Layer 7 (EL. -400 m ~ -600 m)

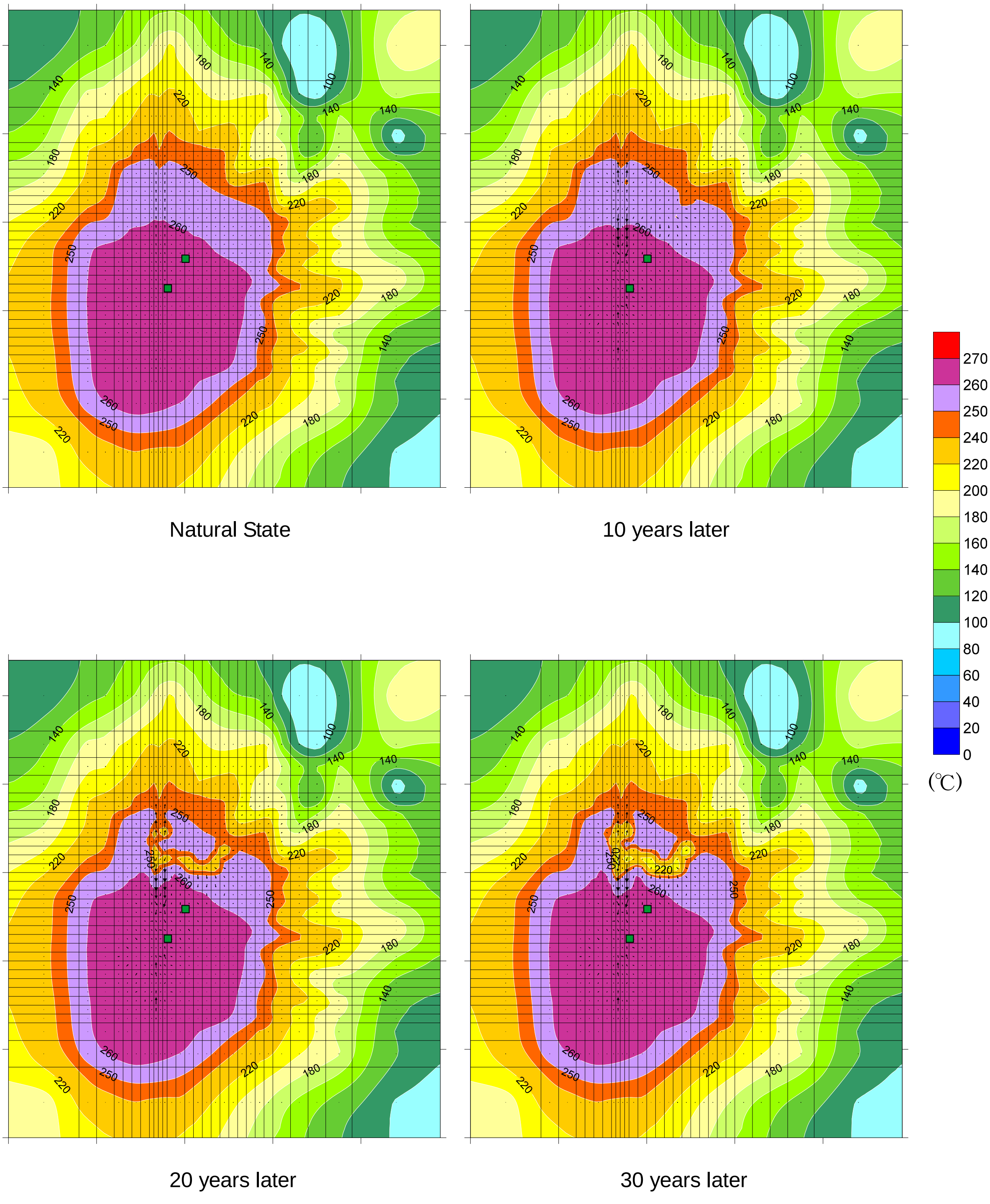


Fig. 3.3-80 Forecasted Temperature Distributions in Layer 7 (EL. -500 m asl)

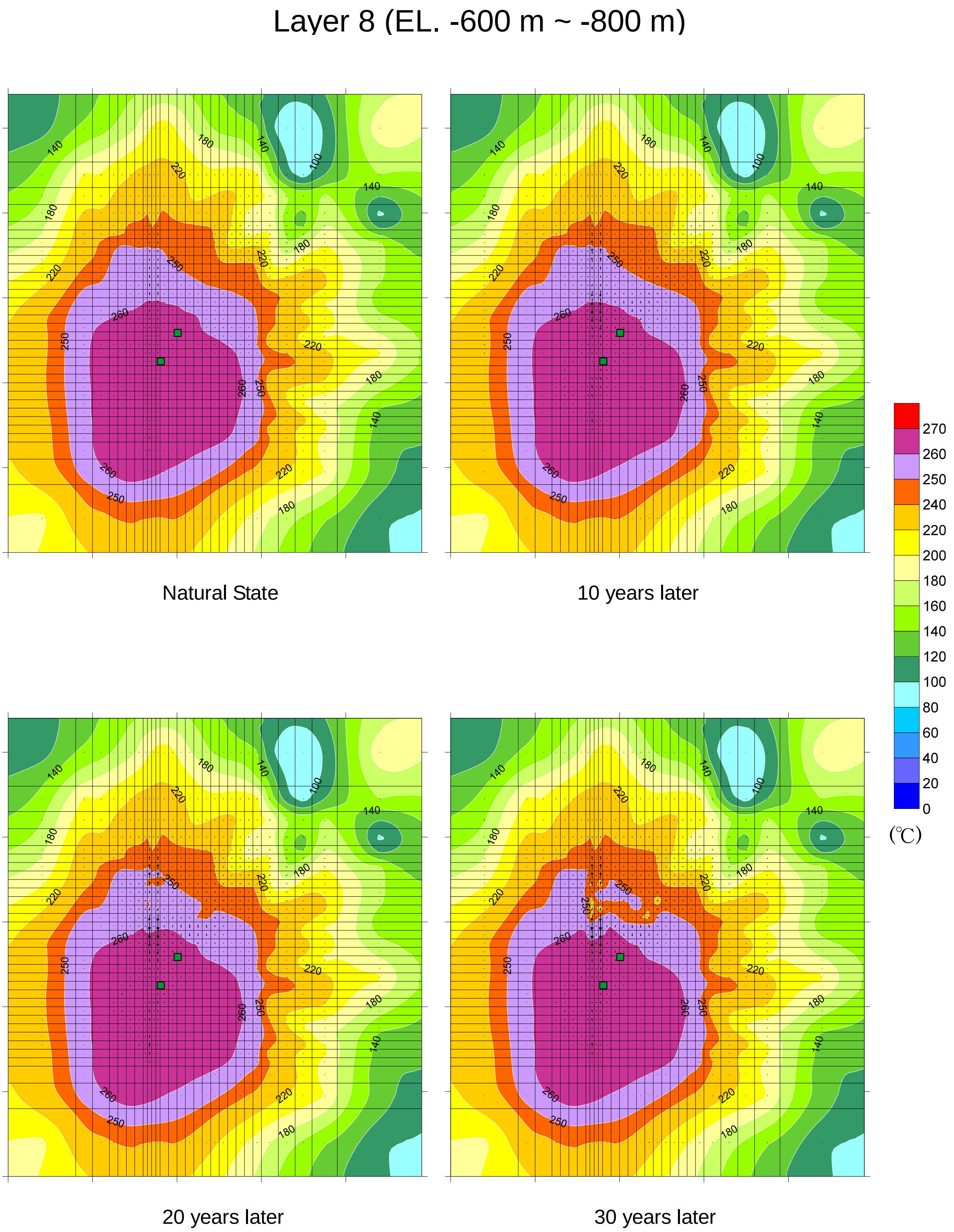


Fig. 3.3-81 Forecasted Temperature Distributions in Layer 8 (EL. -700 m asl)

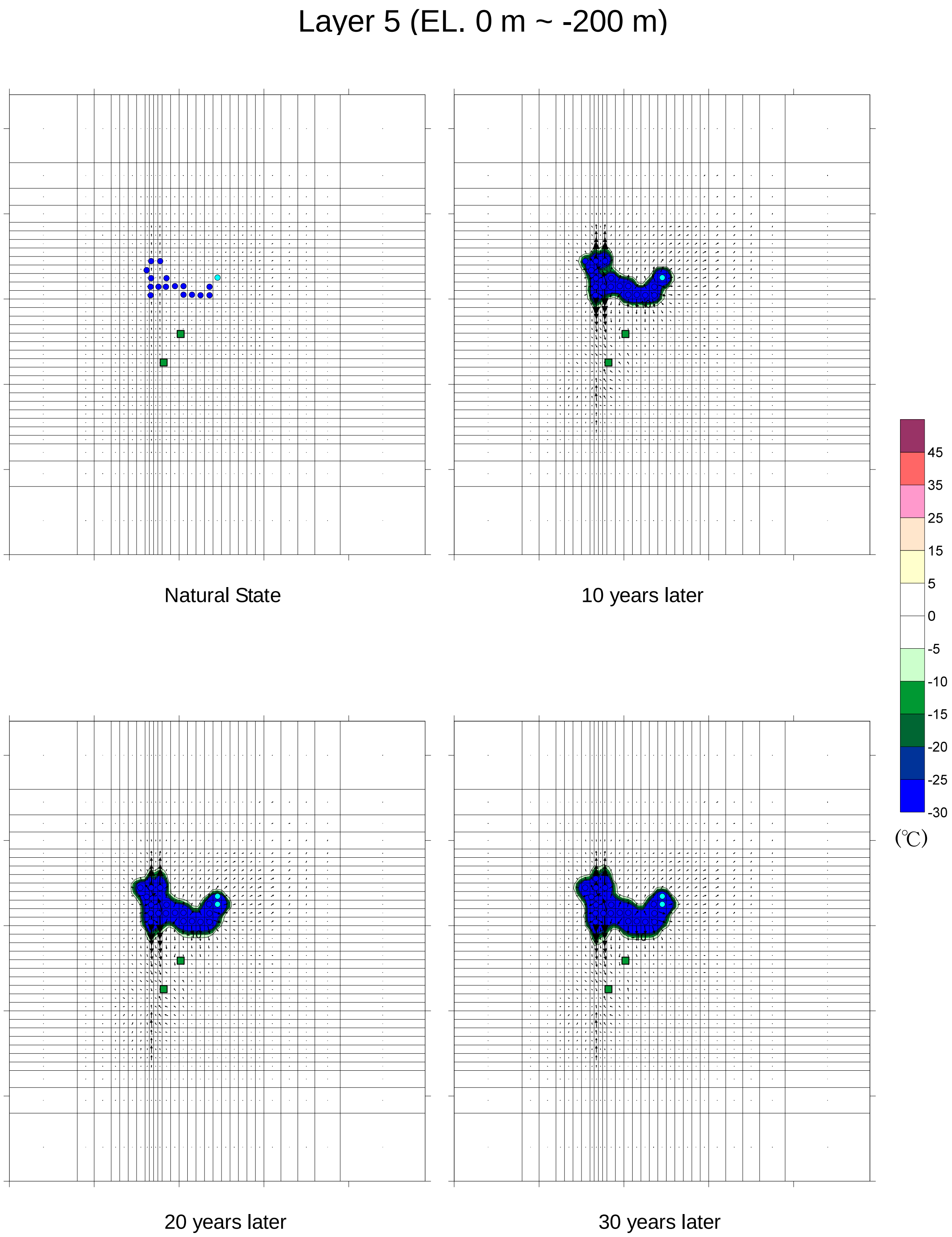


Fig. 3.3-82 Temperature Difference from Steady State in Layer 5 (EL. -100 m asl)

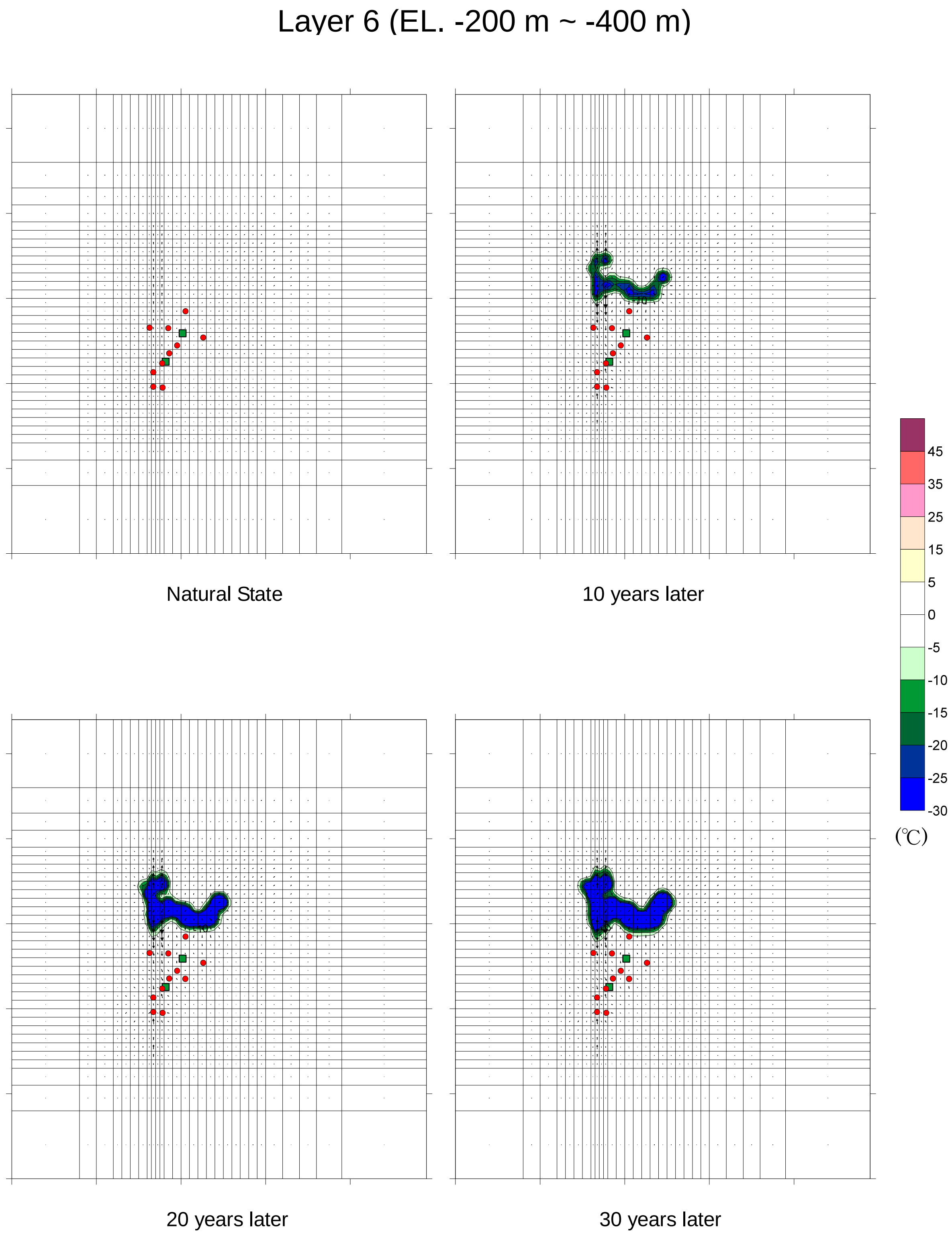


Fig. 3.3-83 Temperature Difference from Steady State in Layer 6 (EL. -300 m asl)

Layer 7 (EL. -400 m ~ -600 m)

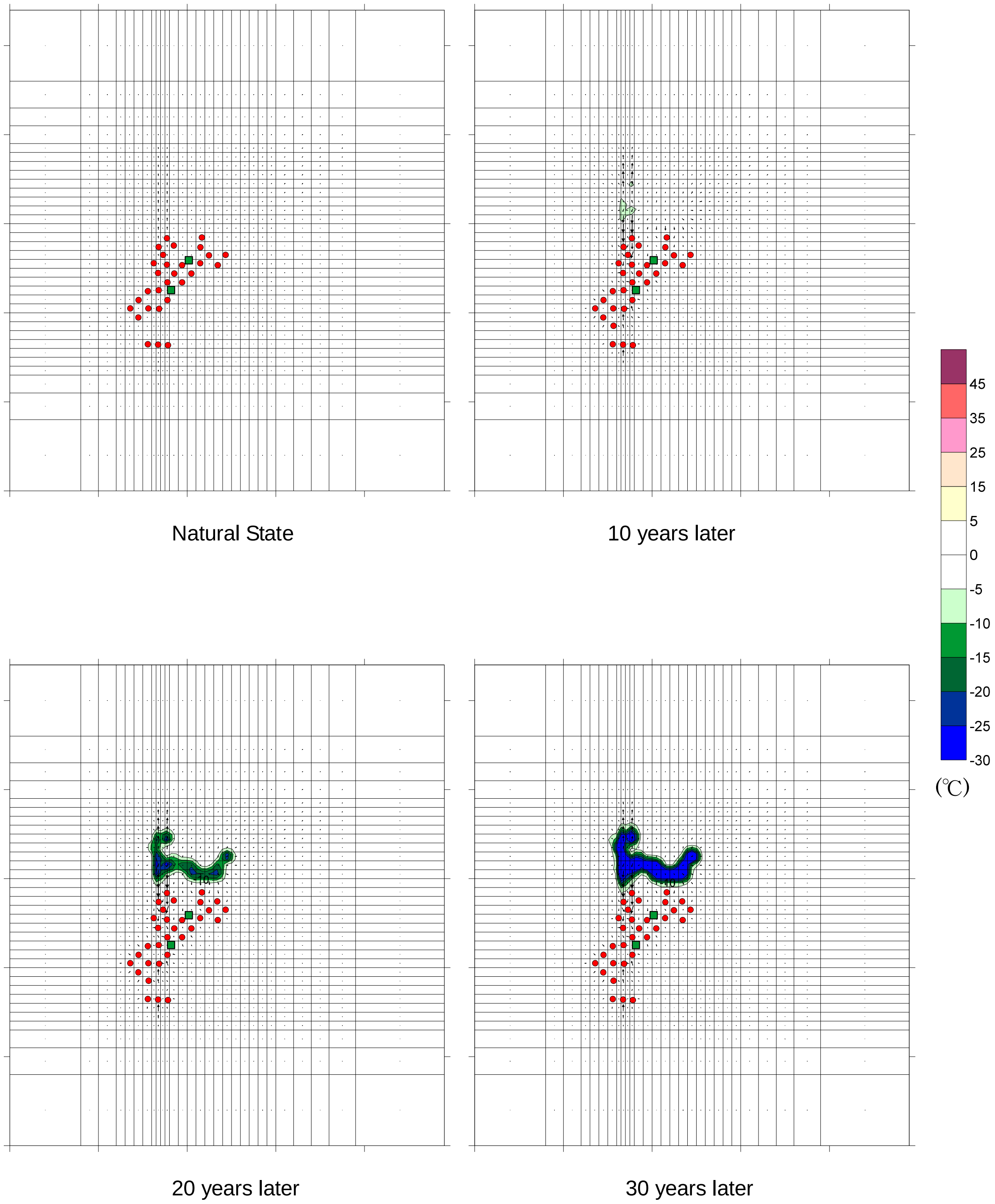


Fig. 3.3-84 Temperature Difference from Steady State in Layer 7 (EL. -500 m asl)

Layer 8 (EL. -600 m ~ -800 m)

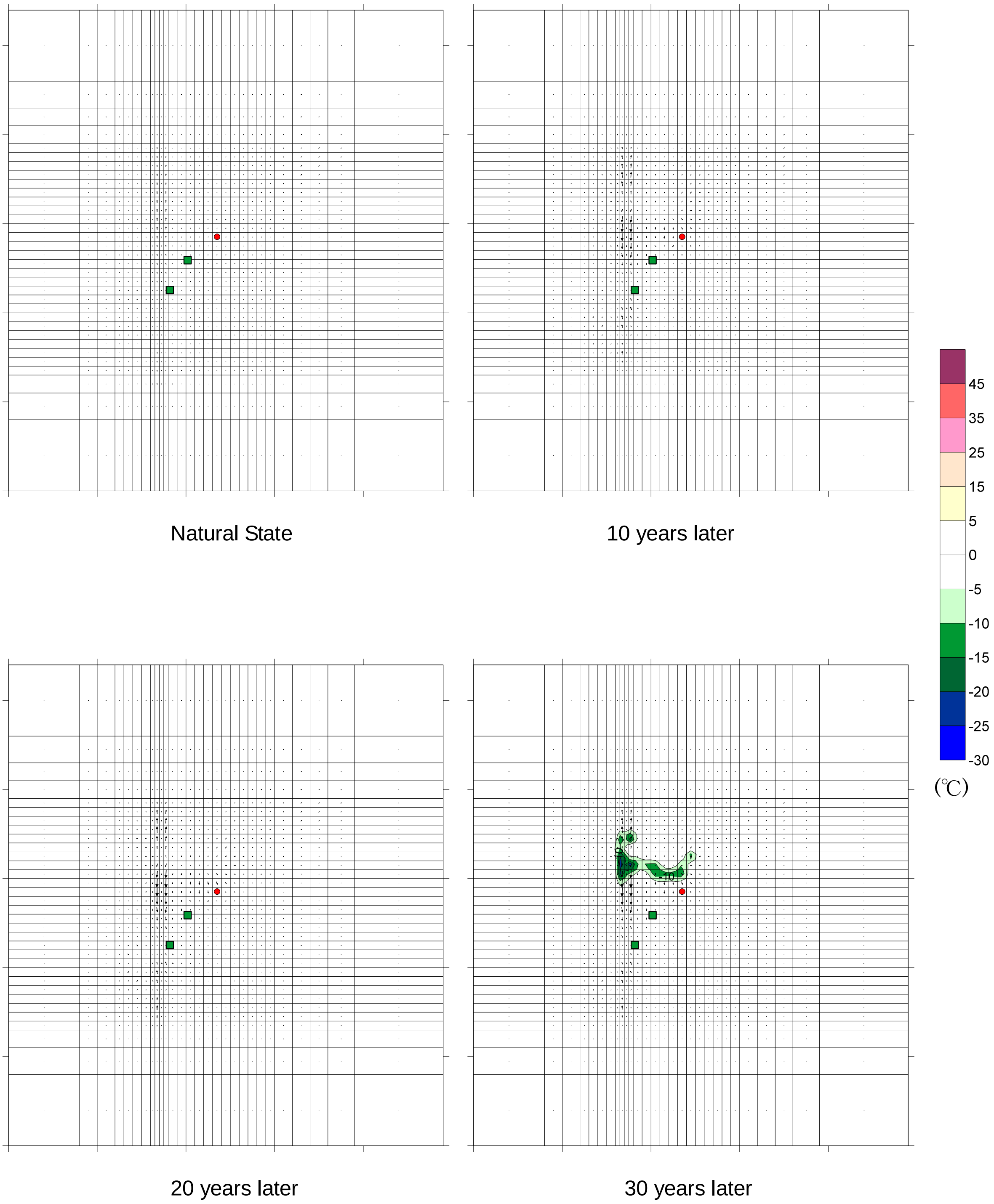


Fig. 3.3-85 Temperature Difference from Steady State in Layer 8 (EL. -700 m asl)

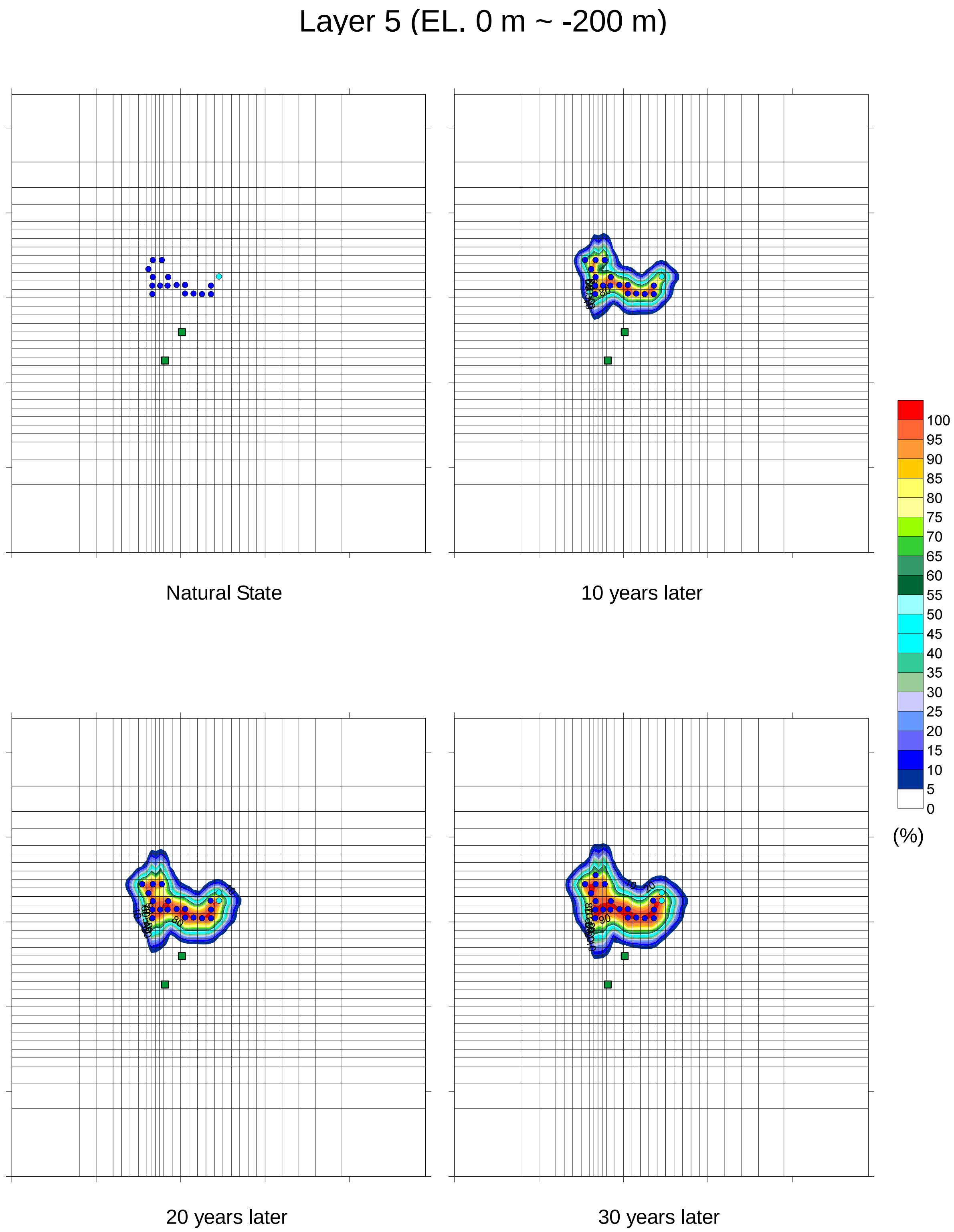


Fig. 3.3-86 Forecasted Reinjected Water Distributions in Layer 5 (EL. -100 m asl)

