Revisiting (Past & Future) the Kaliwa Dam for Metro Manila's Water Supply and Balog-Balog Multipurpose Dam for Tarlac's Irrigation Water Supply

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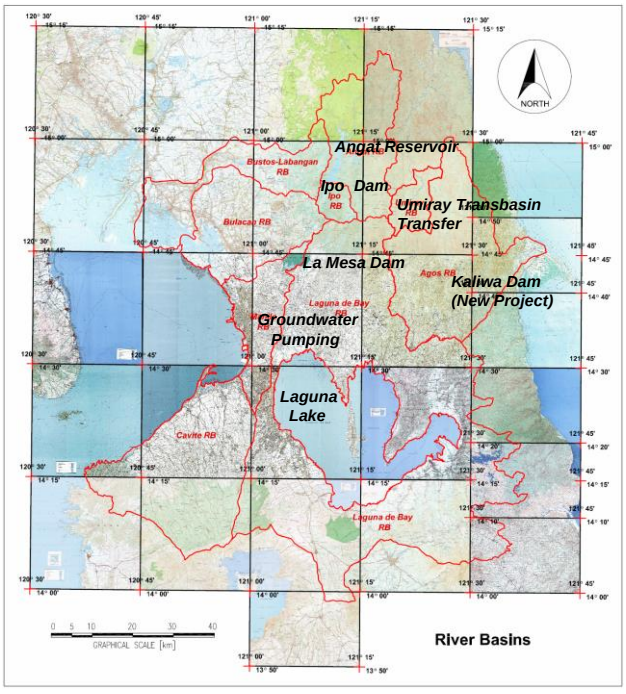
Water Infrastructure S&T Policy Discussion
National Academy of Science and Technology
Microtel Hotel, Diliman, Quezon City
March 9, 2016

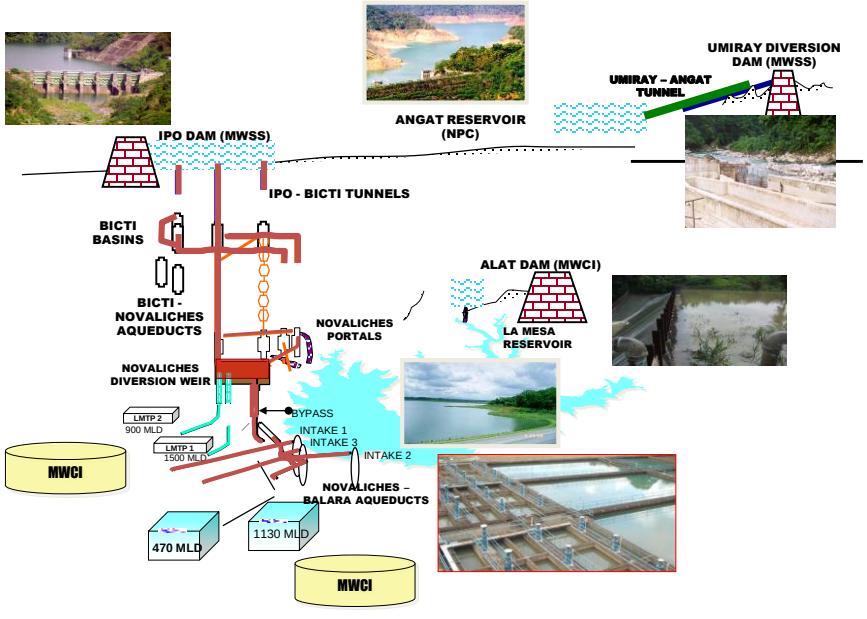
Outline

- ***Water Supply of Metro Manila***
- ***New Centennial Water Supply Project: Kaliwa Dam***
- ***Tarlac Irrigation System and Balog-Balog Multipurpose Dam***
- ***Balog-Balog Single, High Dam versus Multiple Dam System***

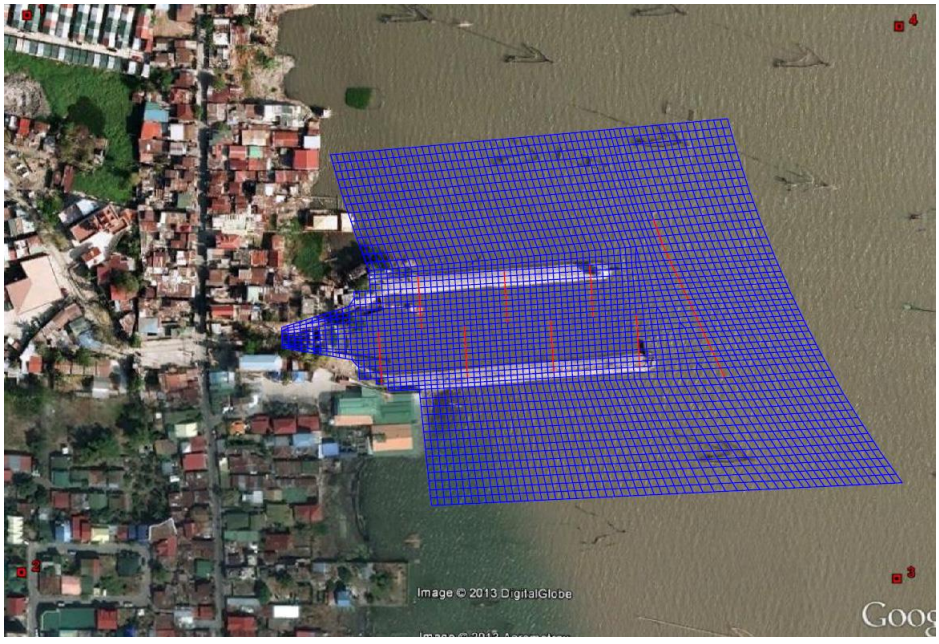
Water Sources of Metro Manila

- Angat Reservoir with Ipo and La Mesa Dams
- Umiray Transbasin Transfer
- Laguna Lake
- Kaliwa Dam (New Project)
- Groundwater Pumping





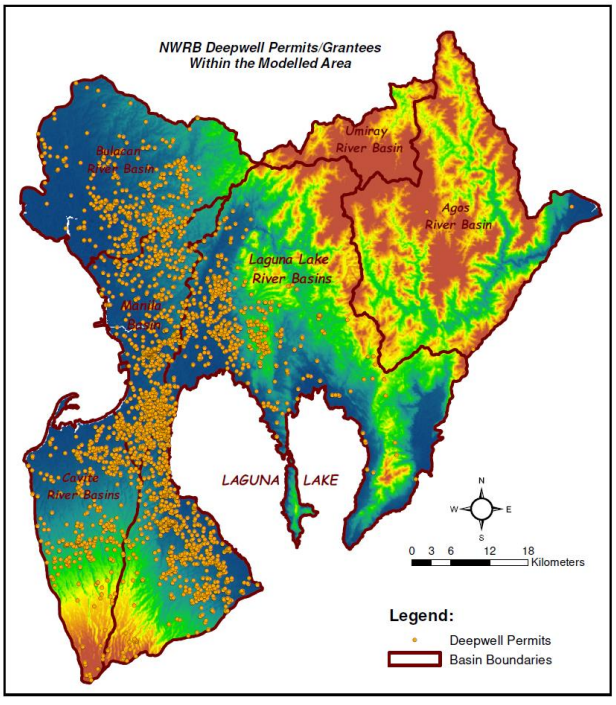
Laguna Lake Water Source: Putatan Intake Structure



Location of Groundwater Water Permits

Amounts Granted:

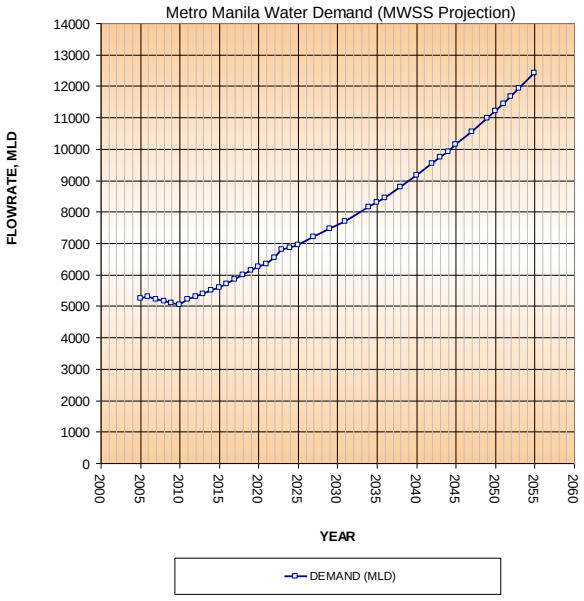
- **Entire Area: 1340 MLD**
- **Metro Manila Area: 780 MLD**



2015 Water Demand:
5500 MLD

2015 Water Supply Available: 5030 MLD

- Angat 4200 MLD
- Laguna Lake 100 MLD (+ 200 MLD)
- Groundwater 780 MLD (++? MLD)



Reliability Analysis Angat Reservoir under Increased Water Demand, Sedimentation and Climate Change

Angat Reservoir Releases to Ipo Dam (CMS) for MWSS Domestic Water Demand

Irrigation Water Demand	
Month	**Demand (CMS)**
Jan	**36.00**
Feb	**39.86**
Mar	**31.00**
Apr	**15.50**
May	**0.00**
Jun	**27.90**
Jul	**28.00**
Aug	**25.00**
Sep	**22.73**
Oct	**13.00**
Nov	**17.57**
Dec	**34.00**

