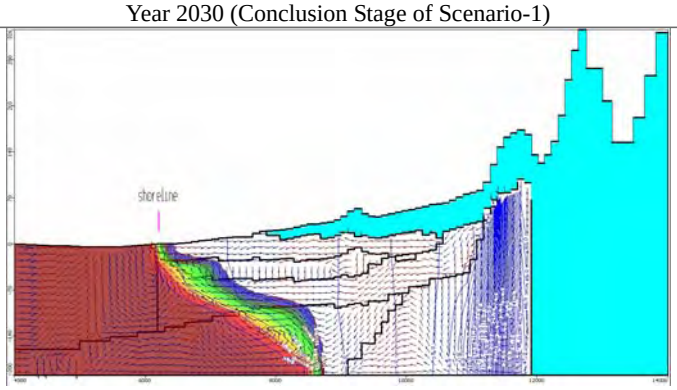
Year 1980 (Incipient Stage of Calibration Term)



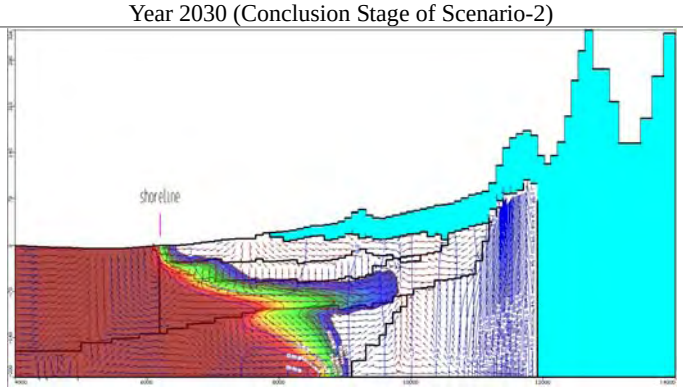
Year 2004 (Incipient Stage of Prediction Term)



Year 2030 (Conclusion Stage of Scenario-1)



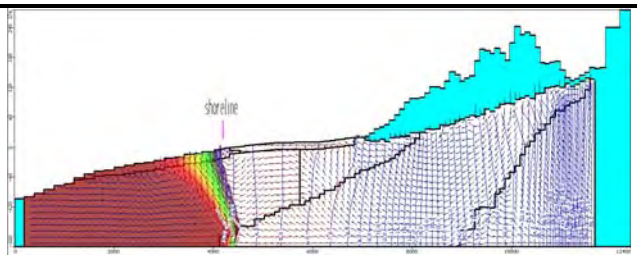
Year 2030 (Conclusion Stage of Scenario-2)



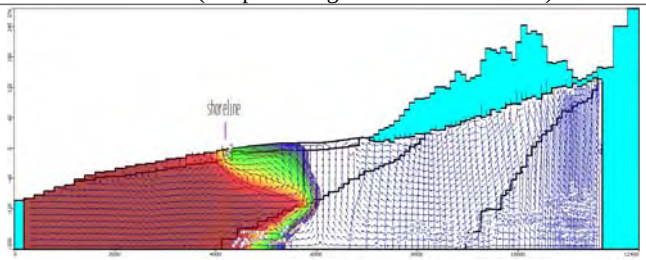
Year 2030 (Conclusion Stage of Scenario-3)

Figure B.III-13 Comparison of Scenarios in Central District

(3) Southern District



Year 1980 (Incipient Stage of Calibration Term)



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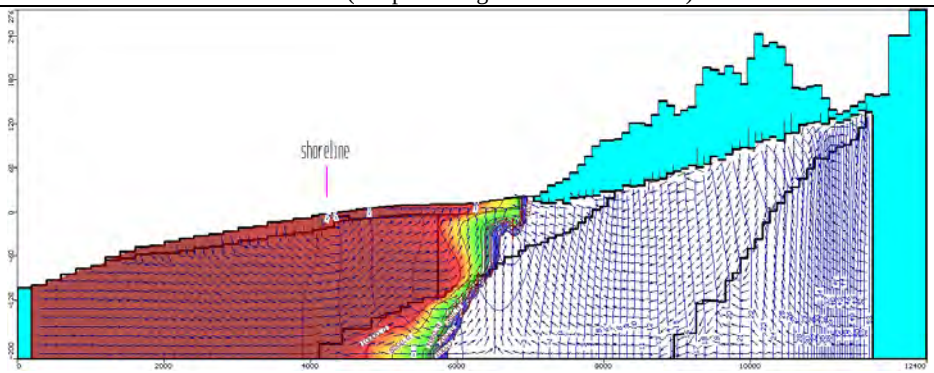
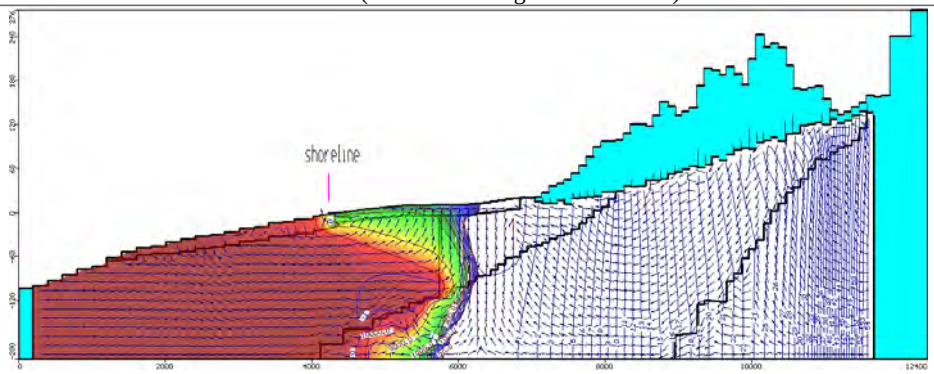
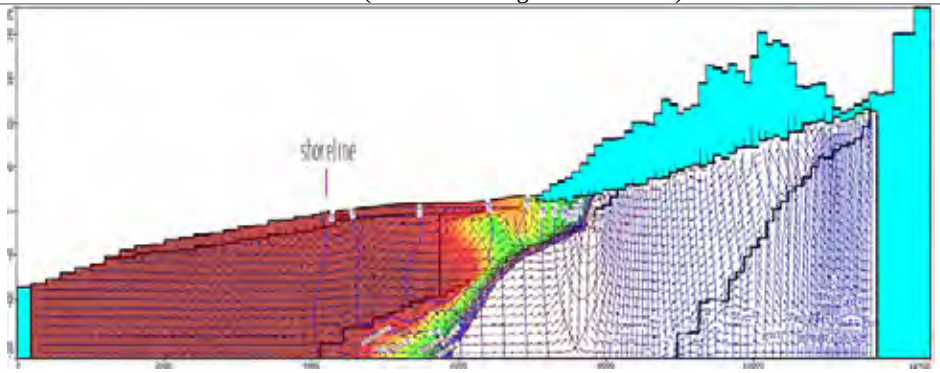


Year 2030 (Conclusion Stage of Scenario-1)



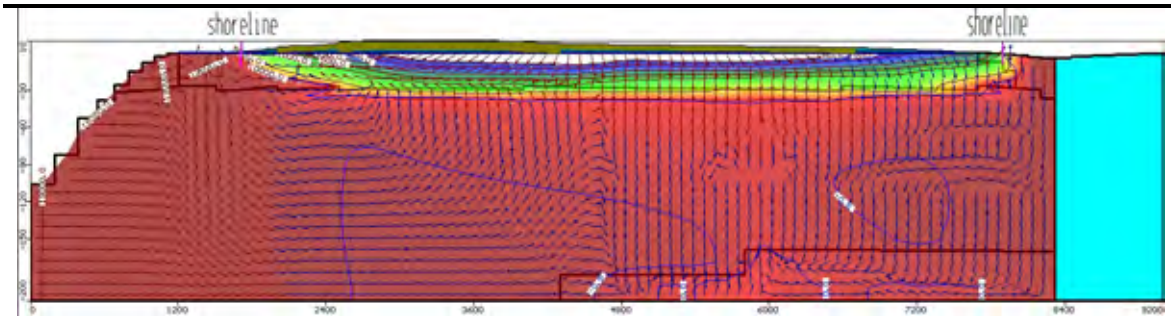
Year 2030 (Conclusion Stage of Scenario-2)



Year 2030 (Conclusion Stage of Scenario-3)

Figure B.III-14 Comparison of Scenarios in Southern District

(4) Mactan District



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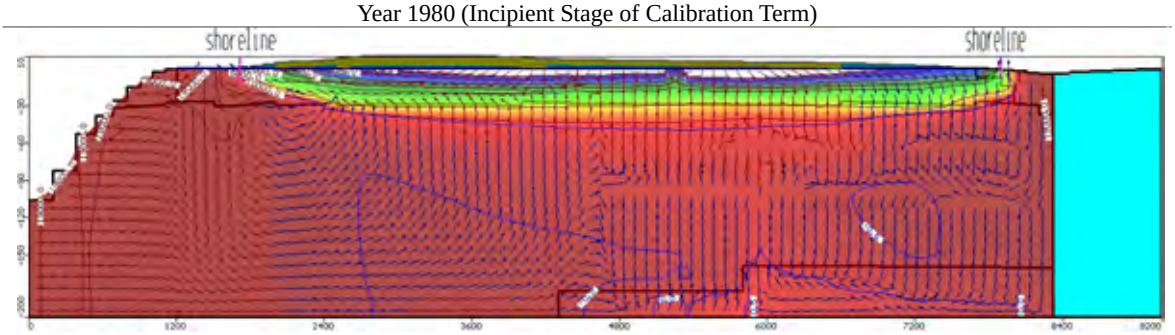
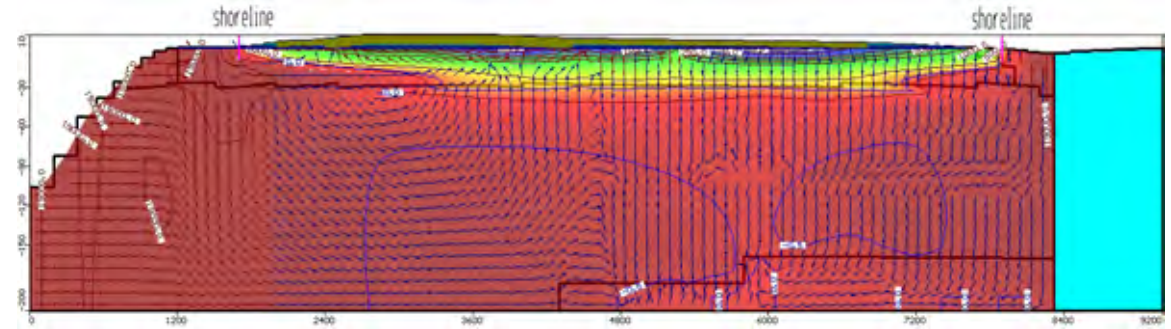
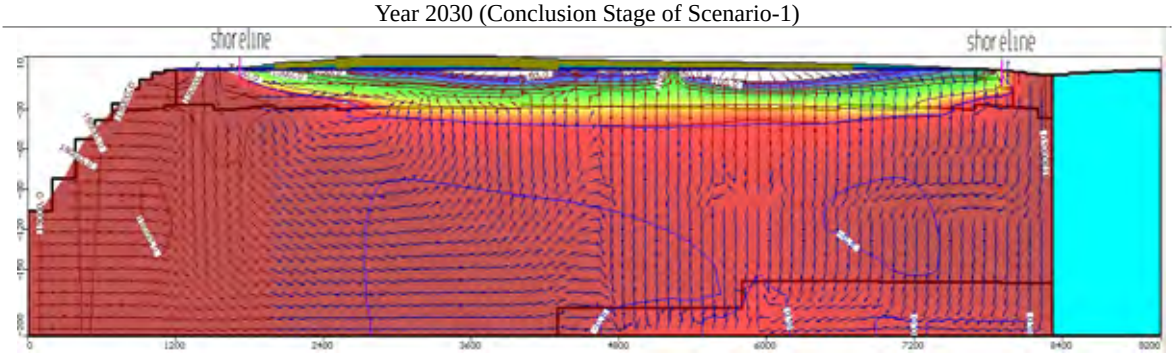


Year 2004 (Incipient Stage of Prediction Term)



Year 2030 (Conclusion Stage of Scenario-1)



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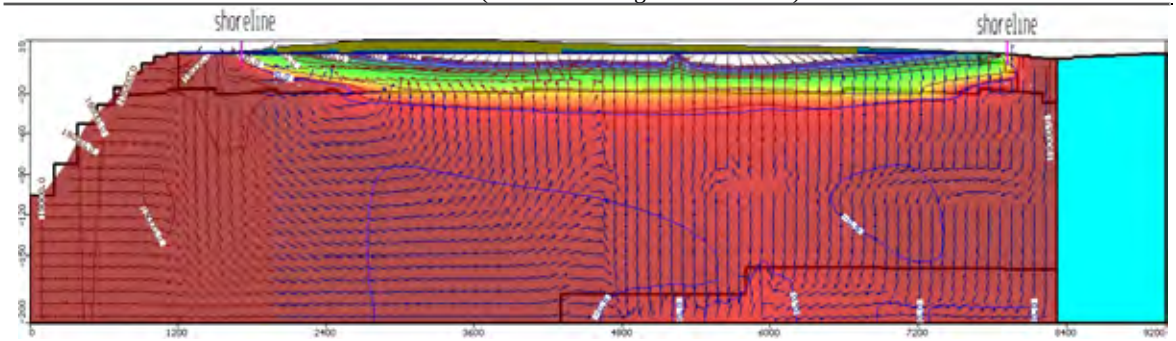

Year 2030 (Conclusion Stage of Scenario-3)

Figure B.III-15 Comparison of Scenarios in Mactan District

III-3.3 Groundwater Potential

Table B.III-03 indicates groundwater potential of 175,840 m^3/day in MCWD franchise area using the scenario-3. As a contrast with current situation, surplus groundwater can be exploitable in the model districts of Central and Southern. Adversary, groundwater developments in the model districts of Northern and Mactan are simulated as over extraction.

Table B.III-03 Groundwater Potential in MCWD Franchise LGUs

Cebu-GWM-09			Predict Simulation				Development Plan			
District	WRMUs	Q-07	Exist.	Q-add	Q-30	Location	Additional Q		Total Q	
Northern	Compostela	799	0	14,800	14,800	-	14,001	-8,163	32,600	175,840
	Kot-kot	4,042	0	0	0	-	**-4,042**			
	Lilo-an	6,076	0	3,000	3,000	-	**-3,076**			
	Cansaga	29,846	0	3,700	14,800	North	**-15,046**			
			0	11,100		South				
Central	Butuanon	28,986	0	17,000	30,600	North	1,614	41,451	109,800	
			0	13,600		South				
	Cebu	39,363	0	24,000	79,200	Cebu River	39,837			
			0	55,200		Others				
Southern	Mananga	5,528	0	12,000	12,00	-	6,472	24,672	30,200	
	M-Talisay	0	0	18,200	18,200	-	18,200			
Mactan	Mactan	3,671	1,080	2,160	3,140	-	**-431**	**-431**	3,240	

Note: Unit of Q (discharge amount in 2007 and 2030) is m^3/day.

Generally, groundwater flows toward the sea in the Cebu Island. Optimal well fields were arranged to meet at right angles with groundwater flow. Therefore, groundwater potential can be rephrased as disturbance limit of its flow within acceptable saltwater intrusion theoretically. In the Mactan Island, groundwater flows toward the outer side from the central portion on the saltwater surface. Optimal well field should be located at central and wide, and controlled by the minimal drawdown.

Figure B.III-16 indicates the well field potential to be used for groundwater source allotment in the development plan. In this report, names of well field are called as following with well field potential.

< Cebu Island: from North to South, totaled at 172,600 m^3/day >

- Compostela Well Field: 14,800 m^3/day
- Lilo-an Well Field: 3,000 m^3/day
- Cansaga North Well Field: 3,700 m^3/day
- Cansaga South Well Field: 11,100 m^3/day
- Butuanon North Well Field: 17,000 m^3/day
- Butuanon South Well Field: 13,600 m^3/day
- Cebu North Well Field: 7,200 m^3/day
- Cebu River Well Field: 24,000 m^3/day
- Cebu South Well Field: 48,000 m^3/day
- Mananga Well Field: 12,000 m^3/day
- Talisay Well Field: 18,200 m^3/day

< Mactan Island: total at 3,240 m^3/day >

- Mactan Well Field: 3,240 m^3/day

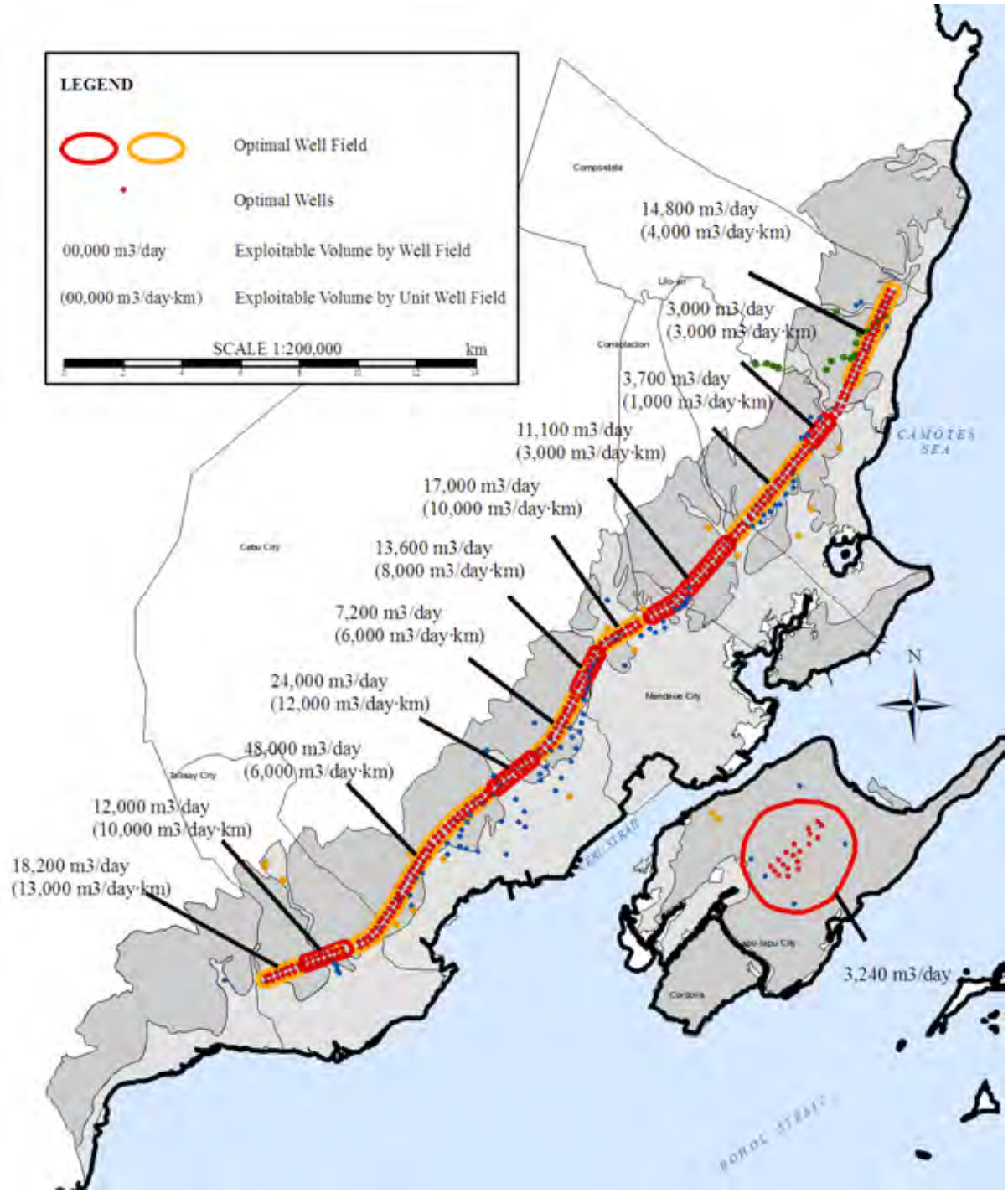

Figure B.III-16 Well Field Potential

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Section-IV
Groundwater Development

IV-1 Basic Conditions

To remove the major cause of water crisis originating from excessive urbanization at the Metropolitan Cebu, the macro-cosmic management of water resource shall be promoted as substantial solution. At the first, concerned stakeholders shall create the active committee of "the Cebu Island Water Resource Management" to reduce the fetters of water supply regulations and political interventions.

Since 1957, groundwater development has been promoted to cope with water supply deficit continuously by both Osmena and MCWD. Saltwater intrusion in Metropolitan Cebu was recognized in early 1970's. NWRB strengthened the water permits system for reduction of non-registered well development, at the same time it also established the groundwater regulation with guideline for control of chaotic abstraction in 2007 for conservation of groundwater environment.

This development plan becomes into realize with the security control of Non-MCWD wells, because definite operation of groundwater regulation is a prerequisite for groundwater potential study. Also required actions shall be recognized as stopgap measure in transition period to the substantial solution. The action plan has a target year of 2015 with due consideration of following.

- effective and rational usage of present intake facilities, and
- preparation of draft technical guideline for groundwater development and M&E.

IV-1.1 Overall Groundwater Development

Presently, solo water supply system is complex in terms of water sources, reservoir application, pipeline network, etc. Water supply services have, therefore, some coverage areas with low pressure and hourly supply. Water supply distribution blocks (DB) will be created to meet each demand for improvement of the present insufficient service level.

Development amount of groundwater shall be increased according to the demand projection and water allocation. Methodology of groundwater development is conceptualized with following procedures.

- Present intake amounts were classified into (1) continuous production, (2) reduced production and (3) abandoned according to problem analysis in terms of qualitative and quantitative,
- Present non-operating wells for stand-by and on-going construction were suggested to be operating intake facilities in 2015 based on formality progress of MCWD,
- Groundwater deficit between supply potential and projected demand is planned by new development with due consideration of (1) groundwater potential by predictive simulation using the model and (2) economical site location for the installation cost of raw water pipeline, and
- New wells will be connected to reservoir economically with overall flow allotment concept in Cebu Island.

(1) Groundwater Development Requirements

Table B.IV-01 shows the DB demand and suitable allotment of water sources development. In short-term, water transmission from Talamban DB to Mactan DB was examined as most economical. However, water transmission between each reservoir directs toward the Casili DB and transfers to Mactan DB. Details are referred to Part-C, Chapter-I, Supporting Report.

Table B.IV-01 Water Balance between Demand and Supply at 2015

DB	Water Source Requirements Descriptions		LGUs	Water Demand and Supply (m^3/day) Well	Production	Balance	Raw Water Pipeline (km)
CLC	Demand in 2015		-			-19,261	Not Applicable
	Intake 1-Compostela		Compostela	2	709	30,598	
	Intake 2-Lilo-an		Lilo-an	10	13,848		
	Intake Direct Feeding to CLC Distribution Block		CLC	8	9,041		
	Other Source	(Abejo-north)			7,000		
	Allocation	Export to Casili	-			-11,337	
	Surplus in 2015		-			+0	
Casili	Demand in 2015		-			-40,323	Not Applicable
	Intake 5-Casili_Old		Consolacion	6	9,918	+9,918	
	Intake Direct Feeding to Casili Distribution Block		Mandaue	0	0		
	Allocation	Import from CLC	-			+11,337	
	Allocation	Export to Mactan				-20,100	
	Allocation	Import from Talamban				+20,567	
	Surplus in 2015		-			-99	
	4-Casili_Planned_2015		Cansaga-South	9	2,700	18,700	4.5
			Butuanon-North	16	16,000		8.0
Talamban	Demand in 2015		-			-58,173	Not Applicable
	Intake 6-Talamban		Cebu	6	20,825	+50,264	
	Intake Direct Feeding to Talamban Distribution Block		Cebu (north)	29	29,439		
	Allocation	Export to Casili	-			-20,567	
	Allocation	Import from Tisa				+5,676	
	Surplus in 2015		-			+0	
	7-Talamban_Planned_2015		Cebu-North	8	4,800	22,800	19.0
			Cebu-River	20	12,000		
			Cebu-South	10	6,000		
Tisa	Demand in 2015		-			-60,956	Not Applicable
	Intake 8-Tisa		Cebu	5	6,902	+66,632	
	Intake Direct Feeding		Cebu (south)	17	15,030		
	Other Source	(Buhisan)	-		4,700		
	Other Source	(Jaclupan: Existing)			27,000		
	Other Source	(Jaclupan: Improvement)			13,000		
	Allocation	Export to Talamban	-			-5,676	
	Surplus in 2015		-			+0	
Lagtang	Demand in 2015		-			-18,301	Not Applicable
	Intake 10-Lagtang		Talisay	5	6,218	+18,538	
	Intake Direct Feeding to Lagtang Distribution Block		Talisay	2	1,320		
	Other Source	(Foremost, Abejo-south)	-		11,000		
	Surplus in 2015		-			+237	
Mactan	Demand in 2015		-			-38,136	Not Applicable
	Intake Direct Feeding to Mactan Distribution Block		Lap-lap	11	3,827	+18,427	
	Other Source	(Mactan Rock)	-		5,000		
	Other Source	(De-salination)			9,600		
	Allocation	Import from Casili	-			+20,100	
	Surplus in 2015		-			+391	
Total Number of the New Production Wells by 2015 excluding the Production Wells converted from existing Stand-by Wells by causes of none LGU Clearance or on-going Construction			Cansaga-South	9	@300	2,700	4.5
			Butuanon-North	16	@1,000	16,000	8.0
			Cebu-North	8	@600	4,800	19.0
			Cebu-River	20	@600	12,000	
			Cebu-South	10	@600	6,000	
			Planned Wells	63	-	41,500	31.5

Note: New well yield was adopted according to the predictive simulation of Cebu-GWM-09 as potential study.