Layer 6 (EL. -200 m ~ -400 m)

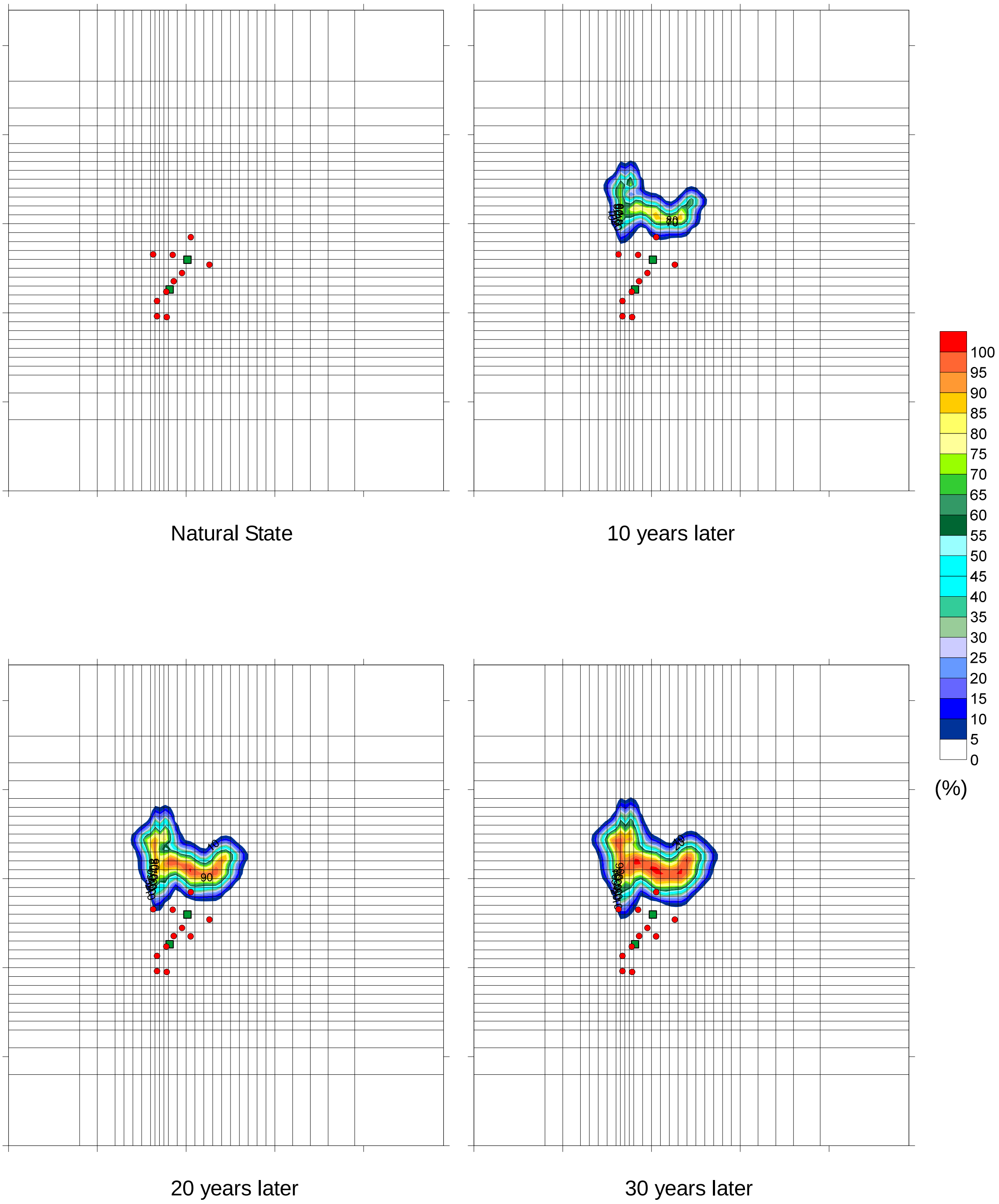


Fig. 3.3-87 Forecasted Reinjected Water Distributions in Layer 6 (EL. -300 m asl)

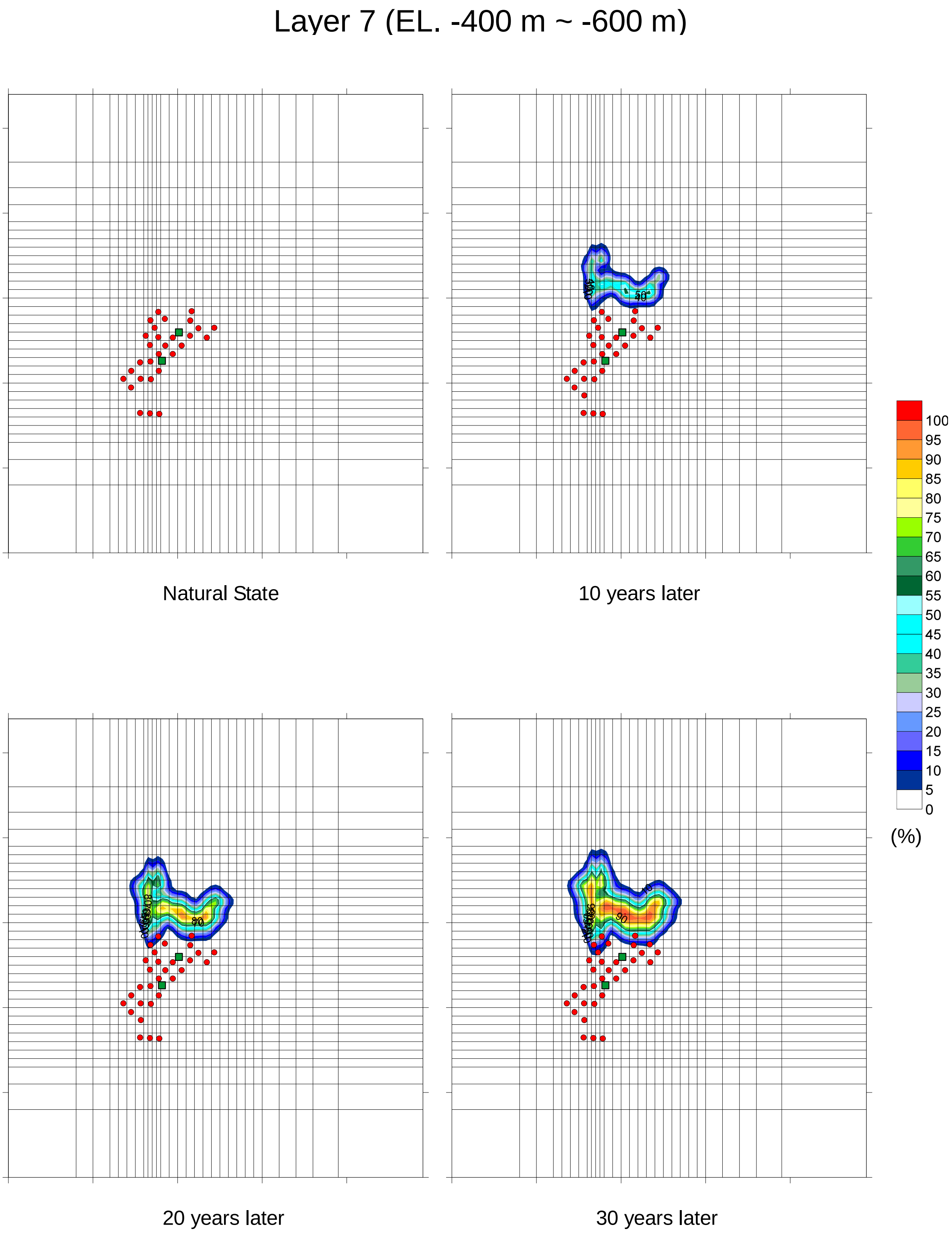


Fig. 3.3-88 Forecasted Reinjected Water Distributions in Layer 7 (EL. -500 m asl)

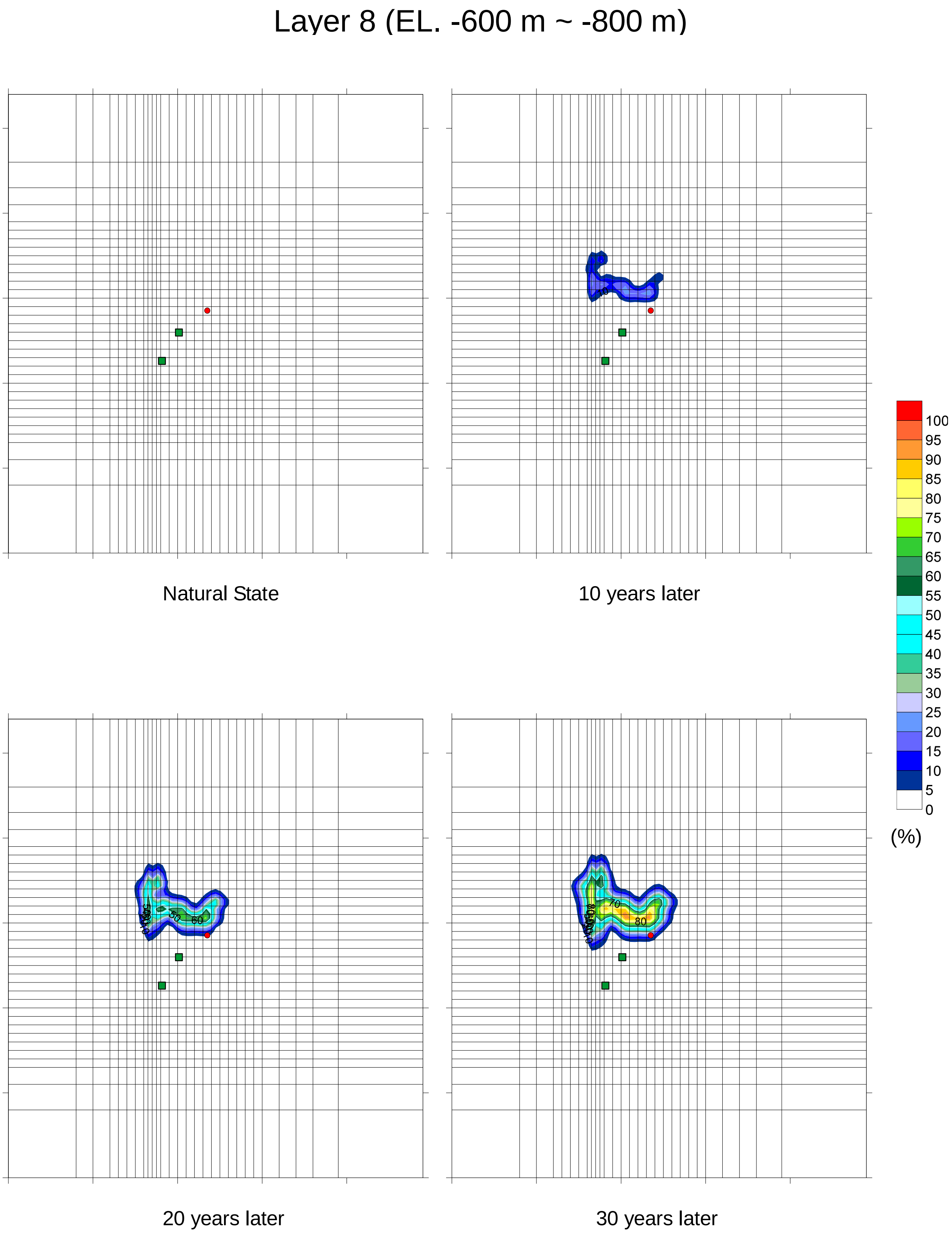


Fig. 3.3-89 Forecasted Reinjected Water Distributions in Layer 8 (EL. -700 m asl)

3.3.4 Conclusions

Since available well data are limited to the northern area around well pad LMB 1 and 3 in the Lumut Balai geothermal field, it is still difficult to finalize the reservoir numerical model. Therefore, the results of this reservoir simulation should be considered as a preliminary study for reference. However, the numerical model explains reasonably the natural state conditions in the reservoirs, although historical data matching has not been conducted because of the lack of well data.

This suggests that the numerical model is useful as a preliminary forecasting simulation that is reasonably reliable for evaluating the sustainability of the reservoirs for the planned power generation. The forecasting simulation leads to the conclusion that the reservoirs in Lumut Balai will have enough capacity to sustain the power plant operation of 220 MW (Units 1 to 4) during the plant operating life of 30 years.

(1) Number of start-up wells

The number of start-up wells that is required for commencing the power plant operation of Units 3 and 4 (110 MW) is 17 for production and 8 for reinjection (7 for brine reinjection and one for steam condensate reinjection). One make-up production well and another two make-up reinjection wells (one for brine and one for steam condensate reinjection) are required over 30 years.

Simulated No. of well	Unit 1&2 (110 MW)		Unit 3&4 (110 MW)		Total (220 MW)	
	Start-up	Make-up	Start-up	Make-up	Start-up	Make-up
Production well	21	2	17	1	38	3
Reinjection well	8	2	8 (1)	2 (1)	16 (1)	4 (1)
Total	29	4	25	3	54	7

* Make-up wells would be required for the 30-year plant operation. () indicates the number of steam condensate injection well

(2) Steam and brine flow rates at each production well pad

Three well pads LMB 2, 7, and 10 should be used as production well pads to commence the power plant operation of Units 3 and 4. Assuming that the maximum number of production wells at each well pad is six, the simulated numbers of wells at the well pads LMB10, 2 and 7 are six, six, and five, respectively. The simulated steam flow rate at each well pad is around 280 to 340 t/h and brine flow rate is around 900 to 1100 t/h.

(3) Optimum turbine inlet pressure

It is recommended that the optimum turbine inlet pressure be 5.5 bara, taking into account appropriate turbine size in terms of the manufacturing cost. In future, detailed turbine design should be discussed after obtaining additional data from production wells at the well pads LMB 2, 5, and 10. If the production wells at these well pads show dominant productivity beyond the current estimation, it will be possible to increase the design turbine inlet pressure. In this case, the manufacturing cost of the turbine will be lower than the current cost estimation, because the turbine size will be reduced.

Power Output (MW)	Unit 1&2	Unit 3&4
Wellhead pressure (bara)	8.0	8.0–8.5
Separator pressure (bara)	6.8	6.8
Turbine inlet pressure (bara)	5.5	5.5
Steam requirement (t/h)	924	924

(4) Number of make-up wells and change of mass flow rate of the produced fluids over time

The forecasted results suggest that only one make-up production well and two make-up reinjection wells will be required to maintain the required steam production and injection capacity of wells. This means that the reservoir will be very stable after producing and reinjecting the geothermal fluids used in power generation. However, it is recommended that an annual decline rate of 3% should be assumed in determining the number of make-up wells for the calculation of O&M cost to avoid overly optimistic predictions, considering that the precision of this reservoir numerical model is still low. As a future task, the model should be revised to validate its reliability based on additional data from the wells.

(5) Changes of properties in the reservoir over time

In the production zones, the reservoir temperature would be almost stable except in the northern area where well pad LMB 3 is located. The productivity of production wells at LMB 3 will decline slightly. However, the degree of cooling in the production zones will be very small, because the distance between production and reinjection zones is great enough to avoid cooling effects due to the migration of reinjected water into production zones. Therefore, the plant power output will be almost stable over the operating life 30 years.

3.4 Field Development Plan

3.4.1 Production and Reinjection Zones

A proposed development plan in terms of well-drilling is shown in Fig. 3.4-1. Considering PGE’s current plan for the utilization of well pads, production wells for Units 3 and 4 will be drilled from well pads LMB 10, 2 and LMB 7, targeting the prospective productive faults F1, F2 and F3, where reservoir temperature and permeability are expected to be higher. Based on the results of preliminary reservoir simulation study, seventeen (17) production wells should be prepared as start-up production wells to commence the 110 MW power plant operation (55 MW x 2 units). Based on the heat balance of the power plant where the steam should be provided at the inlet pressure of 5.5 bara into the turbine, the required steam flow rate is calculated to be 462 t/h for each unit. Therefore, a total steam flow rate of 924 t/h is required for Units 3 and 4. The results of reservoir simulation indicate that each well pad will produce steam of 280 to 340 t/h and brine of 900 to 1100 t/h, which indicates that the total mass flow rate from the three well pads will reach around 4000 t/h (steam 940 t/h and brine 3060 t/h). When additional well data are obtained in the future, production zones to be developed will be distinguished more clearly.

With respect to the reinjection plan, there is no data on the prospective area to date. The current plan is that two reinjection well pads “InjA” and “InjB” will be constructed as reinjection well pads for the disposal of brine and steam condensate. The reinjection wells should be drilled from these well pads, targeting the faults F1, F2 and F4 in the northern area of the field. The results of the reservoir simulation suggest that the distance between the production zones and reinjection zones would be great enough to avoid serious cooling in the production zones due to the migration of reinjected water into the production zones. The simulation results also suggest that eight (8) reinjection wells would be required for the disposal of the 3060 t/h of brine and 380 t/h of steam condensate (about 20% of the total steam flow rate for all units 1 to 4), assuming the permeability-thickness product (kh) of the reinjection zones to be 10 darcy-m. Seven reinjection wells should be used for the brine disposal and one reinjection well for steam condensate.

When the reinjection wells are actually drilled in the prospective area in the future, reinjection zones to be developed will be distinguished more clearly.

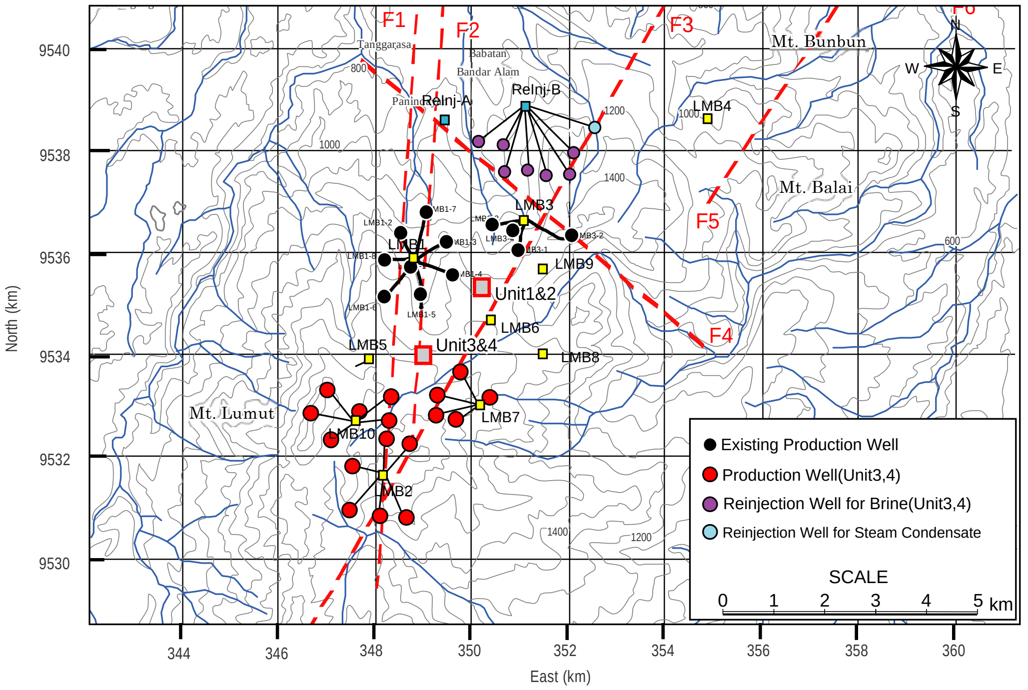


Fig. 3.4-1 Prospective Production and Reinjection Zones

3.4.2 Required Number of Wells

(1) **Start-up Wells**

As mentioned in the previous section, the required numbers of start-up production and reinjection wells were forecasted by the reservoir simulation, and these are summarized in Table 3.4-1 and
Table 3.4-2. The required numbers of start-up wells for Units 3 and 4 (110 MW) are 17 for production and 8 for reinjection (7 for brine reinjection and one for steam condensate reinjection).

Table 3.4-1 Simulated Productivity of Production Wells

Well pad	Well Name	Assumed pressure (bara)			Flow rate (ton/hour)			Power Output (MWe)
		Wellhead	Separator	Turbine	Steam	Water	Total	
LMB10	LMB10-1	8.0	6.8	5.5	53.3	171.9	225.2	6.3
	LMB10-2	8.0	6.8	5.5	58.7	189.4	248.1	7.0
	LMB10-3	8.0	6.8	5.5	59.0	186.0	243.0	6.8
	LMB10-4	8.0	6.8	5.5	54.6	180.5	235.1	6.5
	LMB10-5	8.0	6.8	5.5	58.7	189.4	248.0	7.0
	LMB10-6	8.0	6.8	5.5	57.7	187.3	245.0	6.9
	Sub-total				340.0	1104.4	1444.4	40.5
LMB 2	LMB 2-1	8.5	6.8	5.5	56.6	182.6	239.2	6.7
	LMB 2-2	8.5	6.8	5.5	52.7	169.8	222.5	6.3
	LMB 2-3	8.5	6.8	5.5	52.6	169.5	222.1	6.3
	LMB 2-4	8.5	6.8	5.5	56.4	182.3	238.7	6.7
	LMB 2-5	8.5	6.8	5.5	55.7	179.9	235.6	6.6
	LMB 2-6	8.5	6.8	5.5	55.9	180.6	236.5	6.6
	Sub-total				329.9	1064.7	1394.6	39.2
LMB 7	LMB 7-1	8.0	6.8	5.5	54.4	175.3	229.6	6.5
	LMB 7-2	8.0	6.8	5.5	54.5	176.3	230.8	6.5
	LMB 7-3	8.0	6.8	5.5	58.5	188.6	247.1	7.0
	LMB 7-4	8.0	6.8	5.5	52.9	170.4	223.3	6.3
	LMB 7-5	8.0	6.8	5.5	55.8	180.5	236.3	6.3
	Sub-total				276.1	891.1	1167.1	32.9
Total					946.0	3060.1	4006.1	112.6

Table 3.4-2 Required Number of Start-up Wells

Well pad	Production wells	Reinjection wells		Total
		Brine	Steam condensate	
LMB 10	6	0	0	6
LMB 2	6	0	0	6
LMB 7	5	0	0	5
Reinjection B	0	7	1	8
Total	17	7	1	25

(2) **Make-up Wells**

The power output of a geothermal power plant and the injection capacity of reinjection wells commonly decline over time due to changes that occur in the reservoir after commencing plant operation. The annual rate of decline of power output and injection capacity depends on reservoir properties and the development plan for the geothermal field. If sustainable development can be achieved, the actual rate of decline will be very close to zero, which means that almost no make-up wells are required during the plant life. In fact, the results of the reservoir simulation indicated that only one production well and two reinjection wells would be required over the plant life of 30 years, which suggest that the reservoir can sustain the power generation of Units 3 and 4 for 30 years. One make-up production well and one reinjection well for brine disposal should be added at 4 years after commencement of power plant operation, and one make-up well for steam condensate at 12 years.

However, it is recommended that an annual rate of decline of 3% should be assumed in determining the number of make-up wells for the calculation of O&M costs to avoid overly optimistic predictions, considering that the precision of this reservoir numerical model is still low because the existing well data available for model construction are currently derived only from well pads LMB 1 and LMB 3. Consequently, the following standard assumptions factor into the basic estimate of the number of make-up wells.

Power output of production wells: decline of 3% per year

Injection capacity of reinjection wells for brine disposal: decline of 3% per year

Injection capacity of reinjection wells for steam condensate disposal: decline of 1% per year

The calculated number of make-up wells is represented in Fig. 3.4-2 and Fig. 3.4-3, and summarized in Table 3.4-3. These suggest that 12 make-up production wells and 4 make-up reinjection wells for brine disposal will be required over 30 years of plant operation. A new well pad for production wells LMB 8 and LMBX should be prepared within 6 years and 19 years, respectively, after commencement of plant operation. To arrive at a conservative estimation, the number of make-up wells was finalized by combining the above number of wells with those forecasted as necessary by the reservoir simulation. The total number of wells required for both start-up and make-up is summarized in Table 3.4-4. The timing for adding make-up wells is indicated in Table 3.4-5.