Month	*Percent of Time*	***Angat Releases to Ipo Dam (CMS)***				
		46 CMS MWSS Dem	*50 CMS MWSS Dem*	*Future Reservoir Sed with 46 CMS Dem*	*Climate Change with 46 CMS Dem*	*Fut Res Sed and Climate Chan with 50 CMS Dem*
Jan	80	46.00	47.36	4.59	46.00	6.94
	60	46.00	50.00	9.79	46.00	14.60
	40	46.00	50.00	19.13	46.00	31.36
Feb	80	29.77	23.79	3.37	31.49	2.29
	60	46.00	47.72	5.79	46.00	4.01
	40	46.00	50.00	10.78	46.00	6.88
Mar	80	5.70	3.79	3.06	4.91	2.53
	60	36.70	30.51	5.26	39.95	4.38
	40	46.00	50.00	9.74	46.00	7.83
Apr	80	4.09	3.74	3.67	2.98	2.44
	60	19.43	12.80	7.09	14.31	4.50
	40	46.00	50.00	15.50	46.00	9.91
May	80	14.38	13.49	8.41	3.13	2.06
	60	46.00	50.00	23.85	14.18	6.11
	40	46.00	50.00	46.00	46.00	12.35
Jun	80	46.00	50.00	27.29	38.19	20.01
	60	46.00	50.00	46.00	46.00	37.85
	40	46.00	50.00	46.00	46.00	50.00
July	80	46.00	50.00	43.32	46.00	32.99
	60	46.00	50.00	46.00	46.00	50.00
	40	46.00	50.00	46.00	46.00	50.00
Aug	80	46.00	50.00	44.30	46.00	40.15
	60	46.00	50.00	46.00	46.00	50.00
	40	46.00	50.00	46.00	46.00	50.00
Sep	80	46.00	50.00	38.06	46.00	36.29
	60	46.00	50.00	46.00	46.00	50.00
	40	46.00	50.00	46.00	46.00	50.00
Oct	80	46.00	50.00	23.32	46.00	34.52
	60	46.00	50.00	45.76	46.00	50.00
	40	46.00	50.00	46.00	46.00	50.00
Nov	80	46.00	50.00	13.52	46.00	12.54
	60	46.00	50.00	29.94	46.00	26.02
	40	46.00	50.00	46.00	46.00	50.00
Dec	80	46.00	50.00	9.32	46.00	15.53
	60	46.00	50.00	19.79	46.00	34.64
	40	46.00	50.00	46.00	46.00	50.00

Reliability Analysis Angat Reservoir under Increased Water Demand, Sedimentation and Climate Change

Angat Reservoir Releases to Bustos Dam (CMS) for NIA-AMRIS Irrigation Demand

Irrigation Water Demand	
Month	**Demand (CMS)**
Jan	**36.00**
Feb	**39.86**
Mar	**31.00**
Apr	**15.50**
May	**0.00**
Jun	**27.90**
Jul	**28.00**
Aug	**25.00**
Sep	**22.73**
Oct	**13.00**
Nov	**17.57**
Dec	**34.00**

Month	*Percent of Time*	*Angat Releases to Bustos Dam (CMS)*				
		46 CMS MWSS Dem	*50 CMS MWSS Dem*	*Future Reservoir Sed with 46 CMS Dem*	*Climate Change with 46 CMS Dem*	*Fut Res Sed and Climate Chan with 50 CMS Dem*
Jan	80	36.00	34.42	0.00	36.00	0.00
	60	36.00	36.00	0.00	36.00	0.00
	40	45.98	49.85	0.00	45.98	1.08
Feb	80	27.49	20.50	0.00	29.34	0.00
	60	39.82	34.97	0.00	39.82	0.00
	40	39.86	39.86	0.00	39.86	0.00
Mar	80	1.31	0.08	0.00	0.83	0.00
	60	22.07	15.50	0.00	23.83	0.00
	40	31.00	31.00	0.00	31.00	0.00
Apr	80	0.00	0.00	0.00	0.00	0.00
	60	0.00	0.00	0.00	0.00	0.00
	40	15.50	15.50	0.00	15.50	0.00
May	80	0.00	0.00	0.00	0.00	0.00
	60	0.00	0.00	0.00	0.00	0.00
	40	0.00	0.00	0.00	0.00	0.00
Jun	80	27.90	27.90	0.00	6.27	0.00
	60	27.90	27.90	5.57	27.90	0.00
	40	27.90	27.90	27.90	27.90	8.23
July	80	28.00	28.00	0.00	25.00	0.00
	60	28.00	28.00	25.00	28.00	7.82
	40	28.00	28.00	28.00	28.00	28.00
Aug	80	25.00	25.00	0.00	25.00	0.00
	60	25.00	25.00	22.73	25.00	19.78
	40	25.00	25.00	25.00	25.00	25.00
Sep	80	22.73	22.73	0.00	22.73	0.00
	60	22.73	22.73	13.00	22.73	11.38
	40	22.73	22.73	22.73	22.73	22.73
Oct	80	13.00	13.00	0.00	13.00	0.00
	60	13.00	13.00	0.81	13.00	13.00
	40	13.00	13.00	13.00	13.00	13.00
Nov	80	17.57	17.57	0.00	17.57	0.00
	60	17.57	17.57	0.00	17.57	0.00
	40	17.57	17.57	15.96	17.57	7.00
Dec	80	36.00	36.00	0.00	36.00	0.00
	60	36.00	36.00	0.00	36.00	0.00
	40	45.99	49.99	10.60	45.99	34.15

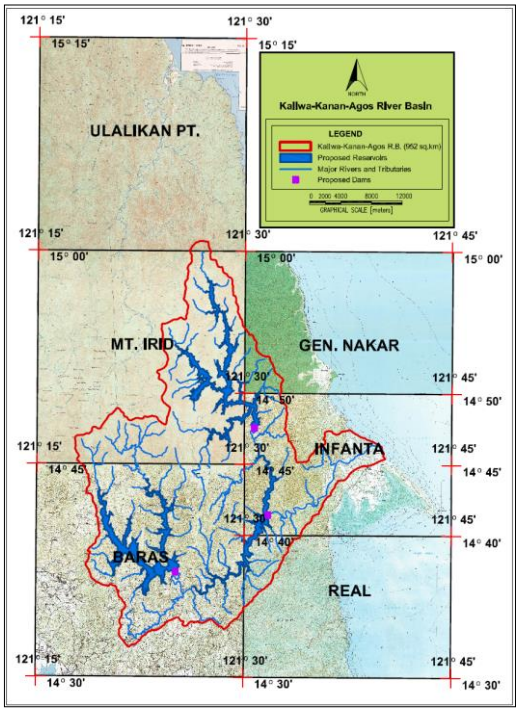
New Centennial Water Supply: Kaliwa Dam Project

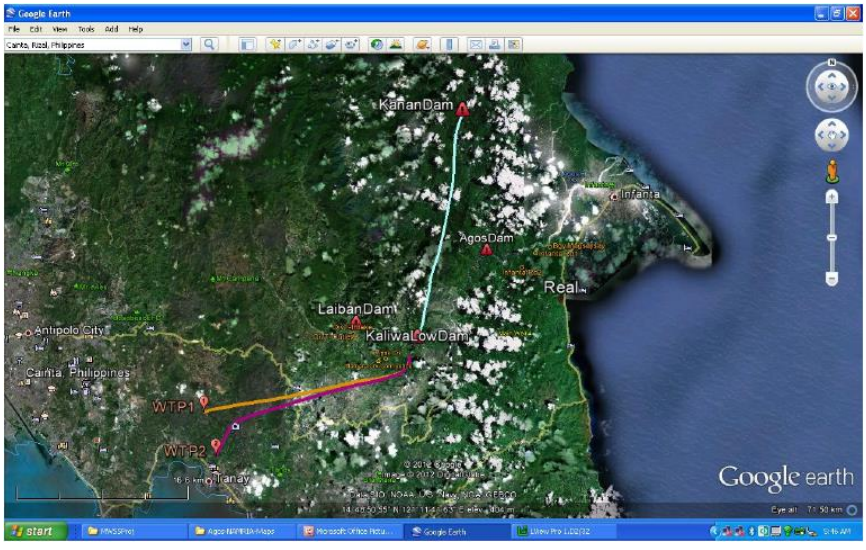
2012 NHRC-UP Diliman Study:

To evaluate and conduct reliability and sustainability analysis of Kaliwa, Kanan and Agos River basins of various river/reservoir/dam configurations for water supply for Metro Manila including hydropower potential and flood control function.