(2) Scope of Well Development

Presently, following well types exist in MCWD. Wells of each statement in 2015 are counted as shown in Table B.IV-02 and located in Figure B.IV-01.

- Production: Well produces groundwater to the system.
- Stand-by: Well was constructed but does not produce groundwater yet (on-going construction or un-clearance from LGUs).
- Monitoring: Well was abandoned by aggravation of chloride concentration, deterioration of yield capacity and physical problems (collapse, sand contents, foreign object). Such wells were converted to monitoring purposes.

Table B.IV-02 State of Wells in 2015 (as of January 2010)

Well Type	Well Statement in 2010 and 2015	Distribution Block CLC	Cas	Tal	Tis	Lag	Mac	sum
Production	Construction by 2015	0	25	28	10	0	0	63
	Existing in 2010 up to 2015	18	6	30	18	4	5	81
	Existing by 2015 from Stand-by in 2010	2	0	5	4	3	6	20
	Sub-total	20	31	63	32	7	11	164
Stand-by	Existing in 2010 up to 2015	16	0	1	0	0	0	17
Monitoring	Existing in 2010 up to 2015	6	3	3	3	0	0	15
	Existing by 2015 from Production in 2010	7	1	9	5	1	0	23
Grand Total		49	35	76	40	8	11	219

Note: DB abbreviations from the left; **C**ompostela/ **L**ilo-an/ **C**onsolacion, **Cas**ili, **Tal**amban, **Tis**a, **Lag**tang and **Mac**tan.

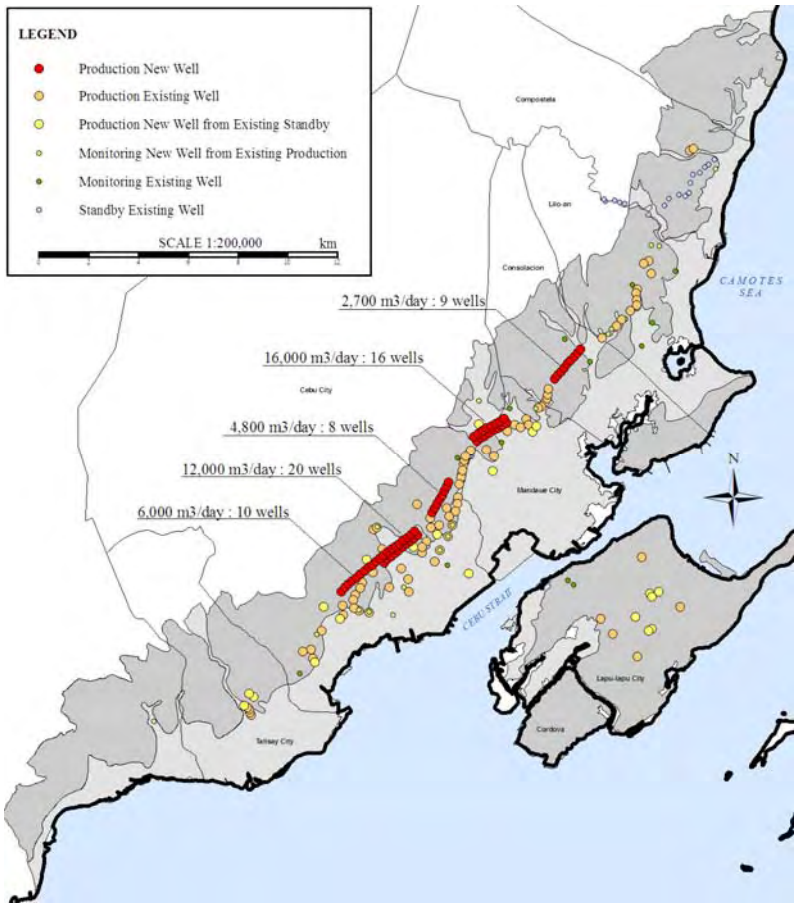


Figure B.IV-01 Location Map of Wells in 2015

Scope of groundwater development work is described in Table B.IV-03.

Table B.IV-03 Scope of Groundwater Development Work

Well		Development		Intake Facility		
Type	Statement in 2010 and 2015	Rehab.	Const.	House	M/E	Pipe
Production	Construction by 2015	-	Yes	Yes	Yes	Yes
	Existing in 2010 up to 2015	Yes	-	Excluded		
	Existing by 2015 from Stand-by in 2010	Yes	-			
Stand-by	Existing in 2010 up to 2015	Not Applicable				
Monitoring	Existing in 2010 up to 2015 Existing by 2015 from Production in 2010	Conservation Plan		Not Applicable		

Note: M/E means that mechanical and electrical works.

Well development plan includes new well construction with intake facility and existing well rehabilitation. This scope was set for estimation of capital expenditure (CAPEX). Well structures, intake pump capacity and pipeline length were fundamentally estimated using particular specifications. Other parameters such as pump house and ground pipeline were designed as standard.

IV-1.2 Design Criteria and Consideration

Following materials were referred to design the production new well to be constructed and the production existing well to be rehabilitated.

- MCWD Technical Standards Manual (2003)
- Optimal Groundwater Development for Predictive Simulation in the Cebu-GWM-09

(1) New Well Construction

Major problems of groundwater environment and well operation in Metropolitan Cebu are;

- Saltwater Intrusion: allows the normal fresh-water and salt-water interface to move both inland and nearer the ground surface.
- Nitrate Contamination: causes from the human waste water without treatment or malfunction of septic tank, and no drainage system in hilly subdivisions.
- Chemical Incrustation: results from the precipitation of carbonates (principally calcium, solution of limestone) in the proximity of the well screen.
- Sand Contents: are mainly caused by either corrosion or incrustation of well screen, and poor well velocity design (or over-pumping).

On these problems, following well design criteria were adopted.

- Well casing shall be installed to protect well bottom intake with gravel stabilization.
- Surface outer pipe shall be installed permanently to protect from surface contaminants.
- Inflow velocity passing into the well shall be less than 1.00 cm/sec to reduce incrustation.
- Filtration thickness in well annular space shall be 4 inches to reduce sand pumping.
- Gravel pipe shall be equipped to reduce the risk of hollow out in well annular space.
- Well screen shall be wedge wound-wire and made of stainless steel to reduce incrustation.
- Sand trap pipe shall be placed at the well bottom to reduce the risk of sand pumping.

Hydrogeological information from the well construction would be very helpful to manage the project. The “MCWD Technical Standards Manual (2003)” reaches the higher level of contract specifications. Following data shall be additionally investigated during the construction period.

- Sieve Analysis
- Geo-physical Logging
- Pumping Test with Water Quality Examination
- Interface Depth Sounding with Water Quality Examination

(2) Existing Well Rehabilitation

Several problems can be observed in operation of the production existing well. Table B.IV-04 shows typical survey methods to identify the problem causes. Among the investigation methods, step drawdown with sand contents test is most simple and effective survey.

Table B.IV-04 Well Investigations and Major Outputs

Type of Survey		Methodology	Output
Pumping Test	Step Drawdown	$sw = BQ + CQ^n$	Aquifer/ Well Losses Specific Yield/ Drawdown Safe/ Maximum Yields Sand Contents
	Time Drawdown	$s = (Q/2\Pi T) \ln(R/r)$	Permeability/ Storage Coefficient Interference/ Influence Circle
Water Quality	On Site Analysis	Cause Analysis	Time - pH/ EC Trend and Reasons Discharge - Sand Contents Trend
	Laboratory Analysis	Characteristics	Physical/ Chemical/ Biological Cation/ Anion
Visual Observation	TV Camera Survey	Groundwater	Level, Color/ Turbidity, Flow
		Well Structure	Inner Casing Pipe, Joint, Bottom Well Screen, Filtration Materials
		Objects	Floater, Sediments, etc.

Note: Complex causes may be observed for well problem.

Table B.IV-05 shows expected measures caused by well efficiency and bottom sediments.

Table B.IV-05 Summary of Typical Measures

Portion	Well Problem	Measures
Pump	Corrosive	• Replacement of facility by anti-corrosive material • Periodical replacement of facility by coating materials
	Over-pumping	• Use proper facility by the results of pumping test • Pump operation: running with long time and small discharge
Screen	Well Loss	• Biological Plugging (periodical disinfection by acidic liquid) • Chemical Incrustation (-ditto-, sulfate, phosphate with physical) • Physical Plugging (surging, jetting, etc.)
	Sand Discharge	• Inner Filtration (double casing installation) • Plug Screen Portion (by inner casing or cement grouting)
	Damage	• -Ditto-
Bottom	Damage	• Cement Grouting
	Sediments	• Dredging
	Sand Trap	• Additional Drilling with Inner Casing Installation
Joint	Leakage, Bending, Damage	• Plug Joint Portion (by inner casing or cement grouting)

Note: First step of rehabilitation and/ or installation shall be to know the conditions of well statements.

Major purpose of well rehabilitation is to recover the well efficiency (or to reduce well loss). Among the survey methods and measures, following works are included in the action plan.

- Step Drawdown with Sand Contents Test
- Well Rehabilitation by chemical and physical methods

IV-2 New Well Development

Number of new well development is shown in Table B.IV-06. Particular standard designs of well, intake pump and raw water pipeline are specified below.

Table B.IV-06 New Well Development in the Action Plan

Distribution Block (LGUs)	Well Field (WRMUs)	Well No. (well)	Expected Yield (m^3/day)	Abstraction by Field (m^3/day)
Casili DB (Mandaue/ Cebu)	Cansaga South	9	300	2,700
	Butuanon North	16	1,000	16,000
Talamban DB (Cebu)	Cebu North	8	600	4,800
	Cebu River	20	600	12,000
	Cebu South	10	600	6,000
Total		63	-	41,500

Note: Prioritization of well development shall be given to abstraction by well field (well number can be adjusted).

IV-2.1 Standard Design

Bill of quantity (BOQ) for new well development is shown in Table B.IV-07. Estimation details are described below.

Table B.IV-07 BOQ of New Well Development

Category	Quantity	
New Well	✓ 200A diameter × 130 m in depth with well screen of 12 m	9 wells
	✓ 200A diameter × 130 m in depth with well screen of 24 m	38 wells
	✓ 200A diameter × 130 m in depth with well screen of 36 m	16 wells
	Total	63 wells
Submersible Intake Pump	✓ 300 m^3/day (0.21 m^3/min.) × 60 m total head	9 pumps
	✓ 600 m^3/day (0.42 m^3/min.) × 65 m total head	38 pumps
	✓ 1,000 m^3/day (0.70 m^3/min.) × 60 m total head	16 pumps
	Total	63 pumps
	Note: Length of riser pipe per well is 60 m (63 sites).	
Raw Water Pipeline	✓ Casili DB	12.5 km
	✓ Talamban DB	19.0 km
	Total	Branch: 31.5 km

(1) Well

Standard well is designed as shown in Figure B.IV-02. Sounding tube made of uPVC or PE 50A (2B) will be installed together with submersible pump. Basic conditions are described below.

- Well Diameter: Uniform well diameter of 200A (8B) is adopted for intake pump capacity up to 1,000 m^3/day (or 0.70 m^3/min. by 24 hours operation).

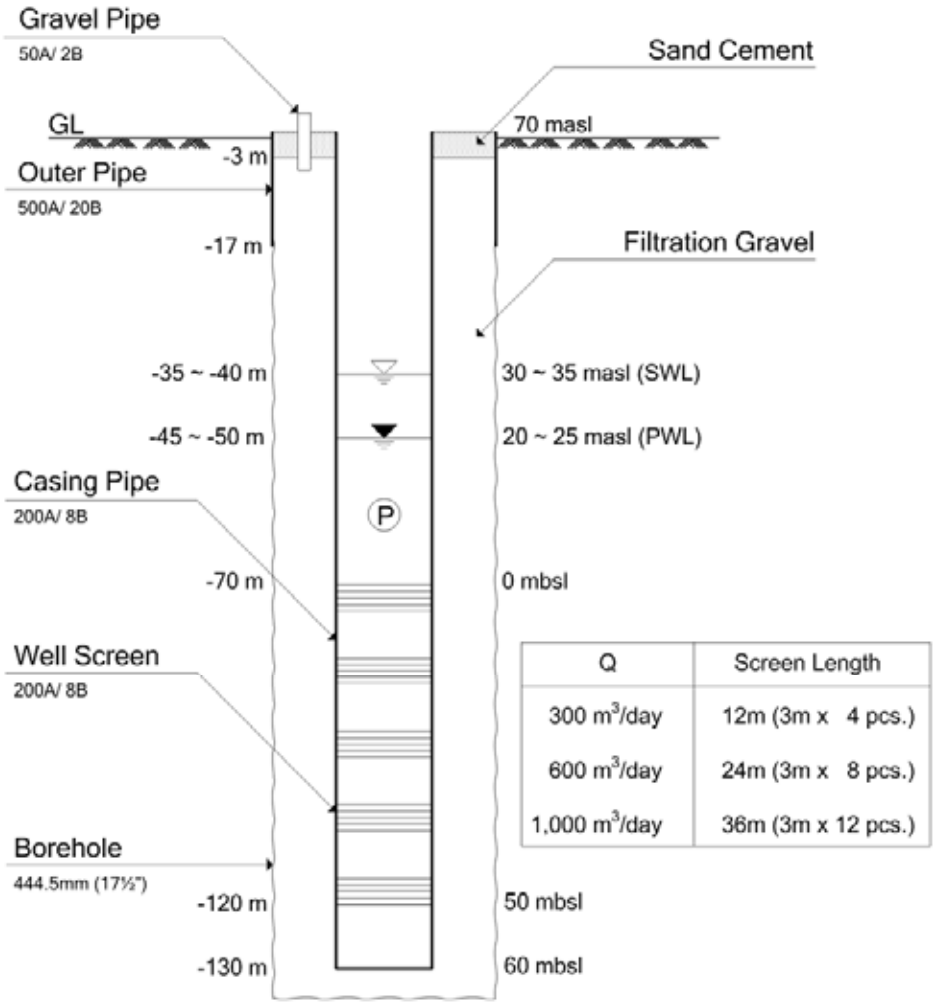


Figure B.IV-02 Standard Design for New Well Development

∗ Well Depth: Well site has elevation of 70 masl. Screen portion in the Cebu-GWM-09 is assumed from 0 mbsl until 50 mbsl. Sand trap pipe has minimum 10 m length. Therefore, well depth is designed 130 m.

∗ Well Screen: Wedge wound-wire type made of SUS304 200A/ 8B with opening ration of 6% is applied. Screen length is depending on the expected discharge rate as shown in Table B.IV-08.

Table B.IV-08 Calculation of Inflow Velocity

Yield (m^3/day)	Screen Length (m)	Inflow Velocity (cm/sec)
300	12	0.77
600	24	0.77
1,000	36	0.85

∗ Borehole Diameter: Thickness of filtration layer in well annular space shall be 100 mm or larger. Borehole size of 444.5 mm or 17-1/2" is applied for 113 mm of filtration thickness.

∗ Outer Pipe: Diameter of 500A or 20B (BI) with total length of 18 m is designed to avoid surface contaminants and to maintain the space of filter materials.

* Gravel Pipe: Diameter of 50A or 2B (GI) with total length of 6 m is designed to add filter materials.
* Gravel Placement: Grain size and uniformity coefficient are depending on the results of sieve analysis at screen portion.
* Sand Cement Seal: Sealing materials with 4 m in depth shall be placed at surface portion to protect the surface water inflow.

(2) Intake Pump

Groundwater drawdown of 10 m and well loss of 10 m are adopted. Therefore, production water level of 10 masl is adopted including 10 m well loss. HWL of new reservoir is assumed at:

* Casili (25 wells): 65.6 masl (expected discharge rate at 300 m^3/day and 1,000 m^3/day)
* Talamban (38 wells): 70.6 masl (expected discharge rate at 600 m^3/day)

Actual total pump head shall have allowance for pipe loss. Proposed intake pumps are:

* 300 m^3/day × 60 m total head 9 pumps
* 600 m^3/day × 65 m total head 38 pumps
* 1,000 m^3/day × 60 m total head 16 pumps

(3) Raw Water Pipeline

Main pipe was designed as common transmission pipeline between reservoirs. Length of branch pipe to connect main pipe was merely assumed at 0.5 km per well.

IV-2.2 Well Test

Following well tests were included in the action plan.

(1) Sieve Analysis

Car-car limestone formation has sandy portion occasionally. As shown in Figure B.IV-03, grain size of aquifer is related to soil porosity.

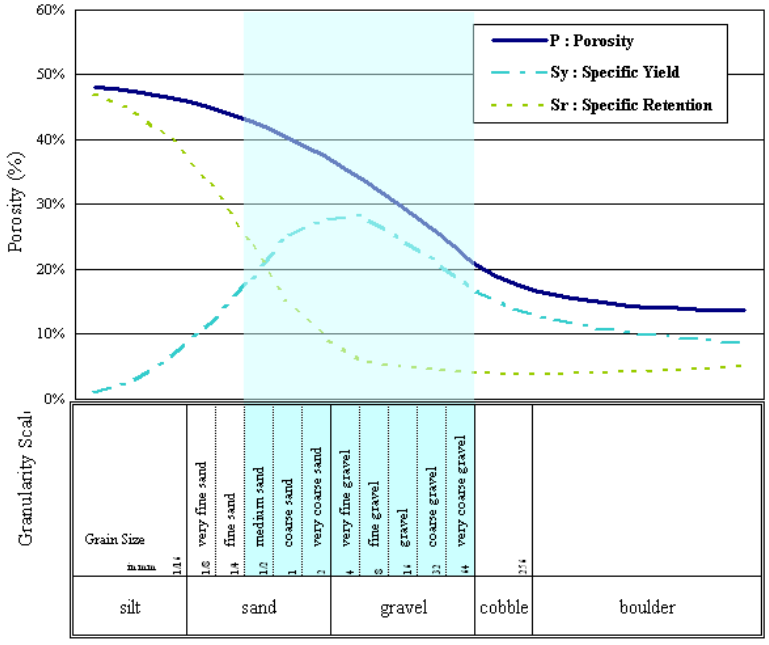


Figure B.IV-03 Soil Porosity and Groundwater

Following two parameters shall be used for slot size designing of well screen. Typical sieve analysis information is shown in Figure B.IV-04.

- Effective Grain Size: grain size at 90%
- Uniformity Coefficient: grain size ratio at 90% and 40%

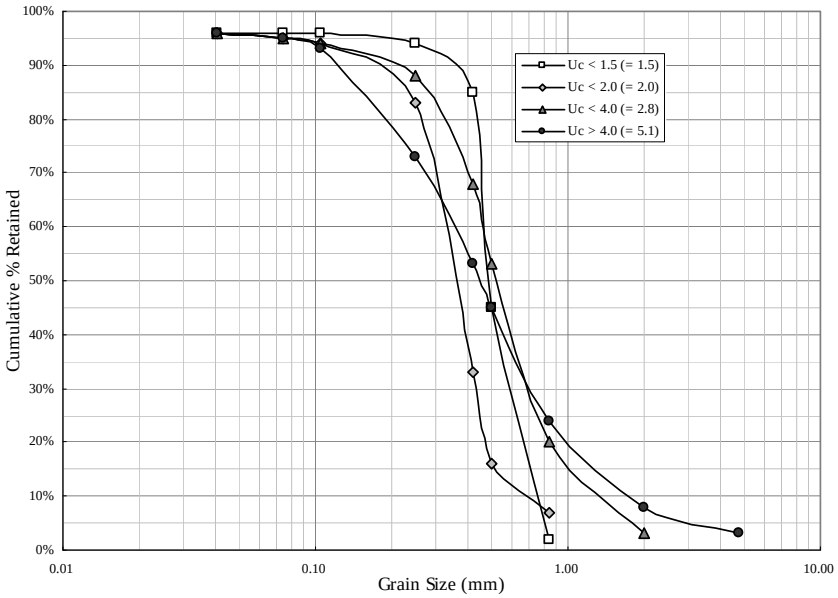


Figure B.IV-04 Sieve Analysis Graph

(2) Geo-physical Logging

Normally, combination log (long and short resistivity, and spontaneous potential: SP) has been conducted in the well field by the local contractor. Resistivity log is related to soil porosity but also strongly influenced by chloride and calcium concentrations. Natural gamma log is recommended to research the boundary depth of lithology change as shown in Figure B.IV-05.

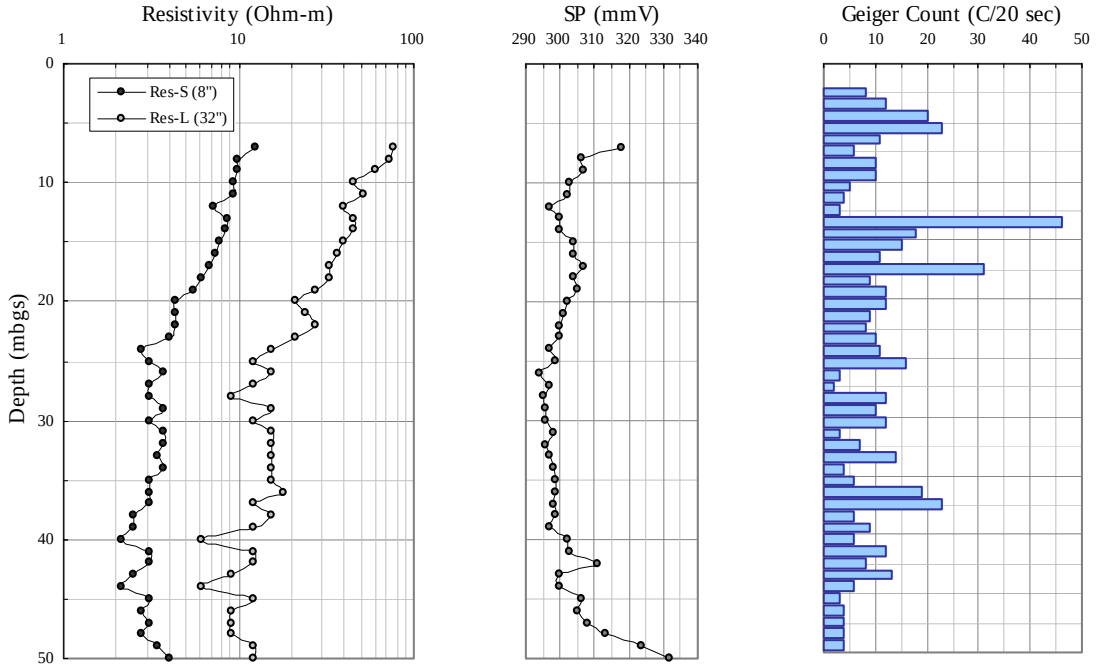
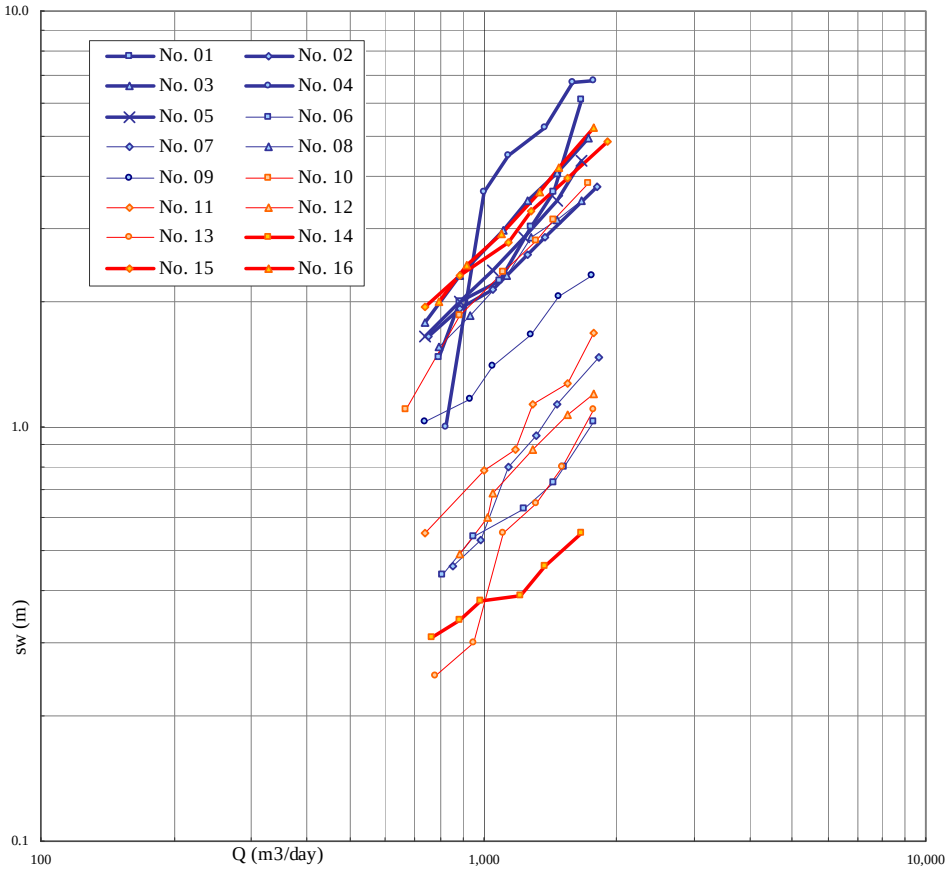


Figure B.IV-05 Geo-physical Logging Graph (Mactan at OW-06)

(3) Pumping Test

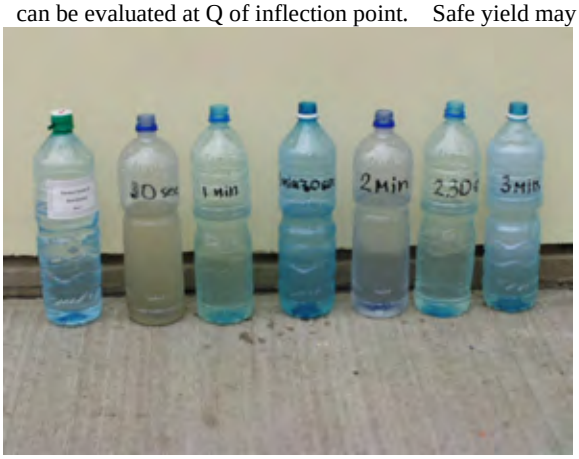
There are following two pumping tests with different purposes.