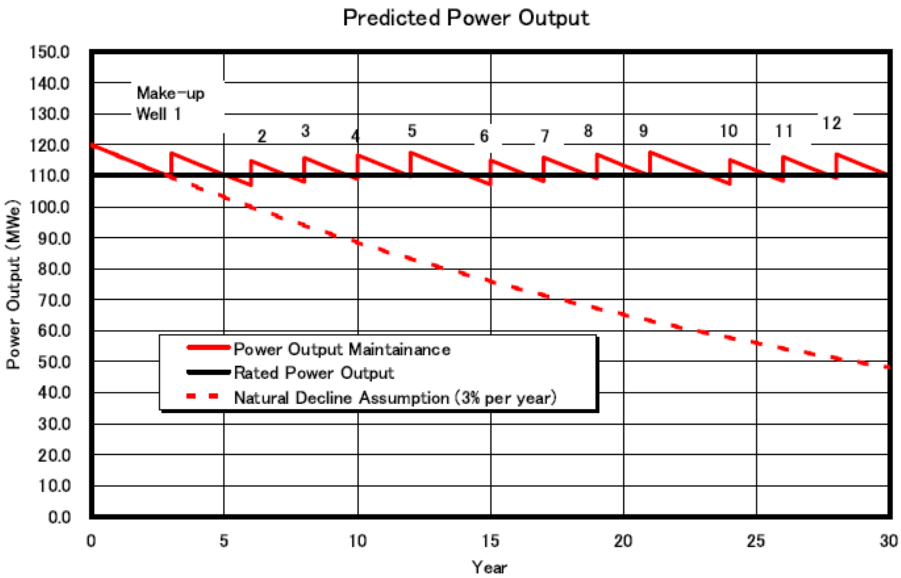


Fig. 3.4-2 Timing for Adding Make-up Production Wells

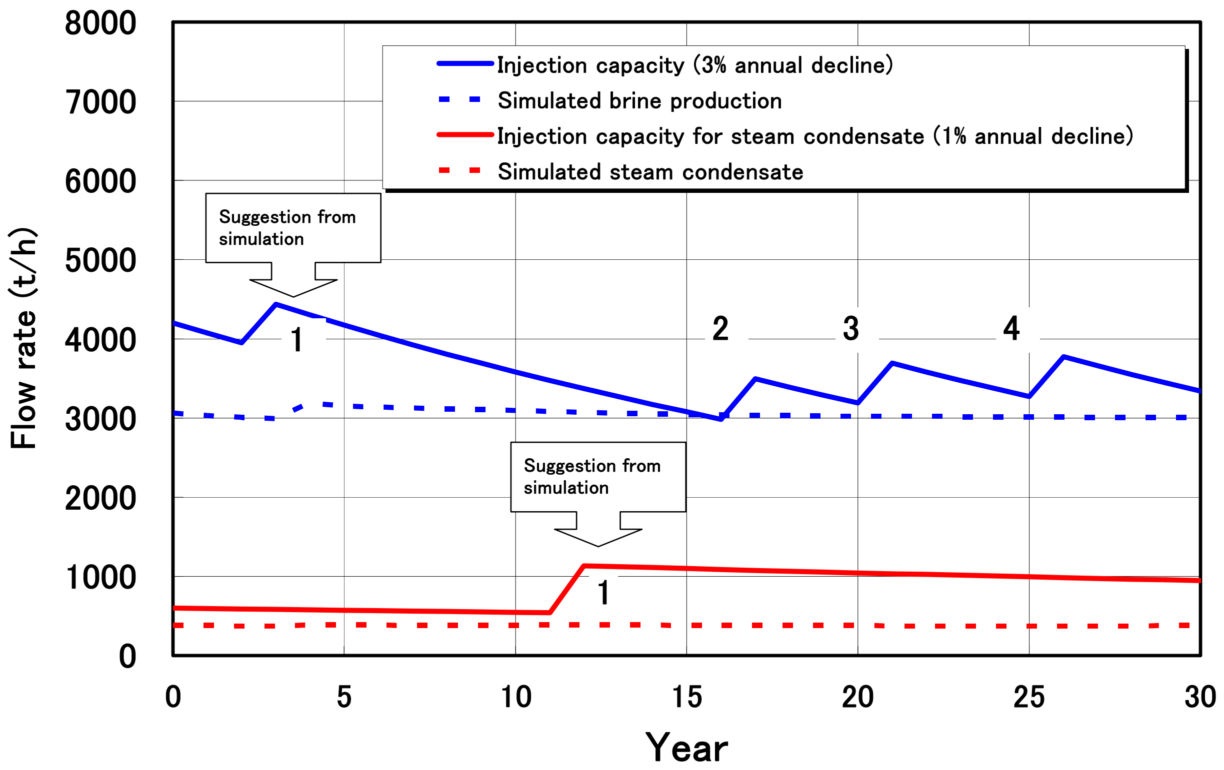


Fig. 3.4-3 Timing for Adding Make-up Reinjection Wells

Table 3.4-3 Required Number of Make-up Wells

Well pad	Production wells	Reinjection wells		Total
		Brine	Steam condensate	
LMB10	0	0	0	0
LMB 2	0	0	0	0
LMB 7	1	0	0	1
LMB 8	6	0	0	6
LMBX	5	0	0	5
Reinjection B	0	4	1	5
Total	12	4	1	17

Table 3.4-4 Required Number of Start-up and Make-up Wells

Well pad	Production wells	Reinjection wells		Total
		Brine	Condensate	
LMB10	6	0	0	6
LMB 2	6	0	0	6
LMB 7	5+1	0	0	5+1
LMB 8	+6	0	0	+6
LMBX	+5	0	0	+5
Reinjection B	0	7+4	1+1	8+5
Total	17+12 = 29	7+4 = 11	1+1 = 2	25+17 = 42

Table 3.4-5 Timing for Adding Make-up Wells

Year	Make-up production well	Make-up reinjection well		Total	Additional well pad
		for brine	for steam condensate		
1	0	0	0	0	
2	0	0	0	0	
3	1	1	0	2	
4	0	0	0	0	
5	0	0	0	0	
6	1	0	0	1	LMB 8
7	0	0	0	0	
8	1	0	0	1	
9	0	0	0	0	
10	1	0	0	1	
11	0	0	0	0	
12	1	0	1	2	
13	0	0	0	0	
14	0	0	0	0	
15	1	0	0	1	
16	0	0	0	0	
17	1	1	0	2	
18	0	0	0	0	
19	1	0	0	1	LMB X
20	0	0	0	0	
21	1	1	0	2	
22	0	0	0	0	
23	0	0	0	0	
24	1	0	0	1	
25	0	0	0	0	
26	1	1	0	2	
27	0	0	0	0	
28	1	0	0	1	
29	0	0	0	0	
30	0	0	0	0	
Total	12	4	1	17	

3.4.3 Drilling Strategy

(1) Drilling Pads

The Lumut Balai project area is located in the mountainous district of Bukit Lumut and Bukit Balai and is characterized by a relatively steep topography. In this area two drilling pads (Cluster LMB 1 and Cluster LMB 3) for Units 1 and 2 have already been constructed. Another well pad, LMB 4, is prepared for investigation in Kelumpang-Sindawan-Bunbun Sector in the northeastern area of the field, but is more than 4 km from well pad LMB 3. This well pad can not be used for this project, because it is too far away to utilize as a reinjection well pad. At the existing drilling pad of Cluster LMB 1, 8 wells (LMB 1-1, LMB 1-2, LMB 1-3, LMB 1-4, LMB 1-5, LMB 1-6, LMB 1-7 and LMB 1-8) have been drilled, and 4 wells (LMB 3-1, LMB 3-2, LMB 3-3 and LMB 3-4) have also been drilled at Cluster LMB 3. These drilled geothermal wells will be utilized for Units 1 and 2. Access roads from the existing road to these drilling pads have been constructed and extended in a southerly direction for the new clusters LMB 5, LMB 10 and LMB 2 that are under construction.

Based upon the field development scenario stated above for 2 x 55MW geothermal power generation (Units 3 and 4), seventeen (17) start-up production wells and eight (8) start-up reinjection wells (seven for brine, one for condensate) are estimated to be required. In terms of make-up wells to sustain 110MW output from the power plant for thirty (30) years, an additional twelve (12) production wells and five (5) reinjection wells for brine will be necessary. Therefore, it will be necessary to prepare additional drilling pads for development and make-up well drilling. For development well drilling, six (6) production wells each will be drilled at the new pads of Cluster LMB 2 and Cluster LMB 10. The remaining five (5) production wells will be drilled at the new pad of Cluster LMB 7. The eight (8) reinjection wells will be drilled at the new drilling pad of Cluster Reinj B. For the make-up wells, twenty (12) production wells will be drilled at Cluster LMB 7, LMB 8 and LMB X and five (5) reinjection wells will be drilled at Cluster Reinj B.

In conclusion, three new production pads (Cluster LMB 2, LMB 7 and LMB 10) and one reinjection pad (Cluster Reinj B) should be newly constructed for the development wells, and for the make-up wells LMB 8 and LMB X should be also constructed. The drilling pad locations and their scope are summarized in Fig. 3.4-4 and Table 3.4-6; well pad layout, including rig equipment arrangement, is shown in Fig. 3.4-5.

(2) Production tests

Production tests and interference tests using not only existing wells but also new wells are strongly recommended to confirm well deliverability and reservoir properties, including gas and chemical conditions. This information is of extreme importance for the detailed design of the power facilities and also for reservoir management over the course of power plant operation. If testing is to be done and investment in the required facilities is to be made, then it is desirable to provide permanent production testing equipment and installations at all production well pads so that the steam and water flow rates of production wells can be measured whenever it is necessary.

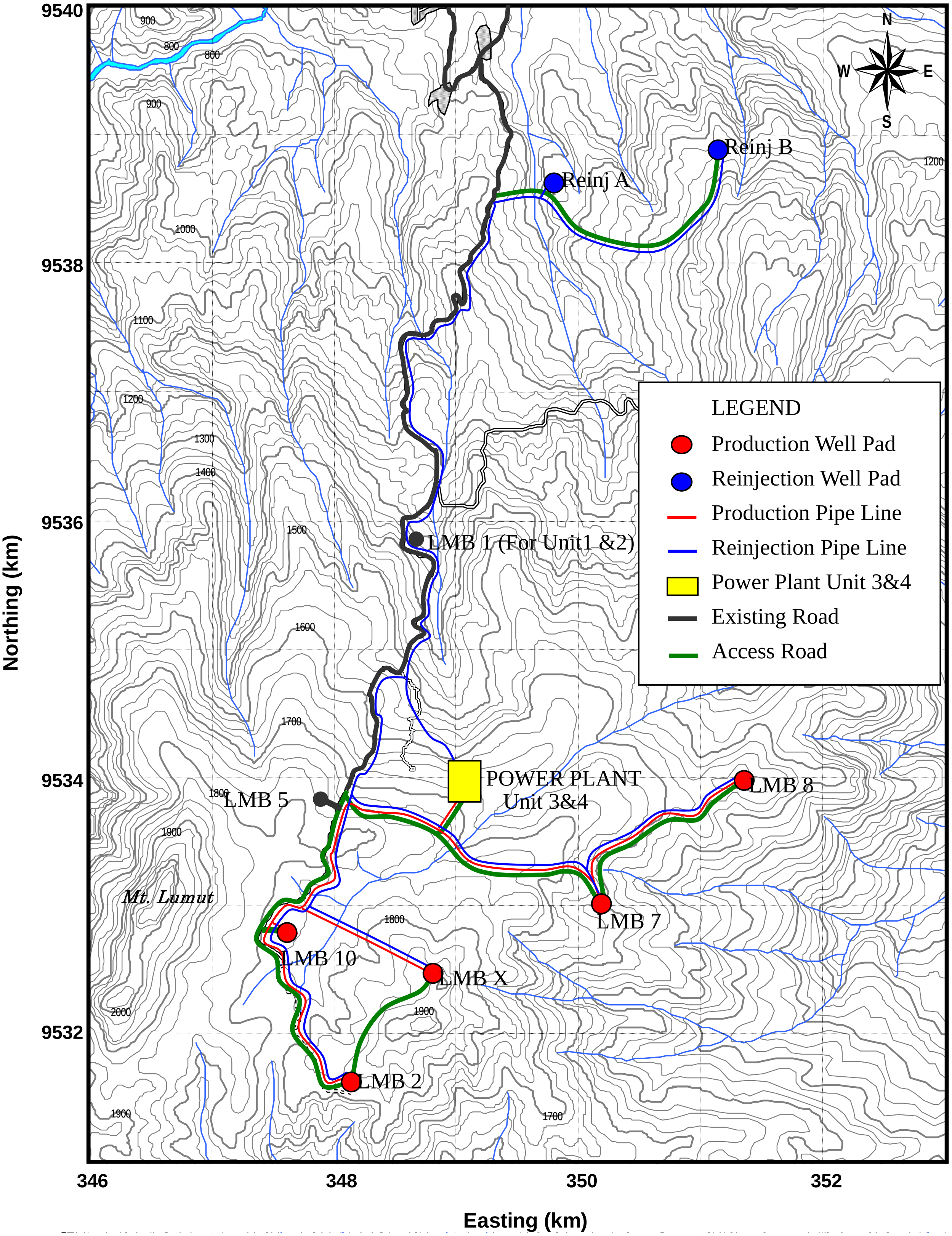


Fig. 3.4-4 Layout of Well Pads, Power Plant and Access Roads

Table 3.4-6 Required Size of Well Pads and Access Roads

Item	Size	Note
LMB 10	50m x 100m	6 Production wells (6 + 0)
LMB 2	50m x 100m	6 Production wells (6 + *0*)
LMB 7	50m x 100m	6 Production wells (5 + 1)
LMB 8	50m x 100m	6 Production wells (0 + *6*)
LMB X	50m x 100m	5 Production wells (0 + *5*)
Reinj B	60m x 100m	13 Reinjection wells (8 + *5*)
Access Road	5m W x 3,500m	Between LMB 5 and LMB 2
	5m W x 100m	Between main road and LMB 10
	5m W x 3,000m	Between LMB 5 and LMB 7
	5m W x 2,000m	Between LMB 7 and LMB 8
	5m W x 1,200m	Between LMB 2 and LMB X
	5m W x 3,000m	Between main road and Reinj B
	5m W x 300m	Between access road and Power Plant
Power Plant	225m x 260m	55MW x 2Unit

Note : (Start - up well + *Make - up well*)

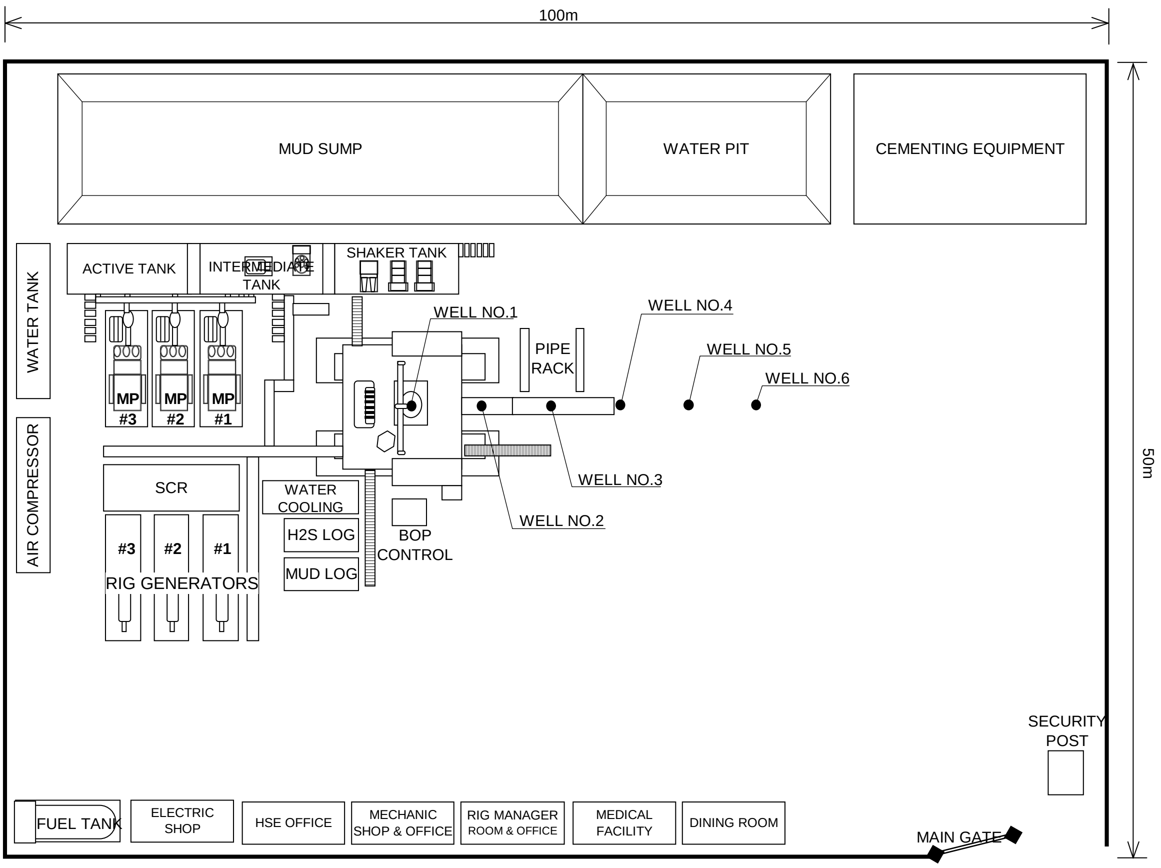


Fig. 3.4-5 Typical Rig Layout (Non-Scale)

(3) Well Specification

Production Wells

In the Lumut Balai area, twelve appraisal/production wells for Units 1and 2 have been drilled, all of which tap the reservoir, although their production characteristics have not yet been clarified. Ten wells, excluding LMB 1-1 and LMB 1-2, were of the big-hole completion type (a combination of 10-3/4” and 8-5/8” slotted liner completion) and were drilled with good results. Similar results will be expected when additional development wells are drilled with a big-hole completion casing program. In PGE’s drilling plan, big-hole completion has also been mentioned for the production wells. Thus it is recommended that the development wells and make-up wells for production should be drilled under a big-hole completion program. A typical production casing program for Lumut Balai is shown in Fig. 3.4-6. However the actual depth at which casing is set should be decided on the basis of the geoscientific parameter set for each of the wells to be drilled, especially once production test data becomes available that includes the feed zones from which geothermal fluids flow out.

Reinjection Wells

In the Lumut Balai area, no reinjection wells have been drilled. These will be provided to inject the separated brine and condensate into the reservoir to support reservoir pressure and mass production. A typical reinjection casing program for Lumut Balai is shown in Fig. 3.4-7. A 7” slotted liner standard completion program will be proposed. The depth at which the casings are set should be decided on the basis of the geoscientific parameter set for each of the wells to be drilled.

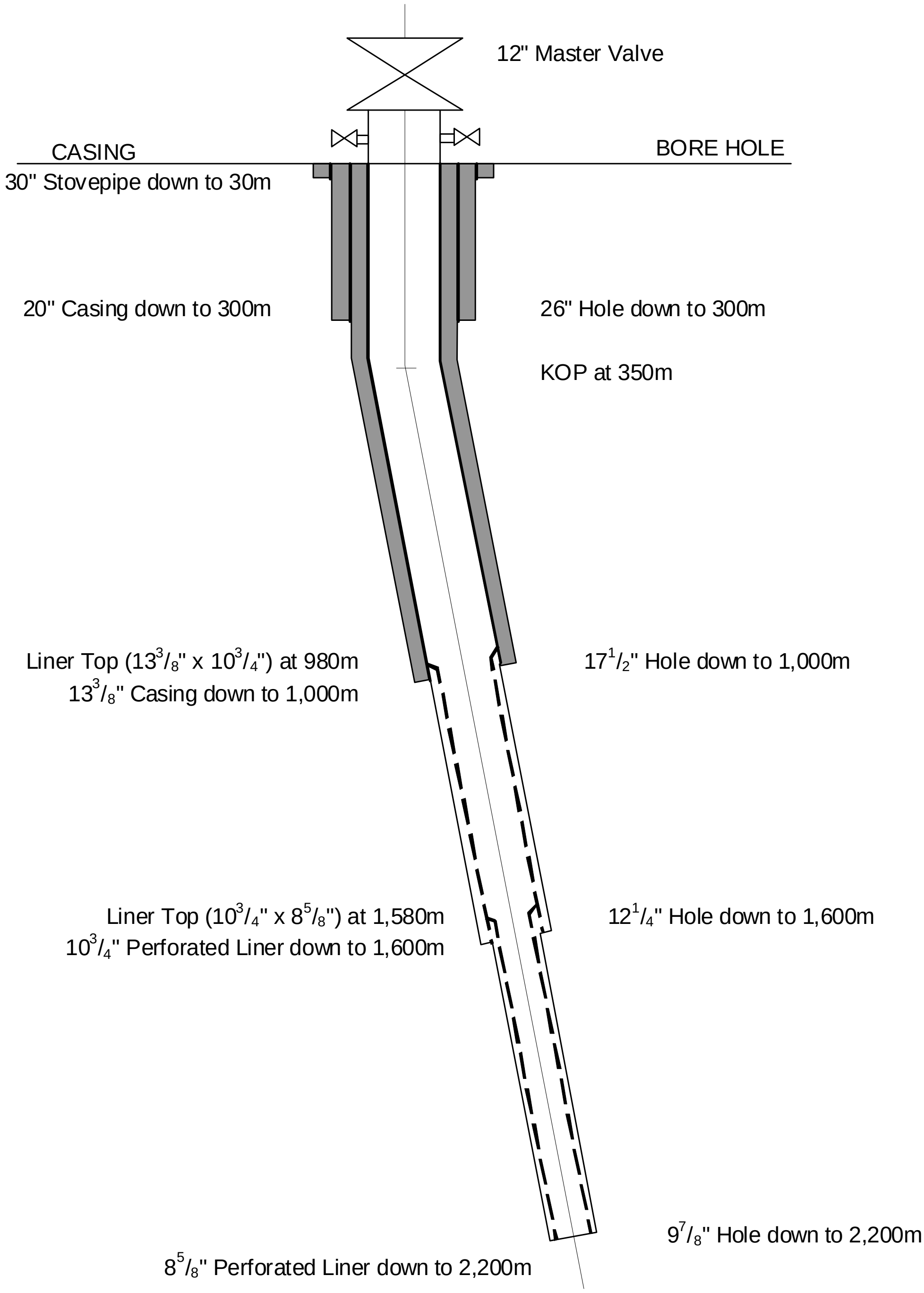


Fig. 3.4-6 Typical Production Well Casing Program

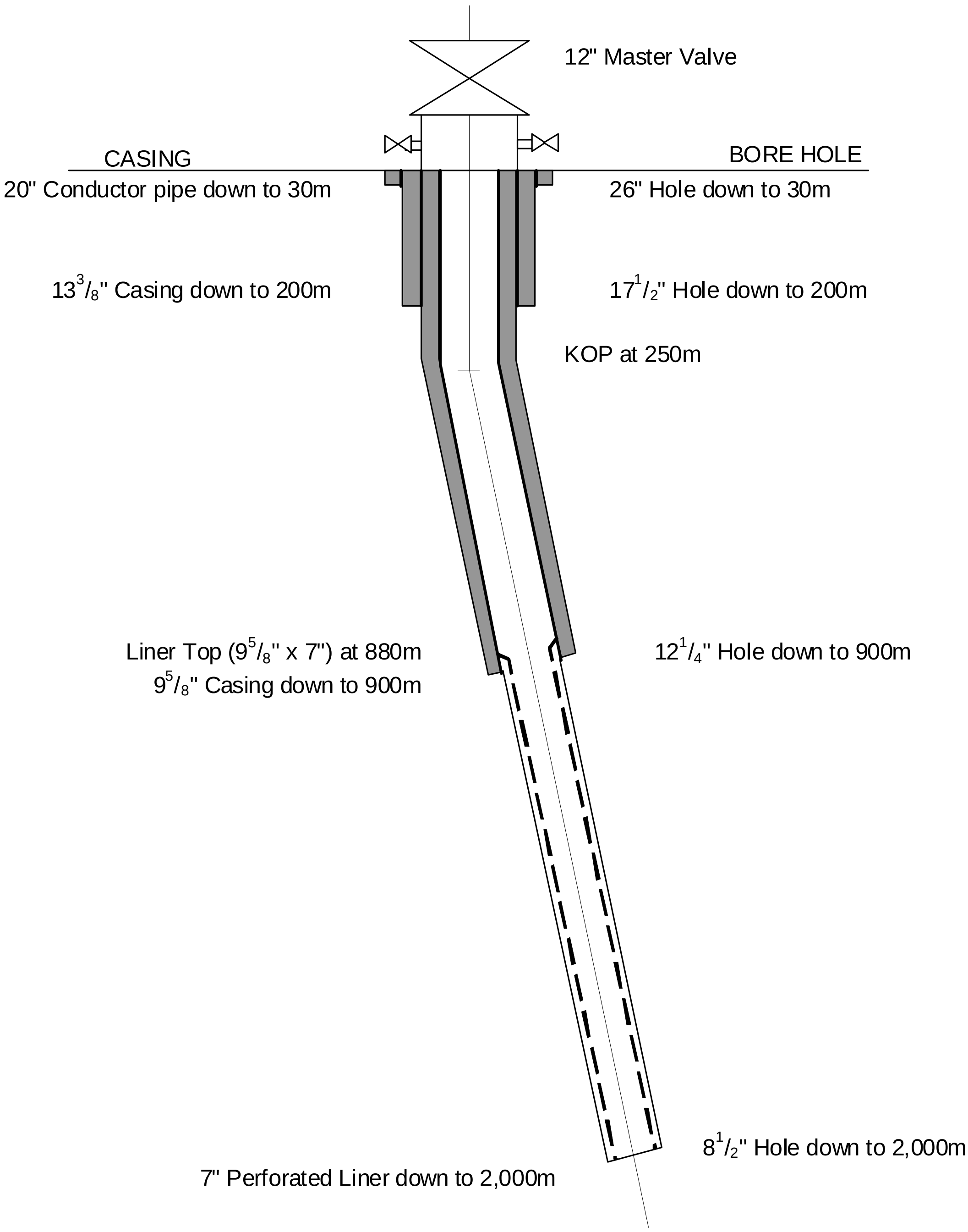


Fig. 3.4-7 Typical Reinjection Well Casing Program

3.4.4 Resource development cost

Resource Development Cost is divided into two (2) categories; one will be completed by the end of 2011 under the extension access road and new drilling contract, the other will be completed by the end of 2012 under a new drilling contract. Based on the discussion with PGE, it has been clarified that the preparatory work for both categories of drilling is being or will be carried out by PGE at its own expense. The work categories and cost estimates - other than land acquisition and PGE administration costs - are shown below in Table 3.4-7.

Table 3.4-7 Resource Development Cost

Work Category	Work Item	Cost Estimate (US$)
Work done by PGE by the end of 2011	Well Pad construction (LMB 2, LMB 10, Reinj B)	1,440,000
	Access road construction (for new Well Pad)	2,582,500
	Drilling (11 wells) including two (2) Rig Mob/Demob Production : 7 wells Production : (LMB10-1,10-2,10-3,10-4,10-5,10-6 LMB2-1) Reinjection : 4 wells (Reinj B-1,B-2,B-3,B-4)	63,725,000
	Well testing (7 Production wells)	700,000
	Sub-total	68,447,500
Work done by PGE by the end of 2012	Well Pad construction (LMB 7, LMB 8)	900,000
	Access road construction (for new Well Pad)	1,625,000
	Civil Work for Power Plant	1,267,500
	Drilling (14 wells) including two (2) Rig Mob/Demob Production : 10 wells Production : (LMB2-2,2-3,2-4,2-5,2-6 LMB7-1,7-2,7-3,7-4,7-5) Reinjection : 4 wells (Reinj B-5,B-6,B-7,B-8)	81,890,000
	Well testing (10 Production wells)	1,000,000
	Sub-total	86,682,500
Grand total		155,130,000

The necessary costs for each well, estimated based on recent market prices and the drilling methodology that has been selected by PGE, are assessed and shown in Table 3.4-8. Make-up drilling costs and their distribution are also shown in Table 3.4-9. A construction cost estimate for well pads and access roads is shown in Table 3.4-10.