Location of Study Area /Agos River Basin (951.7 sq. km)

(Assembled 1:50,000-Scale NAMRIA Maps)





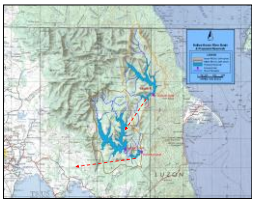
General Layout and Location of Components

9 Alternative Water Resources System Configurations for Simulation-Optimization Studies

WRS 1: Kaliwa Low Dam (Thru Kaliwa – Baras or Tanay Transfer Facilities)

WRS 2: Kaliwa Low Dam and Laiban Dam (Thru Kaliwa – Baras or Tanay Transfer Facilities)

WRS 3: Kaliwa-Low & Laiban Dams & Kanan Diversion (Thru Kaliwa – Baras or Tanay Transfer Facilities)



WRS 4: Kaliwa Low. Laiban & Kanan Dams (Thru Kaliwa – Baras or Tanav Transfer Facilities)

WRS 5: Kaliwa Low. Laiban. Kanan & Agos Dams (Thru Kaliwa – Baras or Tanav

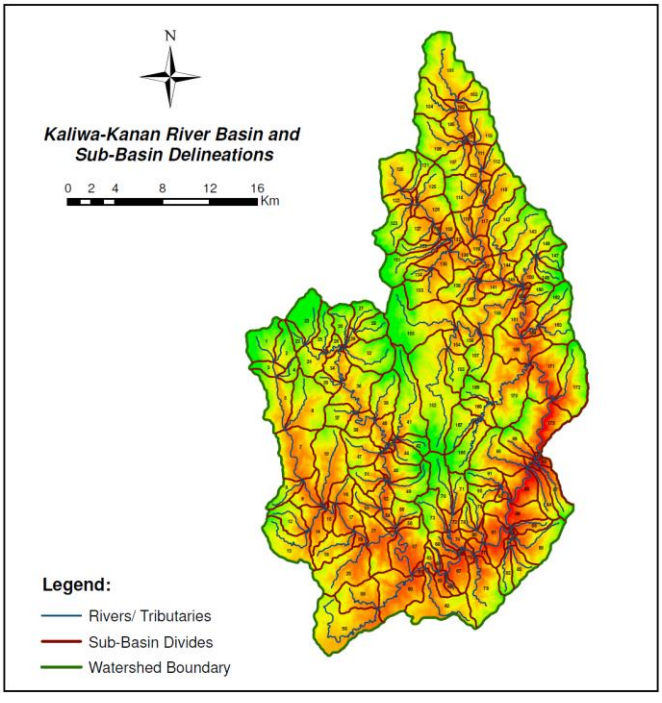
WRS 6: Laiban Dam Only (Thru Kaliwa – Baras or Tanav Transfer Facilities)

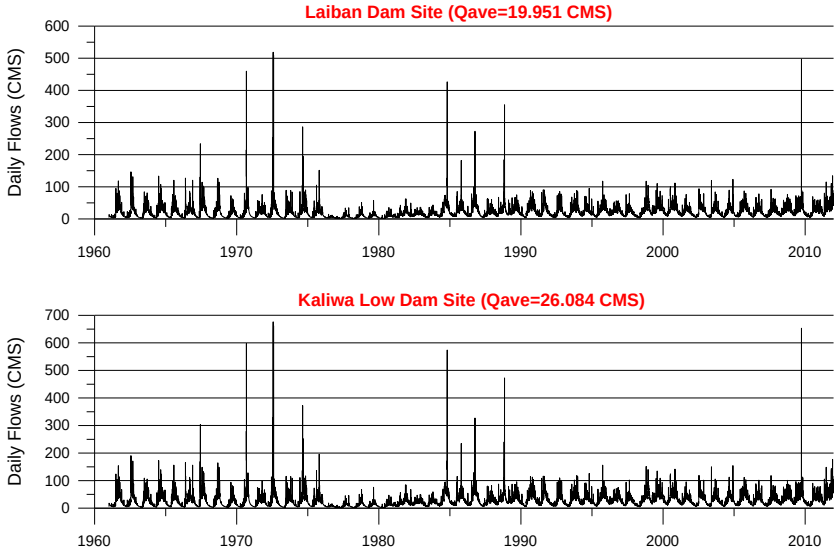
WRS 7: Kaliwa Low & Kanan Dams (Thru Kaliwa – Baras or Tanay Transfer Facilities)

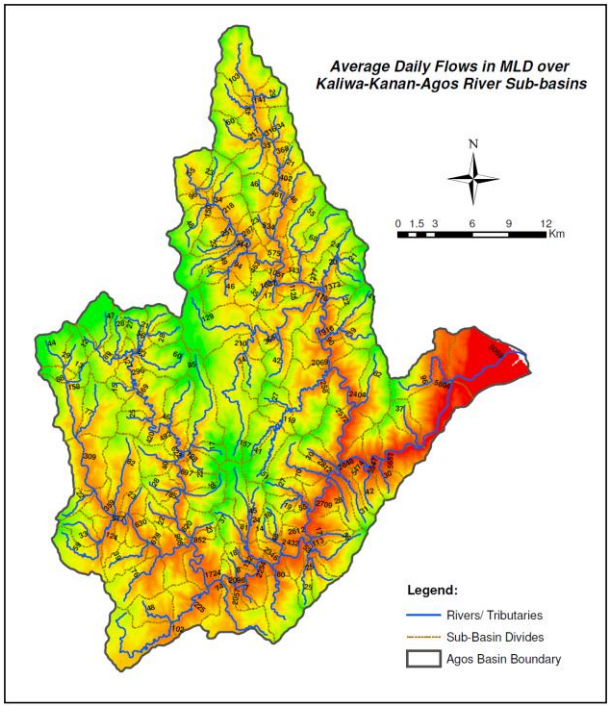
WRS 8: Laiban Dam & Agos Dam (Thru Kaliwa – Baras or Tanay Transfer Facilities)

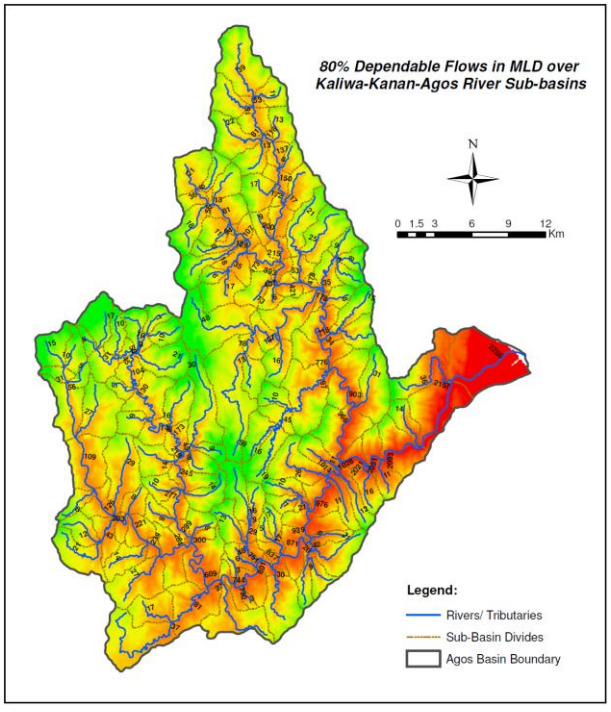
WRS 9: Kaliwa Low & Agos Dams (Thru Kaliwa – Baras or Tanay Transfer Facilities)

Watershed and Sub-basin Delineations of Agos-Kaliwa-Kanan River Basin



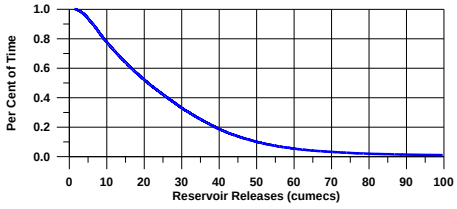

Laiban Dam Site (Qave=19.951 CMS)
Daily Flows (CMS)
600
500
400
300
200
100
0
1960
1970
1980
1990
2000
2010
Kaliwa Low Dam Site (Qave=26.084 CMS)
Daily Flows (CMS)
700
600
500
400
300
200
100
0
1960
1970
1980
1990
2000
2010

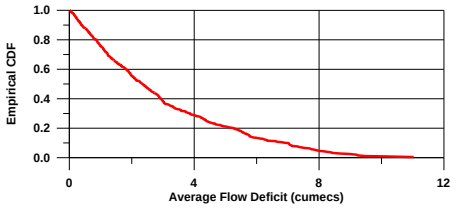

Average Daily Flows in MLD over
Kaliwa-Kanan-Agos River Sub-basins
N
0 1.5 3 6 9 12
Km
Legend:
Rivers/ Tributaries
Sub-Basin Divides
Agos Basin Boundary

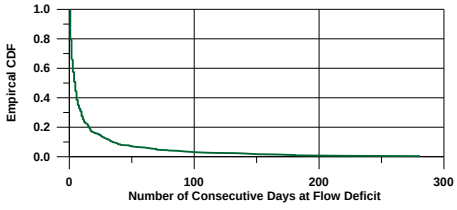


Kaliwa River Flows
(at Kaliwa Low Dam Site)

- **Average Flows = 26.01 CMS (has a reliability of 40.27%)**
- **Flow of 15 CMS has a reliability of 64.01%)**