* Step Drawdown with Sand Contents Test: to analyze the well efficiency and well development progress (see Figure B.IV-06).
* Time Drawdown and Recover Test: to examine the aquifer properties such as permeability, storage coefficient, etc.



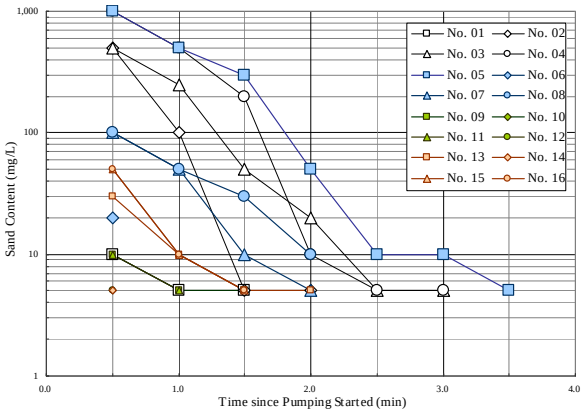
<Q – sw Graph by Step Drawdown Test>

Maximum and safe yields can be analyzed. If duration is too short, Q and sw are not proportional. Maximum yield can be evaluated at Q of inflection point. Safe yield may be 70% of maximum yield.



<Samples of Sand Contents>

Initial sand contents are result of filtration performance or well development progress. Maximum 50 mg/L is acceptable for solid content for pump liquid.



<Trend Curve of Sand Content>

Sands are contained in water at initial pumping period and decreased logarithmically. This result may be according to inadequate design or lack of well development.

Figure B.IV-06 Step Drawdown with Sand Contents Test

Specifications of step drawdown with sand contents test are:

- No. of Steps with Duration Time: at least 4 steps × 2 hrs/step (8 hours or more longer)
- Discharge Rate: 40%, 60%, 90% and 140% (100% with drawdown 10 m)
- Sand Contents: 1 min. each until 10 min. after discharge rate changed

Time drawdown and recover test is referred to the MCWD Manual.

(4) Water Quality Examination

Following parameters were included in the development plan.

- Cl: Chloride
- NO_3: Nitrate
- Ca: Calcium
- TH or TDS: Total Hardness or Total Dissolved Solid
- EC: Electric Conductivity

(5) Interface Depth Sounding

According to the results from JICA hydrogeological investigation, seasonal variation of chloride ion concentration was observed. Following sounding should be conducted at completion period.

- Electric Conductivity Profile
- Water Sampling with Examination

IV-3 Existing Well Rehabilitation

Number of existing well rehabilitation is shown in Table B.IV-09. Particular specifications are described below.

Table B.IV-09 Rehabilitation of Existing Well by 2015

DB	Existing Well Situation in 2015			Abstraction % in 2015 by DB Supply Total*[1]
	Number of Well (well)	Total Abstraction (m^3/day)	Average Discharge (m^3/day/well)	
CLC	20	23,598	1,180	123%
Casili	6	9,918	1,653	25%
Talamban	35	50,264	1,436	86%
Tisa	22	21,932	997	36%
Lagtang	7	7,538	1,077	41%
Mactan	11	3,827	348	10%
Total	101	117,077	-	-

Note*[1]: Remaining portion of water sources is composed of surface water, new well development, de-salination plant, water source imported from and exported to, and bulk water supply. At CLC DB, production amount from existing wells exceeds demand volume, because remaining water is exported to Casili DB. On the other hand, groundwater source is only 10% in Mactan DB because of water sources exported from Cebu Island, bulk water imported from Mactan Rock and new water source of de-salination plant.

IV-3.1 Step Drawdown with Sand Contents Test

This part can be referred to "Section IV-2.2 Well Test, (2) Pumping Test" mentioned above. To evaluate the rehabilitation progress and its effect, the step drawdown with sand contents test shall be executed twice at pre and post well rehabilitation.

IV-3.2 Well Rehabilitation

The aim of well rehabilitation is to recover the well efficiency. Benefits of well rehabilitation are to extend the well life (life-cycle cost) and to reduce the well loss (operating cost: electric power). To date, the production new well has been re-constructed instead of deteriorated old well. Following are proposed methodology and expected schedule of exiting well rehabilitation.

(1) Methodology

Well efficiency of 70% (well loss of 30%) is one of key performance indicators to inspect well completion or to research well development progress. Well loss is understood that plugging material disturbs inflow toward the well. There are two causes of plugging the porous media.

Chemical plugging is mainly caused of carbonate incrustation in Metropolitan Cebu. Because of the reduction in pressure, some carbon dioxide is released from the water. When this occurs, the water is often unable to carry its full road of dissolved calcium carbonate and part of this material is then precipitated onto the well screen and in the formation materials adjacent to the well screen.

* $Ca(HCO_3)_2$ + delta Pressure to $CaCO_3$ (deposition) + CO_2 (gas) + H_2O

Physical plugging is caused by over velocity (excess discharge rate and or little screen opening) and higher uniformity coefficient. Failure design of filtration system and careless pump operation will induce this worse problem.

Both chemical and physical methods are adopted to remove plugging materials such as carbonate incrustation and fine particles. Additionally, well bottom dredging will be included for well cleaning using air-lifting method. With due consideration of surrounding wells and qualitative safety, following reagent is recommended to use for chemical rehabilitation.

* Polyphosphate: 7% to 10% of water weight in well with at least 24 hours on leave

Physical methods are referred to the MCWD Manuals. Depending on the well screen strength, individual or compound of following tools would be applied.

* Over-pumping (intermittent) and or Back-washing
* Mechanical Surging and or Brushing
* High-velocity Water and or Air Jetting

(2) Work Schedule

Basically, existing well rehabilitation can be implemented after operating of new well development to avoid water source deficit.

IV-4 Technical Guideline

The guideline for groundwater development is composed of technical and institutional portions. This guideline is concentrated to technical portion and contains following parts.

- Water Balance in Well Field: (1) site selection and (2) facility operation
- Performance Indicator: (1) well efficiency and (2) sand contents
- Monitoring and Evaluation: (1) water balance and (2) performance indicator

Management of groundwater abstraction in the well field is described in “Water Balance in Well Field”, while management of individual well is guided in “Performance Indicator”. Upon completion of new wells selection, the Cebu-GWM-09 shall be re-simulated using exact locations for monitoring activity.

IV-4.1 Water Balance in Well Field

Indispensable condition of groundwater potential study was to regulate Non-MCWD well abstraction definitely. Assumptions of optimal well are positioning and abstraction rate.

(1) Site Selection

Optimal well arrangement for groundwater potential study was concluded in the Cebu-GWM-09 depending on the location as shown in Table B.IV-10.

Table B.IV-10 Input Criteria on Optimal Wells in the Cebu-GWM-09

Island	Particularity (well field)	Interval (m)	Elevation (masl)	SWL (masl)	Intake Portion (mbsl)
Cebu	Well fields are formed by two rows lineally along hilly side.	200	70	30 to 35 (Sep-09)	0 to 50
Mactan	Well field is located in the central portion of island (southern part of Mactan Interna-tional Airport).	200 to 500	10	3 to 5 (Jun-09)	0 to 3

Note: Detailed locations are referred to Figure B.III-15.

Site selection priority shall be given to the elevation of 70 masl and intake portion of 0 to 50 mbsl. These criteria were drawn in Figure B.IV-02 the standard design of new well development.

Candidate site with lower elevation can be selected where distance from coastline and static water level are almost the same shown in Figure B.III-15 and Table B.IV-10. Finally, distance between well intervals is designed at 200 m. It is also able to modify together with the control of pumping rate (details are referred to next article).

(2) Facility Operation

It has been experienced that some production wells produce brackish groundwater but surrounding wells can pump up still freshwater. This was occurred in the present San Vicente well field. On the other hand, giving the depreciation of groundwater level by freshwater abstraction, fluid with heavier density intrudes upper portion with lighter density to keep it equilibrium.

In either case, groundwater abstraction shall be managed by water level in elevation. Accordingly, the following operation standards are guided for adequate groundwater development. Fresh water like a thin coating in Mactan Island may stay while it flows toward the sea.

- Cebu Island: water level at 20 masl or higher (10 m drawdown)
- Mactan Island: water level at 0 masl or higher (3 m drawdown)

There are two feedback notices for abstraction control. First one is interference between individual wells, while the other one is gross volume limitation within well field as shown in Table B.IV-11.

Table B.IV-11 Feedback Notices from Groundwater Modeling

Feedback Items	Notice
Control of Well Interference	Larger drawdown is not allowed to apply even if well interval is longer than 200 m. Adversely, smaller drawdown shall be given to apply when well interval is shorter than 200 m. This consideration is related to Non-MCWD wells also.
Abstraction Limit within Well Field	Well field potential was estimated by it extent distance as shown in Table B.IV-12 based on Cebu-GWM-09. Of course, gross potential by well field may be changed according to gross abstraction from the Non-MCWD wells.

Note: Operation of water level at each well and discharge amount within well field shall be monitored monthly.

Table B.IV-12 Well Field Potential

Location		Potential Indicator			Remarks
Island	Well Field	Gross m^3/day	Width km	Density m^3/day/km	
Cebu	Compostela	14,800	3.7	4,000	LGU clearance is not issued.
	Lilo-an	3,000	1.0	3,000	Present gross abstraction exceeds the potential volume.
	Cansaga North	3,700	3.7	1,000	
	Cansaga South	11,100	3.7	3,000	Many Non-MCWD wells may exist.
	Butuanon North	17,000	1.7	10,000	
	Butuanon South	13,600	1.7	8,000	Surplus abstraction is not allowed.
	Cebu North	7,200	1.2	6,000	There is surplus potential but permeability of this limestone has slightly smaller than that in northern model district.
	Cebu River	24,000	2.0	12,000	
	Cebu South	48,000	8.0	6,000	
	Mananga	12,000	1.2	10,000	Hydrogeological investigation in limestone aquifer will be required.
	Talisay	18,200	1.4	13,000	
	Cebu Sub-total	172,600	-	-	Depending on the regulatory operation.
Mactan	Mactan	3,240	-	-	Potential was studied by planed well.
MCWD Grand Total		175,840	-	-	-

Note: Detail location can be referred to Figure B.III-15.

IV-4.2 Performance Indicator

Definition of well depends on its purposes and exploitable subjects as shown in Figure B.IV-07.

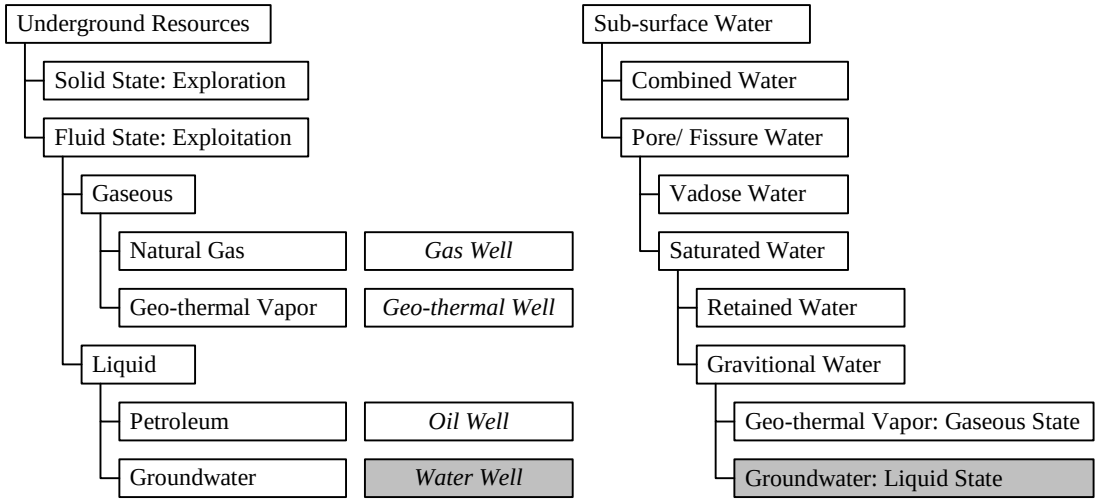


Figure B.IV-07 Definition of Water Well

Required performances of "Water Well" are to separate the soil and the groundwater effectively, and to clear the housing space of intake pump in well. Functional diagnosis has been conducted mostly for deterioration of well yield. Safety yield shall be evaluated by following three viewpoints.

- Drawdown shall be controlled at maximum 10m with due consideration of less incrustation.
- Inlet velocity from well screen shall not exceed 1 cm/sec. because of filtration design.
- Intake amount shall not affect hydraulic balance for avoidance of groundwater level depreciation.

Following performance indicators (PIs) shall be monitored periodically to judge the rehabilitation plan. Normally, testing at every 5 year is recommended for wells penetrating the limestone aquifer.

(1) Well Efficiency

Management data and information are:

- Background Information: completion year, well structures (diameter, depth), well screen (type, opening), water level (SWL/ PWL), pump (type, installation depth, discharge rate, daily operation), etc.
- Loss Coefficients: $sw = BQ + CQ^2$, where
  B is aquifer loss coefficient and C is well loss coefficient

Loss coefficients shall be analyzed by the results of step drawdown test. Proposed specification and analysis method of step drawdown test are described below.

< Technical Specifications >

There are many existing wells surrounding in the test well. Well interference is most careful point of testing. In this regard, test plan would be better at nighttime on Saturday or Sunday to avoid private well operation. Test Specifications are:

- ✓ Pre-test: at least 8 hours on leave before testing,
- ✓ Step: at least 4 steps and maximum 8 steps,
- ✓ Duration: at least 1 hour and maximum 2 hours each,
- ✓ Discharge Rate: at even interval logarithmically (range: 50% to 150%)
- ✓ Water Level: at every 10 min. interval

< Analysis Method >

Table B.IV-13 shows typical result of step drawdown test as sample analysis.

Table B.IV-13 Test Result and Analysis Parameters (Sample)

Test Results				Analysis Parameters	
Pre-rehabilitation					
Step No.	N data number	Q m^3/min	sw m	Q^2 m^6/min^2	sw/Q min/m^2
1	1	752	5.22	565,504	6.94E-03
2	1	853	6.29	727,609	7.37E-03
3	1	954	7.23	910,116	7.58E-03
4	1	1,051	8.33	1,104,601	7.93E-03
5	1	1,149	9.42	1,320,201	8.20E-03
6	1	1,298	11.19	1,684,804	8.62E-03
7	1	1,459	13.09	2,128,681	8.97E-03
8	1	1,600	15.06	2,560,000	9.41E-03
Σ	8	9,116	75.83	11,001,516	6.50E-02
Post-rehabilitation					
Step No.	N data number	Q m^3/min	sw m	Q^2 m^6/min^2	sw/Q min/m^2
1	1	801	4.69	641,877	5.85E-03
2	1	856	5.17	731,950	6.04E-03
3	1	959	5.71	919,873	5.95E-03
4	1	1,062	6.55	1,127,791	6.17E-03
5	1	1,163	7.36	1,352,356	6.33E-03
6	1	1,348	8.69	1,816,097	6.45E-03
7	1	1,460	9.64	2,130,239	6.61E-03
8	1	1,564	10.60	2,446,183	6.78E-03
Σ	8	9,212	58.41	11,166,366	5.02E-02

Important notice is data verification. Major items are:

- ✓ SWL: SWL will be changed without pumping depending on the interference and the atmospheric pressure. Schedule of testing shall be considered these two factors.
- ✓ PWL: Interpretation of drawdown curve shall be verified and determined at first. There are some cases of (1) well near recharged layer, (2) well near intercepted layer and (3) their complex layer. Time duration of the test shall be defined which drawdown will be adopted.
- ✓ Discharge: discharge rate will be changed according to the water level and the output level from power unit. Stable data shall be confirmed at the site.

Figure B.IV-08 shows the test graphs (log Q-sw and section Q-sw/Q) of pre and post well rehabilitation according to Table B.IV-13.

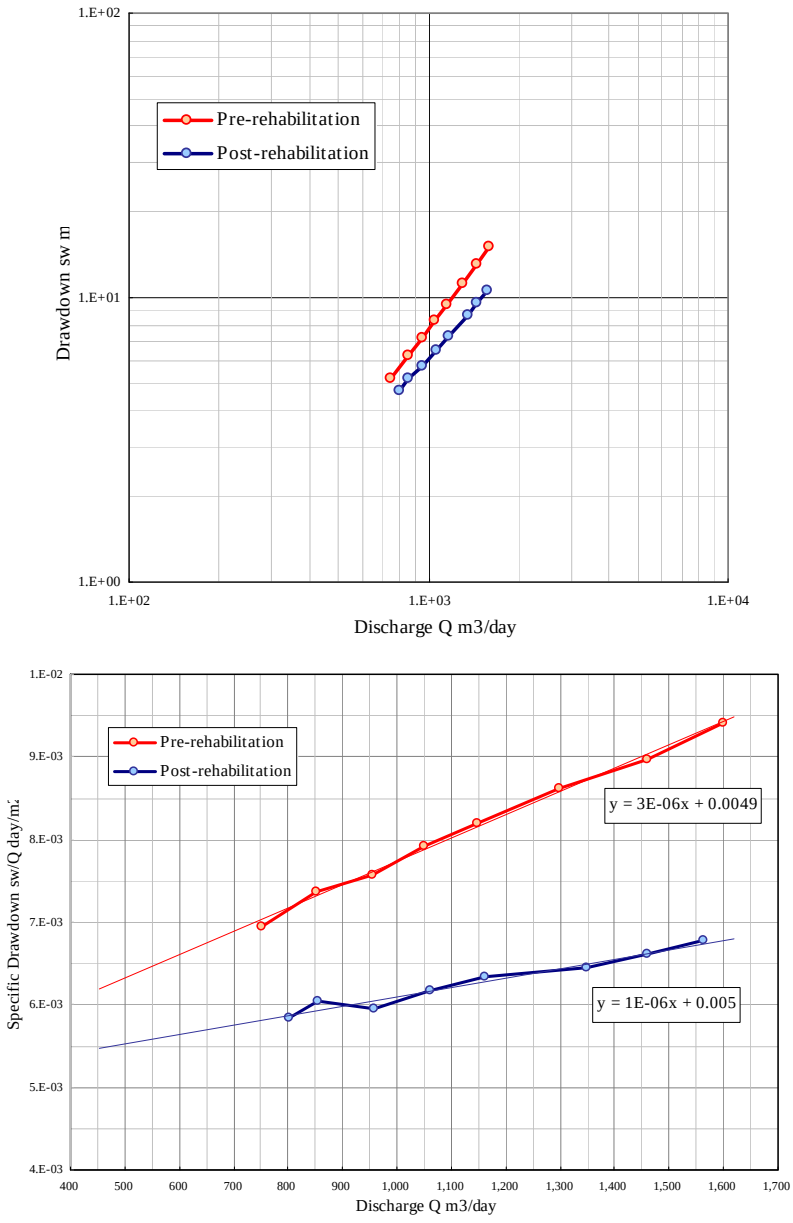


Figure B.IV-08 Analysis Graphs on Step Drawdown Test (Sample)

Following solutions of simultaneous equations are well coefficients B and C calculated by LINEST. Tables B.IV-14 and 15 indicate such analysis solutions and well efficiency (BQ/sw).

- ✓ Σ(sw) = BΣ(Q) + CΣ(Q^2)
- ✓ Σ(sw/Q) = BΣ(N) + CΣ(Q)

Table B.IV-14 Analysis Results of Step Drawdown Tests

Test Period	Drawdown Equation	B (aquifer loss)	C (well loss)
Pre-rehabilitation	$sw = 4.91E\text{-}03 \times Q + 2.83E\text{-}06 \times Q^2$	4.91E-03	2.83E-06
Post-rehabilitation	$sw = 4.97E\text{-}03 \times Q + 1.13E\text{-}06 \times Q^2$	4.97E-03	1.13E-06

Note: Chemical and physical rehabilitation was done in this case.

Table B.IV-15 Well Efficiency at before and after Rehabilitation

Test Period	Q	Aquifer Loss	Well Loss	Drawdown	Efficiency
Pre-rehabilitation	1,100 m^3/day	5.46 m	4.46 m	9.93 m	55 %
Post-rehabilitation		5.46 m	1.37 m	6.83 m	80 %

(2) Sand Contents

Excessive sand contents make the life of well and pump shorter. But it is impossible to make zero sand content while groundwater pumping from the tube well. This test will normally be conducted every 5 years. Design criteria on the sand contents are:

- Permissive: 50 mg/L pump damage limitation
- Allowable: 5 mg/L pump abrasion limitation

Fine particles will move when pumping started by initial movement. It will be released from well screen and fallen in the well (if surface velocity is lower than fall velocity). Therefore, most of pump housing depth is designed at upper portion of the first screen.

For the inspection of new well completion, submersible pump shall be set below the last screen to check the sand contents easily. It is proposed that the existing pump will be also re-setting at well bottom portion after well depth is measured. Field supervisor shall estimate the time of sand discharge (maybe within 10 minutes) in case sand moved from each well screen.

Sand contents can be inspected by sample bottles. Probably sample bottles will contain the fine sand of 5, 10, 30, 50, 100, 200 mg/L. Normally, sand contents become smaller according to time passed after pump started.

IV-4.3 Monitoring and Evaluation

Groundwater monitoring shall be referred to groundwater regulatory operation. In this section, water balance and performance indicators are the subjects.

(1) Water Balance

Monitoring results of MCWD wells will be used for groundwater development and conservation. Water sources availability of MCWD still depends on groundwater development. Therefore, observation records in Table B.IV-16 shall be accumulated and analyzed annually.

Table B.IV-16 Monitoring Well and Parameters

Description		Monitoring or Stand-by Wells	Production Well
Location		∗ CLC: E-4, SV-12 ∗ Casili: K-2.1 ∗ Talamban: W-1.3b, W-4.5 ∗ Tisa: MC-9, MC-18b ∗ Lagtang: W-1.1, E-3 ∗ Mactan: ObW-6, ObW-7	∗ All Production Well
Parameter	Monthly	∗ SWL (atmospheric pressure) by elevation	∗ Water Quality Cl, NO_3, Ca by pumping water sampling ∗ Discharge Record (monthly average, daily maximum) ∗ PWL (atmospheric pressure) by elevation
	Quarterly	∗ Water Quality EC, Cl, NO_3, TDS/ TH (interface of freshwater and saltwater) by different depths	∗ SWL (atmospheric pressure) by elevation: it shall be measured after 8 hours pump stopped
	Annually	∗ Water Quality NO_3 (Mactan only) by depth	∗ none

Note: Monitoring plan shall be reviewed every 5 years.

(2) Individual Well

PIs at individual wells will be accumulated from now on. Following are judgment criteria on planning of well rehabilitation.