Table 3.4-8 Drilling Cost Estimates

Unit: US$

Item	Production well Ave. Depth: 2,200m (Big hole) Ave. Drilling Days: 45	Reinjection well (Hot) Ave. Depth: 2,000m (Standard hole) Ave. Drilling Days: 35
1. Rig Hire		
a. Drilling cost	1,975,000	1,525,000
a-1 Rig Operation ($35,000/day)	1,575,000	1,225,000
a-2 Air drilling package	400,000	300,000
b. Rig Move (On location)	400,000	400,000
Sub-total	2,375,000	1,925,000
2. Drilling Services		
a. Directional drilling service	500,000	400,000
b. Cementing services	400,000	300,000
c. Mud Log	100,000	80,000
d. Mud Engineering	40,000	30,000
e. Top drive	300,000	250,000
f. H2S Monitoring	70,000	50,000
g. Well logging	100,000	50,000
Sub-total	1,510,000	1,160,000
3. Drilling materials		
a. Bits and others	180,000	150,000
b. Casing and accessories	800,000	700,000
c. Wellhead and valves	200,000	150,000
d. Mad materials	100,000	80,000
e. Cement and additives	150,000	120,000
f. Fuel and Oil supply	500,000	400,000
g. Drilling consumable-Foreign	100,000	70,000
h. Drilling consumable-Local	20,000	10,000
Sub-total	2,050,000	1,680,000
4. Drilling support		
a. Transport (in site)	50,000	30,000
b. Water supply	50,000	30,000
c. Others	20,000	10,000
Sub-total	120,000	70,000
Grand Total for Drilling	US$6,055,000/well	US$4,835,000/well

Table 3.4-9 Cost Estimates for Make-up Wells

Unit: US$

Year	Production well	Reinjection well		Rig Mob/Demob	Total
		for Brine	for Condensate		
1	-	-	-	-	-
2	-	-	-	-	-
3	6,055,000	4,835,000	-	2,000,000	12,890,000
4	-	-	-	-	-
5	-	-	-	-	-
6	6,055,000	-	-	1,000,000	7,055,000
7	-	-	-	-	-
8	6,055,000	-	-	1,000,000	7,055,000
9	-	-	-	-	-
10	6,055,000	-	-	1,000,000	7,055,000
11	-	-	-	-	-
12	6,055,000	-	4,835,000	2,000,000	12,890,000
13	-	-	-	-	-
14	-	-	-	-	-
15	6,055,000	-	-	1,000,000	7,055,000
16	-	-	-	-	-
17	6,055,000	4,835,000	-	2,000,000	12,890,000
18	-	-	-	-	-
19	6,055,000	-	-	1,000,000	7,055,000
20	-	-	-	-	-
21	6,055,000	4,835,000	-	2,000,000	12,890,000
22	-	-	-	-	-
23	-	-	-	-	-
24	6,055,000	-	-	1,000,000	7,055,000
25	-	-	-	-	-
26	6,055,000	4,835,000	-	2,000,000	12,890,000
27	-	-	-	-	-
28	6,055,000	-	-	1,000,000	7,055,000
29	-	-	-	-	-
30	-	-	-	-	-
Total	72,660,000	19,340,000	4,835,000	17,000,000	113,835,000

Table 3.4-10 Cost Estimates for Civil Work

UNIT:US$

ITEM		UNIT	QUANTITY	UNIT PRICE	PRICE	REMARKS
I	**PRODUCTION WELL PAD**	**L.S.**	**1**		**1,800,000**	Including Cellars, Mud pit and Drainage, etc.
I-1	LMB 2	m2	5,000	90	450,000	Size:50m x 100m
I-2	LMB 10	m2	5,000	90	450,000	Size:50m x 100m
I-3	LMB 7	m2	5,000	90	450,000	Size:50m x 100m
I-4	LMB 8	m2	5,000	90	450,000	Size:50m x 100m
II	**REINJECTION WELL PAD**	**L.S.**	**1**		**540,000**	
II-1	Reinj B	m2	6,000	90	540,000	Size:60m x 100m
III	**ACCESS ROAD**	**L.S.**	**1**		**4,305,000**	
III-1	LMB 5 to LMB 2	m	3,500	450	1,575,000	Width:5m, Unpaved, Steep Topography
III-2	Main road to LMB 10	m	100	325	32,500	Width:5m, Unpaved
III-3	LMB 5 to LMB 7	m	3,000	325	975,000	Width:5m, Unpaved
III-4	LMB 7 to LMB 8	m	2,000	325	650,000	Width:5m, Unpaved
III-5	Main road to Reinj B	m	3,000	325	975,000	Width:5m, Unpaved
III-6	To Power Plant	m	300	325	97,500	Width:5m, Unpaved
IV	**POWER PLANT**	**L.S.**	**1**		**1,170,000**	
IV-1	Power Plant (Unit 3 &4)	m2	58,500	20	1,170,000	Size:225m x 260m
GRAND TOTAL					**7,815,000**	I + II + III +IV

CHAPTER 4 POWER PLANT AND TRANSMISSION LINE

4.1 Fluid Collection and Reinjection System

4.1.1 Type of FCRS

The applicable type of FCRS generally depends on geothermal fluid conditions, topography, and the elevations of production well pads, the prospective power plant site and reinjection well pads. When only dry steam is produced from production wells, as in the Kamojang fields, the steam is transported from production wells to the power plant through steam pipelines. On the other hand, in the Lumut Balai field, large amounts of hot-water-dominated two-phase fluids (steam and brine) will be produced. Taking into account these factors, the most suitable type should be selected from among (1) wellpad separation type, (2) two-phase flow type, and (3) separator station type. In this study for Lumut Balai Units 3 and 4, the wellpad separation type was selected.

(1) Wellpad Separation Type

Steam and brine are separated at each production well pad: Separated steam is transported to the power plant, and brine is transported to reinjection wells. Therefore, a separator, steam line and brine line will be constructed for each production pad. This type of FRCS requires more space than the other types and, generally, the construction cost is higher. Since several wells are drilled at each production well pad, and taking into account the topography, locations and elevations of production well pads, the prospective power plant site and reinjection well pads, it is recommended that separator stations be constructed adjacent to production well pads and linked with production wells through short two-phase pipes.

(2) Two-phase Flow Type

The produced two-phase fluid (a mixture of steam and brine) is transported from production wells to separators installed adjacent to/near the power plant. The separated steam is transported to the power plant, and the brine is transported to reinjection wells. The capital cost of this type of FCRS will be the lowest among the three types because the number of separators and total length of brine pipeline can be reduced by transporting both steam and brine through a two-phase pipeline. However, there are some technical difficulties with the two-phase flow type, such as erosion, corrosion, slug flow and large pressure drop. Thus, the two-phase flow type is not recommended for Lumut Balai steam field at this stage.

(3) Separator Station Type

This FRCS is intermediate between the wellpad separation and the two-phase flow type, and has good points and shortcomings similar to those of the two-phase flow type. Both the produced steam and brine are transported through two-phase flow pipelines from the production wells to separator station(s) (typically one or a few) located halfway between the wellpads and the power plant. Separated steam is transported from the separator station to the power plant, while the brine is transported to reinjection well pads. In this case, it is necessary to construct one type of pipeline (a two-phase flow pipeline) between the production well pads and separator stations. Though the length of the two-phase pipes will be shorter than for the two-phase flow type, the pressure drop may be significantly higher than that of the wellhead separation type. Thus this type is not recommended for Lumut Balai steam field at this stage. The possibility of implementing a two-phase flow type or a separator station type of FRCS may be re-examined in the detailed design stage after more detailed well characteristics and topographic data have been obtained.

4.1.2 Outline of Selected FCRS Type

(1) Overall Layout and Process Flow

The Fluid Collection and Reinjection System (FCRS) will consist of two-phase (steam and brine mixture) pipes, separators, steam pipelines, and brine pipelines. The locations of production well pads, pipeline routes, the prospective power plant site and the reinjection well pads are shown in Fig. 3.4-4. The separators will be constructed adjacent to each production wellpad to minimize the length of two-phase pipe. Initially, four production wellpads (LMB-2, LMB-7, LMB-8, and LMB-10) will be developed for Units 3&4. An additional production wellpad (LMB-X) will need to be developed for make-up wells 15 to 20 years after commencement of commercial operation of Units 3&4.

The conceptual process flow of the FCRS is shown in Fig. 4.1-1.

(2) Description of each pipeline

Pipe length, pipe size, and approximate elevation of production well pads, power plant, and reinjection well pads are as follows:

a. Steam pipelines

Diameters of the steam pipelines will be designed in consideration of pressure loss between separator stations and the power plant to achieve a stable and standard flow speed (30 to 50 m/sec) and to allow for the capacity to connect with additional wells in the future:

Table 4.1-1(1/3) Steam pipelines

From Elevation	To Elevation	Flow (t/h) Elevation difference	Length (km)	Pipe size (mm)
LMB 2 1,687.5m	LMB 10 1,800m	360 +112.5m	2.0	1,000
LMB 7 1,612.5m	Power plant 1,650m	720 +37.5m	2.6	1,422
LMB 8 1,700m	LMB 7 1,612.5m	360 -87.5m	2.2	1,000
LMB 10 1,800m	Power plant 1,650m	720 -150m	3.2	1,422
LMB X 1,790m	Power plant 1,650m	360 -140m	(5.3)	(1,000)

b. Brine reinjection pipelines

Brine reinjection pipelines will be as follows:

Table 4.1-1(2/3) Brine reinjection pipelines

From Elevation	To Elevation	Flow (t/h) Elevation difference	Length (km)	Pipe size (mm)
LMB 2 1,687.5m	LMB 1 1,319m	1,080 -368.5m	7.1	450
LMB 7 1,612.5m	LMB 1 1,319m	1,080 -293.5m	5.0	450
LMB 8 1,700m	LMB 1 1,319m	1,080 -381m	7.0	450
LMB 10 1,800m	LMB 1 1,319m	1,080 -481m	4.0	450
LMB X 1,790m	LMB 1 1,319m	1,080 -471m	(5.3)	(450)
LMB 1 1,319m	Reinj A 980m	2,800 -339m	3.0	700
Reinj A 980m	Reinj B 980m	2,800 0m	2.1	700

Table 4.1-1(3/3) Condensate reinjection pipeline

From Elevation	To Elevation	Flow (t/h) Elevation difference	Length (km)	Pipe size (mm)
Power plant 1,650m	Reinj A 980m	100(cold) -670m	7.1	100

c. Interconnection steam pipeline

An interconnection steam pipeline will allow more flexible operation of the steam field by sharing geothermal steam between Units 1&2 and Units 3&4. In this study, however, the pipelines are designed to handle geothermal fluids produced from LMB-2, LMB-7, LMB-8, LMB-10 and LMB-X only for Units 3&4, and are not optimized for the purpose of sharing steam with Unit 1&2. If there is a strong need to share steam between the power plants, the whole design of the FCRS should be reviewed during the detailed design stage after obtaining detailed data concerning well characteristics, topography, and the pipeline design of Units 1&2.

The interconnection steam line is planned as follows.

Table 4.1-2 Interconnection steam pipeline

Fluid	From	To	Flow (t/h)	Length (km)	Pipe size (mm)
Steam	LMB 7&8	Units 1&2	360	1.5	1,200
Brine	LMB 1	(LMB 1)	2,800	0.15	700

(3) Construction of Pipeline Bridges

Since small rivers exist on the pipeline routes, the construction of pipeline bridges made of steel or concrete is required.

(4) Separator Station Equipment

a. Separator equipment

One cyclone separator will be installed adjacent to each production wellpad (LMB-2, LMB-7, LMB-8, and LMB-10). Each Separator will be designed to handle 125% of the maximum flow rate to accommodate possible fluctuations of geothermal fluid in the future. The capacities of the cyclone separators will be as follows:

Table 4.1-3 Capacity of Cyclone Separators

	LMB 2	LMB 7	LMB 8	LMB 10	LMB X
Steam(t/h)	450	450	450	450	450
Brine(t/h)	1,350	1,350	1,350	1,350	1,350
Total(t/h)	1,800	1,800	1,800	1,800	1,800

The brine level in the separators will be controlled by LCVs (level control valves) installed at the brine outlet of the separators.

b. Chemical injection equipment

Chemical injection equipment will be installed to control the pH of the brine for each line, if necessary. The injection point will be at the brine outlet of each separator.

c. Rock mufflers

A rock muffler will be constructed adjacent to each separator to reduce noise during venting of steam to the atmosphere. The drainage will be discharged to a thermal pond.

d. Thermal ponds

A thermal pond will be constructed adjacent to each separator. Drainage from rock mufflers, separator equipment, etc. will be discharged to this pond.

(5) Steam lines

Separated steam from the separators will be transported to the steam turbine and auxiliaries through scrubbers and demisters. The scrubbers, a steam receiver and demisters will be installed outdoors near the powerhouse.

(6) Brine reinjection lines

Separated brine from the separators will be transported to reinjection well pads by separator pressure and gravity after chemical injection for pH control (if necessary). When necessary, chemical injection of mineral acid is used to maintain the pH of the reinjection brine near 5 to avoid silica deposition.

Carbon steel pipes for ordinary piping will be selected for the brine pipelines. Pipe thickness will be specified in consideration of the erosion and corrosion by the fluid.

The pipelines will be thermally insulated to avoid a temperature drop of the brine. Insulation materials will be selected in consideration of their resistance to water absorption, long life, easy workability, etc.

(7) Power plant drain

Carbon steel pipes will be selected for the cold drain pipeline from the power plant. Pipeline thickness will be specified in consideration of the erosion and corrosion by the fluid.

Drainage from cooling towers, condensers, silencers, demisters, etc. will be collected and temporarily stored in the concrete-made reinjection settling basin of the power plant and will be transported to the reinjection well pad A and/or B, by gravity and/or reinjection pumps. Caustic soda dosing facilities will be provided to maintain the drainage at neutral pH.

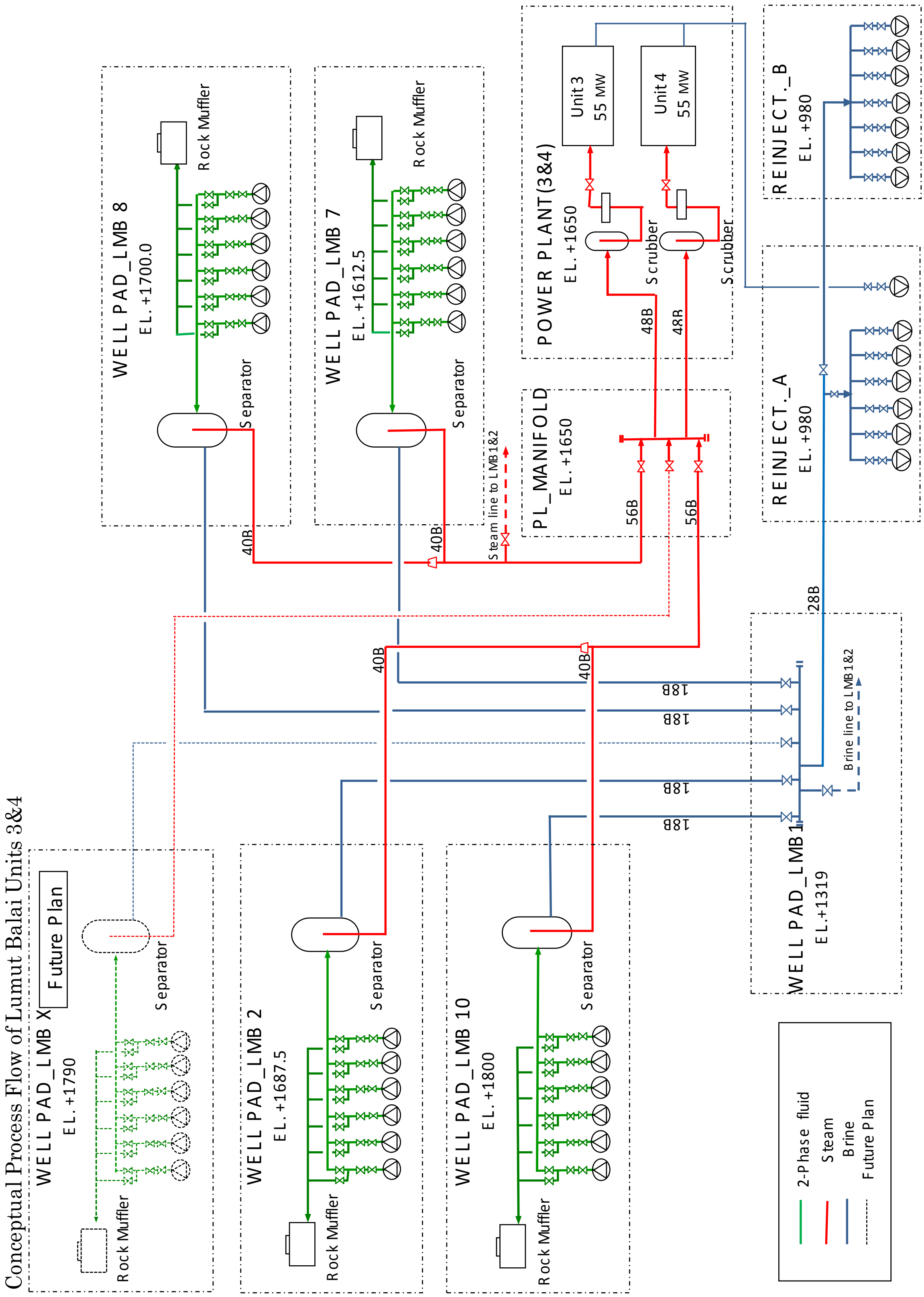


Fig. 4.1-1 Steam Field Process Flow (Preliminary)

4.2 Power Plant

4.2.1 Type of Power Plant

The results of resource evaluation suggest that the generating output will be 2 units of 55 MW (net) at 7.5 to 8.5 bara of production wellhead pressure. The geothermal fluid will be water-dominant, and the NCG content in the steam will be about 1.0% by weight. For these conditions of Lumut Balai field, six geothermal power generating technologies are compared in Table 4.2-1 (1/2) and (2/2).

The single flash steam cycle with condensing turbine can be recommended for the project so that the brine in the reinjection system will be kept at high pressure and high temperature (7bara/165°C to 8bara/170°C) at the separator.

A bottoming cycle plant (brine binary cycle plant) may be installed near the reinjection line in the future when analysis of actual operating data reveals that proper anti-scaling measures allow low brine temperature, so that additional electricity output can be obtained from the thermal energy of the brine.

In the double flash steam cycle with condensing turbine and in binary cycles, the temperature of the brine in the reinjection system will be as low as about 100°C and the thermal energy of the brine can be utilized to gain increased output over a single flash steam cycle. This low brine temperature would cause silica scaling in the reinjection system and heat exchangers (of a binary cycle plant), if left unmitigated. Accordingly, further study would be necessary to identify anti-scaling measures, such as pH modification by mineral acid injection in the brine, to mitigate the scaling problem.

Table 4.2-1 (1/2) Geothermal Power Generation Technologies

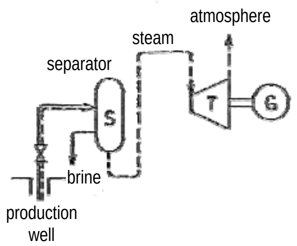
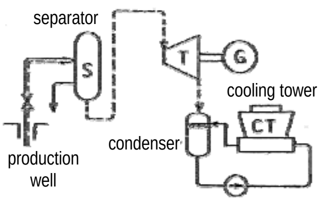
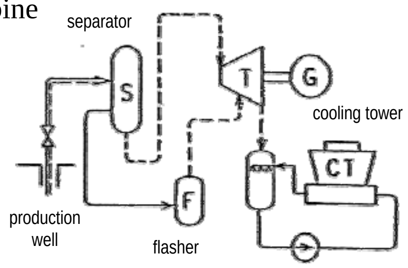
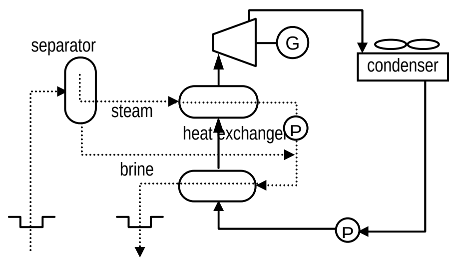
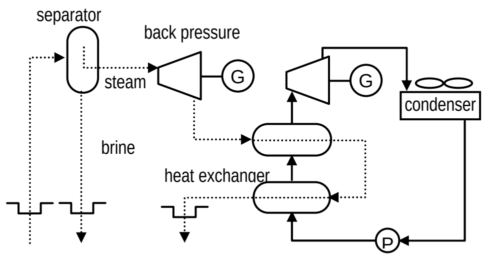
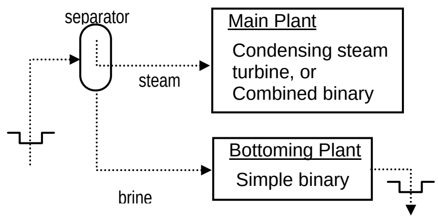
<table>
<tr><th>Cycle</th><th></th><th>Type of Process</th><th>Features</th></tr>
<tr><td rowspan="3">Flashed Steam Cycle</td><td>Not recommended</td><td>Single Flash with Back Pressure Steam Turbine

</td><td>• Suitable for water-dominated resources of high NCG content.
• Small capacity - Usually installed as a wellhead generating pilot plant.
• Lower efficiency (i.e. high steam rate) compared to condensing steam turbine
• Low construction cost.
• High exhaust noise level.</td></tr>
<tr><td>Recommended</td><td>Single Flash with Condensing Steam Turbine

</td><td>• Suitable for water-dominated resources of low NCG content.
• Large capacity
• Low efficiency in utilizing geothermal energy of geothermal fluid of low specific enthalpy.
• Single flash is favored over double flash for preventing silica scale in reinjection line.</td></tr>
<tr><td>Not recommended</td><td>Double Flash with Condensing Steam Turbine

</td><td>• Suitable for water-dominated resources of low NCG content.
• Large capacity
• 15 to 25% more output than single flash depending on quantity of brine.
• Construction cost is about 6% higher than for single flash.
• Low temperature brine from flasher would cause silica scale problem in reinjection line.</td></tr>
</table>

Table 4.2-1 (2/2) Geothermal Power Generation Technologies

Cycle		Type of Process	Features
Binary Cycle	Inconceivable	Two-phase (Biphase) Binary 	• Suitable for water-dominated resources of moderate to medium specific enthalpy. • No gas extraction system (ejector and vacuum pump) is needed. • It would be possible to reinject all NCG into the ground. • High efficiency since it utilizes both steam and brine. • Simple. • Unit capacity is up to around 10 MW.
	Inconceivable	Combined Binary Cycle 	• Suitable for high-pressure, mid to high specific enthalpy resources. • No gas extraction system is needed. • All NCG is reinjected in an actual plant. • Technically possible to utilize brine too. • Usually, a few binary units will be connected to the back pressure steam turbine. • Large capacity is possible.
	Conceivable	Hybrid Type (Bottoming Cycle) 	• Suitable for water-dominated, medium specific enthalpy resources. • High efficiency since it utilizes both steam and brine. • The bottoming plant can adjoin the separator station and be monitored / controlled from the main plant. • The bottoming plant can be constructed along the reinjection line in the future.

4.2.2 Power Plant Site

PGE has selected two (2) prospective power plant sites for Units 1&2 (PP1) and Units 3&4 (PP2), as shown in Fig. 3.4-4.

PP1 is located in a mountainous area in the center of Lumut Balai geothermal field so that the FCRS pipe length from different well pads will be equalized and some of the production wells (LMB-6, LMB-7 and LMB-8) located in the south-east area could supply steam to both PP1 and PP2. On the other hand, PP2 is located in the southern part of the field (also in a mountainous area) in line with PGE's plan to develop the southern part of the field.

4.2.3 Outline of Plant Layout

A geothermal power plant using single flash steam cycle with condensing turbine technology consists of a steam gathering system, steam turbines, generators, a cooling water system including condensers and cooling towers, a control room, electrical equipment, a switchyard, auxiliary equipment, and ancillary facilities such as a fire fighting system and administration building. These facilities are arranged in accordance with the following rules.

- Outline the plant site considering routes of geothermal fluid pipelines, access roads, and the transmission line route.
- Cooling towers should be located downwind of the switchyard and the powerhouse so that cooling tower exhaust plumes including corrosive non-condensable gas and mist will not affect plant equipment. The prevailing wind direction should be considered.
- In order to maximize cooling tower performance, maintain an adequate distance from other structures.
- The powerhouse must accommodate turbine-generators and ancillary equipment, space for operation, maintenance and overhaul work.
- Space for and convenience of operation, daily maintenance and overhaul work should be considered in arranging outdoor equipment.

Generally speaking, for a power plant using flashed steam cycle condensing turbine technology, installing a smaller number of larger units tends to reduce construction costs. For this type of geothermal power plant, 55 MW class units have a proven track record.

4.2.4 Layout of the Facility

Fig. 4.2-1 shows a preliminary layout for Lumut Balai geothermal power plant.

The area required for the installation of two (2) single flash 55 MW units will be approximately 225 m x 260 m. The power plant should be located in a flat place, air must be supplied to each cooling tower cell evenly, and the exhaust plume from fan stacks should not flow toward the powerhouse.

The main transformers and switchyard will be located on the side opposite the cooling tower, that is to say that the powerhouse will be located in between the cooling towers and the main transformer/switchyard. Turbines, condensers, generators, control equipment and electrical equipment will be installed inside the powerhouse. A gas extraction system will be located outside of the powerhouse on the cooling tower side. Cooling water pumps will be located in between the powerhouse and cooling towers.

Generators will be coupled to turbines. Condensers will be located under the turbine pedestals. The main steam strainers, main stop valves (MSV) and control valves (CV) will be located indoors. An oil tank and the electro-hydraulic control (EHC) unit will be installed in front of the turbines. Hotwell pumps will be located outdoors near the condensers. An overhead traveling crane will be installed in the powerhouse for installation and maintenance of turbines, generators, etc. Adjoining the powerhouse, an administration building, and a control and electrical building will be constructed. For the two turbine-generator units, a common control room will be prepared.