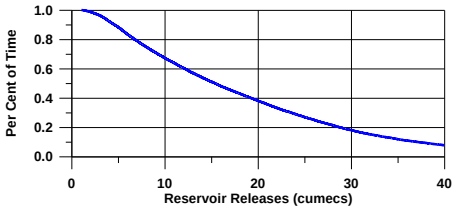


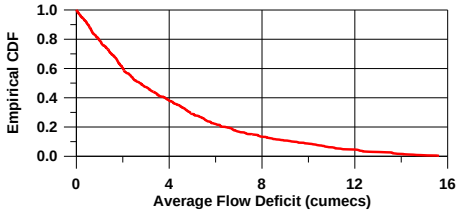


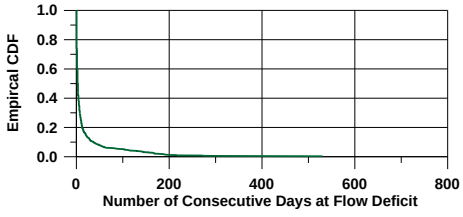


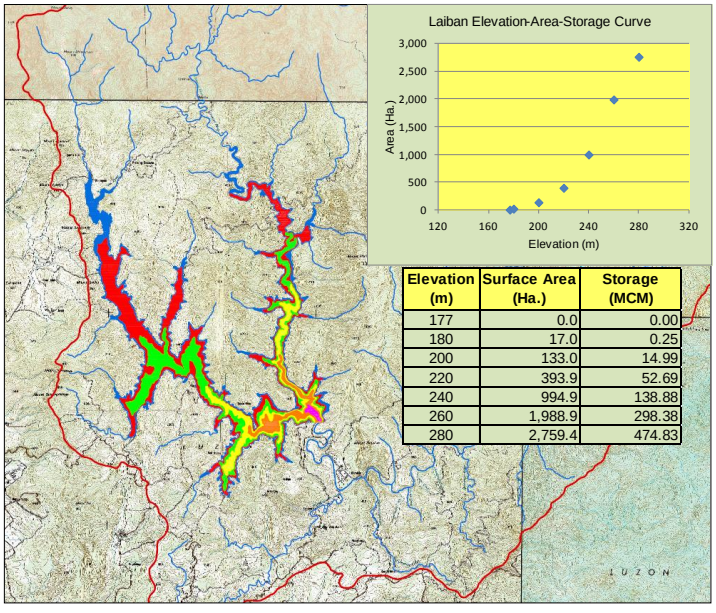
Kaliwa River Flows
(at Laiban Dam Site)

- **Average Flows = 19.21 CMS (has a reliability of 40.08%)**
- **Flow of 20 CMS has a reliability of 38.10%)**
- **Runs Analysis at Flow Demand = 20 CMS**



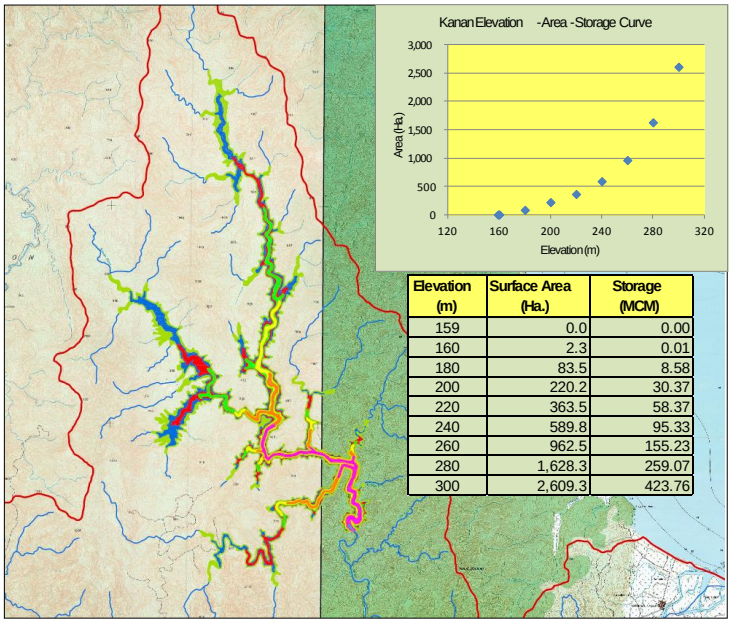






Elevation (m)	Surface Area (Ha.)	Storage (MCM)
177	0.0	0.00
180	17.0	0.25
200	133.0	14.99
220	393.9	52.69
240	994.9	138.88
260	1,988.9	298.38
280	2,759.4	474.83

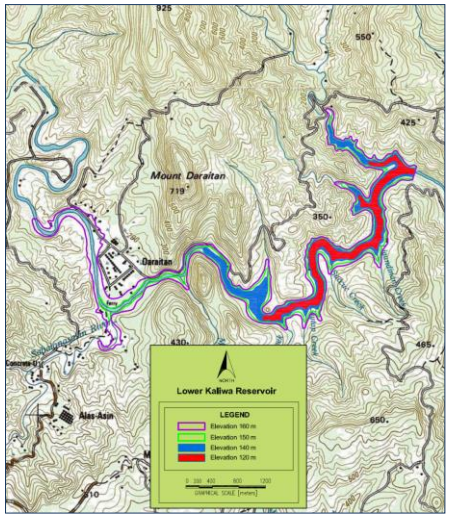
Elevation-Area-Storage Data for the Proposed Laiban Reservoir



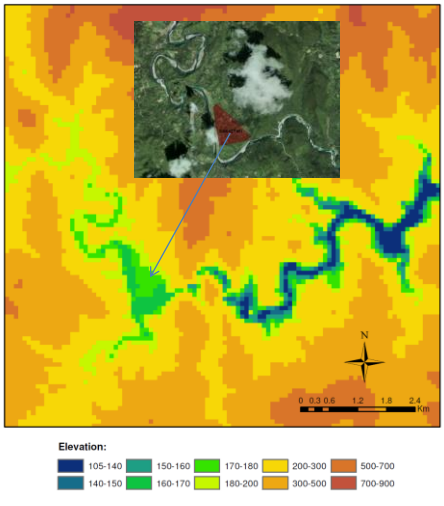
Elevation (m)	Surface Area (Ha.)	Storage (MCM)
159	0.0	0.00
160	2.3	0.01
180	83.5	8.58
200	220.2	30.37
220	363.5	58.37
240	589.8	95.33
260	962.5	155.23
280	1,628.3	259.07
300	2,609.3	423.76

Elevation-Area-Storage Data for the Proposed Kanan Reservoir

Flood Inundation Areas at Different Kaliwa Low Dam Elevations (Note: Elevation 160 m is dam height of 53 m)



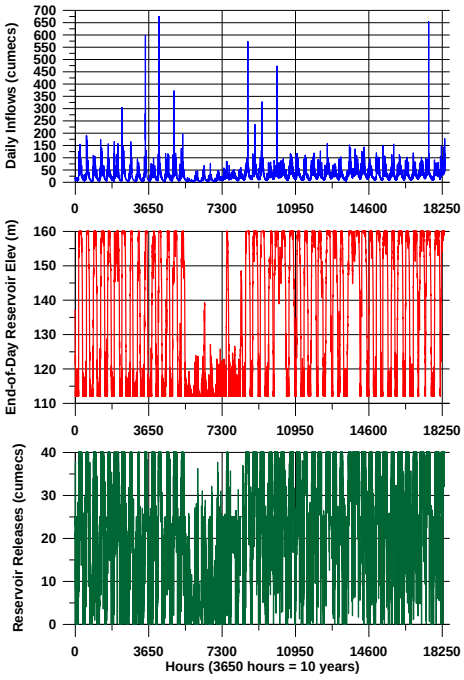
Digital Elevation Map at the Vicinity of Kaliwa Low (SRTM-DEM NASA 90m x 90m Res)



NOTE: The above flood inundation areas were based on NASA SRTM data which were validated by GPS random sampling during field survey early 2012.

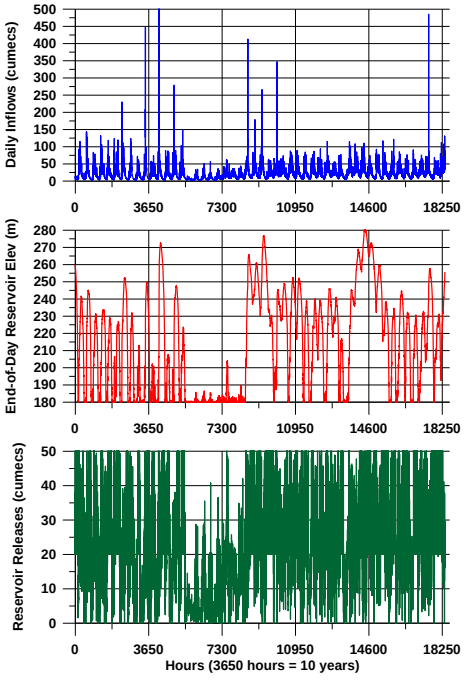
Kaliwa Low Dam
Dam Elevation = 160 m
Dam Height = 53 m
Flow Demand = 15 CMS

Time Series Plots



Laiban Dam
Dam Elevation = 260 m
Dam Height = 83 m
Flow Demand = 20 CMS

Time Series Plots



Kaliwa Low Dam Only

Kaliwa Low Dam 53 m

Target Release (CMS)	Water Supply Reliability (in MLD)		
	50%	80%	85%
10	1930	864	864
15	**1612**	**1294**	**924**
20	1728	833	585

Target Release (CMS)	Power Reliability (MW)		
	50%	80%	85%
10	32.52	15.96	8.70
15	**30.20**	**17.62**	**9.32**
20	25.86	17.94	4.91

Kaliwa Low Dam 43 m

Target Release (CMS)	Water Supply Reliability (MLD)		
	50%	80%	85%
10	1914	864	864
15	**1613**	**1064**	**699**
20	1728	718	549

Target Release (CMS)	Power Reliability (MW)		
	50%	80%	85%
10	27.34	12.75	8.13
15	**26.48**	**14.52**	**7.01**
20	22.94	13.64	4.01

Note: **Target release is desired release imposed in the optimization. The results show that the optimum target release is 15 CMS which implies that an aggressive reservoir release rule (high target release) will result in less flow reliability. However, too passive release rule result in lower firm water yield but have higher reliability especially at 85 percent-of-time.**

Laiban Dam and Kaliwa Low Dam

Laiban Dam 93 m

Cases	Target Release (CMS)	Water Supply Reliability (MLD)		
		50%	80%	85%
1	20/15	1555	549	403
2	**20/20**	**1602**	**898**	**694**
3	20/25	1668	899	657
4	25/15	1642	534	408
5	25/20	1637	561	395