- ∗ Well Efficiency < 50%
- ∗ Sand Contents > 50 mg/L

IV-5 Recommendations for Groundwater Development

Density of water demand is concentrated within the cities of Cebu and Mandaue. Groundwater potential in the said LGUs is still larger than the water demand 2015. Critical issue is limited potential in Mactan Island compare to its water demand. Consequently, water source shall be exported from Cebu Island to Mactan Island. Following are summarized recommendations in this plan.

(1) Pre-conditions of the Plan

The gap between the projected water demand in 2015 and present situation is basis of examination outputs. Many water source matters are on-going such as new well development, bulk water supply scheme, etc. Therefore, this groundwater development plan was prepared with due consideration of possible water source in 2015 according to the project progress. However, it should be reviewed and re-examined when the possibility of new water source is confirmed before 2015.

(2) Scope of Groundwater Development

There are two schemes in the plan of groundwater development; new well construction and existing well rehabilitation.

< New Well Construction >

- ∗ Construction of 63 New Wells
- ∗ Expected Yield was estimated at 41,500 m^3/day
- ∗ Well Fields are located within the hillside of Consolacion, Mandaue and Cebu

< Existing Well Rehabilitation >

- Rehabilitation of 101 Existing Wells
- Purpose of rehabilitation is to increase the well efficiency for saving power cost and extending facility life.

(3) Technical Guideline

This guideline was prepared for judgment criteria to consider the expected measures of following issues while project operation period.

- Water Balance in Well Field: (1) site selection and (2) facility operation
- Performance Indicator: (1) well efficiency and (2) sand contents
- Monitoring and Evaluation: (1) water balance and (2) performance indicator

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Section-V
Groundwater Conservation

V-1 Basic Concepts

The most dissolved ingredients in raw water excluding some of organic matters can not be removed by the general treatment process of slow or rapid sand filtration. Accordingly, the normal treated water with dissolved substances is supplied to users directly, even it affects human health. Therefore, potable water sources shall be conserved if advanced treatment process is not feasible to apply.

In this view point, security and observation of safe water resources are required as important responsibility of the water utility. Following major issues of groundwater conservation are identified.

- Water Quality: Contamination/ Pollution
- Water Quantity: Saltwater Intrusion (subsidence is un-known because of none observation)

Hydraulic cycle has been equilibrated in environment if the human interruption is limited within the permissive range. That balance was deteriorated in compensation for extreme overpopulation and economic activities in Metropolitan Cebu, which has occupied a great part of water resources locally. Interests of human society and re-coverable limits of natural environment are related complexly. Stakeholders should understand the impacts of imbalance as shown in Table B.V-01.

Table B.V-01 Major Consideration Items of Groundwater Conservation

Major Issues		Activity of Human Society	Impact to Natural Environment
Quality	Contamination	• Domestic Wastewater • Medical Goods Disposal	• Infection Sources • Toxicity Materials
	Pollution	• Industrial Wastewater • Waste Disposal • Agricultural Chemicals	• Aggravation of Potable Quality • Malodorous Sources
Quantity	Saltwater Intrusion	• Over Exploitation and Depression	• Change Vegetation Pattern
	Subsidence	• Artificial Inter-flow via Well Screen	• Vanish Surface Water

Note: Above items may concern to Metropolitan Cebu.

Measures of groundwater conservation can be classified into three groups such as prevention, stopgap and improvement in terms of water quality and quantity as shown in Table B.V-02.

Table B.V-02 Major Countermeasures of Groundwater Conservation

Conservation Subject		Major Countermeasures		
		Prevention	Stopgap	Improvement
Quality	Contamination	• Septic Tank (Dipping) • Waste Collection • Housing Permit	• Dis-infection	• Sewerage • Waste Disposal • Neutralization
	Pollution	• Treatment Plant • Factory Permit	• Shutdown	
Quantity	Saltwater Intrusion	• Water Level Control • Water Permit	• De-salination	• Water Supply • Underground Dam
	Subsidence	• Discharge Control • Water Permit	• Infiltration Well	• Recharge

Note: Above items may concern to Metropolitan Cebu. Permit shall include intake quantity and structures.

(1) Water Quality Control

Toxicity elements have no significant concentration yet according to the USC report in 2006. On the other hand, existing collection-treatment system of night soil and solid waste has not enough capacity and was not well operated. Geographical features of Cebu also accelerate groundwater contamination such as frequent local flood with many sinkholes in hilly area.

Significant groundwater issues in terms of quality may be caused of wastewater from household. Action plans of each social stratum shall be mentioned clearly, groups of which are individual, organization and system as shown in Table B.V-03. This issue may be concluded by working group of urban sanitation.

Table B.V-03 Candidate Actions for Contamination/ Pollution Control

Social Stratum		Control Methods
Individual	User (HHs and enterprises)	• Installation, Operating and Maintaining of Septic Tank or Communal Treatment Plant
Organization	Providers	• Maintaining of System Operation with Tariff Collection • Field and Project Monitoring
System	LGUs and National Governments	• Sectoral Monitoring • Preparation and Review of Guideline • Taxation, Subsidy, Penalty, Law and Regulation

Note: This item shall be cooperated with study portion of "Urban Sanitation".

(2) Water Quantity Control

Fresh groundwater as a fluid resource is not connected directly on a world scale like circulation of air and seawater. Therefore, groundwater issues shall be solved within a hydrogeological basin individually under the national policy. Groundwater development potential has different criteria depending on its safety and stability. Following are brief descriptions of groundwater development potential.

< Safety >

In the view point of basic human needs, usual groundwater quality may be judged as potable without treatment. Boundary of self-responsibility and social security in water sector shall have certain solution to be concluded locally by residents including social acceptances.

< Stability >

Recoverable groundwater gross yield in the hydrogeological basin can be estimated using tank-model study. Such development potential is assumed by variables of recharge to and storage in the groundwater basin. A little evolutional study method is flow simulation with due consideration of solute transport.

In this section, the promotion of inlet (recharge) and the control of outlet (extraction) will be examined. For the extraction control, they are divided into technical requirements and institutional operation. Technologies of water reuse and recycle were developed according to the fairness allotment. Therefore, water saving will be referred to the managerial improvement in the main report.

V-2 Promotion of Recharge

Maintaining of groundwater recharge field is one of important activities for in-direct conservation. Rainwater is main source of groundwater recharge and is divided into three portions of (i) infiltration, (ii) surface run-off and (iii) evaporation.

Effective measures to increase recharge rate are:

- Re-forestation
- Permeable Paving
- Infiltration Box

For these activities, core management organization shall be LGUs and the province of Cebu including regional DENR and DPWH.

V-2.1 Re-forestation

Now, many hill side lands have been developed for sub-division as measure of population growth in the cities of Cebu and Mandaue, and the municipalities of Consolacion and Lilo-an. In the Lap-lap city, sub-division developments are concentrated at plat inland area. Quarry site has produced lime-stone for land reclamation, which are scraped away from the hills.

Re-forestation is one of groundwater conservation activities in hilly area. However, palm trees have been planted in Cebu Island for production of oil, coconut and lumber as economical activities, even though storage and infiltration capacities of palm farm are limited. On the other hand, MCWD has been implementing re-forestation in the watershed area of existing Buhisan dam site for reduction of soil spillage. Function of forest is a part of environmental cycle (see Figure B.V-01).

Figure B.V-01 Functions of Re-forestation

Decline of forest indicates the starting point of environmental disruption. In view points of Metro-politan Cebu, major roles of forest are to help the maintenance of infiltration capacity and to reduce the soil spillage as shown in Figure B.V-02 according to the monograph in Japan.

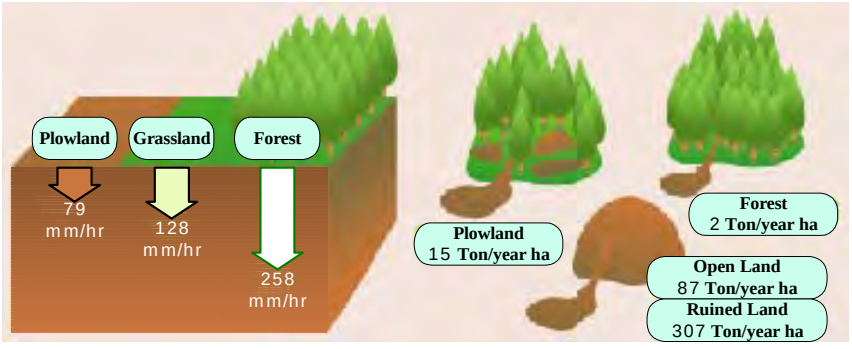


Figure BV-02 Infiltration Capacity and Soil Spillage Rate

Source: Research Paper "Preservation Capacity of Water and Soil in Forest, 1970/ 1975" by University of Practice Forestry

Deciduous broad-leaved forest has higher rate of infiltration capacity and lower maintenance cost comparing to evergreen coniferous forest. Especially, layer made of fallen leaves can store much rain-water momentary as buffer zone until infiltrating.

V-2.2 Permeable Paving

Normal paving is designed by strength, durability and cost. There are several paving types related to secondary aims as shown in Figure B.V-03. Other paving types have additive functions, the aims of which are mainly improvement of frictional resistance on the road surface for safety driving.

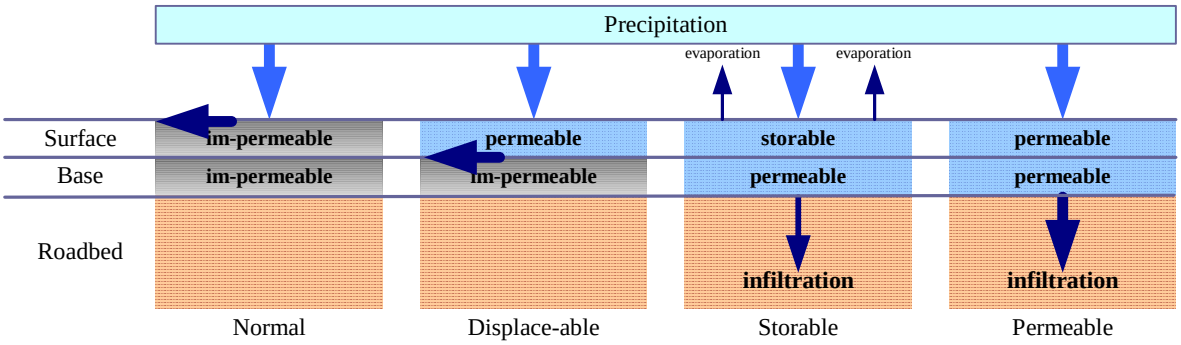


Figure B.V-03 Structures of Paving (Road and Walkway)

Displace-able paving is applied for flyover or parking lot building, while storable paving can be adopted in heat island area (great city). Permeable paving has been constructed in area where less groundwater recharge or frequent flood is observed. Disposed old tire can be re-used to product construction materials for permeable and storable paving.

However, weak points of storable and permeable paving will be appeared when infiltration capacity of roadbed is low and high water level.

V-2.3 Infiltration Box

Infiltration capacity has been deteriorated in urbanized district with rapid economical growth in recent years, due to covering of ground surface by paving and asphalt. Most of local governments in Japan have subsidy system for promotion on individual installation of infiltration box with conditions below. Subject types of rainwater collection are (see Figure B.V-04):

- by gutter and spout from roof and
- on the paved ground.

Disqualified installation areas are:

- collapsible slop land,
- upper place of protective wall,
- edge of precipice,
- high water level area,
- impermeable land and
- none coverage of drainage system.

Owner of housing or building should consider roofing material and maintenance works.

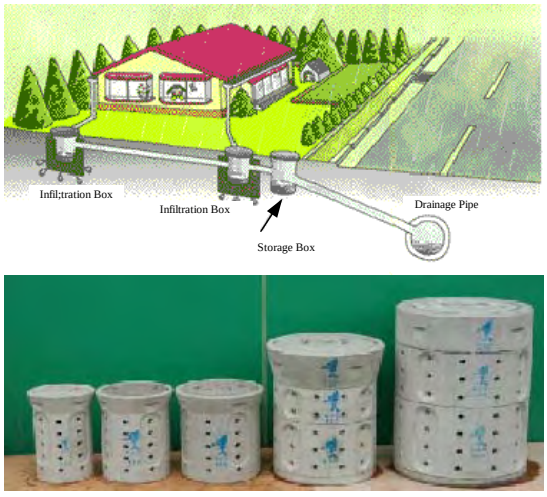


Figure BV-04 Installation Model and Infiltration Box

V-3 Control of Groundwater Extraction

Table B.V-04 shows the assumed abstraction in Dec-2004 using tank and flow models.

Table B.V-04 Groundwater Potential in MCWD Service Area

Temporal Section	Modeling Results (m^3/day)			
	Tank Model (Water Remind)		Flow Model (JICA Study)	
Dec-2004	MCWD	112,000	MCWD	112,000
	Non-MCWD	298,000	Non-MCWD	391,000
	Entire (9-WRMUs)	410,000	Entire	503,000
Dec-2030	MCWD	(152.5 MCM/y*[1]) 418,000	MCWD	176,000
	Non-MCWD		Non-MCWD	468,000
	Entire (9-WRMUs)		Entire	644,000
Criteria	Mining Yield (50 years)		Groundwater Regulation*[2] (NWRB, 2007)	

Note: *1; Unit of MCM/y is million cubic meters per year. *2; Social acceptance was not considered.

Following water permits in Table B.V-05 were issued by NWRB as of Dec-2007. It is noted that amount of permits and extraction have different meaning. Actually, MCWD has several stand-by wells in Compostela because of non-clearance from LGUs issue.

Table B.V-05 Water Permits issued by NWRB (m^3/day as of Dec-2007)

Water Resources	Gross	MCWD	Non-MCWD
Surface Water	1,012,557	12,873	999,684
Groundwater	577,140	173,005	404,135

Note: Mean of water permit is to have a right to use.

Referring to the analysis result of various models, water permits and present situation of groundwater system, the present extraction may be closed to the potential amount with due consideration of permissive saltwater intrusion.

The groundwater regulation "Resolution No.004-0507" issued by NWRB on 16-May 2007 was referred for technical requirements as the extraction control. The said resolution was issued as the guideline of previous resolution (No.002-1106 on 15-November 2006), which can be used for management and development of groundwater source in Metropolitan Cebu including acceptance and processing of water permit applications.

According to the said resolution (No.004-0507), following are major contents.

- Declared Critical Areas: Consolacion, Lilo-an, Cebu and Mandaue within topographically below 70 masl contour line on coastal side excluding fluvial river plain and inland basin, and whole Mactan Island (Lap-lap and Cordova) are declared.
- Policy in Critical Area: The NWRB shall issue Cease and Desist Orders against users without water permits and shall cause the immediate closure of water sources within fifteen (15) days from receipt of the order excluding hospitals for back-up use by not exceeding 250 mg/L salinity and 50 mg/L nitrate.
- Existing Water Permits: Permittees shall be required to monitor their source at least twice a year and to reduce their volume of extraction when salinity level of 210 mg/L or above. Water permit shall be canceled or revoked when the

salinity level exceeds 250 mg/L. Water permits shall be canceled or revoked if water permittee resides within area adequately served by water service provider.

- Water Permit Applicant: No water permit applications shall be processed in areas adequately served by water service provider excluding hospital back-up use. Water permit applications may be processed in areas not adequately served by water service provider, until the water service available.
- Adequately Served Area: MCWD shall submit the service area and business plan. NWRB shall use such map and plans for policy guideline and references in granting of water permits.
- Regulatory Operation: The NWRB shall enter into a "Memorandum of Agreement (MOA)" with LGUs in Metropolitan Cebu and or MCWD for joint monitoring and enforcement of the policies on the sourcing of water and its use. Water permit applications may be processed in reclaimed areas extracting brackish water or saltwater for de-salination. Water permit applications fro de-salination of seawater may be allowed.
- Conservation Measure: Promotion of water conservation measures (e.g. water re-use and re-cycling, rainwater harvesting, etc.) shall be encouraged.

There are contradictions and unclear articles here and there in the regulation. It can be revised, modified and amended easily when the regulator, operator, monitor and supporter related to this regulation can sit on the same table together. The plan on short-term strategy and long-term strengthening of the groundwater regulation matter would be prepared by the stakeholders in the Philippines.

V-3.1 Application of PCM Method

The aim of the groundwater regulation is to control the chaotic extraction. If clear objectives and milestones are indicated in the regulation, implementing agencies would handle the matter quickly.

The project cycle management (PCM) method to be applied "low politics: administrative operators" for cooperative public works is introduced to create the managerial operation system that is a recommended method of JICA technical assistance.

When the saltwater intrusion is taken up as core groundwater issue, following information can be referred in the PCM workshop. Participants to the PCM workshop can be nominated mainly from the category of; (1) decision makers, (2) funding agencies, (3) implementing agencies, (4) supporting groups, etc. as shown in Table B.V-06.

Table B.V-06 General Category of Stakeholders Analysis

Category	Definition
Beneficiaries	Stakeholders who will likely benefit from the project.
Negatively Affected Groups	Stakeholders who will be negatively affected by the project.
Decision Makers	Stakeholders with decision making authority.
Funding Agencies	Stakeholders whowill bear expenses.
Implementing Agencies	Stakeholders who will implement the project.
Community Leaders	Stakeholders who may represent the community.
Potential Oppounents	Stakeholders who may oppose or obstruct the project.
Supporting Groups	Stakeholders who will likely cooperate with the project implementation.

Note: Source is applied from FASID.

Core problem with serious economic crisis shall be identified at first, because saltwater intrusion may include complex causes and effects in different fields such as: physical phenomena (water quality/ water level), capacity and activities of social strata (individual/ organization/ system), type of characteristics (institutional/ managerial/ technical), etc.

Plural core problems can be selected appropriately depending on the participants of PCM workshop. The line of "selection of core problem - problem tree analysis - objective analysis - project selection" is normal procedures. Along this activity line, project approaches can be selected with schemes of;

- Capacity Development,
- Social Development,
- Maintaining of Facility/ Instrument (Construction and Procurement),
- Institutional Reform, and
- Combination of above items.

Selection criteria of the cadidate project can be added or changed depending upon region, sector, assistance-related organization and schemes. Bearing in mind the selection criteria, consider questions such as comparing "approaches" to one another.

Comparison and selection of approaches should be considered from various viewpoints, such as (i) policies, (ii) technologies, (iii) social, political and physical environment, (iv) society and culture, (v) organization and institution, and (vi) economy and financial administration. Selection criteria such as, "needs, policy priority," "feasibility," "inputs," "possible negative impact" and "sustainability" are in line with the five evaluation criteria.

Project design matrix (PDM) has clear items below. Plan of operation (the regulatory operation) will be realized upon authorization of PDM and PO. When the common understanding is integrated among the stakeholders, the frailness notification system of official paper between organizations at the moment could be also strengthened.

- Pre-conditions
- Inputs (mainly human power)
- Activities (grouping with different outputs)
- Outputs (project purposes, overall goal shall be included)
- Objectively Verifiable Indicators (OVIs) with means of Verification
- Important Assumption (for risk management)

Problem tree was prepared among the MCWD members as shown in Figure B.V-05. Tentatively, core problem of "groundwater regulation is not complied" was nominated. Problem cards were categorized into four groups; public relation, operation system and locality.

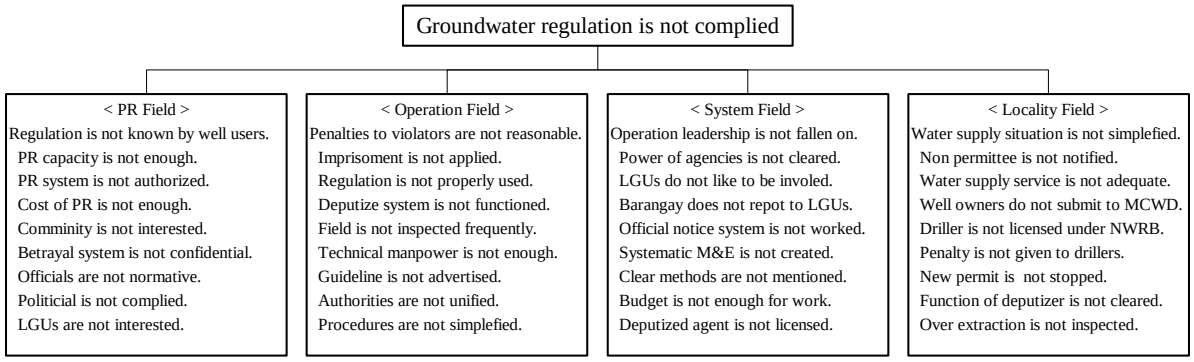


Figure B.V-05 Problem Tree of "Groundwater regulation is not complied."

Residents in the study area fetch drinking water from plural sources listed below. Differences of accessibility are its service level in terms of safety (quality), stability (quantity) and affordability (cost). On this present situation, water supply services are available in declared critical areas.

- Water Provider (with or without business license),
- Own Water Source (well and or spring),
- Indirect Users of above (to buy water from the subscribers),
- Water Vendor (20 L delivery), and
- Water Supply Association (for mainly sub-division).

The most of water source at water provider depends on groundwater extracting from their owned wells. Groundwater source of MCWD occupies about 73% of intake amount including bulk water supply. In this regard, groundwater for public drinking water supply shall be categorized as special exemption according to the regulation.

When the reduction of impacts to groundwater environment is objective of the regulation, it is acceptable to the people that the subject of regulation shall be given to private business users as a consequence of "destructor pay principal."

Private users for individual domestic purpose may install the intake facility into the well with limited extraction capacity; by pail, hand-pump or motor pump with discharge outlet of less than one inch. Accordingly, subject of the regulatory operation can be limited to the private users with pump outlet of one inch or larger.

V-3.2 Proposed Institutional System as Final Goal

Primary factor of difficulties to handle the regulation is conceivably complex stakeholders in terms of great number of groups and persons. If the groundwater regulator and developer can be unified into single organization, optimal development and appropriate conservation in critical area would be realized. Adversely, overall responsibility on monitoring and evaluation of groundwater environment shall be fallen on the said organization.

In this case, following policy and management concept would be alternatively sought. However, the first step or activity toward the final goal shall be prepared by integration of opinions from the stakeholders. Therefore, the meeting with NWRB, LWUA and UP would be a start line to the said goal.

< Institutional System >

- Sectors of water supply and sanitation shall be linked for water environment conservation.
- Stakeholders Committee shall be composed of concerned organizations.
- Stakeholders' Sub-committee shall provide the transparent data and information to the society.
- Stakeholders committee shall improve the current regulation according to the sector needs.
- Provisional period of 5 to 10 years may be required from the proclamation until the enforcement.
- Solo provider for public drinking water supply can extract groundwater.

< Pre-conditions >

- Essentially, groundwater extraction and drainage within Metropolitan Cebu shall be prohibited.
- Private business shall connect the water supply system of licensed public provider when needed.
- The privilege of water resources development within Cebu Island shall be given to the provider under the approval condition from the stakeholders committee.
- Provider shall monitor the groundwater environment continuously and shall report his plans to the stakeholders committee periodically for regulatory approval.

V-4 Operation of Groundwater Regulation

The regulation shall move from the general to the particular for definite regulatory operation. Following are proposed contents for effective operation of the groundwater regulation.

V-4.1 Institutional System

Presently, MCWD prepares the well inventory in the city of Lap-lap with the memorandum agreement between NWRB - LGUs - MCWD. Results from this activity and its experiences will be serviceable for future management of groundwater environment. It is proposed that the stakeholders committee shall be created for appropriate regulatory operation.

< Proposed Member of Stakeholders Committee >

- Regulator: Representatives from DOH, LWUA, DENR, NWRB, DPWH, DTI, NIA...
- Monitor: PPDO/ CPDO/ MPDO from Provincial Government, LGUs (including Barangay)
- Provider: Representative from EWRKC of MCWD
- Developer: Representatives from Water Provider, Sub-division Developer, Industrial Estate
- Supporter: Representatives from Well Contractor, Pump Supplier, Electric Power supplier
- Academe: USC, UP
- Observer: Donor, NGO, NPO...

< Technical and Managerial Sub-committee >

- Technical: Hydrogeologist, Meteorologist, Chemist, Hygienist, Environmentalist, WATSAN Planner, Facility Planner, Mechanical Engineer, Electrical Engineer, Civil Engineer, Architectural Engineer, Groundwater Modeler
- Management: Jurist, Financial Analyst, Economist, PR Specialist, PCM Moderator, Coordinators
- Secretariat: Secretary, Accounting

Pre-meeting for objectives, activities and creation method of stakeholders committee shall be held repeatedly among the NWRB, LGUs and MCWD. For the long-term strategy, Figure B.V-06 indicates the WATSAN management system as final goal of the sector improvement.