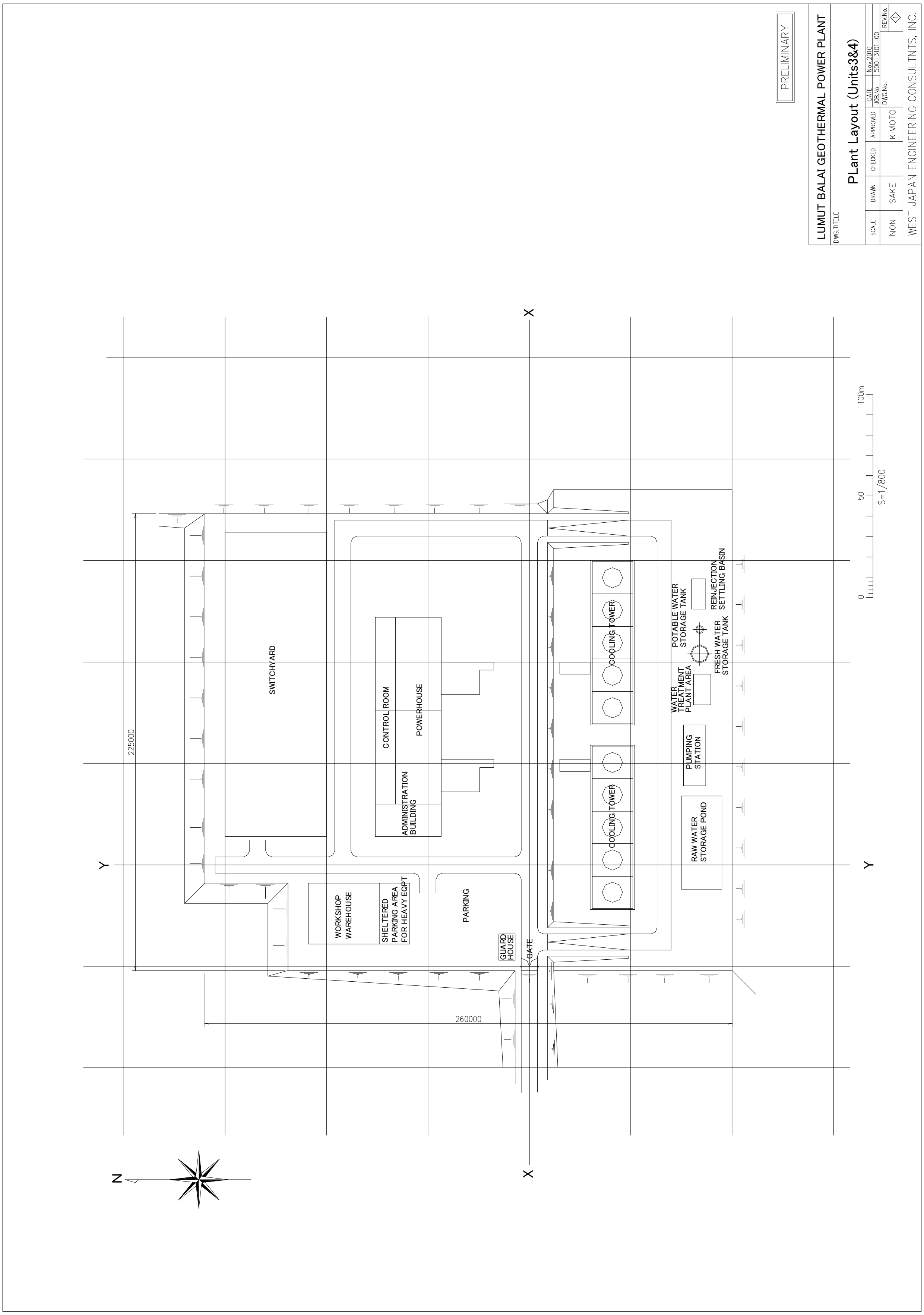


Fig. 4.2-1 Plant Layout for Units 3 and 4 (Preliminary)

4.2.5 Civil and Architectural Work

All of the major equipment will be installed on reinforced concrete foundations on the ground floor. The powerhouse will be a steel-framed structure with aluminum exterior and roof panels.

4.2.6 Outline of Process

The preliminary process flow of the Lumut Balai geothermal power plant (Units 3 and 4) is shown in Fig. 4.2-2.

Steam flows to a steam turbine through a mist eliminator, strainer, main stop valves, and control valves. Exhaust steam from the turbine flows into a direct-contact-type main condenser through an exhaust duct. An expansion joint is installed between the turbine and condenser to accommodate erection allowance and thermal expansion. In the condenser, exhaust steam is condensed by direct contact with cold water from the cooling tower basin, and a mixture of cold water and condensate is sent to the cooling tower top by hotwell pumps. In the cooling tower, the mixture is cooled down and sent back to the condenser by gravity and condenser vacuum. NCG is cooled down in the main condenser to reduce accompanying steam, extracted by a two-stage ejector system and sent to cooling tower fan stacks for dispersion into the atmosphere. After the first stage and second stage ejector, an inter-condenser and after-condenser are installed to condense motive steam.

A gas extraction system removes NCG that is contained in the steam from the main condenser. The gas removal system consists of a 1st stage ejector, inter-condenser, 2nd stage ejector and after-condenser. The motive steam for the ejectors is drawn from the main steam line. Drains from the inter-condenser and after-condenser lead into the main condenser.

Cold water from the cooling tower basin is used not only for condenser cooling but also for turbine oil cooling, generator air cooling, air compressor cooling, and for the inter-condensers and after-condensers. Cooling towers are of multi-cell mechanical-induced draft wet type, with either cross flow or counter flow. Cooling towers are equipped with maintenance stairs and lifting facilities. At the outlet of the cooling tower basin, a mesh screen is installed to prevent foreign particles entering into the system.

Excess water from the cooling towers is sent to a settling basin, and then on to a cold reinjection well.

All equipment and instruments must be fully tropicalized, H_2S gas corrosion-proof, vermin and rodent-proof and entirely suitable for the climatic conditions of the Lumut Balai geothermal field.

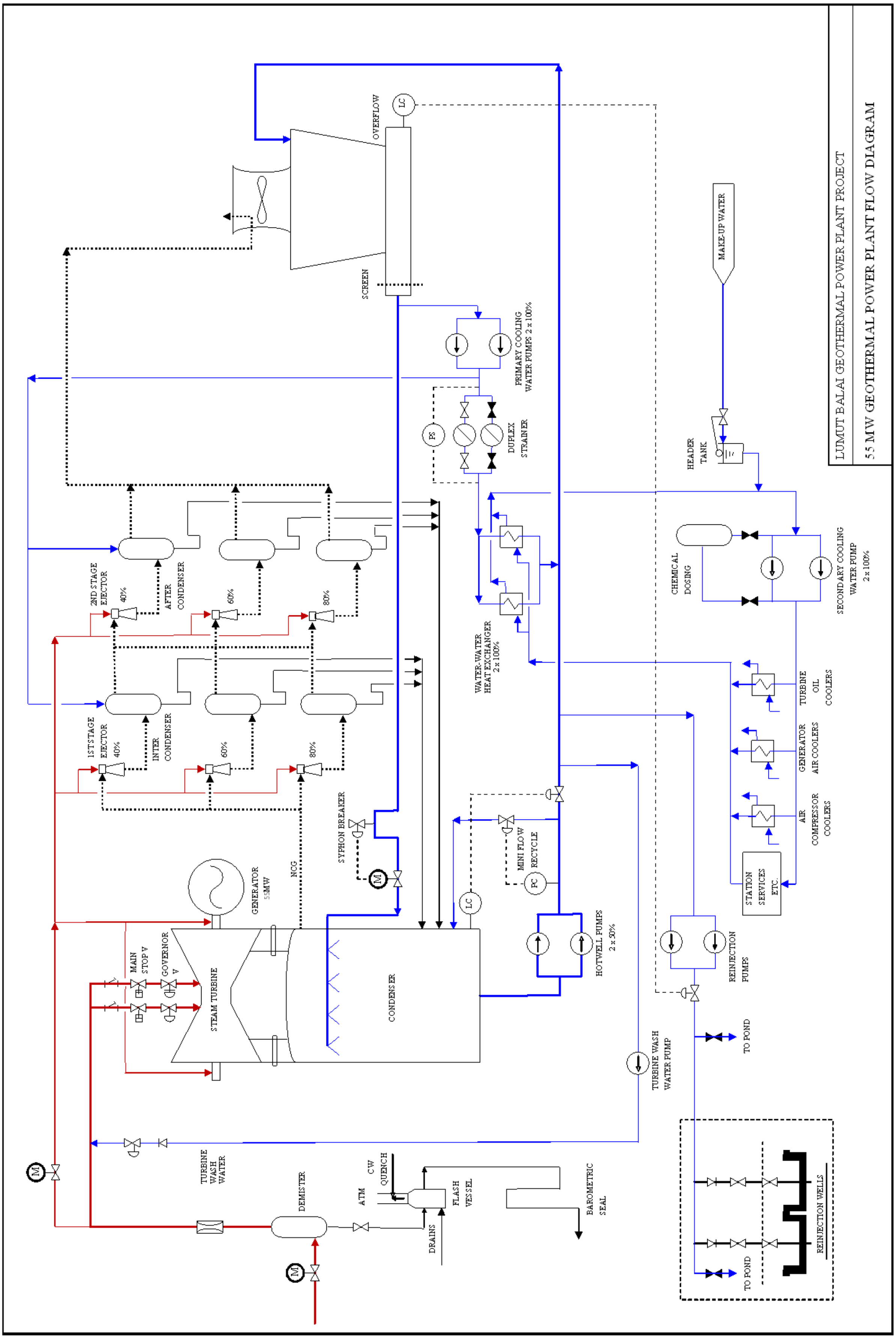


Fig. 4.2-2 Process Flow Diagram (Preliminary)

4.2.7 Power Plant Equipment

(1) Power Plant Design Parameters

a. Steam conditions at turbine inlet

Pressure:	5.5 bara
Temperature:	approx. 155 ˚C (saturation temperature)
NCG content:	1.0% wt

b. Meteorological conditions

Design wet bulb temperature: 21 ˚C *(tentative)*

Note: (1) Design wet bulb temperature of Kamojang Unit 4 (1,500 m a.s.l.) is 21 ˚C.

(2) Hourly meteorological data should be collected at site for a minimum of 1 year:

- *Dry bulb temperature (average, maximum, minimum)*
- *Wet bulb temperature (average, maximum, minimum)*
- *Humidity (average, maximum, minimum)*
- *Dominant wind direction (wind rose)*
- *Wind speed*

c. Altitude and barometric pressure

Altitude:	Approx. 1,650 m asl
Barometric pressure:	840 hPa

(2) Preliminary plant performance

Based on the aforementioned process flow and design parameters, a preliminary heat and mass balance is assessed as shown in Fig. 4.2-3.

In order to attain a net output of 55 MW per unit, preliminary plant performance will be as follows:

Required steam	:	462 t/h/unit
Generator output	:	57.6 MW
Parasitic load (house load + main transformer loss)	:	2,600 kW (4.5%)
Net Output	:	55 MW

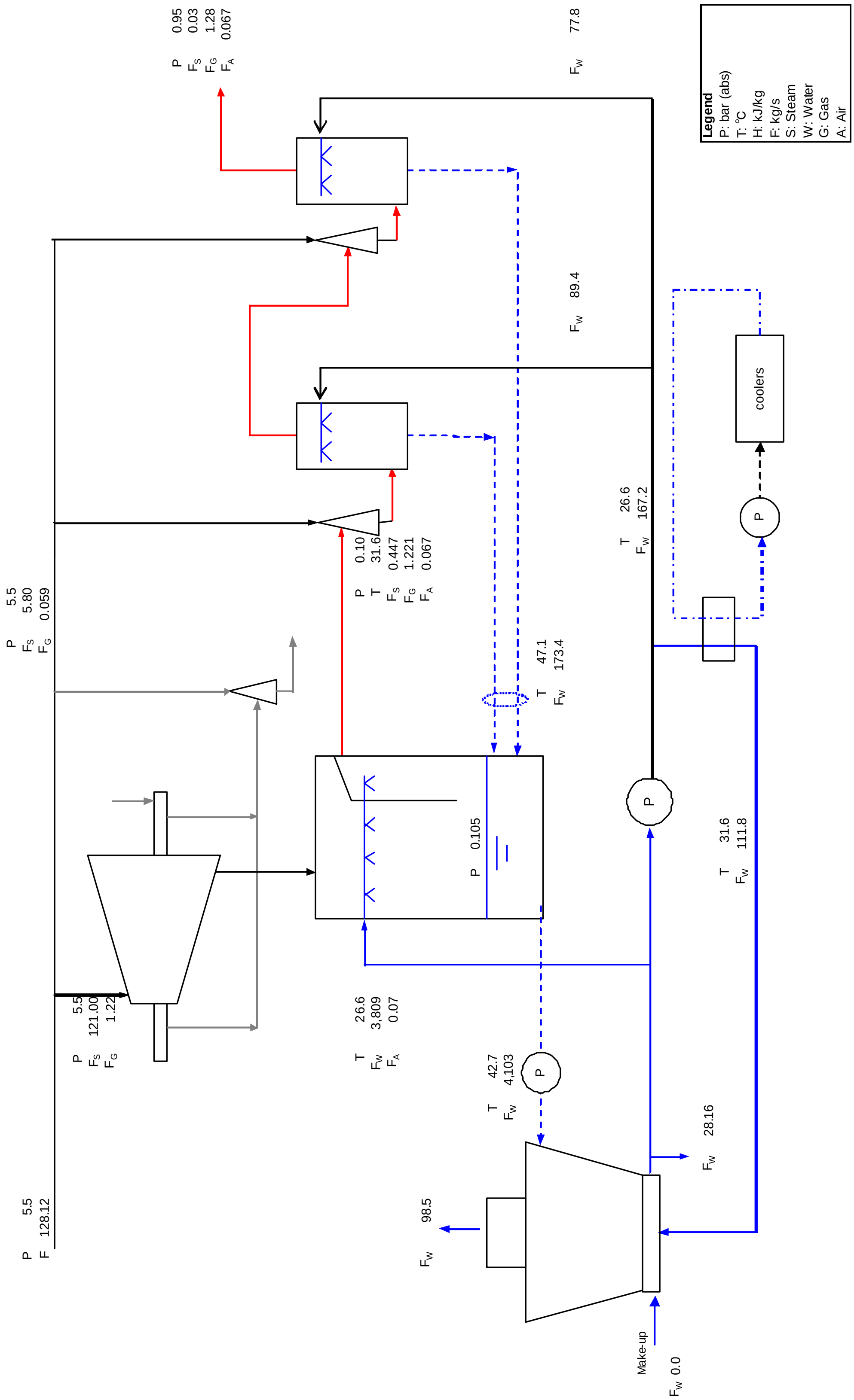


Fig. 4.2-3 Heat and Mass Balance Diagram (Preliminary)

(3) Mechanical Equipment

a. Steam turbines

The steam turbines will be single-cylinder, double-flow, horizontal-shaft, condensing units.

For a geothermal power plant, it is essential to protect against erosion/corrosion, so it is considered that the rotor should have an erosion/corrosion protection overlay in the gland seal areas and nozzle stationary blade labyrinth seal areas.

b. Main steam pipes

In order to prevent inflow of mist or drainage into the turbine, a mist eliminator is installed in the main steam piping before the turbine inlet. For control and monitoring of plant operation, a venturi-type steam flow meter is installed on the downstream side of the mist eliminator so that the effect of scale buildup on its accuracy shall be minimal. Either a poppet-type or triple-offset butterfly-type MSV will be used. The poppet-type shall have an integral strainer and the triple-offset valve will have a separate strainer. CV will be a triple-offset butterfly valve.

c. Condensers

Direct contact type condensers will be installed. They require large vertical hotwell pumps.

d. NCG extraction system

Since the NCG content of the Lumut Balai geothermal resource is 1.0% wt, a 2-stage ejector system will be installed.

Variations in NCG (up to 1.8% wt) will be considered in ejector sizing, and three (3) different sized ejectors (40%, 60% and 80%) will be installed so that the system can cope with NCG variations from 0.40% wt up to 1.8% wt

e. Cooling water system and cooling towers

The cooling water system will be of the closed type between the cooling towers and condensers.

Between the cooling tower basin and condenser, a mesh screen will be installed to prevent foreign particles entering into the system. Cooling water from the cooling tower basin will mainly supply the main condenser, but some amounts will be used for turbine oil cooling, generator air cooling, and for the inter-condensers and after-condensers.

The cooling towers are of the rectilinear multi-cell mechanical-draft wet type with either cross-flow or counter-flow. The towers are equipped with maintenance stairs and a lifting facility. If the prospective site is not sufficiently large to construct a rectilinear tower due to topography, multi-faced towers such as octagonal mechanical draft towers may be considered.

Two (2) x 50% capacity hotwell pumps will be installed. Two (2) x 100% capacity auxiliary cooling water pumps will be installed.

Major specifications for power plant mechanical equipment are as follows:

Plant cycle	Single Flash, Condensing
Turbine	
No. of units	1 set / unit
Type	Single Casing, Double Flow, Impulse or Reaction, Condensing Type
Rated output	55,000 kW net
Max. capacity	105% Rated output
Speed	3,000 rpm
Steam press. / temp.	5.5 bar absolute / 154.6 ^{o}C
NCG content in steam	1.0% in weight
Steam rate	Approx. 462 t/h (at rated output)
Condenser	
No. of units	1 set / unit
Type	Spray, Direct Contact type Condenser
Pressure	approx. 0.1 bar absolute
Gas Extractor	
No. of units	1 set / unit
Type	Steam Ejector
Number of trains	1st Stage: Steam Ejector 40%, 60%, 80% 2nd Stage: Steam Ejector 40%, 60%, 80%
Cooling Tower	
No. of units	1 set / unit
Type	Rectilinear or Octagonal, Counter or Cross flow, mechanical draft, concrete basin/foundation and FRP structure
Number of cells	5 or 6 cells
Hotwell Pump	
No. of units	2 sets / unit
Type	Vertical, centrifugal, double suction, single stage, canned pump
Capacity	50% /set
Demister	
No. of units	1 set / unit
Type	Vane or cyclone centrifugal type
Steam dryness	At least 99.98% at outlet
Turbine Wash Water Pump	
No. of units	1 set / unit
Type	Horizontal, centrifugal, to inject geothermal condensate (Hotwell pump discharge water) to main steam
Capacity	100% / set
Primary Cooling Water Pump	
No. of units	2 sets / unit
Type	Horizontal, Centrifugal
Capacity	100% / set
Fluid	Geothermal condensate (Cooling Tower outlet)

Water-water Heat exchanger

No. of units	2 sets / unit
Type	Plate type or shell and tube type
Capacity	100% / set
Fluid	Treated fresh water

Secondary Cooling Water Pump

No. of units	2 sets / unit
Type	Horizontal, Centrifugal
Capacity	100%/set
Fluid	Treated fresh water

Main Oil Tank

No. of units	1 set / unit
Type	Rectangular steel tank
Capacity	100% / set
Fluid	Turbine lubricant oil

Oil Cooler

No. of units	2 sets / unit
Type	Vertical shell and tube type, Two (2) pass
Capacity	100 % /set
Fluid	Turbine oil / Treated fresh water

Main Oil Pump

No. of units	1 set / unit
Type	Main turbine driven, centrifugal type
Capacity	100% / set
Fluid	Turbine lubricant oil

Auxiliary Oil Pump

No. of units	1 set / unit
Type	AC motor driven, centrifugal type
Capacity	100% / set
Fluid	Turbine lubricant oil

Emergency Oil Pump

No. of units	1 set / unit
Type	DC motor driven, centrifugal type
Capacity	100% / set

Vapor Extractor

No. of units	1 set / unit
Type	Centrifugal type turbo-blower
Capacity	100%/set

Oil Heater

No. of units	1 set / unit
Capacity	100%/set

Oil Purifier

No. of units	1 set / unit
Type	Centrifugal type
Capacity	100% / set
Fluid	Turbine lubricant oil

Instrument Air Compressor

No. of units	1 set each for units 3 and 4, and 1 set for common standby
Type	Oil free rotary screw
Pressure	7.5 bar
Capacity	100% / set

Service Air Compressor

No. of units	1 set for common use
Type	Oil free rotary screw
Pressure	7.5 bar
Capacity	100%/set

Chemical Dosing System

No. of units	1 lot for common use
Type	Chemical storage and dosing system

Fire Fighting Equipment

No. of units	1 lot for common use
Type	Water storage, pumps, piping networks, hydrants, sprinklers, detectors, alarm, and fire extinguishers

Cranes (Turbine Hall, Hotwell Pump, Warehouse)

No. of units	1 lot
Type	Overhead cranes, hoists

Workshop (Scope of Units 1&2)

Laboratory Furnishings (Scope of Units 1&2)

Warehouse

No. of units	1 lot for minimum use

Ventilation and Air Conditioning System

No. of units	1 lot for common use
Type	Ventilation fans ductworks and Air conditioning with H_2S filters

Service Water Supply System

No. of units	1 lot for common use
Type	Raw water supply, water storage, filters, sterilizing, pumping, and distribution system

Waste Water Treatment System

No. of units	1 lot for common use
Type	Oily water separator, settling, pH control system

(4) Electrical, Instrumentation and Control System

a. General

The voltage of the generator output is stepped up to 275 kV by the Main transformers and delivered to the 275 kV Lahat substation through 275 kV switchgears in the power plant.

On the other hand, power for the auxiliary equipment in the power plant is supplied through Unit transformers and an auxiliary circuit is formed in the power plant, as shown in Fig. 4.2-4 “Single Line Diagram”. For auxiliary equipment with capacities greater than or equal to 200 kW, such as Hotwell pumps etc., 6.3 kV will be applied in order to reduce the electrical current (ampere), while 400 V will be applied to auxiliary equipment with less than a 200 kW capacity.

The auxiliary power in the power plant will be supplied from the grid with the generator circuit breaker (CB) open at the time of Unit start-up. As soon as the turbine is started, the generator is synchronized with the grid using the generator CB. Thus, the generated power becomes the source of auxiliary power. After the generator has achieved its rated output, the start-up operation is complete. When a Unit is shutdown, auxiliary power must be derived from the grid again with the generator CB open.

b. Generators

Air-cooled, three-phase synchronous generators will be installed. They are easy to operate, require less maintenance and are well-proven in a geothermal environment. Corrosive gas like H_2S must be removed from the cooling air for the generator, utilizing oxidized catalytic filters etc., since the atmosphere around the geothermal field contains highly corrosive H_2S gas. A brushless exciter system will be applied.

The main specifications of the generators are as follows:-

- Type : Cylindrical rotating field type, totally enclosed, air-cooled, three-phase synchronous generators
- Rated Output : Approx. 58 MW (Net 55 MW)
- Rated voltage : 13.8 kV (Manufacturer’s standard)
- Frequency : 50 Hz
- Speed : 3,000 rpm
- Power Factor : 0.8 (Lagging)
- Neutral Grounding : Transformer
- Excitation System : Brushless

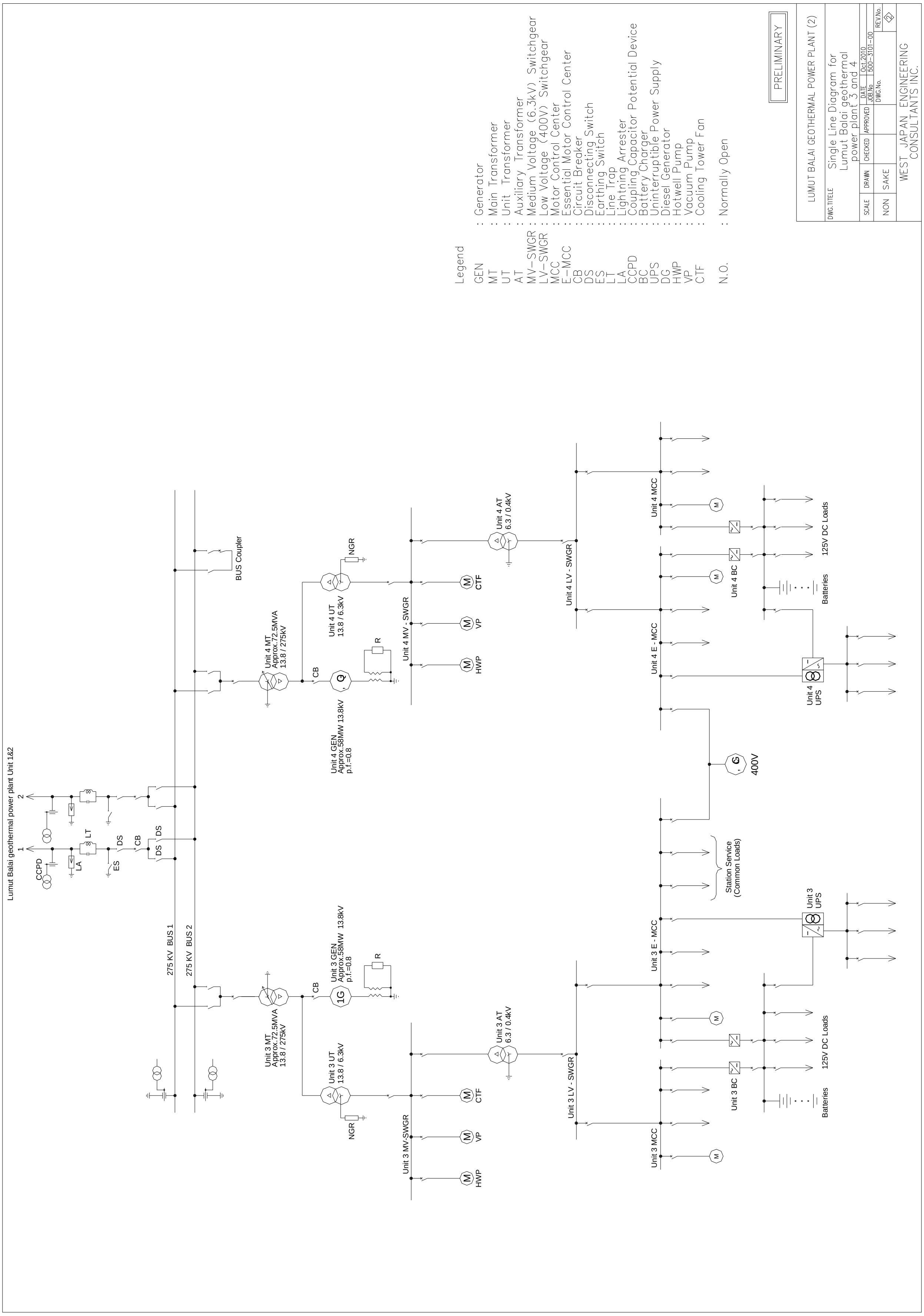


Fig. 4.2-4 Single Line Diagram (Preliminary)

c. Specifications of other major electrical equipment

Equipment	Q'ty	Specification
a) Main transformer	2	Approx. 72.5 MVA、13.8 kV / 275 kV +/-10 % (with On-load tap changer)
b) Unit transformer	2	13.8 kV / 6.3 kV +/-5 % (with No-load tap changer, 5 taps)
c) Auxiliary transformer	2	6.3 kV / 400 V +/-5 % (with No-load tap changer, 5 taps)
d) 6.3 kV Metal-clad switchgear (M/C)	3 sets	6.3 kV, for auxiliary equipment with capacities greater than or equal to 200 kW and for feeder to Auxiliary transformers
e) 400 V Power center (P/C)	2 sets	400 V, For auxiliary equipment with capacities greater than or equal to 75 kW and for feeders to MCC
f) 400 V Motor control center (MCC)	2 sets	400 V, For auxiliary equipment with capacities less than 75 kW i) Common MCC For the auxiliary equipment used for common use (Power supply for Office, etc.) ii) Unit MCC For the auxiliary equipment used for unit operation iii) Emergency MCC For essential loads in case of emergency (for safe shut-down)
g) Distribution panels	2 sets	230 V / 110 V AC, For control, instrumentation, lighting and others
h) Control equipment	2 sets	Overall control system for power plant with Data acquisition system such as DCS (Distributed control system), Automatic Voltage Regulator Panel, EHG Control panel, Automatic synchronizing panel and all other control systems
i) Protection panels	2 sets	Turbine protection panels, Transformer protection panels, Transmission line protection panels, Sequence of Event recorders and all other protection panels
j) DC Power supply system (125 V and 48 V DC)	2 sets	i) 125 V DC for control and protection Battery charger panels, 125 V DC Batteries and their distribution panels ii) 48 V DC for Communication equipment Battery charger panels, 48 V DC Batteries and their distribution panels
k) Uninterruptible power supply (UPS)	2 sets	230 V AC, Inverter panel, Distribution panels, for digital control, protection and instrumentation equipment
l) Emergency diesel generator	1 set	Diesel engine and 400 V Generator, fuel tank and other necessary materials

Note: All electrical equipment including Generators must be suitable for an altitude of 1,650 m above sea level.

d. Control and Instrumentation equipment

A micro-processor-based Distributed control system (DCS) will be installed to control the whole system and monitor various parameters of the geothermal power plant including FCRS. The DCS contributes to the highly reliable, fail-safe operation and productivity of the power plant.