Cases	Target Release (CMS)	Power Reliability (MW)		
		40%	60%	80%
1	20/15	40.39	23.90	8.90
2	**20/20**	**42.10**	**34.55**	**17.68**
3	20/25	40.88	29.43	14.60
4	25/15	37.02	21.76	7.89
5	25/20	41.35	25.05	8.76

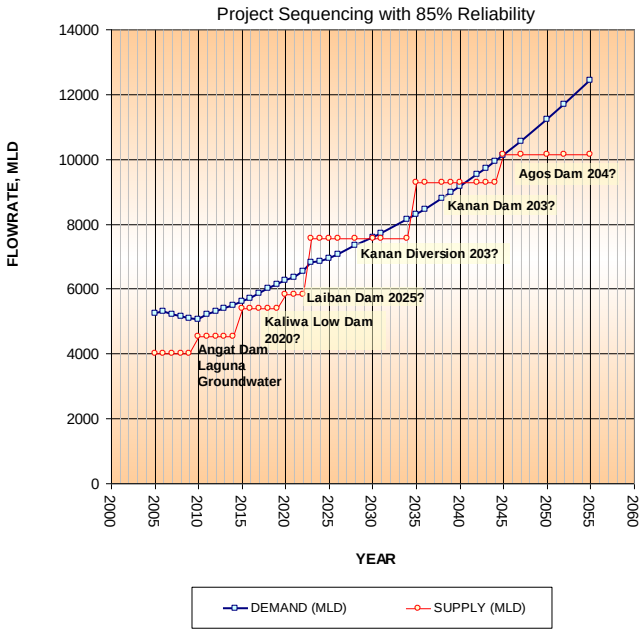
Kaliwa Low Dam 53 m

Cases	Target Release (CMS)	Water Supply Reliability (MLD)		
		50%	80%	85%
1	20/15	2152	1296	260
2	**20/20**	**1926**	**1655**	**1527**
3	20/25	2263	1724	1385
4	25/15	2335	1296	1251
5	25/20	2119	1441	1141

Cases	Target Release (CMS)	Power Reliability (MW)		
		40%	60%	80%
1	20/15	36.78	25.45	15.50
2	**20/20**	**30.46**	**26.33**	**22.20**
3	20/25	34.70	30.56	16.53
4	25/15	38.75	27.58	15.69
5	25/20	34.95	26.27	16.11

Notes:

- **Target release is desired release imposed in the optimization. In Case 1, 20/15 target release means 20 CMS for Laiban Dam and 15 CMS for Kaliwa Low Dam.**
- **The results show that the optimum target release is Case 2 (20/20) which implies that an aggressive reservoir release rule (high target release) will result in less flow reliability. However, too passive release rule result in lower firm water yield but higher reliability at higher percent-of-time.**
- **The releases at Laiban Dam goes to Kaliwa Low Dam so only the water supply reliability of Kaliwa Low Dam is meaningful to deliveries to Metro Manila.**
- **The hydropower generated are separate for Laiban and Kaliwa Low Dams so that for Case 2 at 60% reliability, the total is 72.56 MW.**



Balog-Balog Multipurpose Dam and Tarlac River Irrigation System

2014 PIDS Policy Notes:

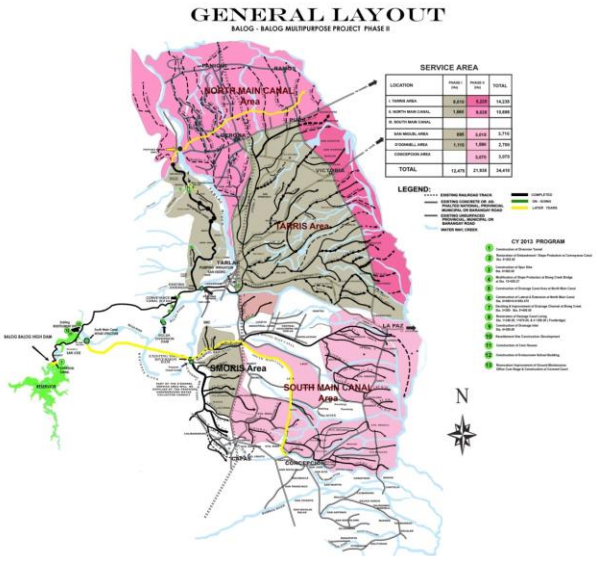
Appraisal of Methodology in Estimating Irrigable Areas and Processes of Evaluating Feasibility of NIA Irrigation Projects (Tabios and David)

2015 NHRC-UP Diliman Study:

Reliability and Cost-Benefit Analyses of the Balog-Balog Multipurpose Dam versus Balog-Balog Multiple Dam Project

Balog-Balog RIS (Existing)

Existing Service Area 12,475 ha
Actual Irrigated 4,600 (?)
Rainfed 15,815 (?)



Historical Service Area

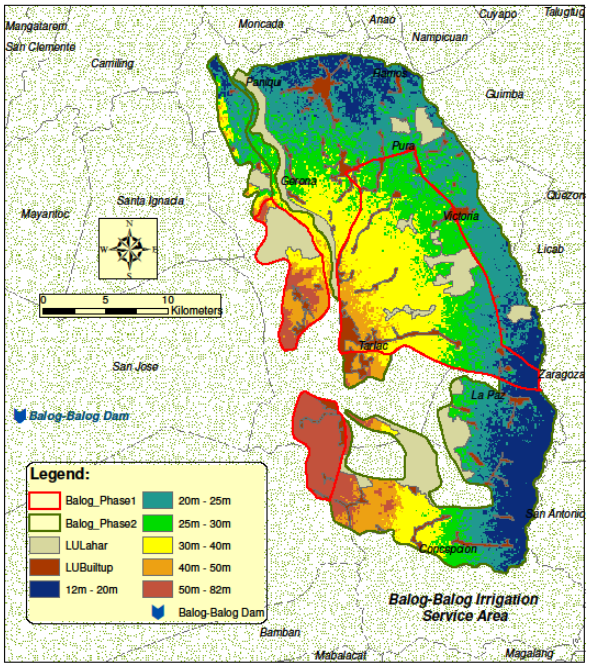
Year	Wet (has)	Dry (has)
1976	12904	4253
1977	12473	3934
1978	11263	3184
1979	10910	1488
1980	10765	2496
1981	10811	2089
1982	13595	2389
1983	10638	2866
1984	11120	1647
1985	11751	4689
1986	8883	3198
1987	9459	2415
1988	9815	2310
1989	9868	3948
1990	11202	3864
1991	0	447
1992	1576	1263
1993	0	0
1994	0	0
1995	0	0
1996	0	0
1997	680	0
1998	2129	610
1999	3507	1660
2000	2294	434
2001	3531	1500
2002	3414	2000
2003	3739	1800
2004	3708	1880
2005	4200	1836
2006	2934	2000
2007	3305	2025
2008	4600	2676

Balog-Balog RIS

Design Service Area 34,410 ha

Target Service Areas with Balog-Balog Dam (reasonable)
Phase 1: 12,475 ha
Phase 2: 21,935 ha

Phase I:		
Total Area (footprint)		**23,028**
Built-up Area	2,069	
Lahar Area	2,893	
Roads/ Streets	1,059	
Fish Pen/Ponds	1,283	
Others (i.e. grass, scrub, etc.)	532	
Area Below 17m (flooded)	89	
Total Non-Irrigable		**7,926**
Net Irrigable Area*		***15,102***
Phase 2:		
Total Area (footprint)		**39,328**
Built-up Area	4,253	
Lahar Area	5,043	
Roads/ Streets	2,624	
Fish Pen/Ponds	902	
Others (i.e. grass, scrub, etc.)	1,944	
Area Below 17m (flooded)	1,485	
Total Non-Irrigable		**16,250**
Net Irrigable Area*		***23,078***



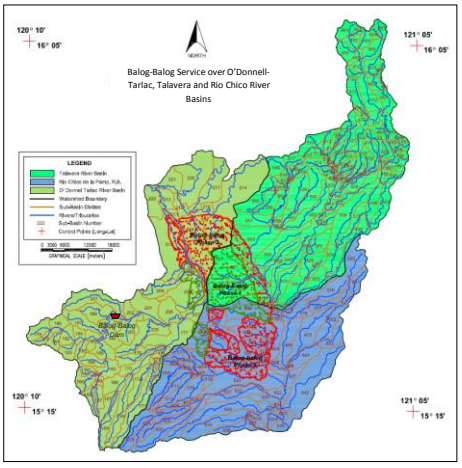
Balog-Balog Dam

Drainage Area = 280 sq.kms
Average Flow = 16.7 CMS
Q80% Dep Flow = 4.7 CMS
Q60% = 8 CMS
Q40% = 14 CMS
Q20% = 25 CMS

Issues:

- ***Underestimated cost of dam***
- ***Undersize spillway capacity***
- ***Sedimentation allocation (remedied with flushing gate)***
- ***Flood control function (uncontrolled)***
- ***Water yield inadequate for entire project area***
- ***Overestimated fisheries benefits***

DAM	
Type	Rock fill dam
Height	105.50 m.
Crest Width	15.00 m.
Crest Length	1,429.47 m.
Crest Elevation	245.00 m.
Volume of Embankment	11.85 MCM
RESERVOIR	
Area	1,230 hectares
Storage Capacity	425 MCM
Sediment Storage	50 MCM
Max. Water Surf. Elev.	238.00 m.
SPILLWAY	
Capacity	3,250 cu.m./sec
Ungated	3 units, 10m X 14.90 m. Radial Gates