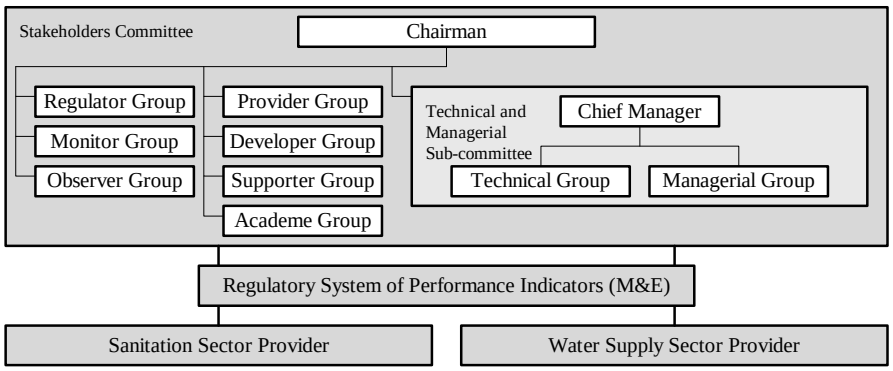


Figure B.V-06 Proposed Diagram on Integrated Management in WATSAN Sector

V-4.2 Operation Role and Responsibility

Basically, stakeholder committee issues the license of WATSAN provider on condition that the provider shall maintain the service level within jurisdiction of Metropolitan Cebu which was subjected to the performance indicators agreed between the committee and the provider. At the first, the stakeholders committee shall study the performance indicator system including strengthening of obligation and penalty system, which was authorized by ISO/ TC-224 24500 series.

< Major Action to be taken by Stakeholders Committee >

- Creation on Regulatory System of PIs (especially security of water rate and service level)
- Independent and or Corporative Monitoring on Service Level and Environment with Provider
- Recommendation on Improvement of Service Level and Environment Conservation
- Examination and Negotiation of Renewal Conditions with Provider
- Integration and Coordination of Stakeholders Opinions (individually and or jointly)
- Distribution of Committee Resolution through Formality System and PR

< Major Action to be taken by Provider >

- Provide Appropriate Services to Users within Conditional Water Rate
- Appropriate Operating and Management of Water Utility
- Enforcement and Report on Monitoring of Service Level and Environment Impact
- Prepare the Mid and Long Term Plan on Improvement and Expansion of Service
- Raising Necessary Fund for Water Utility Operation (including PPP)

V-4.3 Source of Fund

Sources of funding for the activities of stakeholders committee and the project implementing by the provider shall be considered.

(1) Stakeholders Committee

When the law and regulation relating to this organization setting is approved by the stakeholders, the government of the Philippines may prepare the budgets for this activity.

(2) Provider

To date, MCWD has funding sources from bank or LWUA loan. When the unification in WATSAN sector is realized, a vast sum of fund will be required for expansion and improvement of the water supply system.

In recent years, many water providers raise the required fund from the stock market using the scheme of PPP (public-private partnership). Accordingly, following important items are notified for introduction of the PPP scheme.

< Clarification on Objects and Milestones of PPP Introduction >

- ✓ improvement of efficiency in terms of managerial and technical fields
- ✓ application of private capital (reduction of load from official budget)

< Measures to minimize the Risks >

- ✓ Institutional: un-clearness and under-development of law and regulation, complicated procedures of water rate change
- ✓ Financial: reduction of tariff collection rate, high NWR rate
- ✓ Technical: difficulties of demand projection, huge cost for system improvement, short facility life according to low construction quality
- ✓ Commercial: difficulties of interest rate prediction, un-qualified contractor technology, high reliance on foreign market

< Regulatory Management for PPP Introduction >

- ✓ achievement on objectives of public water supply service
- ✓ required social and environment consideration
- ✓ establishment of the system for sharing the benefits among the stakeholders

V-5 Recommendations for Groundwater Conservation

(1) Institutional System

- Social acceptance shall be determined and relative laws shall be reviewed for transformation of evaluation criteria on groundwater potential.
- Long-term policy and plan with short-term strategies for improvement of groundwater environment shall be prepared by the Philippines side applying the PCM method.
- Stakeholders committee shall be created by following organizations for setting up of operation system and critical decision.
  - ✓ Regulator: DOH, LWUA, DENR, NWRB, DPWH, DTI
  - ✓ Monitor: Provincial Government, Local Government Units (including Barangay)
  - ✓ Developer: MCWD, Water Provider, Sub-division Developer, Industrial Estate
  - ✓ Academe: USC, UP
- Stakeholders' technical sub-committee shall be established by following experts to support the upper committee.
  - ✓ Technical: Hydrogeologist, Meteorologist, Chemist, Hygienist, Environmentalist, WATSAN Planner, Mechanical Engineer, Electrical Engineer, Civil Engineer, Architecture Engineer, Groundwater Modeler
  - ✓ Managerial: Jurist, Financial Analyst, Economist, PR Specialist, PCM Moderator, Coordinators

(2) Promotion of Groundwater Recharge

< Groundwater Pollution Preservation >

- Transparent activities with objectively verifiable indicators of social stratum (user, provider and regulator) will be created by the stakeholders committee.

< Promotion of Popularization on Recharge Activities >

- Activities of re-forestation, permeable paving and infiltration box shall be promoted by the governmental agencies (DENR, DPWH, LGUs).
- M&E system shall be created by regulators (DENR, DPWH, NWRB, LGUs).

(3) Control of Groundwater Extraction

< Technical Requirements >

- Both activities in regulation and development would be unified for certain control of chaotic extraction with provisional period of stopgap measure.
- Authorization procedures of the groundwater flow model (the Cebu-GWM-09) shall be confirmed by the stakeholders committee with collaborated activities of model improvement.
- Technical term in the regulation shall be reviewed, defined and confirmed by the stakeholders' technical committee for easier and certain operation.

< Regulatory Operation >

- Periodical meeting of stakeholders' technical committee shall be held for integration of monitoring information and critical decision including periodical review of the regulation.
- Present regulation would reviewed with due consideration of essential solutions on;
  - ✓ Cebu Island Groundwater Resources Management (not only Metropolitan Cebu)
  - ✓ Unification of Groundwater Regulator and Developer
  - ✓ Exhaustive Groundwater Monitoring and Evaluation under the Unified Organization

.....

Section-VI
Requirements for Model Improvement

VI-1 Model Limitation and Weak-points

Brief composition and building indicators of the Cebu-GWM-09 are described below.

- Simulation Code: SEAWAT version 4 (USGS, 2008)
- Boundary Conditions: boundaries of Non Flow, Constant Head and General Head
- Input Assigned Parameters:
  Fluid Density:
  seawater 1.025 g/cm^3 with Cl of 19,000 mg/L
  freshwater 1.000 g/cm^3 with Cl of 20 mg/L
  Aquifer Property: final figures after calibration

Zone	k_H (cm/sec)	S_S (m^{-1})	S_Y (none)
Alluvial	1E-0 to 1E-4	1E-3 to 1E-04	2E-1 to 1E-2
Limestone	1E-0 to 1E-3	4E-3	3E-1 to 5E-2
Volcanic	5E-5	1E-3	1E-1

- Temporal Discretization:
  Initial Term 1,000 years (12,000 months)
  initial 985 years for constant stresses without abstraction
  next 15 years for constant stresses with constant abstraction
  Calibration Term 25 years (300 months)
- Input Stresses:
  Constant Stresses in Initial Term
  Transient Stresses in Calibration Term
  recharge: allocation by geology and undulation by land-use
  lateral flow: fixed (no verification)
  abstraction: MCWD and Non-MCWD (including dummy)
  return flow: undulation by pop-growth and service area
  Stresses Zone: constantly 31 zones within 9-WRMUs
- Calibration Priority:
  Parameters: quality (Cl) > quantity (WL)
  Observations: individual seasonal variation > contour map
  Reflection (within calibrating works)
  aquifer property > abstraction > recharge allocation
- Calibration Results:
  Chloride
  Cl observation points: 119 wells
  Cl observed > 20 mg/L: 40 wells
  Cl calculated > 20 mg/L: 36 wells
  Cl both observed and calculated > 20 mg/L: 27 wells
  Chloride and Water Level
  Cl and WL observation points: 119 wells
  acceptable Cl and WL calibration points: 48 wells
  acceptable only Cl calibration points: 62 wells
  poor Cl calibration points: 9 wells
- Sensitivity Analysis: User is required to evaluate the effect of parameter on calibration and prediction models, because of still uncertain parameters exist.

Following limitation and weak points were observed during modeling period of the Cebu-GWM-09.

(1) Limitation of the Soft-ware

A soft-ware was nominated with due consideration of its operability and modeling manifest (density flow). The V-MODFLOW by FDM was selected beyond the advantage of FEM. Additionally, the Cebu-GWM-09 is much competitive to the other Cebu-GWM-04 in NWRB. In this regard, un-confined groundwater flow can not be simulated. In the Cebu-GWM-09, unsaturated zones were adopted as passing layer of recharging from the surface.

(2) Weak Points of the Cebu-GWM-09

Following data are still uncertain information while the Cebu-GWM-09 was built. The sensitivity of the model was not analyzed because there were still many assumption parameters in the calibration and prediction models. These weak points can be categorized into two groups; (1) parameters can be measured in the field and (2) parameters would be assumed using actual data. Prioritized investigations are listed below.

< Data to be investigated >
- Non-MCWD well information
- fluid density with high TDS groundwater
- geological boundary in deeper portion
- conduit flow belts
- confining layer in coastal alluvial
- verification of observed data (SWL-PWL, Interface Depth)

< Data to be assumed >
- water balance from Water Remind
- water budgets zoning and its allocation
- non-verification area
- interaction between modeling districts

VI-2 Accumulation of Modeling Data

MCWD has increased groundwater source development since the water utility was turned over from the Osmena Waterworks. A turning point of water source security may come nearby, since the amount of bulk water has been increased to meet the demand. It becomes unprecedented situation even in the concessionaire contract that MCWD depends 20% of water source from the third party.

Model domain of the Cebu-GWM-09 was given condition to this study, where MCWD service area within his franchise LGUs includes into. Reconsideration of modeling conceptualization may be needed when the Cebu-GWM-09 is improved, for example;

- Expansion of model domain to both northern coast, southern coast and hilly sides,
- Deduction of Mactan district (renunciation of groundwater development by MCWD), etc.

Implementing period of the action plan until 2015 should be significantly utilized for the modeling data collection. Following monitoring activity and investigations are planned.

VI-2.1 Monitoring Activity

The monitoring activity is divided into two categories; (1) Non-MCWD well inventory and (2) groundwater monitoring using MCWD wells.

(1) Non-MCWD Well Inventory

The aims of "Non-MCWD Well Inventory" are;

- to establish the systematic works on periodical data collection of abstraction and water quality from Non-MCWD wells including re-evaluation of permitted amount, and
- to collect the hydrogeological information within non-verification area (especially the municipality of Minglanilla and the city of Danao) in the Cebu-GWM-09.

< Inventory Database on Abstraction and Water Quality of Non-MCWD Wells >

According to the groundwater regulation (NWRB Resolution No.004-0507 on 16 May 2007), following problems will be arisen.

- ✓ Control Methodology and Indicators
  Groundwater resources at coastal area topographically below 70 masl in Metropolitan Cebu shall be conserved by the control of water quality indicators (Cl and NO_3). Users in hilly area may get more benefit under the present regulation. Social acceptance is much important regulatory concept even if it will take longer time. Also, NO_3 contamination is not caused of violation permittee. "Polluter Pays Principal" shall keep in the regulation.
- ✓ Reduction of Illegal Well Users
  Registration measure of users without water permit was not mentioned in the groundwater regulation. Coordination PR systems with authorization from LGUs including Barangay to Provincial levels shall be established for effective activities. It is also good chance to obtain the new MCWD subscribers.
- ✓ Regulatory Area
  Judgment of inadequate water supply service area is un-cleared. MCWD can supply potable water to subscribers within franchise LGUs. Adversely, MCWD does not have any responsibility to supply potable water to peoples within franchise LGUs. Additionally, there are many Non-MCWD water providers exist within the same area.
- ✓ Activity of Permittee
  Permittee shall submit the water quality report to NWRB twice a year for re-evaluation of permitted amount. Permittee does not have any benefit to follow this article. Additionally, institutional system for inspection of re-evaluated permitted amount was not established.

Under these situations, MCWD started to prepare the inventory of Non-MCWD well in the city of Lap-lap since August 2009. Probably, the one round research may take 5 years or more within MCWD franchise LGUs. As a parallel work with inventory activity, following items for the regulatory operation are recommended to discuss among the stakeholders.

- ✓ rational operation system with guideline on procedures and charge of responsibility,
- ✓ friendly application system with transparent information and PR activity,
- ✓ data gathering system with due consideration of minimal load to the stakeholders,
- ✓ sharing of fieldwork expenses with objectively verifiable indicators, and
- ✓ periodical meeting to improve the system including feedback information exchange.

Land subsidence in downtown Tokyo was observed sinking 10 cm annually due to over extraction of groundwater in early 1970's. Measures to deal with natural calamities and its cost sharing lay heavily on the people. The national government of Japan enforced the regulation.

The first activity of regulatory operation was to prepare the guideline including following problems.

- ✓ Scope of regulation (target wells for monitoring),
- ✓ Vested water rights without water permit,
- ✓ Penal and reward regulation, etc.

< Inventory Database on Hydrogeological Information in outside of MCWD service area >

Comparatively, hydrogeological information in MCWD service area is much better than that in outside franchise area. In this regard, activity for inventory of Non-MCWD well is also recommended to conduct in the municipality of Minglanilla and the city of Danao including periodical abstraction and water level data.

(2) Groundwater Monitoring Facility

Several observation wells were constructed during the study period. MCWD has also several observation wells in the service area, which were converted from the previous production well due to aggravation of water quality or deterioration of well yield. Proposed monitoring wells are nominated in the technical guideline and listed below.

- ∗ CLC: E-4, SV-12
- ∗ Casili: K-2.1
- ∗ Talamban: W-1.3b, W-4.5
- ∗ Tisa: MC-9, MC-18b
- ∗ Lagtang: W-1.1, E-3
- ∗ Mactan: ObW-6, ObW-7

Monitoring items are two parameters of water quality and water level with following important notices.

- ∗ Water Quality: Addition to the usual parameters of Cl and NO_3, interface depth sounding between freshwater and saltwater will be conducted at least twice a year as a fixed point observation.
- ∗ Water Level: During the model calibration works, water level can not be verified whether it was SWL or PWL. SWL shall be sounded at least 8 hours after pumping stopped, while aquifer loss shall be analyzed from PWL with discharge rate according to the drawdown equation resulting from the step drawdown test.

VI-2.2 Investigation Required

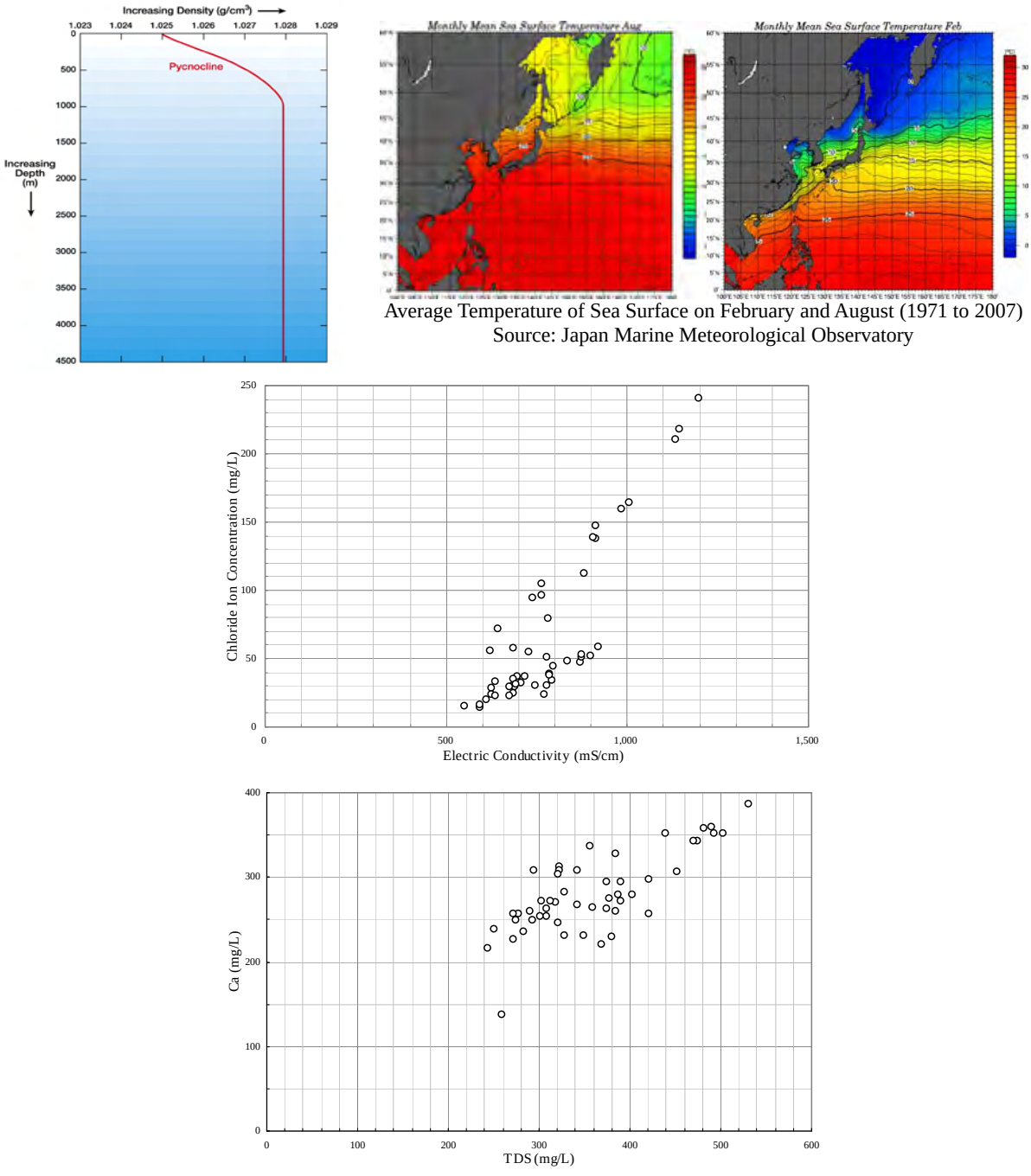
The aim of proposed hydrogeological investigation is to acquire following information for reflection to the Cebu-GWM-09. Among these requirements mentioned above, three investigation schemes are proposed.

Table B.VI-01 Lacking Information and its Investigation Scheme

Lacking Information	Investigation Scheme
• fluid density with high TDS groundwater	MCWD (laboratory) or USC (contract out)
• geological boundary in deeper portion • confining layer in coastal alluvial	MCWD Hydrogeologist with procured instrument
• conduit flow belts	Contracted Out

Fluid densities in the Cebu-GWM-09 are (1) 1.000 mg/L as freshwater with 20 mg/L chloride and (2) 1.025 mg/L as seawater with 1,900 mg/L chloride, respectively. Density of fluid has been changed according to pressure, dissolved constituents and temperature (see Figure B.VI-01).

- Density increases when pressure increases,
- Density increases when dissolved constituent increases (salinity and hardness), and
- Density decreases as temperature (27 to 29 Celsius at Bohol Strait) increases.



Average Temperature of Sea Surface on February and August (1971 to 2007)
Source: Japan Marine Meteorological Observatory

Figure B.VI-01 Groundwater Quality in Metropolitan Cebu (2009)

Geo-resistivity and test well were investigated in the JICA study. Additionally, geological information was collected from the contractor of Mactan II Bridge and Cebu coastal highway. Especially, geological boundary between alluvial and limestone with confining layer was identified as critical information to the model.

Accordingly, it may be cheaper and can be proposed that MCWD will procure the instruments and conduct logging at existing Non-MCWD wells in Metropolitan Cebu. For this activity, communication system between well owners and MCWD shall be established.

Finally, conduit flow will be investigated using tracer or prospecting. Tracer method can identify the location and aquifer property of fissure zone. Generally, sodium chloride was used for tracer survey, however saltwater is already intruded in the subject area (northern limestone, especially San Vicente Well Field). Therefore, prospecting is proposed even it will be indirect measurement.

Technical specifications with estimated cost are described below.

(1) Fluid Density

< Specifications >

- Model: DA-130N (see the right picture)
- Homepage: http://www.kyoto-kem.com
- Type: Peculiar Oscillation Cycle
- Fluid: 0 to 40 Celsius
- Range: 0.0000 to 2.0000 g/cm^3
- Accuracy: ±0.001 g/cm^3
- Analysis: 0.0001 g/cm^3
- Power: Dry Battery (1.5V × 2 pieces)
- Manufacturer: KYOTO Electronics Manufacturing Co., Ltd.

< Cost >

MCWD is required to measure the density of groundwater and seawater seasonally. There are two cases; (1) procurement of instrument or (2) contract research. In both cases, MCWD shall chose taking water samples or field measuring.

- Procurement: JPY190,000.- (equivalent to PHP95,000.- excluding exporting fee and tax)
- Research: PHP400,000.- (PHP200/sample × 200 samples × 2 seasons/year × 5 years)

(2) Borehole Logger

< Specifications >

- Probe: normal/ micro resistivity, SP, EC, natural gamma and sonic within box
- Module: covering above probes
- Cable: armored coaxial, 300 m in well depth with power winch and counter pulley
- Power: 12V or 24V, DC

< Cost >

- Procurement: US$65,000.- (equivalent to PHP2,925,000.- excluding exporting fee and tax)
- Contract: PHP15,000,000.- (PHP30,000/site × 100 sites × 5 years)

(3) Seismic Prospecting

< Specifications >

- Method: Refraction (Reflection may be supplementary done)
- Sounding: 10 sites
- Observation: 50 points
- Depth: 300 to 500 mbsl

< Cost >

* Contract: PHP6,500,000.- (including reports)

VI-3 Improvement of the Cebu-GWM-09

Issues related to the model inaccuracy are:

- to calibrate the model using many presumed parameters, and
- to analyze its sensitivity with plural presumptions (creation of new contradictions).

MCWD is required to acquire the actual information. Regarding the interaction between modeling district, regional modeling is one of countermeasure. In this case, simulating of trial and error in the Cebu-GWM-09 may take whole day or longer time with semi-workstation computer.

Water budgets in the Water Remind project were presumed using the sensitivity analysis because the study on planning should be completed using limited information and within limited period. Finally, data accumulation and verification would be remained way to improve the both models.

VI-3.1 Calibration Order

According to the experiences of trial and error for the model calibration, following procedure is recommended.

(1) Investigated Data

Parameters shown in Table B.VI-02 will be replaced for re-calibration of the Cebu-GWM-09.

Table B.VI-02 Comparison of Input Data

Initial Model			Improved Model
Parameters		Method	
Amount of abstraction from Non-MCWD Wells		Assumed 400,000 m^3/day was deducted from the recharge. Portion from water remind project was transient, while remaining portion was constant.	Amount and position of extraction from Non-MCWD wells could be identified. When MCWD becomes the unified organization of the water provider, model can be calibrated much easier.
Fluid Density		Assumed densities of freshwater and seawater are 1.000 g/cm^3 and 1.035 g/cm^3, respectively.	Actual densities could be given to fluid assignments with transient conditions, because TDS will be increased according to the contact time between freshwater and limestone with its elution.
Aquifer Assignment	Geological Boundary	Massive limestone was merely supposed with its dips.	Truth boundaries of geological boundary and confining layers will be investigated with data accumulation of gamma logging at existing wells when it is possible.
	Confining Layer	Aquitard was supposed to distribute below 20 mbsl in alluvial.	
	Conduit Flow	It was considered as porous media with constant value.	Fracture zone can be identified with different assignment values.
Observation Data	SWL-PWL	They were not verified yet.	Monitoring data shall have pumping rate.
	Interface Depth	Entire Mactan and coastal line in Cebu were reflected.	Interface depth will be reflected in Butuanon and Cebu river plains. Seasonal variation would be calibrated.
	Chloride	Trend in fixed well was reflected.	

(2) Data Verification

MCWD maintains the available data from MCWD wells. Using logging instrument, MCWD can accumulate some data from Non-MCWD wells. Additionally, well inventory survey will provide very helpful information which is on-going activities in the city of Lapu-lapu.

In this study, regional model was divided into 4 districts. This was because of time saving in trial and error operation during the calibration period. Problem of sub-division is to create lacking of consistency near the district boundary. Regional model (would be combined by the sub-regional models) may have following validities.

* reduction of non-verification area
* dissolution of interaction between modeling districts

Parameters obtaining from the Water Remind Project would be confirmed using results of actual inputs mentioned above. In this period, following items shall be considered.