The control systems in the geothermal power plant are mainly as follows:

i) Main steam supply

- Separator level control
- Steam supply control

ii) Turbine and Generator control

- Automatic start-up and shutdown of the turbine (from turbine start-up at cold condition to 100% load and vice versa)
- Automatic start-up of the turbine and load regulation in conjunction with digital electro-hydraulic control (EHC) governor

iii) Condenser level

The hot water level in the Condenser is controlled by the DCS to protect the Hotwell Pumps. The hot water level is detected by the level switch with a transmitter. If the level falls lower than a pre-set level, DCS issues a hot water low-level alarm as a level-low alert, and if the level falls further, the DCS finally triggers unit shutdown as an emergency trip.

iv) Electrical equipment control

- Automatic synchronization to the Grid
- Electrical equipment on/off control

Units 3 and 4 will be remotely controlled from the Units 1 and 2 control room.

In addition to the control system, a plant interlock system must be provided to protect the power plant equipment. The software interlock systems for equipment operation are included in the DCS. For emergency tripping of the major equipment, a hard-wired interlock system should be provided.

The operation of the plant can be carried out using Operator work stations (OWS) with display and keyboard, which are the man-machine interface between the DCS and operators in the control room. Power for the DCS should be supplied by an Uninterruptible power supply system (UPS) so that the power supply is available to the DCS even in case of emergency.

e. Communication System

The power plant must have the following Communication equipment in accordance with Sumatra Grid code (2007).

- Voice
  - Operational: Special Communications Circuit and Redundancy for big power plant connected to 275 kV networks
  - Administrative: Telecommunication network of PT PLN (Persero) or special circuit of general telecommunications for all Grid Users
- Data
  - Circuit of special communications for SCADA

- Circuit of special communications for protection net
- Telecommunication network of PT PLN (Persero) or special circuit of general telecommunications for facsimile; and
- Telecommunication network of PT PLN (Persero) or special circuit of general telecommunications for Computer network.

In addition, power plants must have two independent voice communications channels (redundant system).

f. Tariff metering

Tariff metering will be done at an interface between Power plant and Grid owner. The interface point varies depending on the scope of the Transmission line work and/or the connected substation extension. An agreement will be made between the power plant owner and Grid owner later. Metering equipment and its accuracy must be in accordance with Sumatra Grid code, as follows.

- Metering equipment
  - kWh import
  - kWh export
  - kvarh import
  - kvarh export
  - Maximum kVA demand
- Accuracy
  - Instrument transformer : Class 0.2 (IEC Standard 185)
  - kilowatt-hour Meter : Class 0.2 (IEC Standard 687)
  - kilovar-hour Meter : Class 0.2 (IEC Standard 1268)
  - Maximum kVA demand Meter : Class 0.5S (IEC Standard 687)

g. Switchyard Equipment

The configuration of the switchyard will be of 275 kV, outdoor, conventional type, with a Double busbar system, which is the standard system in Indonesia. See Fig. 4.2-4 Preliminary drawing of Single line diagram for Lumut Balai geothermal power plant. In order to protect the switchyard equipment and transmission lines from corrosion due to H_2S gas, the switchyard area will be located on the opposite side from the Cooling tower facilities. The switchyard equipment must be suitable for an altitude of around 1,650 m asl. The main specifications of the 275 kV switchgears are as follows:

- Switchyard type : Outdoor, conventional type
- Bus system : Double busbar system
- Rated voltage : 300 kV
- Rated current : 1,250 A

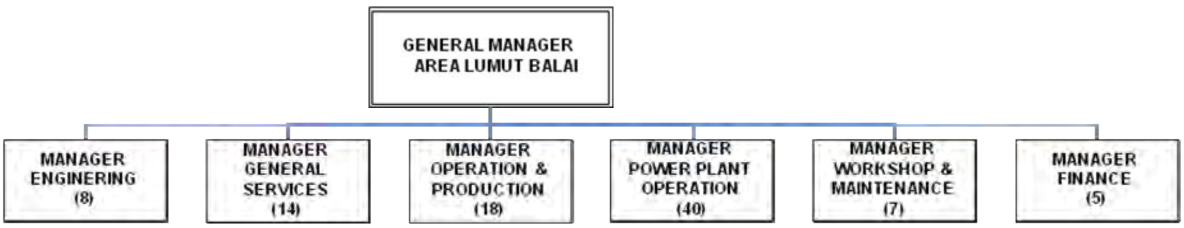
- Rated interrupting current : 31.5 kA
- Rated insulation level
  - Lightning impulse withstand voltage : 1,050 kV
  - Power frequency withstand voltage : 435 kV
- Transmission line protection
  - Main protection : Impedance relay protection
  - Back-up protection : Directional earth fault protection and Overcurrent protection with Auto-reclose

If the prospective site is not large enough to construct conventional switchyard equipment due to topography, GIS (gas-insulated switchgear) may be considered.

4.2.8 Operation and Maintenance

PGE will be responsible for operation and maintenance of the Lumut Balai geothermal power plant both upstream and downstream.

The organizational structure of Operation and Maintenance for Lumut Balai geothermal power plant Units 1&2 and 3&4 will be similar to that for the existing Kamojang Unit 4 shown below:



Employees = 92 persons

Outsourcing = 255 persons

Based on the above organizational structure, PGE will perform routine preventive maintenance, periodical maintenance and predictive maintenance.

Improvement work such as plant rehabilitation/revamping/reconditioning/retrofitting/renovation and relocation will be arranged and implemented by PGE.

It will be possible to operate Units 3&4 with the same number of personnel, if they are controlled remotely from the Units 1&2 power plant. Common use of maintenance equipment and spare parts for Units 3&4 would also reduce total O&M cost.

4.3 Transportation

Lumut Balai is located in South Sumatra Province and roughly 260 km away from Palembang, which is the capital city of the Province. The land around the prospective project site is in a mountainous area with an altitude of about 1,000 to 1,800 m above sea level. To confirm the ease of transportation of the equipment and materials for the geothermal power plant, a survey of transportation routes and unloading ports has been carried out.

4.3.1 Transportation Route to the Site

The survey team started from Jakarta in vehicles and crossed the Sunda Straits by car ferry from Merac to Bakauheni. The main transportation route to the site will be from Panjang Seaport to Lumut Balai via Batu Raja. The distance between the port and the site is approximately 370 km. From Panjang Seaport up to a branch point about 35 km before the project site, the road is completely paved and no major obstacle was found to transporting the power plant equipment and materials. However, since several truss and concrete bridges, including a railway overpass, are found on the route, it is strongly recommended that a detailed survey, including inspection of the height of the truss bridges and their strength be carried out to ensure safe transportation of the equipment and materials once an EPC Contractor for the power plant has been selected.

From the branch point mentioned above, the road is in very poor condition in parts for transporting heavy and long equipment and materials. In particular, the dirt road passing through small villages such as Babatan and Bandaralam is very narrow, and it seems that it will be difficult to transport the equipment and materials safely. Considering these conditions, it is recommended that the existing road passing through such villages be widened or that a new access road by-passing the villages be constructed.

Approximately 1 km before PGE's Base Camp, the road is unpaved and very steep, and it seems that it will be very difficult to transport heavy-duty project cargo to the prospective power plant site, especially during the rainy season.

In conclusion, repair/reinforcement of the existing access road should be carried out before bringing in the power plant equipment and materials to the site so that safe transportation can be achieved.
The survey results are summarized in Table 4.3-1, and the transportation routes are shown in Fig. 4.3.1.

4.3.2 Unloading Ports

Two candidates for unloading ports for power plant equipment and materials have been surveyed, Panjang Seaport and Palembang River port. Panjang Seaport is one of the largest ports in Lampung Province and Palembang River port is also a rather large-size port in South Sumatra Province. Available facilities and features at both ports are summarized as follows:

Panjang Seaport

- 24 hour operation of large harbor facilities
- Depth of the water is rather deep, at 15-20m in depth.
- Wharfing of a large size vessel/barge is possible.
- Shore cranes and mobile cranes in the 60 ton range are available.

Palembang River port

- 24 hour operation of medium-sized harbor facilities
- Depth of the water is not so deep, at 6.5-7m in depth.
- Wharfing of a large size barge is possible, but a large vessel is impossible.
- Shore cranes and mobile cranes in the 35 ton range are available.

On the other hand, the project cargo is expected to be limited to the following range as long as the maximum unit capacity is assumed to be 55MW:

- Maximum Weight (generator): 80-90 tons per cargo
- Maximum Length (generator): 10-12 meters per cargo

Considering the characteristics of the two port facilities and expected project cargo, Panjang Seaport, which has enough facilities to discharge the cargo, is the most suitable unloading port for the project. Since the maximum unit weight of the equipment exceeds the capacity of the cranes which are currently installed in the port, it will be necessary to employ a 100-ton mobile crane or a crane barge/vessel to discharge the cargo directly from the vessel to the wharf. Palembang River port is also available as an unloading port for auxiliary equipment and materials.

Table 4.3-1 Transportation Route (Panjang Port – Lumut Balai)

From	To	Distance (km)	Bridges			Overhead Signboards	Remarks
			Truss	Railway Overpass	Concrete		
Panjang Port	Batu Raja	273	9	1	2	7	- Paved road - Need to check height of signboards and 3 truss bridges with overhead truss
Batu Raja	Branch to Site near Sugiwaras	59	2	0	18	0	- Paved road - Need to check height of 2 truss bridges with overhead truss
Branch to Site near Sugiwaras	PGE Base Camp	35	0	0	*	0	- First 6 km: paved road - Remaining 29 km: dirt road - Steep road near the site * There are several small concrete bridges.
Total		**367**	**11**	**1**	**20**	**7**	

Fig. 4.3.1 Transportation Routes

4.4 Transmission Lines and Substation

4.4.1 275kV Transmission Lines

The output of Lumut Balai geothermal power plant will be delivered to Lahat substation, which is the nearest substation to the power plant. Lahat substation is located 50 km north of the power plant. Fig. 4.4-1 shows a conceptual drawing of the transmission line. The transmission line will be designed as a double circuit to Lahat substation. The existing Lahat 150/20 kV substation will be upgraded to a 275/150/20kV substation. Due to insufficient land space for a 150 kV switchgear extension and in order to reduce power line loss, a 275kV design will be adopted by PLN for the transmission line instead of 150kV.

Therefore, the transmission line from the Lumut Balai Geothermal power plant will be connected to the 275kV Lahat substation directly. The conductor for the transmission line is selected in consideration of transmission loss and voltage drop. Calculations were done for the double DOVE conductors (2 x 556.5MCM, equivalent to 2 x 282 mm^2) which are proposed by PLN. Table 4.4-1 below shows the transmission capacity and the calculation results for the transmission loss and voltage drop. The calculations were done assuming 4 units of 55 MW with a power factor 0.8.

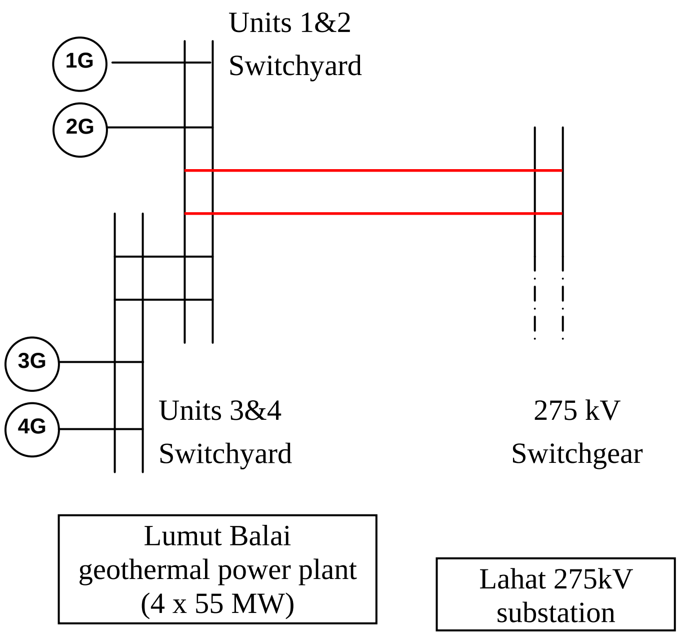


Fig. 4.4-1 Transmission Lines (Conceptual)

Table 4.4-1 Calculation Results for Transmission Loss and Voltage Drop

Code Name	*ACSR Conductor size	Output	Normal operation				**n-1 security (cont. 60% load)			
			Transmission Loss		Voltage Drop		Transmission Loss		Voltage Drop	
			Loss (MW)	%	Voltage (kV)	(%)	Loss (MW)	%	Voltage (kV)	%
DOVE	2 x 282 mm^2	220MW (***PF:0.8)	1.8	0.8	7.4	2.7	1.3	1.0	8.9	3.2

Note) * ACSR: Aluminum conductor steel reinforced

** "n-1 security" means transmission line should be able to load 60% of the output when one circuit in the double circuit cannot be used due to faults, or for other reasons.

*** PF: Power Factor

According to RUPTL 2010-2019, a power plant is planned at Rantau Dedap (total 220 MW) located south of Lumut Balai. If the transmission line from Rantau Dedap is connected to the transmission line from Lumut Balai to Lahat substation, the transmission capacity will be sufficient to carry the generation outputs of both Lumut Balai and Rautau Dedap.

The transmission voltage of the power plant will be regulated by a generator AVR (+/- 5%) and a main transformer OLTC (+/- 10%).

The main specifications of 2 x DOVE are as follows.

- Operating Voltage : 275 kV
- Material / Code Name : ACSR / DOVE
- Cross section : 556.5 MCM (282 mm^2)
- Number of conductors : 2
- Number of Circuits : 2
- Transmission Capacity : Approx. 480 MVA (per circuit)
- Length : Approx. 63 km (to Lahat substation)

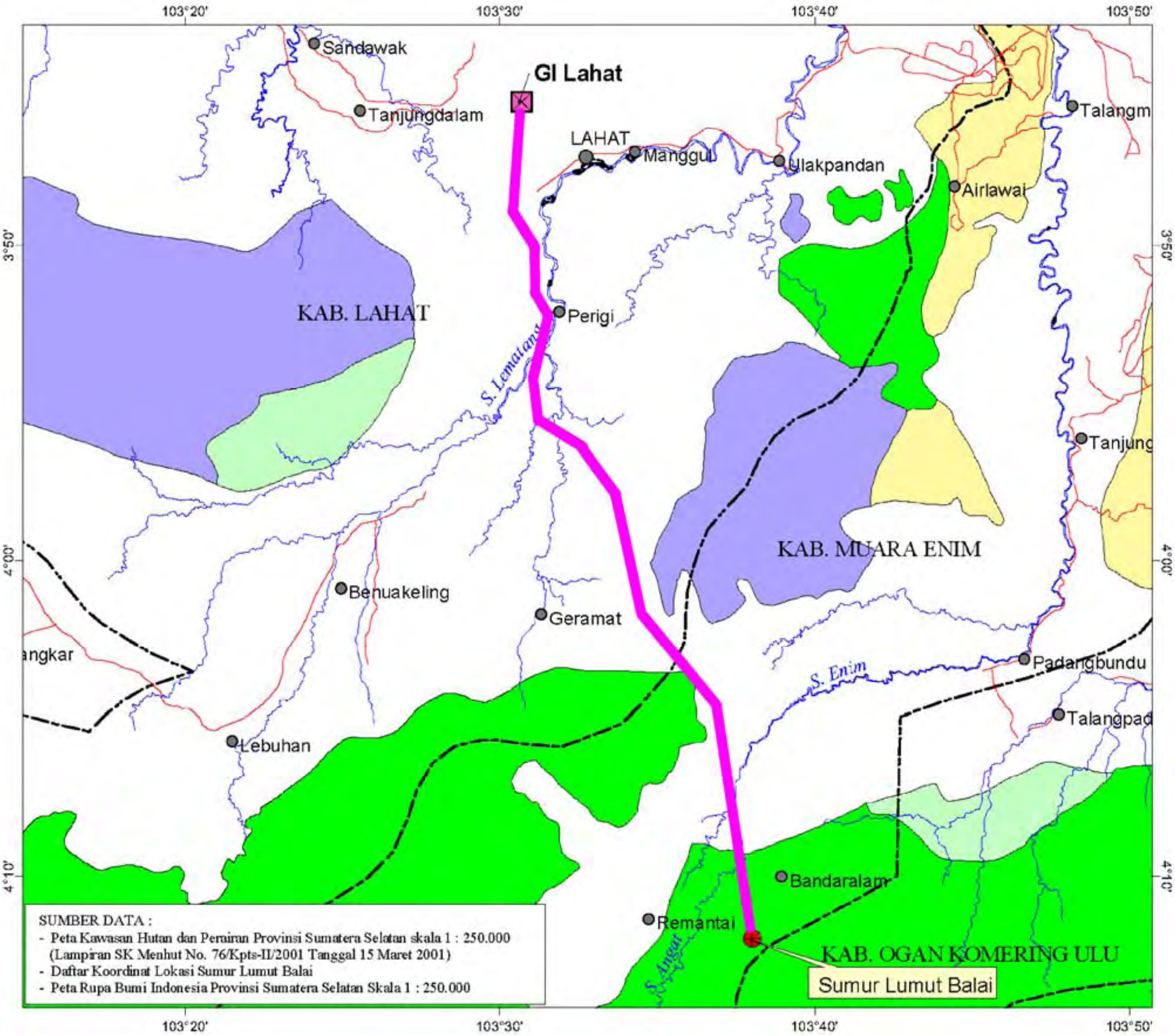


Fig. 4.4-2 Transmission line route from Units 1&2 to Lahat 275kV substation
(in planning by PLN Pikitring SBS)

A transmission line interconnecting Units 1&2 and Units 3&4 should be constructed. It is recommended that negotiations between PLN and PGE should be held early to agree who will construct the transmission line, and preparation of AMDAL should be commenced for construction of transmission line.

The transmission line lengths are approximately 2km, as shown in Fig. 4.4-3 Conceptual design of Transmission line route

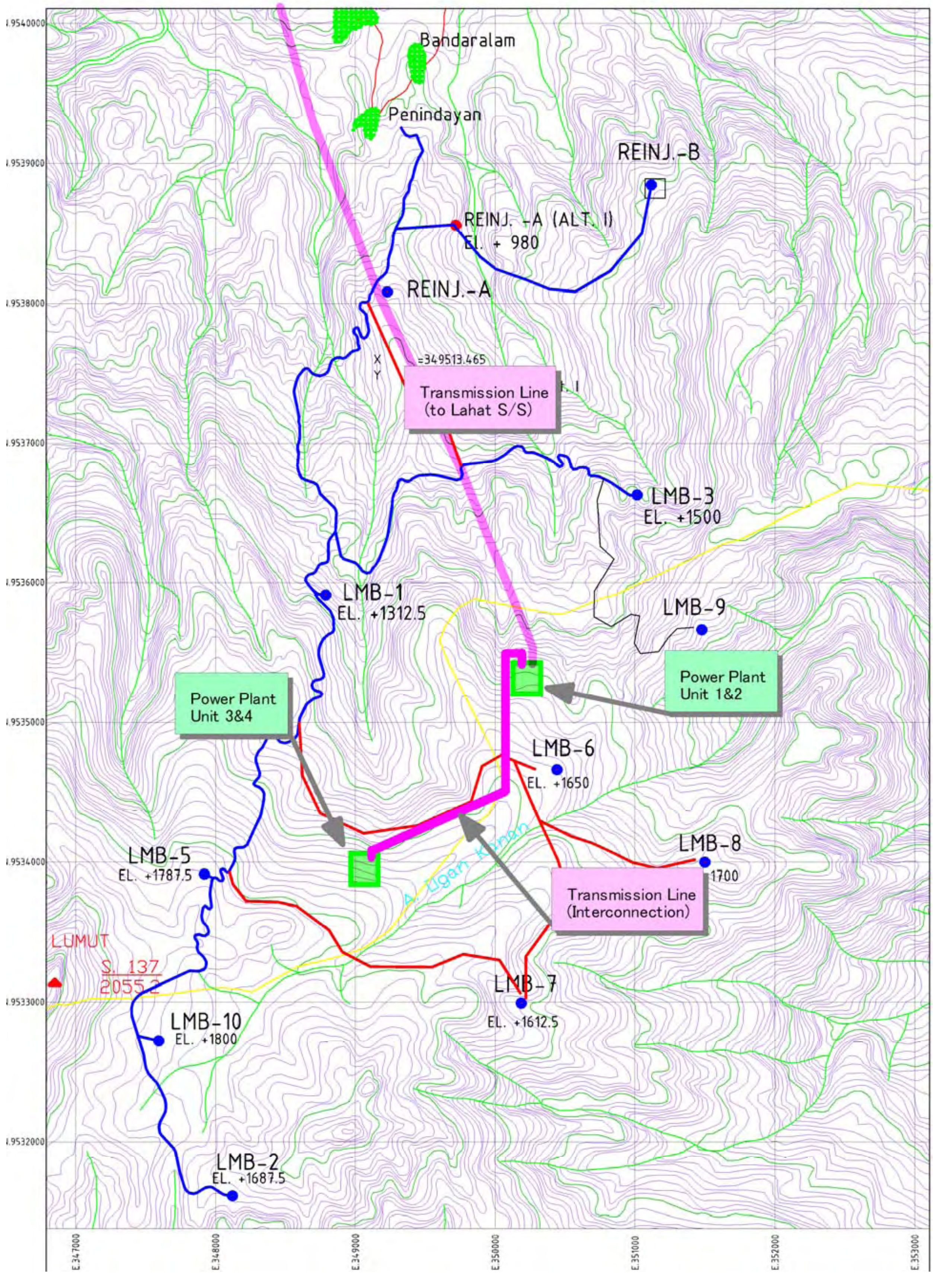


Fig. 4.4-3 Conceptual design of interconnection line route between Units 1&2 and Units 3&4.

4.4.2 275 kV Substation

As stated in 4.4.1, the output of Lumut Balai geothermal power plant will be delivered to the Lahat 275kV substation. This substation is one of the major substations in the South Sumatra network and it will be upgraded from a 150 kV system to a 275kV system. According to RUPTL 2010 - 2019, the construction of Lahat 275kV substation and 275kV upgrading work are scheduled for completion in 2012 by World Bank loan.

Two sets of 275 kV complete line bay should be expanded to connect the transmission line from Lumut Balai. Fig.4.4-4 shows the layout of the Lahat 275 kV substation.