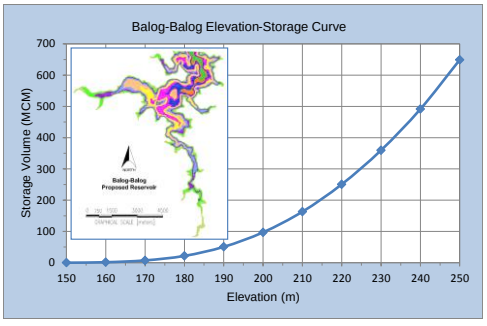


Balog-Balog Multipurpose Dam Project (single reservoir/high-dam)

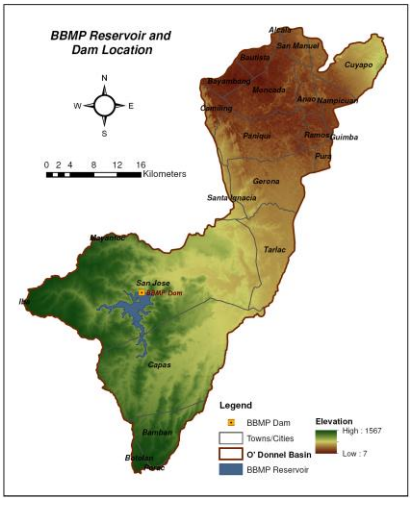
Balog-Balog Elevation-Area-Storage Data

Spillway Elevation (m): 245
Min. Dam Base Elev (m): 150
Design Spillway Height (m): 95

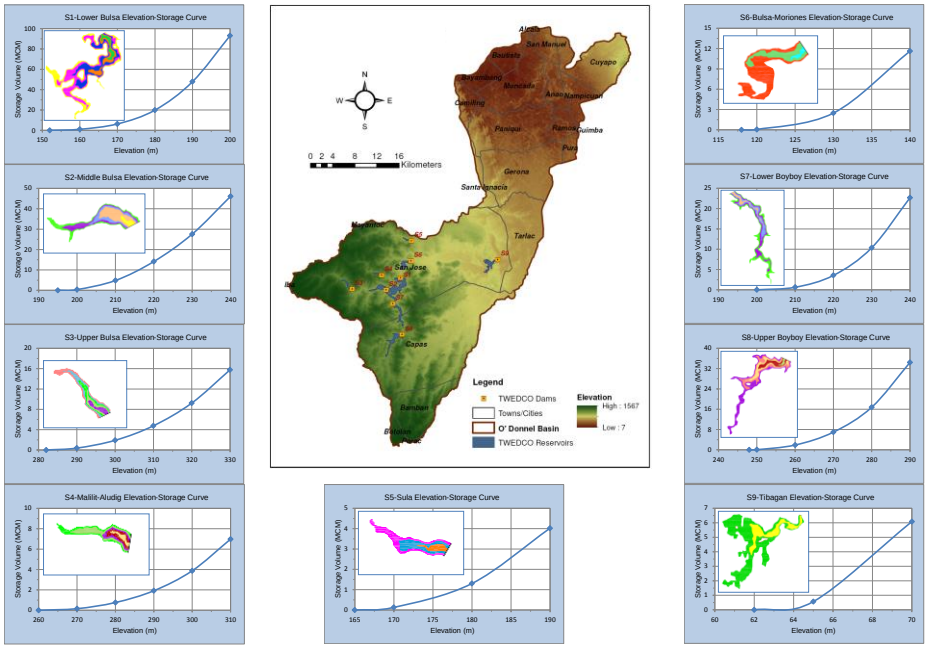
Elevation (m)	Height (m)	Surface Area (m^2)	Res Storage (m^3)	Res Storage (MCM)
150	0	0	0	0.000
160	10	295,882	1,479,409	1.479
170	20	874,062	7,329,130	7.329
180	30	2,010,808	21,753,482	21.753
190	40	3,789,677	50,755,907	50.756
200	50	5,500,020	97,204,390	97.204
210	60	7,693,940	163,174,191	163.174
220	70	9,828,056	250,784,174	250.784
230	80	11,964,812	359,748,513	359.749
240	90	14,386,213	491,503,637	491.504
250	100	17,107,778	648,973,593	648.974



Reservoir Elevation-Area-Storage Curve Created using SRTM (Shuttle Radar Topography Mission) 90m x 90m resolution data

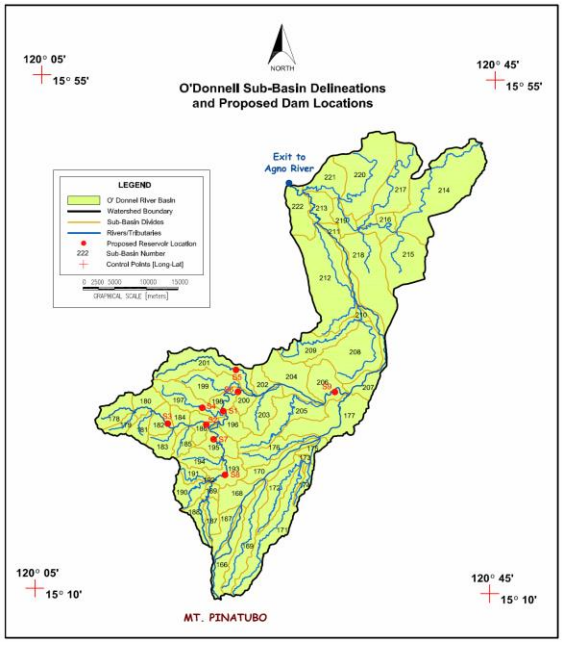


Proposed Balog-Balog Multiple Dam Project (9 reservoirs)

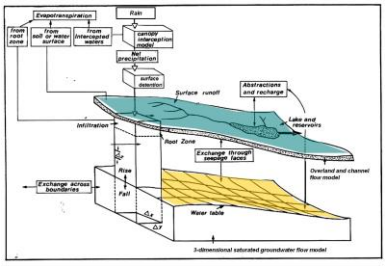


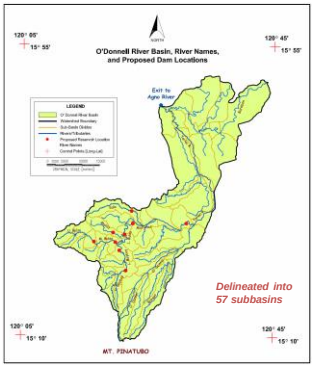
Comparison of BBMP and Multiple Dam Project at S1 location for the following:

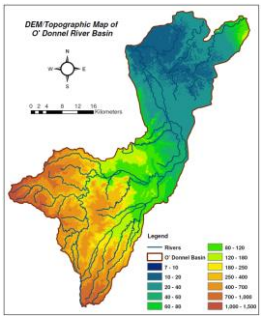
- Reservoir life due to sediment deposition
- Reliability of irrigation water delivery
- Reliability of hydropower generation
- Economic analyses in terms of B/C ratio, NPV and EIRR
- Dam backwater upstream inundated areas
- Flood control benefits to downstream

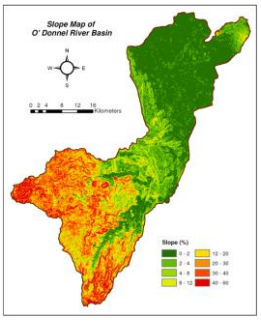


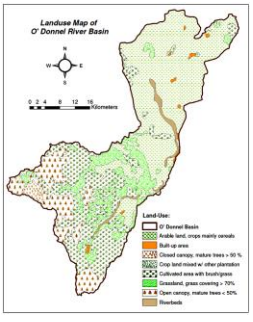
Watershed Modeling: To reconstruct daily streamflow as input to the reservoir system (using 1950-2000 historical rainfall)



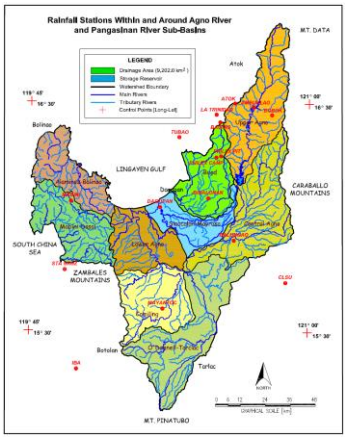


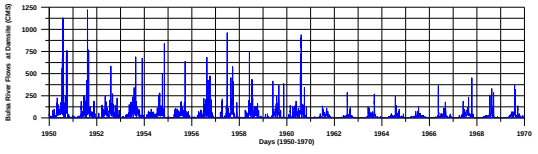


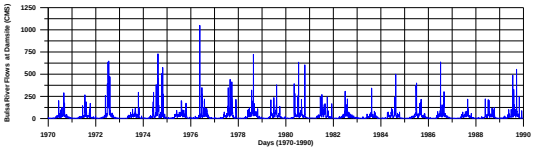


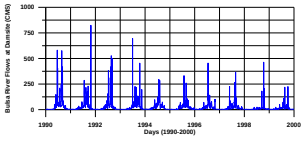


Bulsa River Daily Flows: Generated (or reconstructed) from watershed model using historical rainfall data from 1950 to 2000 (50 years of Data)









Reservoir Optimization-Simulation Modeling: To decide irrigation water deliveries and hydropower releases including reservoir spill control

- **A combined optimization-simulation model is used where the *simulation model* describes the water movement in the watershed, river system and reservoir system and the *optimization model* uses the COMPLEX algorithm to make decisions such as reservoir releases subject to the objective function and physical system constraints.**