* water balance from Water Remind
* application of infiltration capacity test done by JICA study
* water budgets zoning and its allocation

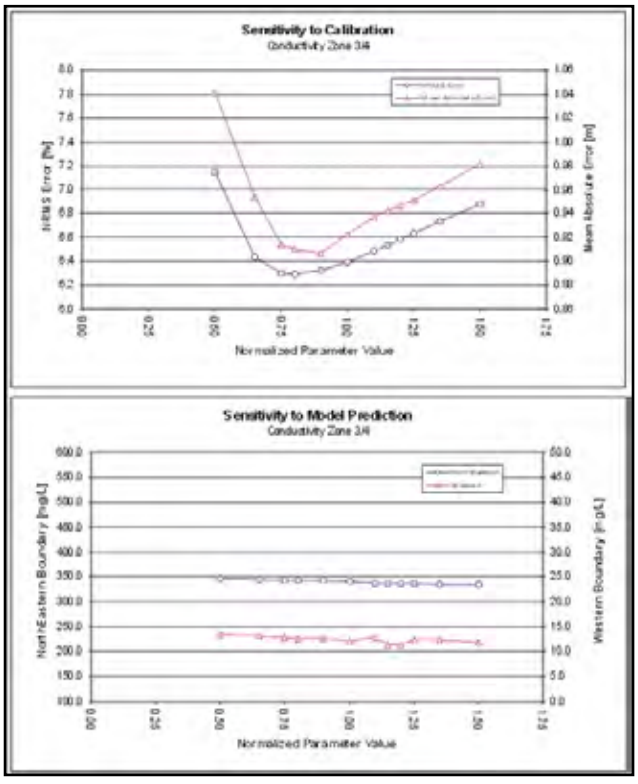
VI-3.2 Sensitivity Analysis and Post Audit

Because of validated data lacking for thoroughly calibration and simulation, sensitivity analysis was not examined in this study. Post audit is also required. Following are recommended to operate when the Cebu-GWM-09 is improved fully.

(1) Sensitivity Analysis

A sensitivity analysis is the evaluation of model input parameters to see how much they effect model output. The objective is to answer the following questions:

* Do small variations in the input data cause large changes in the model results?
* Is the input data reasonable?
* Is the model defensible?
* Are the model assumptions valid?



It shall be recommended to apply for calibration and prediction simultaneously.

A sensitivity analysis is useful to determine the possible range of answers that can be derived from the model. Each parameter is classified into 4 types depending on sensitivity for calibration and prediction (ASTM standard).

Result of sensitivity analysis is categorized within following matrix as shown in Figure B.VI-02. Auto-command will modify the values from the most sensitive parameter.

Change in Prediction	Change in Calibration: In-significant	Change in Calibration: Significant
In-significant	**Type-I** Both estimated parameters in calibration and prediction are exceeded allowable limitation values of observation.	**Type-II** Estimated parameters in calibration are within limitation but prediction parameters are exceeded allowable limitation values of observation.
Significant	**Type-IV** Estimated parameters in prediction are within limitation but calibration parameters are exceeded allowable limitation values of observation.	**Type-III** Both estimated parameters in calibration and prediction are within allowable limitation values of observation.

Figure B.VI-02 Sensitivity Matrix

(2) Post Audit

A post audit is to compare the outputs of calculation and observation based on the actual input results within confirmation term.

VI-4 Recommendations for Model Improvement

The Cebu-GWM-09 can be improved with accumulated observation data and measured values in the field. Following are recommended activities of data accumulation and model improvement in future.

(1) Data Accumulation

- Well Inventory: Database on abstraction and water quality from Non-MCWD wells
  Hydrogeological information in outside of MCWD franchise area
- Monitoring Wells: 11 sites are nominated as fixed monitoring among MCWD wells
  water quality of Cl, NO_3 and interface freshwater and seawater
  water level of SWL and PWL (well loss)
- Investigation: Fluid Density (PHP95,000) and Borehole Logger (PHP2,925,000)
  to be procured, the cost is quoted without exporting and tax fee
  Seismic Prospecting for conduit flow (PHP6,500,000)
  to be contracted out (surveyor is available in the Philippines)

(2) Model Improvement

- Investigated Data: Abstraction and Water Quality from Non-MCWD Wells
  Fluid Densities of Fresh to Sea Water with TDS
  Geological Boundary by Gamma Log at existing wells
  Confining Layer by Gamma Log at existing wells
  Conduit Flow by Seismic Prospecting at San Vicente Well Field
- Observation Data: SWL/ PWL and Cl at MCWD Wells
  Interface Depth at MCWD Monitoring Wells
- Data Verification: Application of Regional Model
  Review the Water Budgets (both Water Remind and JICA Study)
- Performance: Sensitivity Analysis and Post Audit (2011 until 2015)

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Part-C: Water Supply Improvement
Section-I: Water Demand Projection

II-1 Water Demand Projection

II-1.1 Summary of Assumptions for Water Demand Projection

	A. Domestic Available Demand		EDC Study	MCWD Update		2009 JICA Review
1	Household Population (Based on 2000 NSO Survey)		1995	2000	2006	2007
	Cebu City		654,839	662,171	766,775	798,809
	Lapu-lapu City		173,109	200,303	231,497	292,530
	Mandaue City		194,290	256,262	277,055	318,575
	Compostela		26,389	31,527	33,544	39,167
	Consolacion		49,200	37,871	66,454	87,544
	Cordova		26,553	29,005	36,302	45,066
	Lilo-an		50,844	65,476	69,305	92,181
	Talisay		117,747	99,811	157,991	179,359
	Metro Cebu		1,292,971	1,382,426	1,638,923	1,853,231
2	Population Growth Rate					
	Cebu City		3.00%	1.30%	1.30%	1.46%
	Lapu-lapu City		3.00%	1.30%	1.30%	3.16%
	Mandaue City		3.00%	1.30%	1.30%	2.62%
	Compostela		3.00%	1.30%	1.30%	2.77%
	Consolacion		3.00%	1.30%	1.30%	1.61%
	Cordova		3.00%	1.30%	1.30%	1.81%
	Lilo-an		3.00%	1.30%	1.30%	2.36%
	Talisay		3.00%	1.30%	1.30%	2.67%
3	Degree of Urbanization:					
	Cebu City		100.00%	100.00%	100.00%	100.00%
	Lapu-lapu City		100.00%	100.00%	100.00%	100.00%
	Mandaue City		100.00%	100.00%	100.00%	100.00%
	Compostela		25.10%	25.10%	31.20%	31.80%
	Consolacion		100.00%	100.00%	100.00%	100.00%
	Cordova		100.00%	100.00%	100.00%	100.00%
	Lilo-an		39.70%	39.70%	55.00%	56.60%
	Talisay		100.00%	100.00%	100.00%	100.00%
	Metro Cebu		96.10%	96.10%	96.69%	
4	Degree of Urbanization Growth Rate					
		1995 - 2000	2.02%	2.02%	2.02%	
	Compostela	2001 - 2020	1.98%	1.98%	1.98%	
		2001 - 2030				1.98%
		1995 - 2000	3.21%	3.21%	3.21%	
	Lilo-an	2001 - 2020	2.85%	2.85%	2.85%	
		2001 - 2030				2.85%
5	Percentage of Urban Population Served by MCWD					
	Cebu City		33.62%	45.54%	42.26%	48.26
	Lapu-lapu City		5.18%	11.55%	7.63%	15.58
	Mandaue City		19.15%	18.92%	27.46%	34.27
	Compostela		45.04%	45.04%	52.40%	34.52
	Consolacion		11.33%	11.33%	25.22%	28.63
	Cordova		1.44%	1.44%	56.62%	18.45

	Lilo-an	19.83%	19.83%	29.31%	57.72
	Talisay	10.58%	10.58%	19.47%	21.38
	Metro Cebu	23.48%	30.06%	31.96%	34.88
6	No. of persons per Household (period)	1995-2000	2000-2020	2000 - 2020	2000 - 2030
	Cebu City	5.1	5.1	5.1	5.1
	Lapu-lapu City	5.2	5.1	5.1	5.1
	Mandaue City	4.8	5.1	5.1	5.1
	Compostela	5.1	5.1	5.1	5.1
	Consolacion	4.9	5.1	5.1	5.1
	Cordova	5.3	5.1	5.1	5.1
	Liloan	5.0	5.1	5.1	5.1
	Talisay	5.2	5.1	5.1	5.1
	Metro Cebu	5.1	5.1	5.1	5.1
7	Distribution of Domestic Concessionaires (NSO data)				
	Service Connection	73.00%	73.00%	73.00%	90.00%
	Communal Connection	27.00%	27.00%	27.00%	10.00%
8	Per Capita Consumption (m3/day)				
	Service Connection — 91.6% of served/ un-served population	0.168	0.168		
	Service Connection — 8.4% of served/ un-served population	0.198	0.198		
	Service Connection — Domestic			0.182	0.150
	Communal Connection	0.041	0.041	0.033	0.025
9	Percentage of Un-served Population with HH Connections	29.25%	29.25%	29.25%	40.00%
10	Hose Connection's Per Capita Consumption (m3/day)	0.038	0.038	0.038	0.030
	B. Domestic Demand Niche	**EDC Study**	**MCWD Update**		**2009 JICA Review**
1	Percentage of Un-served Population who are willing to have additional water source	37.14%	37.14%	37.14%	
2	Percentage (of the above) who opt to connect to MCWD	36.44%	36.44%	36.44%	26.00%
	C. Commercial/Industrial Available Demand & Niche	**EDC Study**	**MCWD Update**		**2009 JICA Review**
1	Area (ha)				
	Commercial/Industrial Area	2,738	2,738	3,085	
	Commercial	1,292	1,292	1,276	370
	Industrial	1,446	1,446	1,809	350
2	Development Growth Rate				
	Commercial 1995 - 2000	6.30%	6.30%	6.30%	
	Commercial 2001 - 2030	3.20%	3.20%	3.20%	
	Commercial (Water Remind) 2005 - 2030				3.20%
	Industrial 1995 - 2000	2.79%	2.79%	2.79%	
	Industrial 2001 - 2030	0.69%	0.69%	0.69%	
	Industrial (Water Remind) 2005 - 2030				0.69%
3	Demand Density (m3/day.ha)				(Water Remind)
	Commercial	15	15	15	29.26
	Industrial	27	27	27	129.37
4	Demand Density Growth Rate				
	1995 - 2000	1.00%	1.00%	1.00%	--
	2001 - 2030	1.00%	1.00%	1.00%	--
5	Percentage of Served Commercial/Industrial Demand				
		31.91%	31.91%	31.91%	20.0% in 2007 51.0% in 2015 66.1% in 2030
	D. Government Available Demand & Niche	**EDC Study**	**MCWD Update**		**2009 JICA Review**
1	Total Government Demand (m3/day)	2,021		2,021	2,300
2	Percentage of Government Demand Served by MCWD	100%		100%	100%

I.1-2 Recent Record of Service Connection, Population and Water Consumption in MCWD

Service Connection, Population and Water Consumption in MCWD

Parameter (unit)	Year	Residential		Commercial		Communal		Subdivision/ Condominium		Government		Total	
		No. of SC	Consumption	No. of SC	Consumption	No. of SC	Consumption	No. of SC	Consumption	No. of SC	Consumption	No. of SC	Consumption
Consumption (m^3/year)	2005	98,959	32,327,651	3,529	5,537,508	276	412,669	36	600,367	189	612,296	102,989	39,490,491
	2006	104,262	33,944,819	3,439	5,653,896	232	383,058	39	721,977	184	678,085	108,156	41,381,835
	2007	111,631	34,901,720	3,381	5,533,368	227	368,848	40	756,603	181	761,634	115,460	42,322,173
	2008	115,076	36,463,643	3,369	6,117,383	199	296,848	47	1,108,524	173	843,223	118,864	44,829,621
Consumption (m^3/day)	2005	98,959	88,569	3,529	15,171	276	1,131	36	1,645	189	1,678	102,989	108,194
	2006	104,262	93,000	3,439	15,490	232	1,049	39	1,978	184	1,858	108,156	113,375
	2007	111,631	95,621	3,381	15,160	227	1,011	40	2,073	181	2,087	115,460	115,952
	2008	115,076	99,627	3,369	16,714	199	811	47	3,029	173	2,304	118,864	122,485
Annual Growth Rate (%/ year)	05-06	5.4%	5.0%	-2.6%	2.1%	-15.9%	-7.3%	8.3%	20.2%	-2.6%	10.7%	5.0%	4.8%
	06-07	7.1%	2.8%	-1.7%	-2.1%	-2.2%	-3.6%	2.6%	4.8%	-1.6%	12.3%	6.8%	2.3%
	07-08	3.1%	4.2%	-0.4%	10.3%	-12.3%	-19.8%	17.5%	46.1%	-4.4%	10.4%	2.9%	5.6%
	05-08	5.2%	4.0%	-1.5%	3.3%	-10.3%	-10.5%	9.3%	22.6%	-2.9%	11.1%	4.9%	4.2%
Population Served	2005		504,691				73,195		12,602				590,488
	2006		531,736				61,526		15,443				608,705
	2007		569,318				60,200		16,886				646,404
	2008		586,888				52,775		25,944				665,607
Consumption (Lpcd)	2005		0.1755				0.0155		0.1305				0.1744
	2006		0.1749				0.0170		0.1281				0.1736
	2007		0.1680				0.0168		0.1228				0.1667
	2008		0.1698				0.0154		0.1168				0.1675

II-1.3 Water Demand Projection by LGU

(1) CEBU CITY

2007 Household Population	**798,809**	**Cebu City**	**2007**	**2010**	**2015**
2007 Urban Population	**798,809**	Ave. Population per Household	5.1	5.1	5.1
Population growth rate	**1.46%**	Regular Service Connections	*68,640*	*68,640*	*68,640*
Degree of urbanization	**100%**	Equivalent Served Population	*350,064*	*350,064*	*350,064*
Percentage of urban Pop'n served by MCWD	**48.26%**	Communal Connections	*124*	*124*	*124*
Number of persons per household		Equivalent Served Population	*32,885*	*32,885*	*32,885*
2007 to 2030	**5.1**	Subdivision Connections	*5*	*5*	*5*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equivalent Served Population	*2,550*	*2,550*	*2,550*
Service Connection	**90%**	Total Population Served	*385,499*	*385,499*	*385,499*
Communal Connection	**10%**	Urban Population	798,809	834,300	897,000
Per capita consumption (Lpcd)		% of Domestic Population Served	48.26%	46.21%	42.98%
Residential Connection	**150**				
Communal Connection	**25**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Population Served	*385,499*	*385,499*	*385,499*
Hose connections per capita consumption	**0.030**	Urban Population	964,400	1,036,900	1,114,900
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of Domestic Population Served	39.97%	37.18%	34.58%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**798,809**	834,300	**897,000**	964,400	1,036,900	**1,114,900**
Population growth rate	**1.46%**	1.46%	1.46%	1.46%	1.46%	1.46%
Degree of urbanization	**100%**	100%	100%	100%	100%	100%
Percentage of urban Pop'n served by MCWD (%)	**48.26%**	**46.21%**	**42.98%**	**39.97%**	**37.18%**	**34.58%**
Number of persons per household 2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**798,809**	834,300	**897,000**	964,400	1,036,900	**1,114,900**
Urban Pop'n	**798,809**	834,300	**897,000**	964,400	1,036,900	**1,114,900**
Urban Pop'n unserved	413,310	448,801	511,501	578,901	651,401	729,401

Available Household urban Pop'n	371,979	403,921	460,351	521,011	586,261	656,461
Available domestic demand	55,797	60,588	69,053	78,152	87,939	98,469
Available Communal urban Pop'n	41,331	44,880	51,150	57,890	65,140	72,940
Available communal demand	1,033	1,122	1,279	1,447	1,629	1,824
Total	**56,830**	**61,710**	**70,331**	**79,599**	**89,568**	**100,293**
Less Hose Connection	4,960	4,960	4,960	4,960	4,960	4,960
Add existing domestic S.C.						
Resdl & Commu Available Demand	**51,870**	**56,750**	**65,372**	**74,639**	**84,608**	**95,333**
for Cebu City						
Commercial Available Demand	**23,858**	**24,795**	**26,603**	**28,411**	**30,671**	**32,932**
for Cebu City (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**75,728**	**81,545**	**91,975**	**103,050**	**115,279**	**128,265**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**798,809**	**834,300**	**897,000**	**964,400**	**1,036,900**	**1,114,900**
Urban Pop'n	**798,809**	**834,300**	**897,000**	**964,400**	**1,036,900**	**1,114,900**
Urban Pop'n unserved	0	46,675	132,990	180,617	237,110	303,431
Available Household urban Pop'n	*0*	*42,008*	*119,691*	*162,555*	*213,399*	*273,088*
Available domestic demand	*0*	*6,301*	*17,954*	*24,383*	*32,010*	*40,963*
Available Communal urban Pop'n	*0*	*4,668*	*13,299*	*18,062*	*23,711*	*30,343*
Available communal demand	*0*	*117*	*332*	*452*	*593*	*759*
Total	*0*	*6,418*	*18,286*	*24,835*	*32,603*	*41,722*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***6,418***	***18,286***	***24,835***	***32,603***	***41,722***
for Cebu City						
Commerl Available Demand	***8,475***	***10,189***	***13,551***	***15,034***	***16,710***	***18,747***
for Cebu City (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***8,475***	***16,607***	***31,837***	***39,869***	***49,313***	***60,469***

(2) LAPU-LAPU CITY

2007 Household Population	**292,530**	**Lapu-Lapu City**	**2007**	**2010**	**2015**
2007 Urban Population	**292,530**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**3.16%**	Regular S.C.	*7,766*	*7,766*	*7,766*
Degree of urbanization	**100%**	Equiv. served Pop'n	*39,607*	*39,607*	*39,607*
Percentage of urban Pop'n served by MCWD	**15.58%**	Communal Connections	*18*	*18*	*18*
Number of persons per household		Equiv. Served Pop'n	*4,774*	*4,774*	*4,774*
2007 to 2030	**5.1**	Subdiv. Connections	*3*	*3*	*3*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equiv. served Pop'n	*1,204*	*236*	*236*
Service Connection	**90%**	Total Pop'n served	*45,585*	*45,585*	*45,585*
Communal Connection	**10%**	Urban Population	292,530	321,100	375,200
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	15.58%	14.20%	12.15%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*45,585*	*45,585*	*45,585*
Hose connections per capita consumption	**0.030**	Urban Population	438,300	512,100	598,300
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	10.40%	8.90%	7.62%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**292,530**	321,100	**375,200**	438,300	512,100	**598,300**
Population growth rate	**3.16%**	3.16%	3.16%	3.16%	3.16%	3.16%
Degree of urbanization	**100%**	100%	100%	100%	100%	100%
Percentage of urban Pop'n served by MCWD (%)	**15.58%**	**14.20%**	**12.15%**	**10.40%**	**8.90%**	**7.62%**
Number of persons per household 2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**292,530**	321,100	**375,200**	438,300	512,100	**598,300**
Urban Pop'n	**292,530**	321,100	**375,200**	438,300	512,100	**598,300**
Urban Pop'n unserved	246,945	275,515	329,615	392,715	466,515	552,715
Available Household urban Pop'n	222,251	247,964	296,654	353,444	419,864	497,444
Available domestic demand	33,338	37,195	44,498	53,017	62,980	74,617
Available Communal urban Pop'n	24,695	27,552	32,962	39,272	46,652	55,272
Available communal demand	617	689	824	982	1,166	1,382

Total	**33,955**	**37,883**	**45,322**	**53,998**	**64,146**	**75,998**
Less Hose Connection	2,963	2,963	2,963	2,963	2,963	2,963
Add existing domestic S.C.						
Resdl & Commu Available Demand	**30,992**	**34,920**	**42,359**	**51,035**	**61,182**	**73,035**
for Lapu-Lapu City						
Commercial Available Demand	**19,721**	**20,247**	**21,288**	**22,329**	**23,630**	**24,932**
for Lapu-Lapu City (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**50,713**	**55,167**	**63,647**	**73,364**	**84,812**	**97,967**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**292,530**	**321,100**	**375,200**	**438,300**	**512,100**	**598,300**
Urban Pop'n	**292,530**	**321,100**	**375,200**	**438,300**	**512,100**	**598,300**
Urban Pop'n unserved	0	28,654	85,700	122,527	169,811	229,929
Available Household urban Pop'n	*0*	*25,788*	*77,130*	*110,274*	*152,830*	*206,936*
Available domestic demand	*0*	*3,868*	*11,569*	*16,541*	*22,925*	*31,040*
Available Communal urban Pop'n	*0*	*2,865*	*8,570*	*12,253*	*16,981*	*22,993*
Available communal demand	*0*	*72*	*214*	*306*	*425*	*575*
Total	*0*	*3,940*	*11,784*	*16,847*	*23,349*	*31,615*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***3,940***	***11,784***	***16,847***	***23,349***	***31,615***
for Lapu-Lapu City						
Commerl Available Demand	***3,416***	***5,183***	***8,420***	***9,638***	***10,915***	***12,453***
for Lapu-Lapu City (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***3,416***	***9,123***	***20,204***	***26,485***	***34,264***	***44,068***

(3) MANDAUE CITY

2007 Household Population	**318,575**	**Mandaue City**	**2007**	**2010**	**2015**
2007 Urban Population	**318,575**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**2.62%**	Regular S.C.	*18,829*	*18,829*	*18,829*
Degree of urbanization	**100%**	Equiv. served Pop'n	*96,028*	*96,028*	*96,028*
Percentage of urban Pop'n served by MCWD	**34.27%**	Communal Connections	*47*	*47*	*47*
Number of persons per household		Equiv. Served Pop'n	*12,464*	*12,464*	*12,464*
2007 to 2030	**5.1**	Subdiv. Connections	*1*	*1*	*1*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equiv. served Pop'n	*694*	*136*	*136*
Service Connection	**90%**	Total Pop'n served	*109,186*	*109,186*	*109,186*
Communal Connection	**10%**	Urban Population	318,575	344,300	391,300
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	34.27%	31.71%	27.90%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*109,186*	*109,186*	*109,186*
Hose connections per capita consumption	**0.030**	Urban Population	445,900	507,400	577,500
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	24.49%	21.52%	18.91%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**318,575**	344,300	**391,300**	445,900	507,400	**577,500**
Population growth rate	**2.62%**	2.62%	2.62%	2.62%	2.62%	2.62%
Degree of urbanization	**100%**	100%	100%	100%	100%	100%
Percentage of urban Pop'n served by MCWD (%)	**34.27%**	**31.71%**	**27.90%**	**24.49%**	**21.52%**	**18.91%**
Number of persons per household 2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**318,575**	344,300	**391,300**	445,900	507,400	**577,500**
Urban Pop'n	**318,575**	344,300	**391,300**	445,900	507,400	**577,500**
Urban Pop'n unserved	209,389	235,114	282,114	336,714	398,214	468,314
Available Household urban Pop'n	188,450	211,603	253,903	303,043	358,393	421,483
Available domestic demand	28,268	31,740	38,085	45,456	53,759	63,222
Available Communal urban Pop'n	20,939	23,511	28,211	33,671	39,821	46,831
Available communal demand	523	588	705	842	996	1,171

Total	**28,791**	**32,328**	**38,791**	**46,298**	**54,754**	**64,393**
Less Hose Connection	2,513	2,513	2,513	2,513	2,513	2,513
Add existing domestic S.C.						
Resdl & Commu Available Demand	**26,278**	**29,816**	**36,278**	**43,786**	**52,242**	**61,881**
for Mandaue City						
Commercial Available Demand	**21,562**	**21,973**	**22,808**	**23,644**	**24,671**	**25,699**
for Mandaue City (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**47,840**	**51,789**	**59,086**	**67,430**	**76,913**	**87,580**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**318,575**	**344,300**	**391,300**	**445,900**	**507,400**	**577,500**
Urban Pop'n	**318,575**	**344,300**	**391,300**	**445,900**	**507,400**	**577,500**
Urban Pop'n unserved	0	24,452	73,350	105,055	144,950	194,819
Available Household urban Pop'n	*0*	*22,007*	*66,015*	*94,549*	*130,455*	*175,337*
Available domestic demand	*0*	*3,301*	*9,902*	*14,182*	*19,568*	*26,301*
Available Communal urban Pop'n	*0*	*2,445*	*7,335*	*10,505*	*14,495*	*19,482*
Available communal demand	*0*	*42*	*125*	*179*	*246*	*331*
Total	*0*	*3,343*	*10,027*	*14,361*	*19,815*	*26,632*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***3,343***	***10,027***	***14,361***	***19,815***	***26,632***
for Mandaue City						
Commerl Available Demand	***1,831***	***3,946***	***7,705***	***9,007***	***10,305***	***11,855***
for Mandaue City (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***1,831***	***7,289***	***17,732***	***23,368***	***30,120***	***38,487***