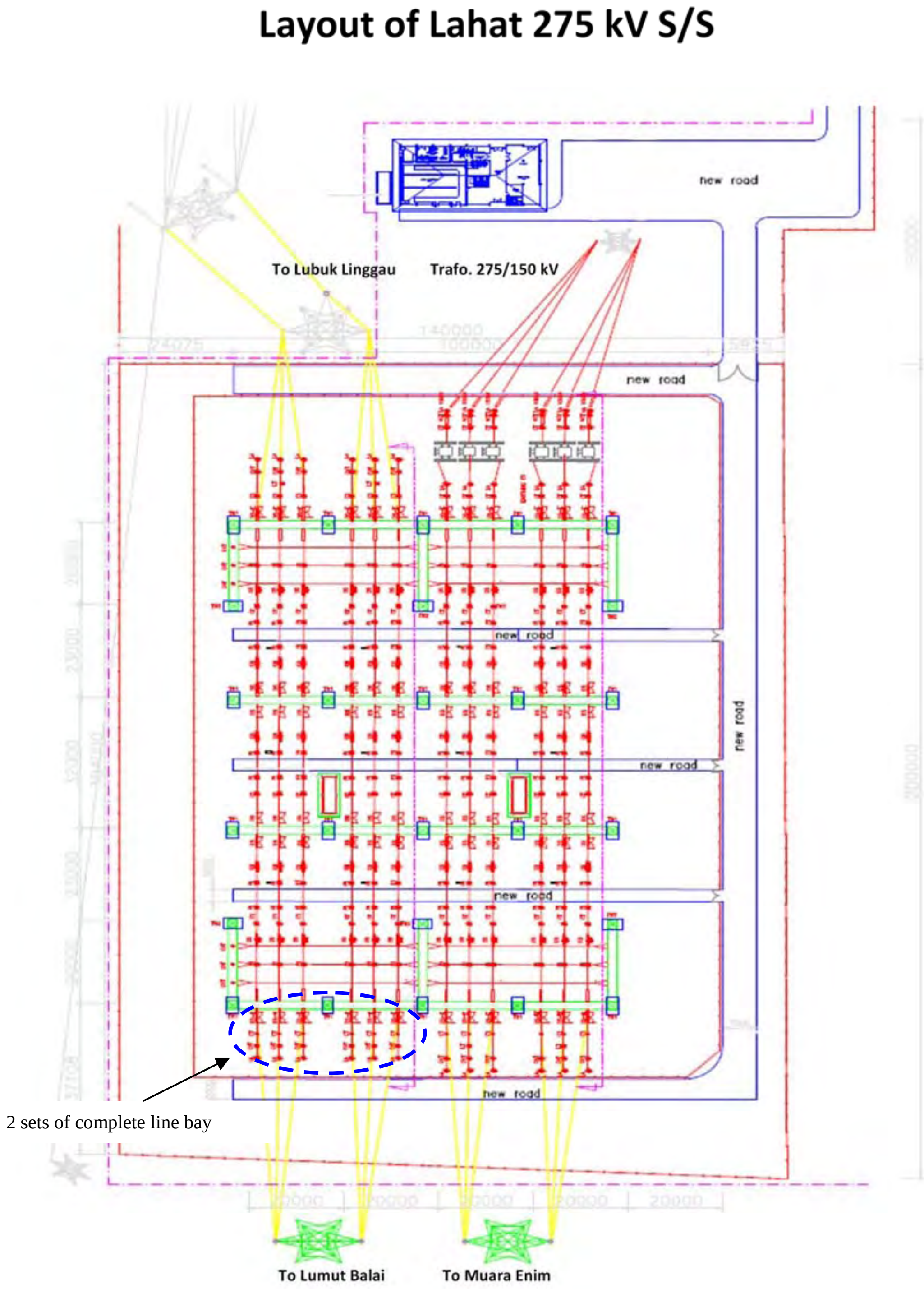


Fig. 4.4-4 Layout of Lahat 275kV Substation (New)

4.4.3 Construction, Operation and Maintenance

PLN will be responsible for construction, operation and maintenance of the 275kV transmission line from Lumut Balai geothermal power plant to Lahat substation.

In Sumatra, PLN organization consists of Pikitring which is in charge of construction for main power plant and network project and P3B which is in charge of operation and maintenance for transmission and central load dispatching. Fig. 4.4-5 shows the organizational structure of PLN in Sumatra.

The construction work of the transmission line will be managed by Pikitring Palembang. After the construction, the transmission line will be maintained by UPT Bengkulu part of P3B Sumatra.

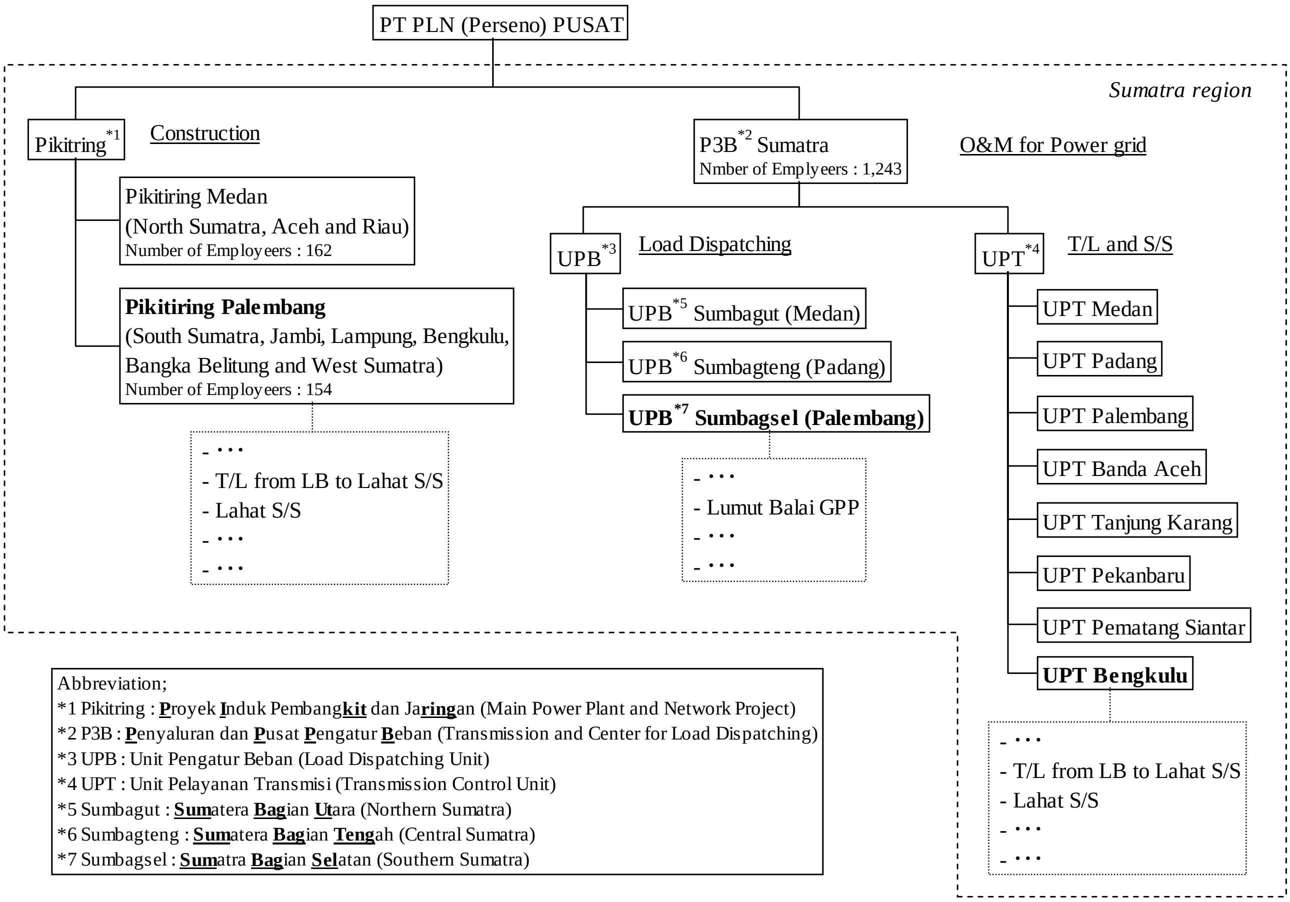


Fig. 4.4-5 PLN Organization in Sumatra (Source: PLN annual report 2009)

PLN should consider the construction schedule of the transmission line taking account of construction schedule of Lumut Balai units 1&2 and units 3&4. The survey team explained to PLN regarding the construction schedule of the transmission line, with and without consulting service using JICA loan.

If PLN applies consulting service using JICA loan, the completion of the transmission line will not be in time by the commissioning of Lumut Balai units 1 & 2. Since PLN has already substantial construction experience of 275kV transmission line over 500km between Lahat S/S and Kiliranjao S/S, consulting service for the 275kV transmission line is not mandatory for PLN.

CHAPTER 5 IMPLEMENTATION PROGRAM

5.1 Implementation Program

5.1.1 The Project

The Project is to construct two 55 MW geothermal power plants (units 3 and 4) at Lumut Balai, South Sumatra and the associated 275 kV x 2 circuit transmission line to the nearest PLN substation at Lahat as well as carrying out some modifications or expansion of the substation, which is about 50 km from Lumut Balai. The project is undertaken in accordance with the national energy policy, MEMR's national Geothermal Road Map and the government's 2nd 10,000 MW fast track program. At the existing Lahat substation, two (2) additional buses will be constructed to receive and transmit the power from the geothermal power stations and its existing capacity as a 150 kV substation will be upgraded to a 275 kV capacity at the same time. The power transmission and substation expansion are planned in consideration of the near-future addition of the 220 MW Rantau Dadap IPP geothermal power plant.

The project is divided into two parts: PGE will undertake construction of the geothermal power plant and PLN will construct the associated transmission line and substation project.

5.1.2 Executing Agency

The executing agency of the geothermal power plant project is PT Pertamina (Persero) who have entrusted the implementation to PT. Pertamina Geothermal Energy (PGE). PGE will carry out the project with its own equity and financing from the Japan International Cooperation Agency (JICA) through a sub-loan agreement with its parent company, Pertamina. To date, PGE has started construction of about 30 km of access roads to the site and has completed several well drillings for No. 1 and 2 units.

5.1.3 Project Components

The Project can be divided into two (2) main components: the PGE work to construct a 55 MW x 2 geothermal power station and PLN work to construct a 275 kV transmission line and expansion work at Lahat Substation. All of this work will be financed principally by a JICA ODA loan.

PGE Work for Construction of 55 MW x 2 Geothermal Power Station

The main component of the project is the work covered by the JICA ODA Loan such as:

1) Project downstream work (55 MW x 2 geothermal power plant and FCRS)

2) PGE administration costs

3) Consultant fee

4) Price and physical contingencies

PLN Work for Construction of 275 kV Transmission Line and Expansion of 275 kV Substation

1) Acquisition of land and rights of way,

2) Access roads and other civil work,

3) Transmission line, and substation expansion,

4) Administration cost (site management, construction office, cost for several permits and EIA processing, etc.)

5.1.4 Finance Procurement

JICA will provide 85% financing to both the PGE and PLN work in addition to the consultant loan, and the remaining 15% of the cost will be covered by PGE's own equity, which is expected to have the following rates of return.

Table 5.1-1 Finance Conditions

	Project Loan	Consultant Loan	PGE Equity
Interest/ROR	0.3% per annum	0.01% per annum	14.48%
Grace Period	10 years	10 years	NA
Repayment	40 years	40 years	NA
Repayment Method	Principal equal installment	Principal equal installment	NA

Other terms and conditions of the Japanese ODA Loan are as follows:

- Generally untied
- The upper limit on JICA financing is 85% of the total project cost, exclusive of land acquisition and the executing agency's administrative costs.
- The interest will be applied after the first disbursement
- A Commitment fee of 0.1% will be levied on the undisbursed amount of the loans 120 days after the signing of the L/A.
- The consultant will be procured according to the Guidelines for Employment of Consultants, and the project will be procured according to the Guidelines for Procurement under Japanese ODA Loans with optimized procurement to accommodate local procurement requirements specified as Indonesian national policy.

5.1.5 Project Implementation Schedule

Assuming that the L/A will be concluded at the end of February 2011 and that a certain period of time for JICA concurrence requirements concerning several procurement procedures is incorporated, the tentative implementation schedule is formulated as shown in Fig. 5.1-1. The JICA guideline schedule is as shown in Table 5.1-2:

Table 5.1-2 JICA Standard Schedule

1. Consultant selection *(Note)*	9 months
2. Project procurement	
a. Bidding document preparation	4 months
b. Bidding period	3 months
c. Bid evaluation	5 months
d. JICA concurrence	1 month
e. Contract negotiation	1.5 months
f. JICA concurrence with the contract	0.5 months
g. L/C opening and issue of L/Com	1 month
Subtotal	16 months

(Note): Consultant selection could be 6 months in the case of direct appointment.
(Needs justification for direct negotiation)

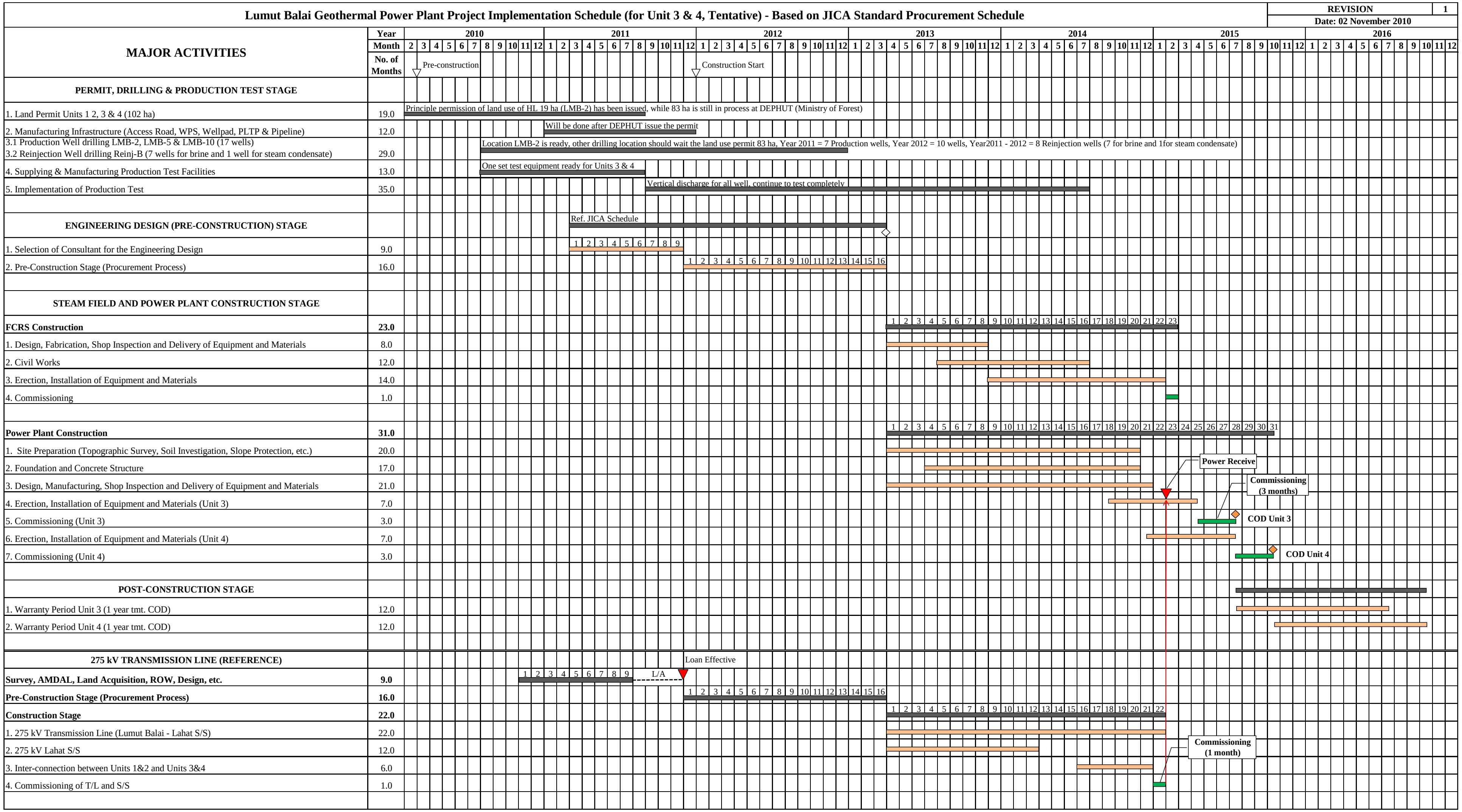


Fig. 5.1-1 Project Implementation Schedule for Lumut Balai Geothermal Power Plant Units 3&4 (Tentative)

5.2 Indices to Confirm Project Effectiveness

Table 5.2-1 shows the criteria for evaluation of the effectiveness of this project. They are based on the standard parameters of JICA's Ex-ante/Ex-post evaluations for power plant projects, and characteristics of geothermal power plant and parameters that should be recorded for the purpose of monitoring power plant operation performance.

(Note: Ex-ante evaluations are performed for all ODA loan projects and the results are released as Ex-Ante Evaluation Reports immediately after the conclusion of loan agreement. Ex-post evaluations are carried out for all projects two years after completion so as to ensure full accountability and to enhance the effectiveness and efficiency of ODA operations.)

(1) Maximum Net Output

The maximum net output for Lumut Balai Units 3&4 is set to the same value as the rated output, i.e. 55 MW(net) x 2 units = 110MW(net). Considering the good operating records of new geothermal power plants in Indonesia (e.g. Wayang Windu and Kamojang IV) and potential of the geothermal resource in this field, there is no reason to assume lower output at the moment.

(2) Capacity Factor

Taking account of the operating records of geothermal power plants that have come online in recent years in Indonesia, which show capacity factors higher than 90% (e.g. Kamojang-IV and Wayang Windu), an average annual capacity factor of 90% is proposed as the target for this project.

(3) Plant Steam Rate

For the purpose of monitoring the performance of a geothermal power plant as a whole, the steam rate should include steam consumption of the turbines and auxiliary steam such as gland steam and motive steam for steam-jet ejectors. The steam rate varies depending on the design conditions shown below, and it cannot be determined precisely at this stage.

- Steam pressure at turbine inlet that should be adjusted based on the results (deliverability curves) of production tests of the wells.
- Contents of non-condensable gases in the steam, which will be determined based on the data obtained during the production tests.
- Design wet-bulb temperature for cooling towers that will be determined based on the meteorological data from the site (hourly data for at least one year) which are not available at the moment.

The target value, therefore, will be determined based on the guaranteed steam rate at 100% load that will be stipulated in the EPC contract documents for the geothermal power plant, and the correction curve of performance which will be submitted by the turbine manufacturer.

(4) Outage Hours from All Causes

- Human Error: The target value is zero.

- Scheduled Outages:

  Assuming a detailed inspection of 21 days every two years and a simple inspection of 7 days for the rest, the recommended target value for scheduled outages for this project will be as follows.

  (21 + 7) / 2 = 14 days per year in average
  14(d/yr) x 24(hr/d) = 336 (hr/yr)

- Equipment Trouble

  Assuming the power plant will be operated as a base load plant at 100% load, the availability factor will also be 90% when the capacity factor is 90%. Thus, the target value for the outage hours due to equipment trouble is 540 hr/yr.

  Equipment trouble = 8760 x (1 - 0.90) - (scheduled outage) - (human error)
  = 8760 x (1 - 0.90) - 336 - 0
  = 540 hr/yr

(5) Net Transmission Power

The electricity generated at the Lumut Balai geothermal power plant will be sold to PLN. The power purchase agreement (PPA) between PGE and PLN is under negotiation and the location of the revenue meter (metering point) has not been decided yet. If the revenue meter is in the switchyard of Units 3&4, the transmission loss will be zero, and the target value for the net transmitted power will be 867 GWh/yr.

$110MW_{net}$ x 0.90 x 8760 = 867,240 MWh/yr

This target value should be revised, if necessary, to factor in transmission losses, when the location of the metering point is determined.

Table 5.2-1 Performance Indicators

Indicator	Target (Expected value 2 years after project completion)	Remarks
Maximum Net Output [MW]	110 MW (net)	
Capacity factor [%]	90%	
Plant steam rate [ton/MWh]	Design value (to be determined after EPC contract)	Including steam consumption of turbines, ejectors, and gland steam.
Outage hours from all causes [hour/year]	Human error: 0	
	Equipment trouble: 336 hr/yr	
	Scheduled outage: 540 hr/yr	
Net transmitted power [GWh/year]	867 GWh/yr	This should be updated when the location of the revenue meter is determined.

CHAPTER 6 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

6.1 For the Power Plant

6.1.1 Required Steps for Project Implementation

Basically, Lumut Balai units 3 and 4 is located in the same area as units 1 and 2. Legal permission for the power plant was checked and cleared last year in the preparatory survey for unit 1 and 2. So this year, we confirmed whether units 3 and 4 are also covered or not. As a result, they are confirmed to be covered.

(1) Government Approval for the Project

PERTAMINA obtained a Confirmation of the Geothermal Working Area (WKP) in Lumut Balai and development permission under the Minister of Mining and Energy Decree No.1268.k/20/M.PE/1993 of 7 February 1993. The topographic coordinates of the Lumut Balai Geothermal WKP described in this decree are as follows.

The Geothermal Working Area in Lumut Balai has an area of 225,000 ha enclosed by the following coordinates A, B, C and D shown in Fig. 6.1-1.

A	04°02′00″ 103°30′00″	B	04°02′00″ 103°52′00″
C	04°32′00″ 103°52′00″	D	04°32′00″ 103°30′00″

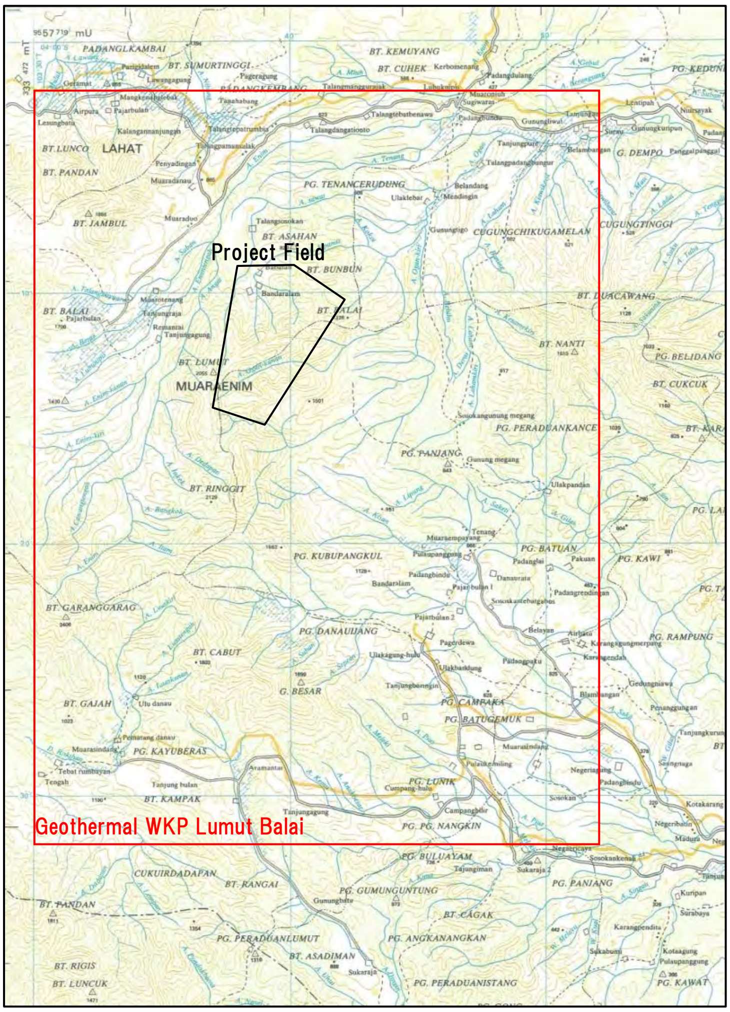


Fig. 6.1-1 Location of Lumut Balai Geothermal WKP

The development area for units 3 and 4 is included in this WKP as well as units 1 and 2.

(2) EIA for the Project

The reports on the Environmental Impact Analysis and the Environmental Management and Environmental Monitoring Plan for the project known as "The Development of Lumut Balai Geothermal Area and the Construction of a Geothermal Power Plant with a capacity of 440 MW over the area of 102 ha in Semende Darat Laut Subdistrict, Muara Enim Regency, South Sumatra Province" were approved by the governor of Muara Enim Regency (No.758/KPTS/BLH-I/2008) on 21 August 2008 based on the Decree of Environment Minister No.5/2008.

Based on the map from Ministry of Forestry published in November 2008, the borderline between Muara Enim regency and OKU (Ogan Komering Ulu) regency runs through the center of the Lumut Balai geothermal field. The borderline between regencies should be determined officially by a National survey and investigation board, but is not yet confirmed whether it has already been changed or not. AMDAL law (Article 24 of No. 27/1999) defines the valid period and cancellation conditions of approved AMDAL, but changes in the borderline of the approving regency are not covered in it. So this AMDAL is still valid.

The Project will take place in Muara Enim Regency and will consist of 4 stages: pre-construction, construction, operation and post-operation. The detailed activities for each stage are as follows:

(1) Preconstruction Phase

a. Administration of permits
b. Field surveys
c. Public consultation
d. Land acquisition

(2) Construction Phase

- Production Well Drilling
  a. Recruitment of manpower
  b. Mobilization of equipment and material
  c. Opening and improvement of land
  d. Construction of drilling sites and supporting facilities
  e. Test well drilling
  f. Construction of piping installation
  g. Disassembly and demobilization of equipment

- Geothermal Power Plant Construction Activity
  a. Recruitment of manpower
  b. Mobilization of equipment and material
  c. Opening and improvement of land
  d. Construction of main structure and supporting facilities
  e. Reduction of manpower

(3) Operation Phase

a. Recruitment of manpower
b. Operation of production wells
c. Operation of Geothermal Power Plant
d. Maintenance of generators
e. Release of manpower

(4) Post Operation Phase

a. Disassembly and demobilization of equipment

b. Storage of used chemicals

c. Rehabilitation of land

(3) Land Acquisition

As the project will take place in a protected forest (Hutan Lindung) of 102 ha, there is no cost for land acquisition, but Ministry of Forestry permission for utilization of the forest area is required based on the Decree of Forest Minister No.P-43Menhut-II/2008. The permission is issued in two different stages, the principal permit and the license-PPKH.

A license for land utilization inside of the protected forest (Hutan Lindung) of Bukit Jambul Asahan and Lumut Balai areas for exploration drilling (17.3ha) was obtained from the Ministry of Forestry on 9 May 2007 under permit No.S.244/MENHUT-VII/PW/2007.

PGE plans to utilize 102 ha of forest area for drilling sites, access roads and power plant site. The principal permit for use of 19 ha of forest area for the development of well pads LMB-5, 6, A and B and their FCRS was issued on 4 May 2010 (No.S222/Menhut-VII/2010). And the principal permit for use of 83 ha of forest area for the development of units 1, 2, 3 and 4 and well pads LMB-1, 2, 3, 4, 7, 8, 9 and 10 and their FCRS was issued on 3 December 2010 (No.S.613/Menhut-VII/2010).

PGE has permission from South Sumatra Province to utilize a 102 ha forest area and is asking for approval from the Ministry of Forestry. PGE is waiting for the license-PPKH for 19 ha and 83 ha.

(4) Planning for Resettlement of People Affected by the Project (Resettlement Action Plan)

There will be no resettlement activities because the project will take place within a protected forest.