- **The multi-objective function is:**

$$F = -p_{IR}\max(QID_t - QIR_t, 0.0) \quad \text{: penalty term for irrigation demand violation}$$
$$- p_{SP}QSP_t \quad \text{: penalty term for spills}$$
$$+ b_{HP}E_t \quad \text{: hydropower generation benefits}$$

Reservoir Life Computations due to Sedimentation:

Sediment inflow used is 3500 m³/year/km²

Reservoir Life Computations							
		Drainage Area (sq.km)	Annual Sediment Inlows (MCM)	Starting Storage (MCM)	Half-Filled Storage (MCM)	Years To Half-Fill Reservoir	Years to 100%-Fill Reservoir
BBMP Single Dam		289.31	1.013	648.97	324.49	321	641
Multiple Dams	S1	36.43	0.128	93.09	46.54	366	731
	S2	48.74	0.171	46.10	23.05	136	271
	S3	67.34	0.236	15.77	7.89	34	67
	S4	24.65	0.086	6.98	3.49	41	81
	S5	41.62	0.146	4.02	2.01	14	28
	S6	10.36	0.036	11.63	5.81	161	321
	S7	42.91	0.150	22.67	11.33	76	151
	S8	69.23	0.242	34.42	17.21	72	143
	S9	182.27	0.638	6.08	3.04	5	10

Watershed/Reservoir	Drainage Area (km²)		Sediment m³/year/km²	
Angat	568.0		5281.0	NHRC 2014
Binga	390.0		3695.0	NHRC 2007
Kaliwa	372.0		3225.0	NHRC 2013
Balog-Balog	283.0		2600.0	JICA 1988
San Roque	365.0		13307.2	NHRC 2003
		Ave (1st 3)	4067.0	
		Ave (4 Res)	3700.3	

Comparison of irrigation water deliveries (m^3/s) of BBMP (single reservoir) and Multiple Dam Project (with 6 reservoirs) including Lower Bulsa River natural flows at S1 location with no sedimentation and after 50 years sedimentation.

Base Case (No Reservoir Sedimentation)									
	Year-Round			Dry Season (Dec-Apr)			Wet Season (May-Sep)		
	Natural	BBMP	MultiDam	Natural	BBMP	MultiDam	Natural	BBMP	MultiDam
Q90 (330/140 days)*	0.96	0.96	0.55	0.77	0.77	0.14	6.86	7.51	4.60
Q80 (290/125 days)	1.35	1.93	1.18	0.96	0.96	0.52	19.08	18.02	16.95
Q60 (220/95 days)	3.76	24.00	6.48	1.25	1.64	1.08	40.00	40.00	39.71
Q40 (145/60 days)	13.40	40.00	38.80	1.73	6.26	2.21	40.00	40.00	39.99
Q20 (70/30 days)	36.53	40.00	40.00	3.86	40.00	6.82	40.00	40.00	40.00
Qave	26.21	25.27	21.11	4.27	14.82	6.19	32.11	32.10	31.58
Integral (Q20-Q90)	14.74	25.23	21.32	2.01	13.84	2.80	31.89	31.83	31.17
Area Irrigated (ha) @1.2 m^3/sec/1000 ha	12281	21027	17763	1679	11534	2337	26576	26525	25977

After 50 years with Sedimentation							
	Year-Round		Dry (Dec-Apr)		Wet (May-Sep)		
	BBMP	MultiDam	BBMP	MultiDam	BBMP	MultiDam	
Q90 (330/140 days)	1.060	1.060	0.771	0.000	7.511	5.737	
Q80 (290/125 days)	1.928	1.928	0.964	0.081	18.024	18.144	
Q60 (220/95 days)	21.030	20.241	1.639	0.832	40.000	39.781	
Q40 (145/60 days)	40.000	40.000	6.265	1.980	40.000	39.991	
Q20 (70/30 days)	40.000	40.000	40.000	5.519	40.000	39.999	
Qave	25.060	25.063	14.825	4.824	32.105	31.865	
Integral (Q20-Q90)	24.654	24.496	13.841	2.230	31.830	31.536	
Area Irrigated (ha)	20545	20414	11534	1859	26525	26280	

Hydropower generation (in MW) at BBMP (1 hydropower plant) versus Multiple Dam Project (5 hydropower plants located at S1, S2, S3, S4 and S5)

Hydropower Generation in MW for 10 Hrs Operations per Day							
	Base Year		*After 25 Years***		*After 50 Years***		
	BBMP	MultiDam	BBMP	MultiDam	BBMP	MultiDam	
Q90 (330 days)	0.000	1.237	0.778	1.794	0.996	1.906	
Q80 (290 days)	0.000	3.647	1.415	4.773	1.810	5.092	
Q60 (220 days)	1.590	7.010	16.943	9.983	20.186	10.526	
Q40 (145 days)	38.464	22.998	43.277	32.850	47.635	34.250	
Q20 (70 days)	60.382	60.322	62.651	64.370	64.746	65.088	
Qave	29.148	26.901	33.487	30.649	35.691	31.419	
Integral (Q20-Q90)	26.125	24.831	31.168	28.863	33.409	29.531	
GWH/Year	95.358	90.632	113.764	105.349	121.942	107.789	
@ 3 pesos/kW-hour	286	272	341	316	366	323	

Note: Last row are revenues in millions of pesos.

**** Hydropower generation are higher as sediment accumulate since reservoirs are operating at higher reservoir elevations but tailhead elevations of hydropower plants are assumed the same during construction, i.e., same with Base Case.**

NIA's BBMP Dam Details and Costs

SITE/LOCATION	CREST W (m)	U/S SLOPE (1V: H)	D/S SLOPE (1V: H)	DAM TOTAL H (m)	RIVER WIDTH B (m)	CREST L (m)	TOTAL VOLUME (m^3)	COST (pesos)
MAIN DAM	15	2	2	115.5	80	1460	5741495	
CLAY CORE	10	0.22	0.22	115.5	80	1460	2474172	873,283,661
ROCKFILL							3267323	3,117,418,459
TOTAL							**5741495**	**3,990,702,120**

Balog-Balog Multiple Dam System: Details and Costs

	SITE/LOCATION	CREST W (m)	U/S SLOPE (1V: H)	D/S SLOPE (1V: H)	DAM TOTAL H (m)	RIVER WIDTH B (m)	CREST L (m)	TOTAL VOLUME (m3)	CLAY CORE VOL (m3)	CLAY CORE Amount (P)	ROCKFILL VOL (m3)	ROCKFILL Amount (P)
S1	LOWER BULSA	10	2	2	47	40	392	799,616.63	204,230.68	72,085,260.81	595,385.95	568,069,642.61
S2	MIDDLE BULSA	10	2	2	45	280	732	1,971,900.00	504,360.00	178,018,905.60	1,467,540.00	1,400,209,264.80
S3	UPPER BULSA	10	2	2	45	70	432	885,150.00	226,935.00	80,098,977.60	658,215.00	628,016,095.80
S4	MALILIT-ALUDIG	10	2	2	45	40	365	691,875.00	177,525.00	62,659,224.00	514,350.00	490,751,622.00
S5	SULA	6	2	2	20	40	218	94,946.67	27,606.67	9,744,050.24	67,340.00	64,250,440.80
S6	BULSA-MORIONES	7	2	2	25	200	510	441,291.66	121,416.66	42,855,224.31	319,875.00	305,199,135.00
S7	LOWER BOYBOY	9	2	2	35	60	279	379,242.50	99,260.00	35,034,809.60	279,982.50	267,136,902.90
S8	UPPER BOYBOY	10	2	2	40	160	547	1,066,200.00	273,620.00	96,576,915.20	792,580.00	756,216,429.60
S9	TIBAGAN	6	2	2	13	40	98	25,436.67	7,704.67	2,719,440.32	17,732.00	16,918,455.84
	TOTAL							**6,355,659.13**	**1,642,658.68**	**579,792,807.69**	**4,713,000.45**	**4,496,767,989.35**
	TOTAL COST											**5,076,560,797.05**

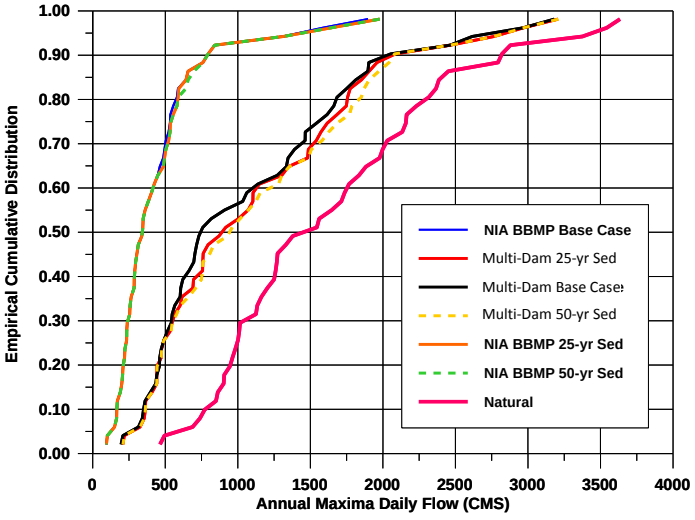
Estimates of B/C ratio, Net present values and IRR for BBMP and Multiple Dam Project for base case and after 25 years & after 50 years with sedimentation. (Irrigation benefits for rice, sugarcane, corn, potato, eggplant, tomato, string beans, ampalaya, etc but excludes hydropower)

Indicator	Base Case		Base plus 20% higher investment & 20% less irrigation benefits		Case with 25 years with sedimentation		Case with 50 years with sedimentation	
	Multiple Dam Proj	BBMP	Multiple Dam Proj	BBMP	Multiple Dam Proj	BBMP	Multiple Dam Proj	BBMP
B/C ratio	1.67	2.77	1.12	1.84	1.19	2.73	1.16	2.71
NPV @ 15% (Mn Pesos)	2,972	6,128	612	3,514	819	5,991	703	5,921
EIRR (%)	20	27	16	21	17	27	16	27

Observation: **Results indicate higher B/C ratios, NPV and IRR for all BBMP single dam cases excluding hydropower component**

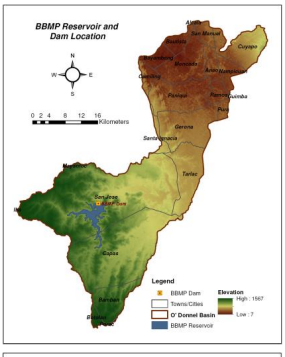
Flood Frequency of Uncontrolled Flows at Location S9: NIA's BBMP versus BB multiple dam system

Clearly NIA's BBMP has lower flood magnitudes compared to those of BB multiple dam scheme.