(4) COMPOSTELA

2007 Household Population	**39,167**	**Compostela**	**2007**	**2010**	**2015**
2007 Urban Population	**12,455**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**2.77%**	Regular S.C.	*843*	*843*	*843*
Degree of urbanization	**31.80%**	Equiv. served Pop'n	*4,299*	*4,299*	*4,299*
Percentage of urban Pop'n served by MCWD	**34.52%**	Communal Connections	*0*	*0*	*0*
Number of persons per household		Equiv. Served Pop'n	*0*	*0*	*0*
2007 to 2030	**5.1**	Subdiv. Connections	*0*	*0*	*0*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equiv. served Pop'n	*0*	*0*	*0*
Service Connection	**90%**	Total Pop'n served	*4,299*	*4,299*	*4,299*
Communal Connection	**10%**	Urban Population	12,455	14,334	18,117
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	34.52%	29.99%	23.73%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*4,299*	*4,299*	*4,299*
Hose connections per capita consumption	**0.030**	Urban Population	22,937	28,965	36,641
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	18.74%	14.84%	11.73%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**39,167**	42,500	**48,700**	55,900	64,000	**73,400**
Population growth rate	**2.77%**	2.77%	2.77%	2.77%	2.77%	2.77%
Degree of urbanization	**31.80%**	33.73%	37.20%	41.03%	45.26%	49.92%
Percentage of urban Pop'n served by MCWD (%)	**34.52%**	**29.99%**	**23.73%**	**18.74%**	**14.84%**	**11.73%**
Number of persons per household						
2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**39,167**	42,500	**48,700**	55,900	64,000	**73,400**
Urban Pop'n	**12,455**	14,334	**18,117**	22,937	28,965	**36,641**
Urban Pop'n unserved	8,156	10,035	13,818	18,638	24,666	32,342
Available Household urban Pop'n	7,340	9,031	12,436	16,774	22,200	29,108
Available domestic demand	1,101	1,355	1,865	2,516	3,330	4,366
Available Communal urban Pop'n	816	1,003	1,382	1,864	2,467	3,234
Available communal demand	20	25	35	47	62	81

Total	**1,121**	**1,380**	**1,900**	**2,563**	**3,392**	**4,447**
Less Hose Connection	98	98	98	98	98	98
Add existing domestic S.C.						
Resdl & Commu Available Demand	**1,024**	**1,282**	**1,802**	**2,465**	**3,294**	**4,349**
for Compostela						
Commercial Available Demand	**745**	**795**	**890**	**986**	**1,123**	**1,260**
for Compostela (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**1,769**	**2,077**	**2,692**	**3,451**	**4,417**	**5,609**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**39,167**	**42,500**	**48,700**	**55,900**	**64,000**	**73,400**
Urban Pop'n	**12,455**	**14,334**	**18,117**	**22,937**	**28,965**	**36,641**
Urban Pop'n unserved	0	1,044	3,593	5,815	8,979	13,454
Available Household urban Pop'n	*0*	*939*	*3,233*	*5,234*	*8,081*	*12,109*
Available domestic demand	*0*	*141*	*485*	*785*	*1,212*	*1,816*
Available Communal urban Pop'n	*0*	*104*	*359*	*582*	*898*	*1,345*
Available communal demand	*0*	*2*	*6*	*10*	*15*	*23*
Total	*0*	*143*	*491*	*795*	*1,227*	*1,839*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***143***	***491***	***795***	***1,227***	***1,839***
for Compostela						
Commerl Available Demand	***118***	***189***	***334***	***404***	***491***	***598***
for Compostela (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***118***	***332***	***825***	***1,199***	***1,718***	***2,437***

(5) CONSOLACION

2007 Household Population	**87,544**	**Consolacion**	**2007**	**2010**	**2015**
2007 Urban Population	**87,544**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**1.61%**	Regular S.C.	*3,661*	*3,661*	*3,661*
Degree of urbanization	**100%**	Equiv. served Pop'n	*18,671*	*18,671*	*18,671*
Percentage of urban Pop'n served by MCWD	**28.63%**	Communal Connections	*12*	*12*	*12*
Number of persons per household		Equiv. Served Pop'n	*3,182*	*3,182*	*3,182*
2007 to 2030	**5.1**	Subdiv. Connections	*8*	*8*	*8*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equiv. served Pop'n	*3,208*	*629*	*629*
Service Connection	**90%**	Total Pop'n served	*25,061*	*25,061*	*25,061*
Communal Connection	**10%**	Urban Population	87,544	91,800	99,500
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	28.63%	27.30%	25.19%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*25,061*	*25,061*	*25,061*
Hose connections per capita consumption	**0.030**	Urban Population	107,700	116,700	126,400
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	23.27%	21.47%	19.83%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**87,544**	91,800	**99,500**	107,700	116,700	**126,400**
Population growth rate	**1.61%**	1.61%	1.61%	1.61%	1.61%	1.61%
Degree of urbanization	**100%**	100%	100%	100%	100%	100%
Percentage of urban Pop'n served by MCWD (%)	**28.63%**	**27.30%**	**25.19%**	**23.27%**	**21.47%**	**19.83%**
Number of persons per household 2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**

Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**87,544**	91,800	**99,500**	107,700	116,700	**126,400**
Urban Pop'n	**87,544**	91,800	**99,500**	107,700	116,700	**126,400**
Urban Pop'n unserved	62,483	66,739	74,439	82,639	91,639	101,339
Available Household urban Pop'n	56,235	60,065	66,995	74,375	82,475	91,205
Available domestic demand	8,435	9,010	10,049	11,156	12,371	13,681
Available Communal urban Pop'n	6,248	6,674	7,444	8,264	9,164	10,134
Available communal demand	156	167	186	207	229	253

Total	**8,591**	**9,177**	**10,235**	**11,363**	**12,600**	**13,934**
Less Hose Connection	750	750	750	750	750	750
Add existing domestic S.C.						
Resdl & Commu Available Demand	**7,842**	**8,427**	**9,486**	**10,613**	**11,851**	**13,184**
for Consolacion						
Commercial Available Demand	**515**	**548**	**616**	**685**	**781**	**877**
for Consolacion (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**8,357**	**8,975**	**10,102**	**11,298**	**12,632**	**14,061**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**87,544**	**91,800**	**99,500**	**107,700**	**116,700**	**126,400**
Urban Pop'n	**87,544**	**91,800**	**99,500**	**107,700**	**116,700**	**126,400**
Urban Pop'n unserved	0	6,941	19,354	25,783	33,357	42,157
Available Household urban Pop'n	*0*	*6,247*	*17,419*	*23,205*	*30,021*	*37,941*
Available domestic demand	*0*	*937*	*2,613*	*3,481*	*4,503*	*5,691*
Available Communal urban Pop'n	*0*	*694*	*1,935*	*2,578*	*3,336*	*4,216*
Available communal demand	*0*	*12*	*33*	*44*	*57*	*72*
Total	*0*	*949*	*2,646*	*3,525*	*4,560*	*5,763*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***949***	***2,646***	***3,525***	***4,560***	***5,763***
for Consolacion						
Commerl Available Demand	***31***	***85***	***195***	***246***	***309***	***386***
for Conslacion (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***31***	***1,034***	***2,841***	***3,771***	***4,869***	***6,149***

(6) CORDOVA

2007 Household Population	**45,066**	**Coldva**	**2007**	**2010**	**2015**
2007 Urban Population	**45,066**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**1.81%**	Regular S.C.	*666*	*666*	*666*
Degree of urbanization	**100%**	Equiv. served Pop'n	*3,397*	*3,397*	*3,397*
Percentage of urban Pop'n served by MCWD	**18.45%**	Communal Connections	*14*	*14*	*14*
Number of persons per household		Equiv. Served Pop'n	*3,713*	*3,713*	*3,713*
2007 to 2030	**5.1**	Subdiv. Connections	*3*	*3*	*3*
Distribution of Domestic Concessionaires		Equiv. served Pop'n			
(2009 JICA Household Survey data)			*1,204*	*236*	*236*
Service Connection	**90%**	Total Pop'n served	*8,314*	*8,314*	*8,314*
Communal Connection	**10%**	Urban Population	45,066	47,600	52,000
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	18.45%	17.47%	15.99%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*8,314*	*8,314*	*8,314*
Hose connections per capita consumption	**0.030**	Urban Population	56,900	62,200	68,100
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	14.61%	13.37%	12.21%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**45,066**	47,600	**52,000**	56,900	62,200	**68,100**
Population growth rate	**1.81%**	1.81%	1.81%	1.81%	1.81%	1.81%
Degree of urbanization	**100%**	100%	100%	100%	100%	100%
Percentage of urban Pop'n served by MCWD (%)	**18.45%**	**17.47%**	**15.99%**	**14.61%**	**13.37%**	**12.21%**
Number of persons per household						
2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**45,066**	47,600	**52,000**	56,900	62,200	**68,100**
Urban Pop'n	**45,066**	47,600	**52,000**	56,900	62,200	**68,100**
Urban Pop'n unserved	36,752	39,286	43,686	48,586	53,886	59,786
Available Household urban Pop'n	33,077	35,357	39,317	43,727	48,497	53,807
Available domestic demand	4,962	5,304	5,898	6,559	7,275	8,071
Available Communal urban Pop'n	3,675	3,929	4,369	4,859	5,389	5,979
Available communal demand	92	98	109	121	135	149

Total	**5,053**	**5,402**	**6,007**	**6,681**	**7,409**	**8,221**
Less Hose Connection	441	441	441	441	441	441
Add existing domestic S.C.						
Resdl & Commu Available Demand	**4,612**	**4,961**	**5,566**	**6,240**	**6,968**	**7,780**
for Cordova						
Commercial Available Demand	**937**	**986**	**1,096**	**1,205**	**1,356**	**1,507**
for Cordova (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**5,549**	**5,947**	**6,662**	**7,445**	**8,324**	**9,287**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**45,066**	**47,600**	**52,000**	**56,900**	**62,200**	**68,100**
Urban Pop'n	**45,066**	**47,600**	**52,000**	**56,900**	**62,200**	**68,100**
Urban Pop'n unserved	0	4,086	11,358	15,159	19,615	24,871
Available Household urban Pop'n	*0*	*3,677*	*10,223*	*13,643*	*17,653*	*22,384*
Available domestic demand	*0*	*552*	*1,533*	*2,046*	*2,648*	*3,358*
Available Communal urban Pop'n	*0*	*409*	*1,136*	*1,516*	*1,961*	*2,487*
Available communal demand	*0*	*7*	*19*	*26*	*33*	*42*
Total	*0*	*559*	*1,553*	*2,072*	*2,681*	*3,400*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***559***	***1,553***	***2,072***	***2,681***	***3,400***
for Cordova						
Commerl Available Demand	***150***	***238***	***415***	***497***	***597***	***720***
for Cordova (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***150***	***797***	***1,968***	***2,569***	***3,278***	***4,120***

(7) LILOAN

2007 Household Population	**92,181**	**Liloan**	**2007**	**2010**	**2015**
2007 Urban Population	**52,174**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**2.36%**	Regular S.C.	*4,441*	*4,441*	*4,441*
Degree of urbanization	**56.60%**	Equiv. served Pop'n	*22,649*	*22,649*	*22,649*
Percentage of urban Pop'n served by MCWD	**57.72%**	Communal Connections	*10*	*10*	*10*
Number of persons per household		Equiv. Served Pop'n	*2,652*	*2,652*	*2,652*
2007 to 2030	**5.1**	Subdiv. Connections	*12*	*12*	*12*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equiv. served Pop'n	*4,814*	*944*	*944*
Service Connection	**90%**	Total Pop'n served	*30,115*	*30,115*	*30,115*
Communal Connection	**10%**	Urban Population	52,174	60,901	78,734
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	57.72%	49.45%	38.25%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*30,115*	*30,115*	*30,115*
Hose connections per capita consumption	**0.030**	Urban Population	101,786	131,690	157,600
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	29.59%	22.87%	19.11%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**92,181**	98,900	**111,100**	124,800	140,300	**157,600**
Population growth rate	**2.77%**	2.77%	2.77%	2.77%	2.77%	2.77%
Degree of urbanization	**56.60%**	61.58%	70.87%	81.56%	93.86%	100.00%
Percentage of urban Pop'n served by MCWD (%)	**57.72%**	**49.45%**	**38.25%**	**29.59%**	**22.87%**	**19.11%**
Number of persons per household 2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**160.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**92,181**	98,900	**111,100**	124,800	140,300	**157,600**
Urban Pop'n	**52,174**	60,901	**78,734**	101,786	131,690	**157,600**
Urban Pop'n unserved	22,059	30,786	48,619	71,671	101,575	127,485
Available Household urban Pop'n	19,854	27,708	43,758	64,504	91,417	114,737
Available domestic demand	2,978	4,156	6,564	9,676	13,713	17,210
Available Communal urban Pop'n	2,206	3,079	4,862	7,167	10,157	12,749
Available communal demand	55	77	122	179	254	319

Total	**3,033**	**4,233**	**6,685**	**9,855**	**13,967**	**17,529**
Less Hose Connection	265	265	265	265	265	265
Add existing domestic S.C.						
Resdl & Commu Available Demand	**2,768**	**3,968**	**6,420**	**9,590**	**13,702**	**17,264**
for Liloan						
Commercial Available Demand	**1,967**	**2,082**	**2,315**	**2,548**	**2,863**	**3,178**
for Liloan (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**4,735**	**6,050**	**8,735**	**12,138**	**16,565**	**20,442**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**92,181**	**98,900**	**111,100**	**124,800**	**140,300**	**157,600**
Urban Pop'n	**52,174**	**60,901**	**78,734**	**101,786**	**131,690**	**157,600**
Urban Pop'n unserved	0	3,202	12,641	22,361	42,255	53,034
Available Household urban Pop'n	*0*	*2,882*	*11,377*	*20,125*	*38,030*	*47,730*
Available domestic demand	*0*	*432*	*1,707*	*3,019*	*5,704*	*7,160*
Available Communal urban Pop'n	*0*	*320*	*1,264*	*2,236*	*4,226*	*5,303*
Available communal demand	*0*	*5*	*21*	*38*	*72*	*90*
Total	*0*	*438*	*1,728*	*3,057*	*5,776*	*7,250*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***438***	***1,728***	***3,057***	***5,776***	***7,250***
for Liloan						
Commerl Available Demand	***120***	***326***	***735***	***919***	***1,138***	***1,404***
for Liloan (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***120***	***764***	***2,463***	***3,976***	***6,914***	***8,654***

(8) TALISAY CITY

2007 Household Population	**179,359**	**Talisay City**	**2007**	**2010**	**2015**
2007 Urban Population	**179,359**	Ave. Pop'n per Household	5.1	5.1	5.1
Population growth rate	**2.67%**	Regular S.C.	*6,785*	*6,785*	*6,785*
Degree of urbanization	**100%**	Equiv. served Pop'n	*34,604*	*34,604*	*34,604*
Percentage of urban Pop'n served by MCWD	**21.38%**	Communal Connections	*2*	*2*	*2*
Number of persons per household 2007 to 2030	**5.1**	Equiv. Served Pop'n	*530*	*530*	*530*
		Subdiv. Connections	*8*	*8*	*8*
Distribution of Domestic Concessionaires (2009 JICA Household Survey data)		Equiv. served Pop'n	*3,213*	*630*	*630*
Service Connection	**90%**	Total Pop'n served	*38,347*	*38,347*	*38,347*
Communal Connection	**10%**	Urban Population	179,359	194,100	221,400
Per capita consumption (cu.m./person/day)		% of domestic Pop'n served	21.38%	19.76%	17.32%
Residential Connection	**0.150**				
Communal Connection	**0.025**		**2020**	**2025**	**2030**
Percentage of unserved Pop'n with Hose Connections	**40.00%**	Total Pop'n served	*38,347*	*38,347*	*38,347*
Hose connections per capita consumption	**0.030**	Urban Population	252,600	288,200	328,800
Domestic Niche: % of unserved Pop'n willing to have	**26.00%**	% of domestic Pop'n served	15.18%	13.31%	11.66%
% who opt to connect to MCWD	**100.00%**				

ACTUAL DATA	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Population	**179,359**	194,100	**221,400**	252,600	288,200	**328,800**
Population growth rate	**2.67%**	2.67%	2.67%	2.67%	2.67%	2.67%
Degree of urbanization	**100%**	100%	100%	100%	100%	100%
Percentage of urban Pop'n served by MCWD (%)	**21.38%**	**19.76%**	**17.32%**	**15.18%**	**13.31%**	**11.66%**
Number of persons per household 2007 to 2030	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
Distribution of Domestic Concessionaires (2009 survey)						
Service Connection	**90%**	**90%**	**90%**	**90%**	**90%**	**90%**
Communal Connection	**10%**	**10%**	**10%**	**10%**	**10%**	**10%**
Per capita consumption (cu.m./person/day)	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**	**0.150**
Communal Connection	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**	**0.025**
Percentage of unserved Pop'n with Hose Connections						
Hose connections per capita consumption						
Domestic Niche:						
% of unserved Pop'n willing to have MCWD connection	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***	***26.00%***
% who opt to connect to MCWD	**0.00%**	**40.00%**	**100.00%**	**120.00%**	**140.00%**	**160.00%**
Available Demand	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**179,359**	194,100	**221,400**	252,600	288,200	**328,800**
Urban Pop'n	**179,359**	194,100	**221,400**	252,600	288,200	**328,800**
Urban Pop'n unserved	141,012	155,753	183,053	214,253	249,853	290,453
Available Household urban Pop'n	126,911	140,178	164,748	192,828	224,868	261,408
Available domestic demand	19,037	21,027	24,712	28,924	33,730	39,211
Available Communal urban Pop'n	14,101	15,575	18,305	21,425	24,985	29,045
Available communal demand	353	389	458	536	625	726

Total	**19,389**	**21,416**	**25,170**	**29,460**	**34,355**	**39,937**
Less Hose Connection	1,692	1,692	1,692	1,692	1,692	1,692
Add existing domestic S.C.						
Resdl & Commu Available Demand	**17,697**	**19,724**	**23,478**	**27,768**	**32,663**	**38,245**
for Talisay City						
Commercial Available Demand	**6,411**	**6,658**	**7,164**	**7,671**	**8,288**	**8,904**
for Talisay City (by Water Remind)						
Total Available Demand (Residential, Communal & Commercial)	**24,108**	**26,382**	**30,642**	**35,439**	**40,951**	**47,149**
Demand Niche	**2007**	**2010**	**2015**	**2020**	**2025**	**2030**
Household Pop'n	**179,359**	**194,100**	**221,400**	**252,600**	**288,200**	**328,800**
Urban Pop'n	**179,359**	**194,100**	**221,400**	**252,600**	**288,200**	**328,800**
Urban Pop'n unserved	0	16,198	47,594	66,847	90,946	120,828
Available Household urban Pop'n	*0*	*14,578*	*42,834*	*60,162*	*81,852*	*108,746*
Available domestic demand	*0*	*2,187*	*6,425*	*9,024*	*12,278*	*16,312*
Available Communal urban Pop'n	*0*	*1,620*	*4,759*	*6,685*	*9,095*	*12,083*
Available communal demand	*0*	*28*	*81*	*114*	*155*	*205*
Total	*0*	*2,214*	*6,506*	*9,138*	*12,432*	*16,517*
Less Hose Connections	*0*	*0*	*0*	*0*	*0*	*0*
Add existing domestic S.C.						
Resdl & Commu Demand (Niche)	***0***	***2,214***	***6,506***	***9,138***	***12,432***	***16,517***
for Talisay City						
Commerl Available Demand	***1,019***	***1,611***	***2,740***	***3,208***	***3,716***	***4,331***
for Talisay City (by Water Remind)						
Total Demand Niche (Residential, Communal & Commercial)	***1,019***	***3,825***	***9,246***	***12,346***	***16,148***	***20,848***

I-1.4 Commercial and Industrial Water Demand Projection

Table C.I-01 Total Commercial and Industrial Water Demand by Water Remind (m^3/day)

LGU	2007	2010	2015	2020	2025	2030
Cebu City	23,858	24,795	26,603	28,411	30,671	32,932
Lapu Lapu City	19,721	20,247	21,288	22,329	23,630	24,932
Mandaue City	21,562	21,973	22,808	23,644	24,671	25,699
Compostela	745	795	890	986	1,123	1,260
Consolacion	515	548	616	685	781	877
Cordova	937	986	1,096	1,205	1,356	1,507
Liloan	1,967	2,082	2,315	2,548	2,863	3,178
Talisay	6,411	6,658	7,164	7,671	8,288	8,904
Metro Cebu	75,715	78,082	82,781	87,479	93,383	99,287

Table C.I-02 Niche Commercial and Industrial Water Demand (m^3/day)

LGU	2007	2010	2015	2020	2025	2030
Cebu City	8,475	10,189	13,551	15,034	16,710	18,747
Lapu Lapu City	3,416	5,183	8,420	9,638	10,915	12,453
Mandaue City	1,831	3,946	7,705	9,007	10,305	11,855
Compostela	118	189	334	404	491	598
Consolacion	31	85	195	246	309	386
Cordova	150	238	415	497	597	720
Liloan	120	326	735	919	1,138	1,404
Talisay	1,019	1,611	2,740	3,208	3,716	4,331
Metro Cebu	15,160	21,767	34,094	38,953	44,181	50,494

Non-MCWD	60,555	62,922	67,621	72,319	78,223	84,127
Connection rate	0.00	0.105	0.28	0.329	0.371	0.42
Available Demand	0	6,607	18,934	23,793	29,021	35,334
Existing Demand	15,160	15,160	15,160	15,160	15,160	15,160
Total	15,160	21,767	34,094	38,953	44,181	50,494

Table C.I-02 Existing Commercial and Industrial Water Demand (m^3/day)

LGU	2007	2010-2030	Zone	Share	MCWD Consu	
Cebu City	8,475	8,475	1-16		1-16: 8475	
Lapu Lapu City	3,416	3,416	19	0.875		
Mandaue City	1,831	1,831	17-18		17-18: 1831	
Compostela	118	118	20	0.092		
Consolacion	31	31	19	0.026	19: 1207	
Cordova	150	150	20	0.116		
Liloan	120	120	19	0.099		
Talisay	1,019	1,019	20	0.792	20: 3647	MEPZA: 23 60
Metro Cebu	15,160	15,160			1-20: 15160	

Table C.I-03 Available Commercial and Industrial Water Demand (m^3/day)

LGU	2007	2010	2015	2020	2025	2030
Cebu City	0	1,714	5,076	6,559	8,235	10,272
Lapu Lapu City	0	1,767	5,004	6,222	7,499	9,037
Mandaue City	0	2,115	5,874	7,176	8,474	10,024
Compostela	0	71	216	286	373	480
Consolacion	0	54	164	215	278	355
Cordova	0	88	265	347	447	570
Liloan	0	206	615	799	1,018	1,284
Talisay	0	592	1,721	2,189	2,697	3,312
Metro Cebu	0	6,607	18,934	23,793	29,021	35,334

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Section-II: Improvements of Water Supply System and Facilities

(1) Framework of the Distribution Block

1) Summary of Distribution Block

- Tisa DB covers 52% of Cebu City population, while Talamban covers 48%
- Government volume, 2,300 m^3/day is included in Tisa DB

Table C.II-01 Summary of Distribution Block

Distribution Block			Lagtang	Tisa	Talamban	Casili	CLC	Mactan	Total
Main Reservoir			Lagtang	Tisa	Talamban	Casili New	Casili Old	Pusok	
LGU covered			Talisay City	South Cebu City	North Cebu City	Mandaue City	Compostela Lilo-an Consolacion	Lupu-lapu City Cordova	
Service Population	Capita	2007	38,347	200,459	185,040	109,186	59,475	53,899	646,406
		2015	85,941	224,730	207,444	182,536	95,063	150,957	946,671
		2030	159,175	323,757	298,852	304,005	168,120	308,699	1,562,608
Unit Volume	lpcd		Residential User 150 L						
			Communal User 25L						
Fluctuation Factor	-		Daily Average : Daily Maximum : Hourly Maximum = 1.0 : 1.2 : 2.2						
Domestic /Government	m^3/day	2007	5,282	33,267	30,209	14,827	9,081	8,338	101,005
		2015	11,901	43,615	38,137	24,553	14,145	21,674	154,025
		2030	21,903	55,816	49,399	41,147	24,125	43,353	235,743
Commercial /Institutional	m^3/day	2007	974	3,223	5,240	1,855	303	3,566	15,160
		2015	2,740	5,149	8,402	7,705	1,264	8,835	34,095
		2030	4,331	7,124	11,623	11,855	2,388	13,173	50,494
NRW (2007 30% 2015 20% 2030 17%)	m^3/day	2007	2,681	15,640	15,192	7,149	4,021	5,102	49,785
		2015	3,660	12,192	11,634	8,065	3,852	7,627	47,030
		2030	5,373	12,891	12,499	10,856	5,430	11,578	58,627
DAF	m^3/day	2007	8,937	52,130	50,641	23,831	13,405	17,006	165,950
		2015	18,301	60,956	58,173	40,323	19,261	38,136	235,150
		2030	31,607	75,831	73,521	63,858	31,943	68,104	344,864
DMF	m^3/day	2007	10,724	62,556	60,769	28,597	16,086	20,407	199,140
		2015	21,961	73,147	69,808	48,388	23,113	45,763	282,180
		2030	37,928	90,997	88,225	76,630	38,332	81,725	413,837
HMF	m^3/day	2007	19,661	114,687	111,410	52,428	29,491	37,413	365,090
		2015	40,262	134,103	127,981	88,711	42,374	83,899	517,330
		2030	69,535	166,828	161,746	140,488	70,275	149,829	758,701

2) Increase Rate by Distribution Block

Compared with fairly matured Cebu City, demand increase rate from 2007 to 2015 of surrounding cities and municipalities are comparatively high as is shown in the following figures.

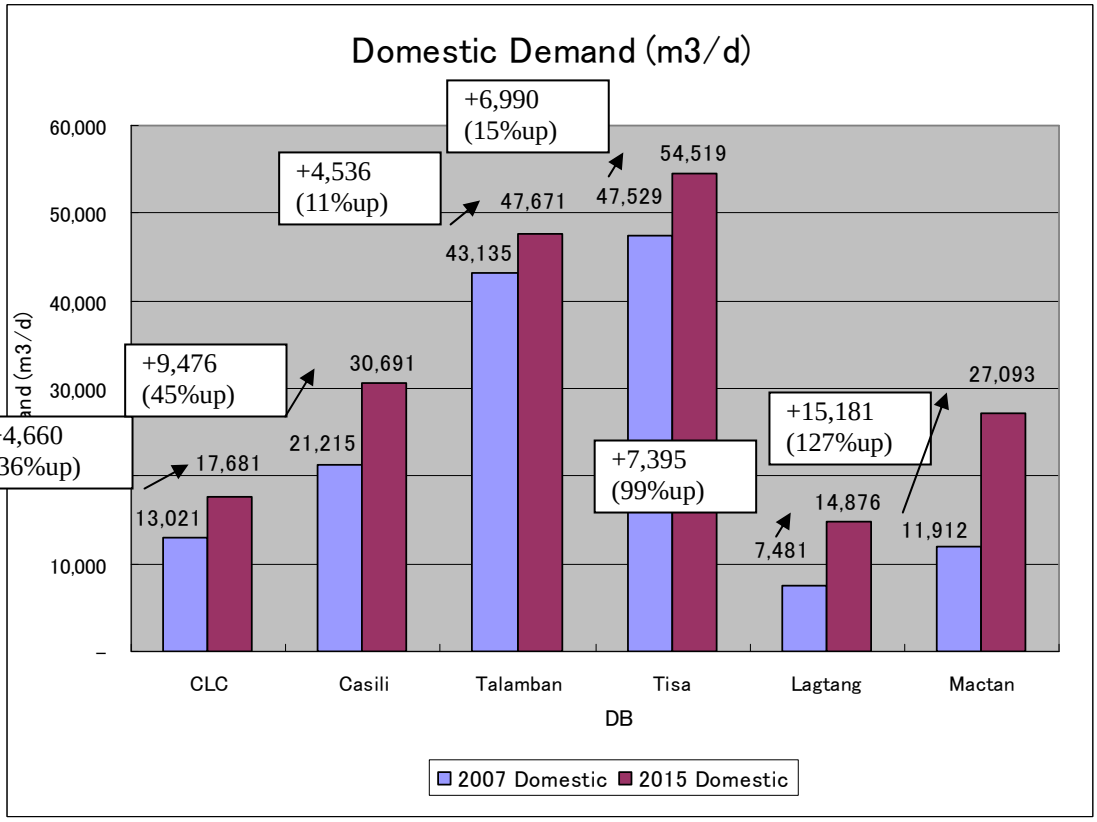


Figure C.II-01 Domestic Demand Increase by DB

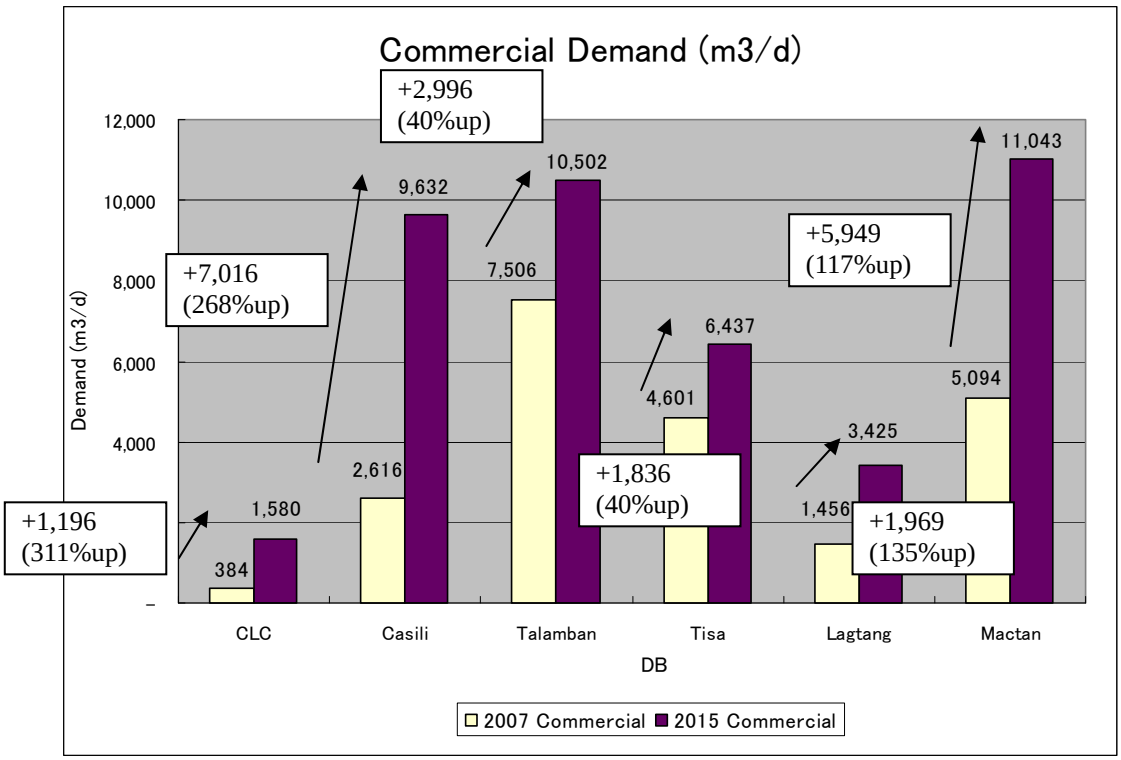


Figure C.II-02 Commercial Demand Increase by DB

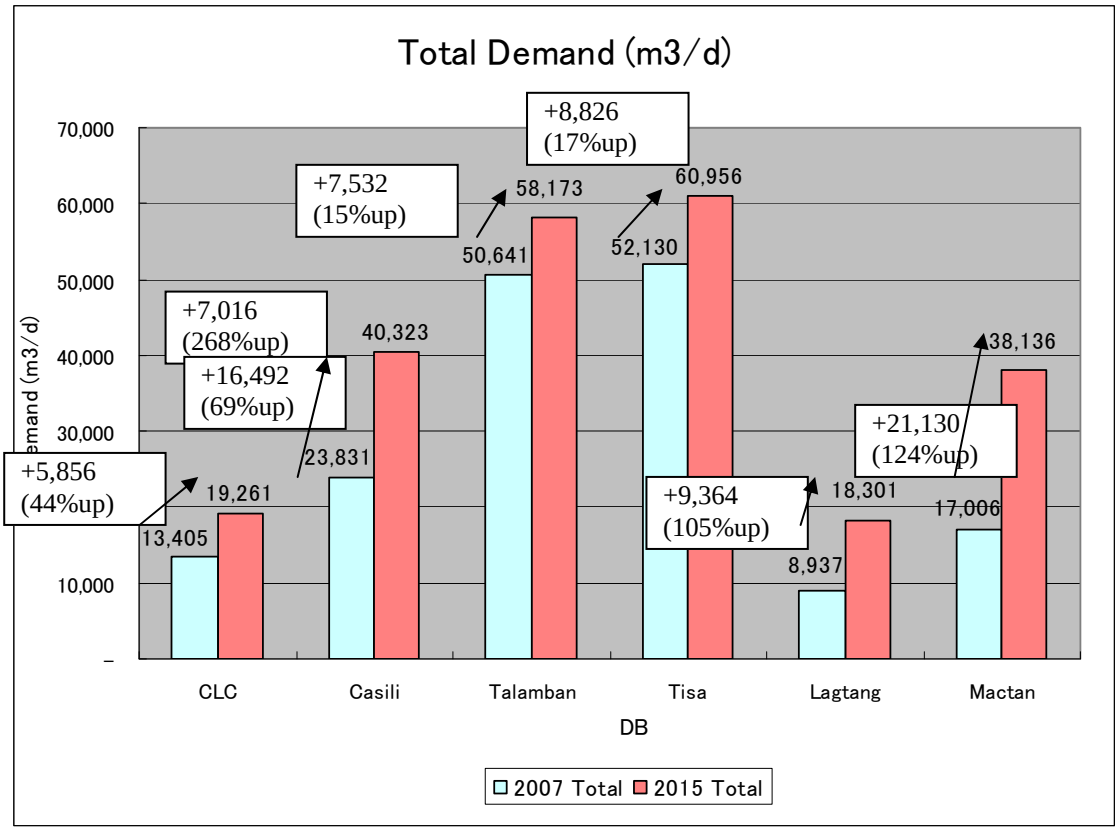


Figure C.II-03 Commercial Demand Increase by DB

This figure is on supply base, which means each volume includes NRW whose rate is 30% in 2007 and 20% in 2015.

Government volume is included in domestic use.

Table C.II-02 Increasing Volume of Water Demand

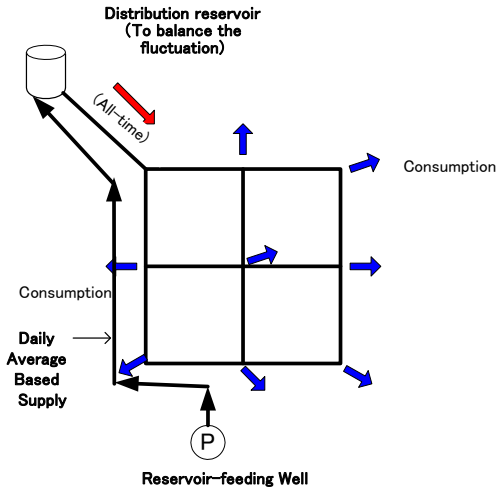
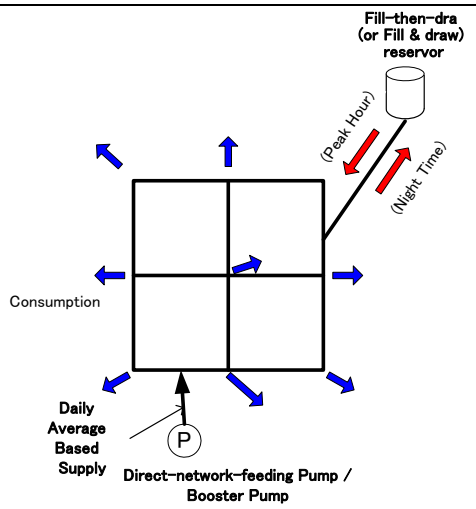
	2007			2015		
	Domestic	Commercial	Total	Domestic	Commercial	Total
CLC	13,021	384	13,405	17,681	1,580	19,261
Casili	21,215	2,616	23,831	30,691	9,632	40,323
Talamban	43,135	7,506	50,641	47,671	10,502	58,173
Tisa	47,529	4,601	52,130	54,519	6,437	60,956
Lagtang	7,481	1,456	8,937	14,876	3,425	18,301
Mactan	11,912	5,094	17,006	27,093	11,043	38,136
Total	144,293	21,657	165,950	192,531	42,619	235,150

(2) Design Concept and Criteria

1) Comparison of Gravity Distribution Reservoir and Fill & Draw Reservoir

Two types of reservoir are compared. Gravity distribution system is recommended as far as it is financially acceptable.

Table C.II-03 Comparison Table of Reservoir

Item	Distribution Reservoir	（Local） Fill & Draw Reservoir
System		
Advan-tage	➢ Flow is one-way, which enables easy flow control ➢ Excessive pressure can be avoided due to stable potential energy, which means water level even during nigh time	➢ Installation Cost is less expensive than left plan
Disad-vantage	➢ Transmission pipe from source well to the reservoir require more cost than fill & draw reservoir system.	➢ Network is over-pressurized by direct injection pump even during night time, when demand is small, which likely to induce high leakage ➢ Management and control of the Fill & Draw type reservoir is difficult

2) Reservoir Capacity Criteria

Required reservoir capacity of 3.81 hour is also calculated from the table in next page

Table C.II-04 Reservoir Capacity Calculation Table

Period in hours	Hourly Demand	Cumulative Demand	Cumulative Pumping	deficit/Surplus
00 to 01	0.46	0.46	1.00	0.54
01 to 02	0.5	0.96	2.00	1.04
02 to 03	0.54	1.5	3.00	1.50
03 to 04	0.58	2.08	4.00	1.92
04 to 05	0.62	2.7	5.00	2.30
05 to 06	1	3.7	6.00	2.30
06 to 07	1.62	5.32	7.00	1.68
07 to 08	1.8	7.12	8.00	0.88
08 to 09	1.62	8.74	9.00	0.26
09 to 10	1.38	10.12	10.00	-0.12
10 to 11	1.46	11.58	11.00	-0.58
11 to 12	1.23	12.81	12.00	-0.81
12 to 13	1.19	14	13.00	-1.00
13 to 14	0.97	14.97	14.00	-0.97
14 to 15	1.08	16.05	15.00	-1.05
15 to 16	1	17.05	16.00	-1.05
16 to 17	1.08	18.13	17.00	-1.13
17 to 18	1.19	19.32	18.00	-1.32
18 to 19	1.19	20.51	19.00	-1.51
19 to 20	0.92	21.43	20.00	-1.43
20 to 21	0.77	22.2	21.00	-1.20
21 to 22	0.69	22.89	22.00	-0.89
22 to 23	0.61	23.5	23.00	-0.50
23 to 24(00)	0.5	24	24.00	0.00

24

Capacity of Reservoir =2.3+1.51 =3.81 ≒ 4.0 hour
equivalent of daily flow

3) Estimated Service Population by Distribution Block

Service population by distribution block is summarized in the following table from the service population by LGU.

Table C.II-05 Service Population by Distribution Block

Distribution Block	2015	2030	
Lagtang DB	85,941	159,175	Talisay City
Tisa DB	224,730	323,757	52% of Cebu City
Talamban DB	207,444	298,852	48% of Cebu City
Casili DB	182,536	304,005	Mandaue City
LCL DB	95,063	168,120	Compostela, Li-loan, Consolacion
Mactan DB	150,957	308,699	Lapu-lapu City, Cordova
	946,671	1,562,608	

(3) Allocation for Water Source and Water Supply

1) Formation of Distribution Block

- **Division into six (6) distribution block**

Based on the location of the existing reservoirs, following six(6) blocks are proposed;

- Lagtang Distribution Block (D.B)
- Tisa D.B
- Talamban D.B
- Casili D.B
- C.L.C (Consolacion, Lilo-an and Compostela) D.B
- Mactan D.B

Part of the water distributed to the Mactan D.B comes from Casili D.B due to shortage of its own water source

Demarcation of the block is decided based on (1) City/Municipality boundary , (2) MCWD billing zone boundary and also (3) existing valve location.

Three alternatives are compared and block demarcation is finalized. As a consequence, Lagtang D.B covers Talisay City, Tisa DB covers south part of Cebu City, Talamban DB covers north part of Cebu City, Casili D.B covers Mandaue City, C.L.C covers three municipality, that is, Consolacion, Lilo-an and Compostela, Mactan D.B covers Lapu-lapu City and Cordova.

Of the three cases, case (1) is the plan whose block boundary is just in accordance with MCWD billing zone. Case (2-1) is arranged from Case (1) considering existing valve location since it is more economical to utilize existing valves for the fabrication of the independent block than new installation of valve. Case (2-2) is the revised plan considering distribution of water source, that means new groundwater abstraction well location.

Demand distribution of each distribution block is almost same between Case (1) and Case (2-1). Meanwhile, part of Casili block demand is removed to Talamban block in Case (2-2) compared with Case (2-1).

From the comparison table, Case (2-2) is selected as optimum plan.

For the completion of block plan, valves indicated in Figure C.II-08 shall be closed.

Coverage area, zone of each plan is described in Table C.II-07.

Concept of the block distribution system and final result is shown in next page. (Figure C.II-04 and Figure C.II-05)

Pipe network is divided into six blocks shown as Figure C.II-06

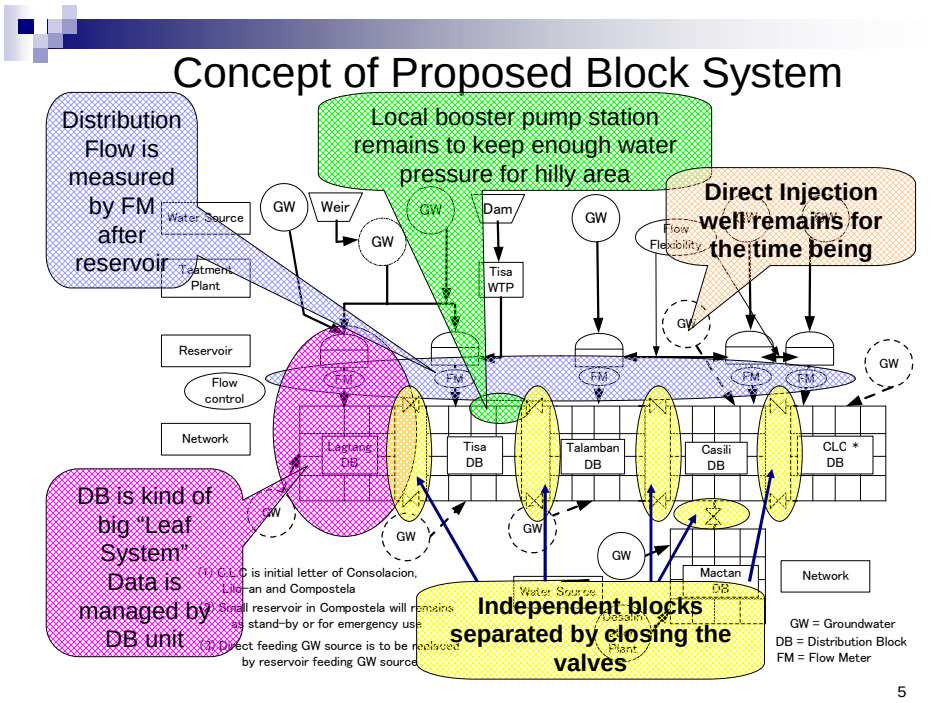


Figure C.II-04 Concept of Block System

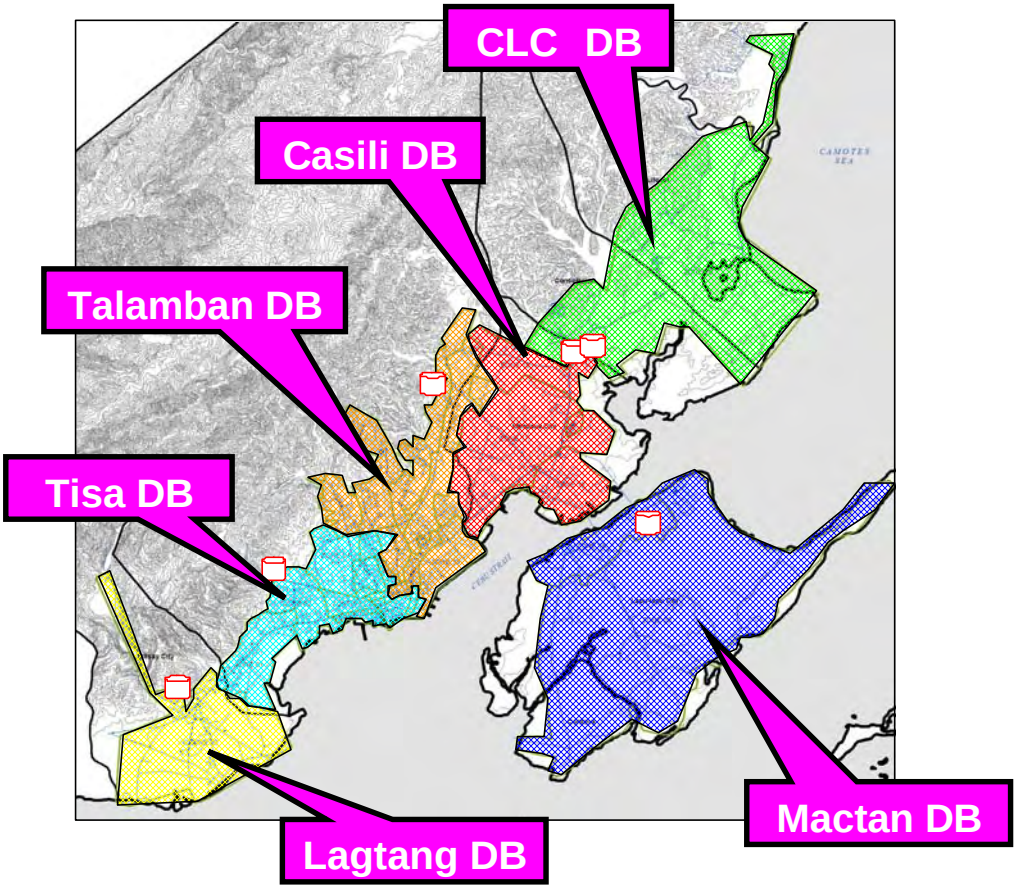


Figure C.II-05 Finalized Distribution Block

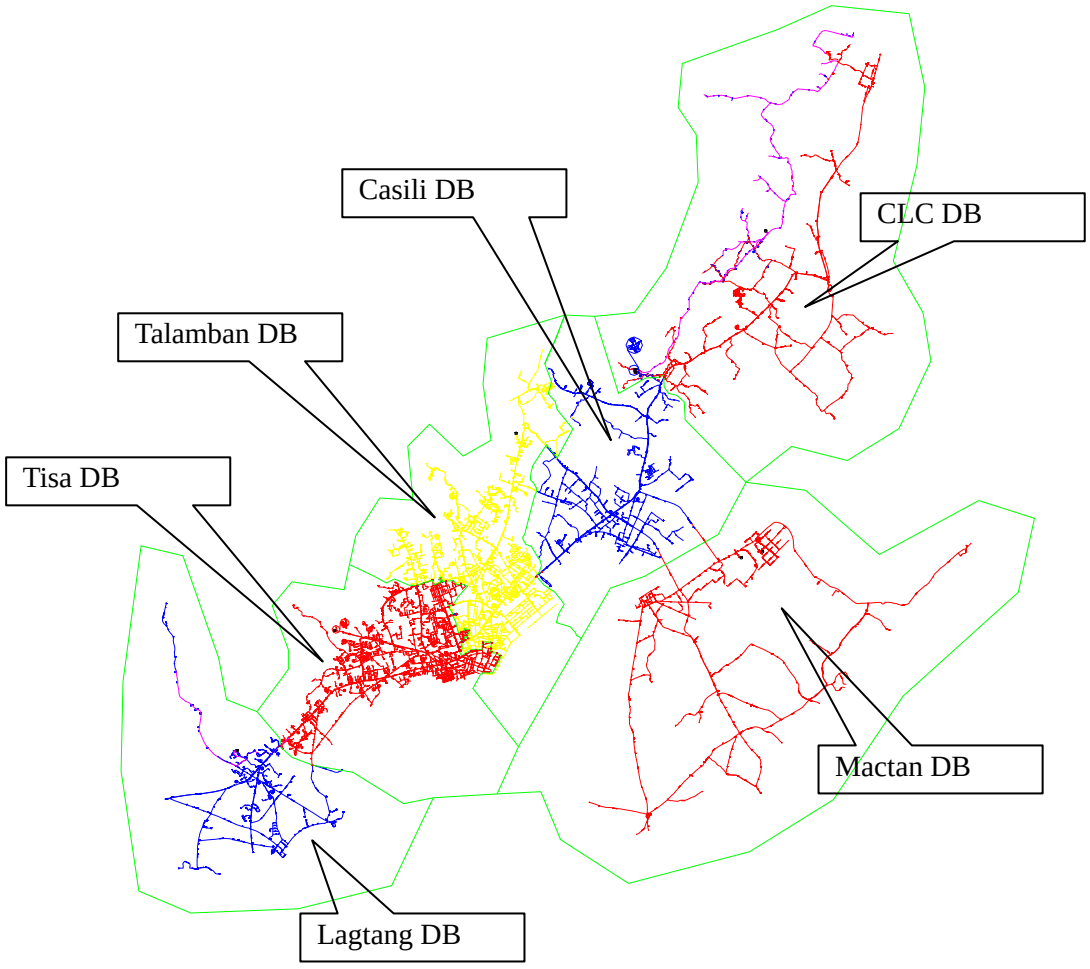


Figure C.II-06 Distribution Network in Each Block