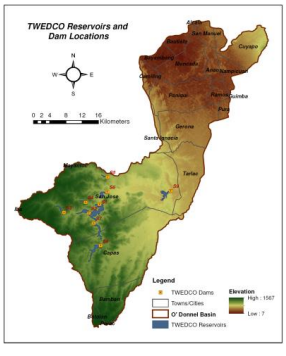


Communities and Household Affected by Dam Backwater Upstream Inundation

BBMP Single Dam	Town_City	Est_Houses
*	San_Jose	238
*	Capas	92
	Total Houses Affected	**330**



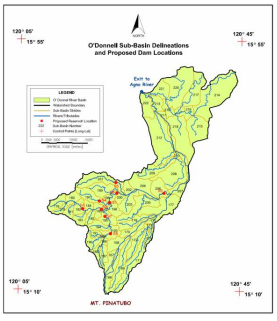
Multiple Dam Proj	Town_City	Est_Houses
S1	San_Jose	78
S2	San_Jose	134
S3	San_Jose	20
S4	San_Jose	4
S5	San_Jose	6
S6	San_Jose	12
S7	San_Jose	4
S7	Capas	40
S8	Capas	142
S9	San_Jose	48
	Total Houses Affected	**488**

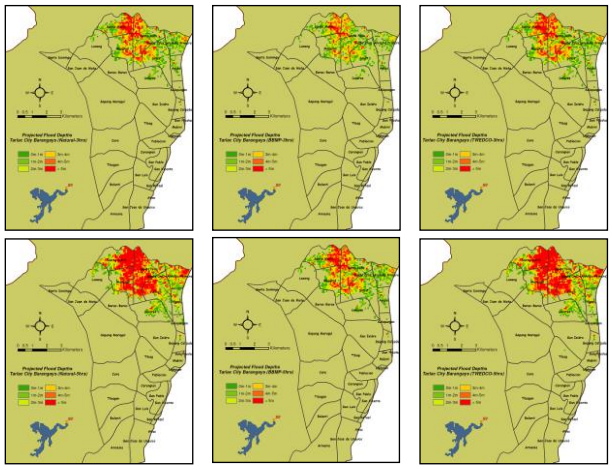


Flood Control Benefits to Downstream Cities

Flood inundated areas with sustained flows of 3 hours.

Flood inundated areas with sustained flows of 5 hours.





(a) without a reservoir (b) with BBMP single dam (c) with multiple dams

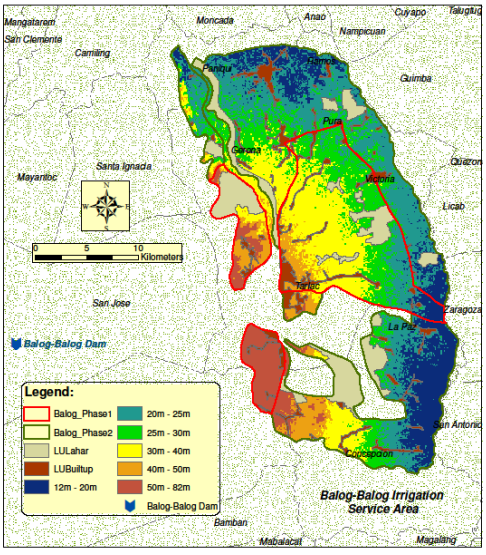
Scenario	Discharge (m^3/s)	Time Sustained (hr)	Total Flood Volume (m^3)	Total Flooded Area (ha)	Flood Water Level (m)	Average Flood Depth (m)
Natural-3Hrs	3650	3	39.420	120.265	39.947	3.278
BBMP-3Hrs	1980	3	21.384	96.073	38.308	2.226
MultiDam-3Hrs	3200	3	34.560	120.265	39.543	2.874
Natural-5Hrs	3650	5	65.700	157.934	41.735	4.160
BBMP-5Hrs	1980	5	35.640	120.265	39.633	2.963
MultiDam-5Hrs	3200	5	57.600	157.934	41.222	3.647

Validation of Balog-Balog Irrigation Service Area

Design Service Area: 34,410 ha
Phase 1: 12,475 ha
Phase 2: 21,935 ha

Estimated in this Study: 38,180 ha
Phase 1: 15,102 ha
Phase 2: 23,078 ha

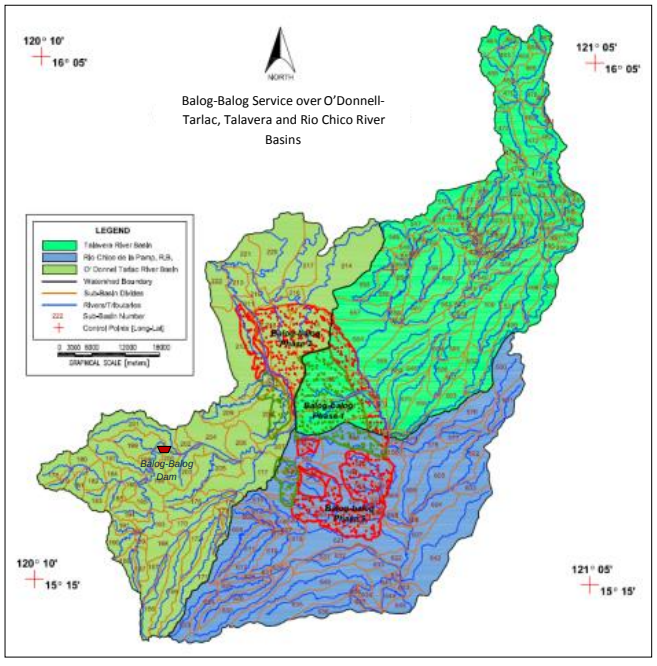
Phase I:		
Total Area (footprint)		**23,028**
Built-up Area	2,069	
Lahar Area	2,893	
Roads/ Streets	1,059	
Fish Pen/Ponds	1,283	
Others (i.e. grass, scrub, etc.	532	
Area Below 17m (flooded)	89	
Total Non-Irrigable		**7,926**
Net Irrigable Area*		***15,102***
Phase 2:		
Total Area (footprint)		**39,328**
Built-up Area	4,253	
Lahar Area	5,043	
Roads/ Streets	2,624	
Fish Pen/Ponds	902	
Others (i.e. grass, scrub, etc.	1,944	
Area Below 17m (flooded)	1,485	
Total Non-Irrigable		**16,250**
Net Irrigable Area*		***23,078***



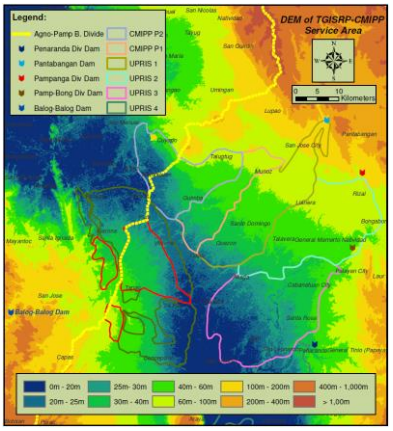
Alternative Water Source for Balog-Balog Irrigation System

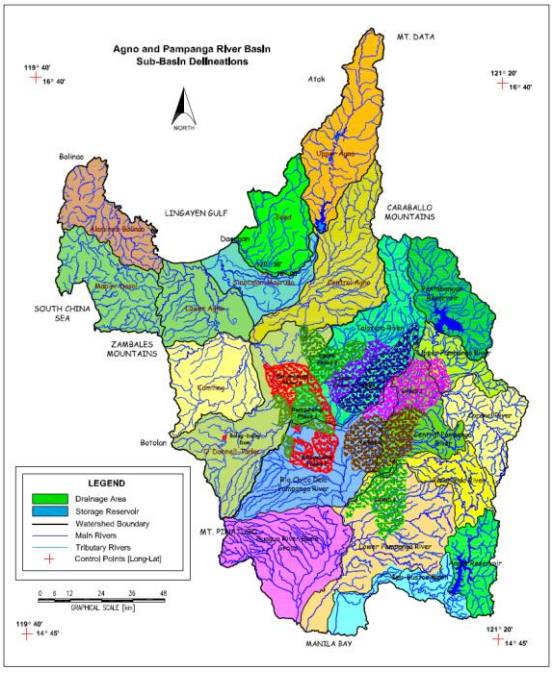
This is especially the case during dry season since Balog-balog reservoir water is not enough!

- **Rio Chico River**
- **Talavera River**



Watershed Divides within Irrigation Projects





Last slide!