(5) Surface Water Utilization

PERTAMINA had been allowed by the Muara Enim Regency to utilize surface water for geothermal exploration drilling activity under Decree No.739/KPTS/Tamben/2007 of 25 July 2007. And this permit was extended for 2 years for PGE by Muara Enim Regency under Decree No. 668/KPTS/TAMBEN/2009 of 12 November 2009 in response to request No. 789/PGE1P2/2009-SO of 21 July 2009 by PGE.

(6) Others

PGE will obtain building construction permits for the power house and warehouse before construction and will obtain a power plant operation permit before selling electricity.

6.1.2 Review of EIA and field survey

(1) Relation between Activity and EIA

Geothermal power plants having a capacity of 55 MW or more must comply with the EIA (AMDAL) requirements. Prior to this EIA of the geothermal power generation project, PGE had prepared the documents required by the Environmental Management Plan (UKL) and Environmental Monitoring Plan (UPL) for drilling and production tests of the geothermal exploitation wells in Lumut Balai following a request from the environmental agency (BAPEDALDA) of the Muara Enim Regency. These documents were accepted by BAPEDALDA on 19 November 2003.

As the Project output is more than 55 MW, in 2008 PGE prepared the documents necessary for the Environmental Impact Statement (ANDAL), Environmental Management Plan (RKL), and Environmental Monitoring Plan (RUL) for development of the geothermal resource for generation, construction of a geothermal power plant and operation of a geothermal power plant with a capacity of 440MW in Muara Enim Regency. These documents were approved by the governor of Muara Enim Regency on 21 August 2008 based on the Decree of Environment Minister No.5/2008 concerning AMDAL Evaluation Commission Procedure. Since the date of AMDAL approval on 21 August 2008, the approved AMDAL documents are open to the public at BAPEDALDA, of South Sumatra Province and Muara Enim Regency and at several institutions concerned with geothermal development, such as the regional office of mines and energy in South Sumatra Province and the regional office of foresty in Muara Enim Regency.

(2) Current Environmental Situation

a. Lumut Balai Site

This project covers an area of 102 ha and lies in hilly zones about 40 km from Plau Panggung, with an elevation of 1,300 m above sea level. The planned land use is for access roads/connectors, drilling pads and their supporting facilities, the geothermal power plant site and its supporting facilities and pipe networks. Access roads to the project site are expected to reach 35 km in length. The vicinity of the Geothermal Area consists of low land cultivated as coffee plantations and paddy fields. Meanwhile, protected forest is found at higher elevations. Based on the Revised Spatial Plan (RTRW) of Muara Enim Regency of 2007, the majority of the Project site will be located in protected forest and only a small part will be in drylands belonging to the local community.

b Social, Economy and Cultural Environment

The project location was initially quite isolated because road access was not adequate. To market agricultural products, the residents had to transport them by carrying them on their shoulders. Now, the road is good and they transport their agricultural products to market using cars. The ability of the residents to travel outside of their region is quite good now due to the opening up of better road access.

The inhabitants of Penindaian Village and Babatan Village are generally native inhabitants, even though there are also immigrants from Java. They socialize with one another and live in harmony and peace. Conflict between ethnic groups has never been a feature of these areas. Population growth in Penindaian Village and Babatan Village is relatively low. In fact, the population is decreasing because many inhabitants leave the villages to seek other sources of income in other places, mainly in Lampung Province.

The population of Babatan Village in 2007 was 2,460 people with density of 72 people/km^2 and the population of Penindaian Village was 911 people with density of 11 people/km^2.

The main occupation of the residents of Babatan Village and Penindaian Village is agricultural production of coffee, rice and pulse, while others are traders, laborers, private employees, military personnel and civil servants. All residents in Babatan Village and Penindaian Village are Moslems.

Tradition in Babatan Village and Penindaian Village plays a significant role in the life of the residents because many aspects of kinship, marriage, inheritance, and land ownership are characteristic of the Semende ethnic group. Semende tradition is called “Bermeraje Anak Belai” tradition, in which two elements cannot be separated from each other, namely Tunggu Tubang and Anak Belai. The Meraje acts as guide, supervisor and guardian, while Anak Belai is the guided party. Residents in the Semende region are matrilineal, and so the recipient of an inheritance in the form of property such as houses, gardens, rice fields, fish ponds and heirlooms is the first daughter in the family (Tunggu Tubang). If the first daughter is not willing or able to receive the inheritance, the inheritance will be handed down to the second daughter, which is called “apit jurai”. If there is no daughter in a family, a son can be chosen to become Tunggu Tubang. This choice is communicated to the meraje to be discussed and approved. In Semende tradition, this is called Tunggu Tubang Ngangkit.

In general the diseases that are endemic among the residents of Babatan Village and Penindaian Village are upper respiratory tract infections (influenza and cough), malaria, and diarrhea due to use of non–hygienic water from the Sepanas River.

c. Natural Environment

(i) Climate

Climate data were obtained from the Meteorology and Geophysical Board (BMG) Climatology Station (SM) Class II Kenten Palembang for the latest 5 years (2005 – 2009). The climate data describe temperature, humidity, pressure, duration of sunlight exposure, rainfall and wind.

Like other areas in Indonesia, Palembang also has two seasons, namely dry season and rainy season. These seasons are determined by the prevailind wind that blows in Indonesia. From June to September, the prevailing wind comes from Australia and contains less water vapor, making this the dry season in Indonesia. In contrast, from December to March the prevailing wind comes from Asia and the Pacific Ocean after passing over several seas and contains much water vapor. These are the months of the rainy season. The season changes every half-year, passing through a transitory period during April – May and October - November.

(ii) Temperature

Temperature in a location is determined by its altitude with reference to sea level and its distance from the coast. Based on data from the Climatology Station of Kenten Palembang, temperature during the 2005 – 2009 period recorded a range of 23.6 ºC – 34.9ºC. Average monthly maximum temperature during the period ranged from 30.02 ºC – 34.9ºC, while the minimum temperature ranged from 23.6ºC – 24.9ºC.

Average temperature during the 2005 – 2009 period shows that both maximum average temperature and the average minimum occur in December and the highest is in September. In addition, the pattern of average maximum temperature at western season (December - February) decreases, subsequently increase at transitory season I and decrease back in eastern season (June - August) , but in transitory season II (September - November) increase back and reach the maximum temperature. Meanwhile, average minimum temperature fluctuates only very slightly, as seen in Fig. 6.1-2.

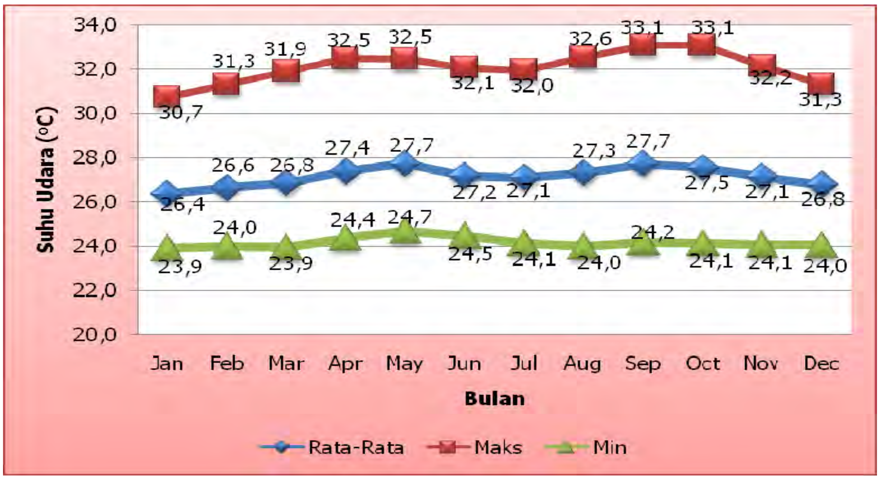


Fig. 6.1-2. Graph of temperature (ºC) during the 2005 – 2009 period

(iii) Humidity

Humidity in the Palembang area, based on data from the Climatology Station of Kenten Palembang during the 2005 – 2009 period, ranges from 47% to 100%. The range is quite large, which may be due to topographical factors: Palembang is relatively flat and far from the influence of the sea. Based on average maximum humidity during the 2005 – 2009 period, the range of maximum humidity is smaller (more homogeneous) compared to average humidity and minimum humidity, which show greater fluctuations. The highest average maximum humidity occurs in January (94.6%) and the lowest occurs in August (90.6%), while the highest average minimum humidity occurs in January (80%) and the lowest occurs in May (90.6%), as seen in Fig. 6.1-3. In the figure, maximum, average and minimum humidity show the same pattern, with relatively high humidity in the western season compared to the other season.

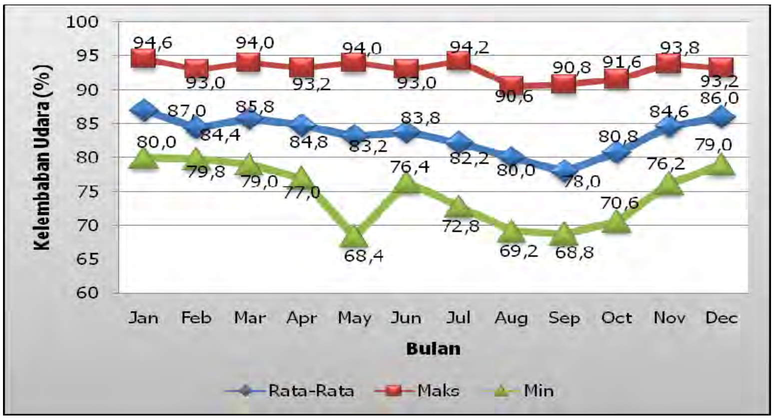


Fig. 6.1-3 Graph of average humidity (%) during the 2005 – 2009 period

(iv) Pressure

Atmospheric pressure represents weight of an atmospheric column per unit of area above a point, where the pressure changes with place and time. Based on data from the Climatology Station of Kenten Palembang during the 2005 – 2009 period, monthly atmospheric pressure in Palembang varies over a range of 1008.3 – 1019.1 mbar. On average, atmospheric pressure during the 2005 – 2009 period varies over a range of 1010.8 – 1013.5 mbar, where the lowest pressure occurs in April and the highest pressure occurs in September, as seen in Fig. 6.1-4. The figure shows that from January (western season) to April the pressure continuously decreases and then increases again, reaching a maximum in October (transitory season II), and then decreases again into January and beyond.

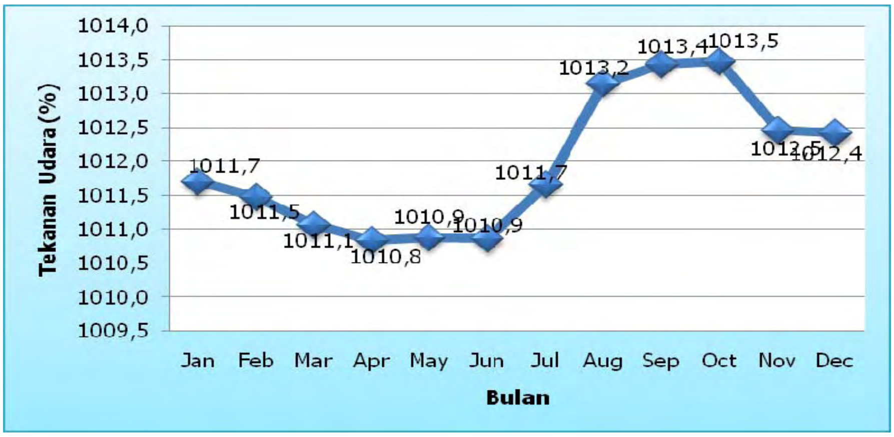


Fig. 6.1-4 Graph of average atmospheric pressure (mbar) during the 2005 – 2009 period

(v) Sun Exposure

Monthly exposure to the sun in Palembang, based on data from the Climatology Station of Kenten Palembang during the 2005 – 2009 period, varies over a range of 0% – 100%. The highest average maximum exposure during the period occurs in August and April (100% each) and the lowest average maximum occurs in December (92.6%), while the highest average minimum occurs in August (6%) and the lowest occurs in February (0.8%), as seen in Fig. 6.1-5. The figure also shows the average sun exposure continuously increasing in the eastern season and reaching a maximum in August, then subsequently decreasing in transitory season II and reaching a minimum in the western season in December.

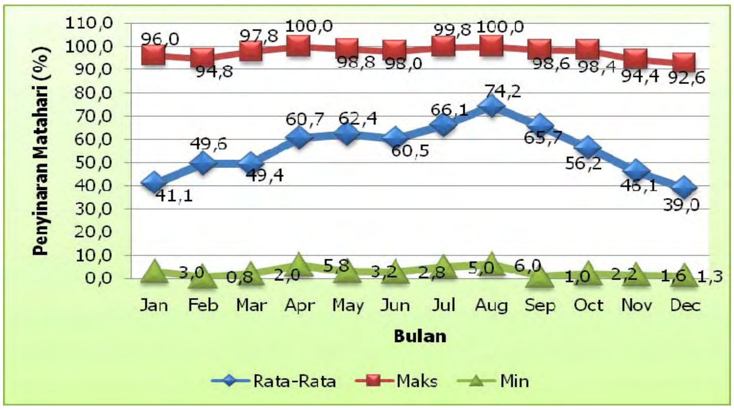


Fig. 6.1-5 Graph of average sun exposure (%) during the 2005 – 2009 period

(vi) Rainfall

Rainfall represents the amount of water that falls on flat ground during a certain period, which can be measured in terms of units of height (mm) above the horizontal surface, if no evaporation, runoff, or infiltration occurs. A rainy day is one 24-hour period with amount of rainfall ≥ 0.5 mm.

Rainfall in a place is affected by climate, topography, and cycles/meetings of air currents. Based on data from the Climatology Station of Kenten in the 2005 – 2009 period, rainfall in Muara Enim in a month varies from 9 mm to 824 mm and the number of rainy days in a month varies from 2 to 22 days. The impacts of El Niño and la Niña strongly affect the Muara Enim area. The highest average rainfall in Muara Enim occurs in December (445.8 mm) and the lowest in June (106.0 mm). The largest average number of rainy days occurs in February (18.2 days), while the smallest occurs in July, which has only 6 rainy days, as seen in Fig. 6.1-6. The figure also shows the pattern of a decreasing average number of rainy days from March (transitory season I), reaching a minimum in June (the eastern season) and then continuously increasing to a maximum in December (the western season).

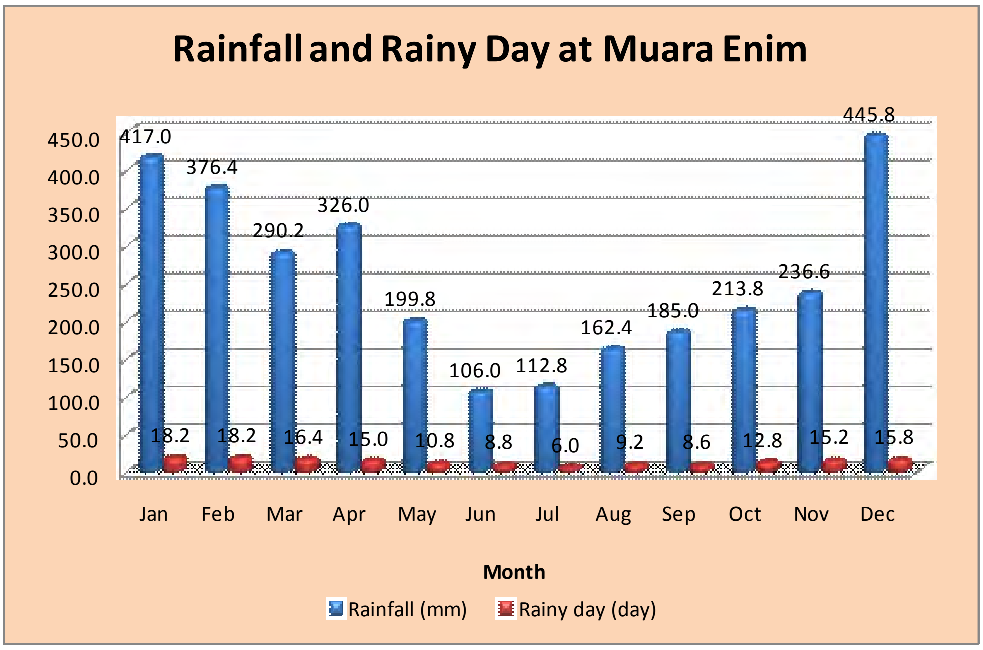


Fig. 6.1-6 Graph of average rainfall (mm) and rainy days during the 2005 – 2009 period in Muara Enim

(vii) Direction and Speed of Wind

Wind is air movement in parallel with the ground surface which is caused by horizontal differential pressure. Maximum wind data from the Climatology Station of Kenten Palembang were analyzed to determine the frequency and percentages of wind speed as presented in Table. 6.1-1, while Fig. 6.1-7 presents a wind rose based on the data in Table. 6.1-1. The figure and table show that the direction of maximum wind is primarily from the northwest (26.67%), secondarily from the southeast (23.33%). The maximum dominant wind speed is 10 – 15 knots (35%), and next 15 – 20 knots (25%).

From the data for Palembang and its surroundings presented in Table. 6.1-1 and Table. 6.1-2 ,Fig. 6.1-7 and Fig. 6.1-9 , in the western season (December – February) the dominant wind is from the southwest (66.67%), with a dominant speed in the range of 15 – 20 knots (53.33%).

In transitory season I (March – May), the dominant wind direction is from the north (33.33%), and its speed is more distributed and mostly in the range of 10 – 15 knots (33.33%). In this season, the highest wind speed of ≥ 20 knots is reached 13.33% of the time.

In the eastern season (June – August) the dominant wind speed changes back to coming mostly from the southeast (53.33%), with a lower dominant wind speed in the range of 5 – 10 knots (40%) and the largest wind speed of ≥ 20 knots being reached 13.33% of the time. In transitory season II (September – November) the dominant wind direction is from the east (46.67%), with dominant speed increasing to a range of 10 – 15 knots (46.67%). Maximum wind speed in this season (≥ 20 knot) is reached 33.33% of the time.

Table. 6.1-1. Frequency and percentage of maximum wind during 2005 – 2009

Wind Direction	0 – 5 Knot		5 – 10 knot		10 – 15 knot		15 – 20 knot		≥ 20 knot		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
N	-	-	2	3.33	4	6.67	1	1.67	1	1.67	8	13.33
NE	-	-	-	-	-	-	-	-	-	-	-	-
E	-	-	3	5.00	7	11.67	-	-	1	1.67	11	18.33
SE	-	-	5	8.33	4	6.67	4	6.67	1	1.67	14	23.33
S	-	-	1	1.67	1	1.67	1	1.67	-	-	3	5.00
SW	-	-	-	-	-	-	2	3.33	4	6.67	6	10.00
W	-	-	-	-	1	1.67	1	1.67	-	-	2	3.33
NW	-	-	2	3.33	4	6.67	6	10.00	4	6.67	16	26.67
Total	-	-	13	21.67	21	35.00	15	25.00	11	18.33	60	100

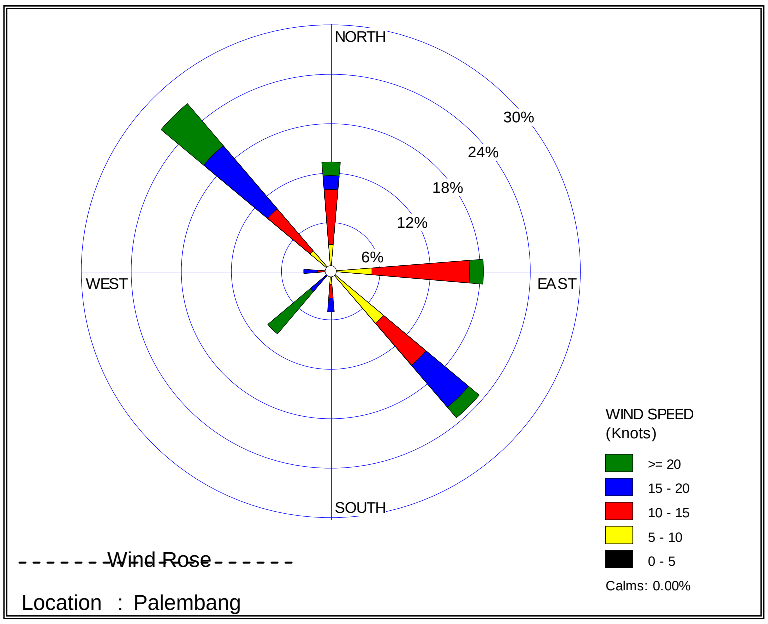


Fig. 6.1-7 Wind rose for the period 2005 – 2009 in Palembang and its surrounding

(viii) Wind Direction and Speed at Site

In order to know patterns of wind direction and speed at the geothermal power plant location, wind measurements were carried out each hour for 10 days from September 24 2010 to October 4 2010. The sampling point was the LMB-1 pad (Fig. 6.1-8). Wind data from the measurements was then analyzed by using WRPlot 59 program to determine the dominant wind direction and determine the ranges of wind speed. The results of the analysis can be seen in Table6.1-2, the wind rose is shown in Fig. 6.1-9, and the frequency of wind distribution can be seen in Fig. 6.1-10.

The table and figures show a dominant wind coming from the north (41.67 % of the time), then from the west (25.42%), with a dominant speed in the range of 1 – 2 knots (50.83%) and then 2 – 3 knots (23.75 %), while there was no wind 8.33% of the time. Maximum wind speed from the measured results only reaches 5.2 knots, with an average speed of 1.75 knots. The largest wind speed generally occurs in the daytime.

For comparison with field data, wind direction and speed date in the nearest weather station Palenbang in the same season (transitory season II, September – November, 2005-2009) is shown in Fig. 6.1-10b and Table 6.1-3. Wind direction and speed of the field is different from that of Palenbang. Weaker wind is blowing in Lumut Balai field.

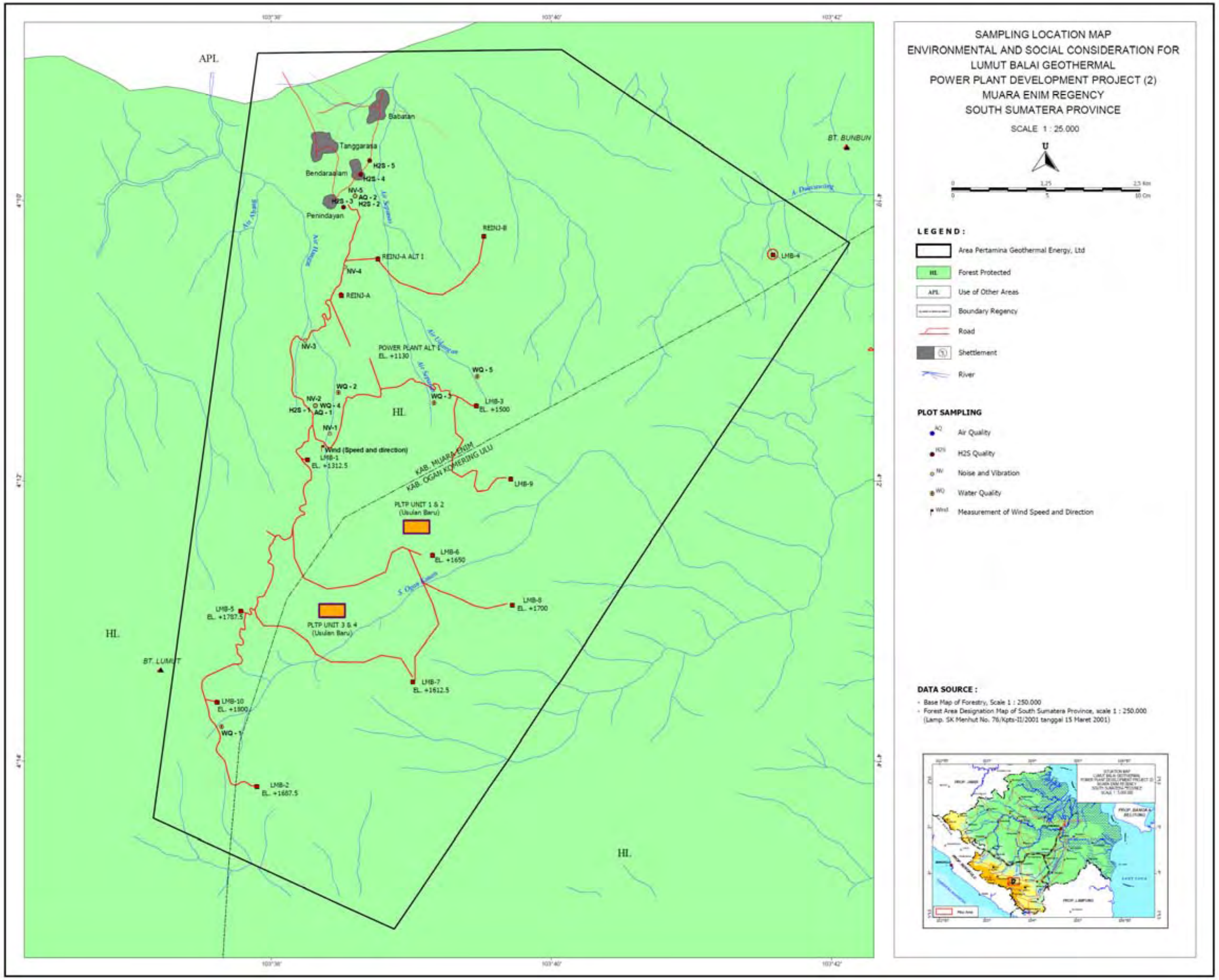


Fig. 6.1-8 Sampling point for wind velocity and direction, H_2S, noise and vibration and water quality

Table. 6.1-2 Frequency and percentage of maximum wind September 24 –October 4 in Lumut Balai

Wind Direction	Calms		1 - 2 knot		2 - 3 knot		3 - 4 knot		≥ 4		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
N	-	-	51	21.25	22	9.17	18	7.50	9	3.75	100	41.67
NE	-	-	-	-	-	-	-	-	1	0.42	1	0.42
E	-	-	3	1.25	1	0.42	-	-	-	-	4	1.67
SE	-	-	-	-	-	-	-	-	-	-	-	-
S	-	-	7	2.92	2	0.83	1	0.42	-	-	10	4.17
SW	-	-	16	6.67	-	-	1	0.42	2	0.83	19	7.92
W	-	-	27	11.25	18	7.50	7	2.92	9	3.75	61	25.42
NW	-	-	18	7.50	14	5.83	4	1.67	1	0.42	37	15.42
Total	8	3.33	122	50.83	57	23.75	31	12.92	22	9.17	240	100

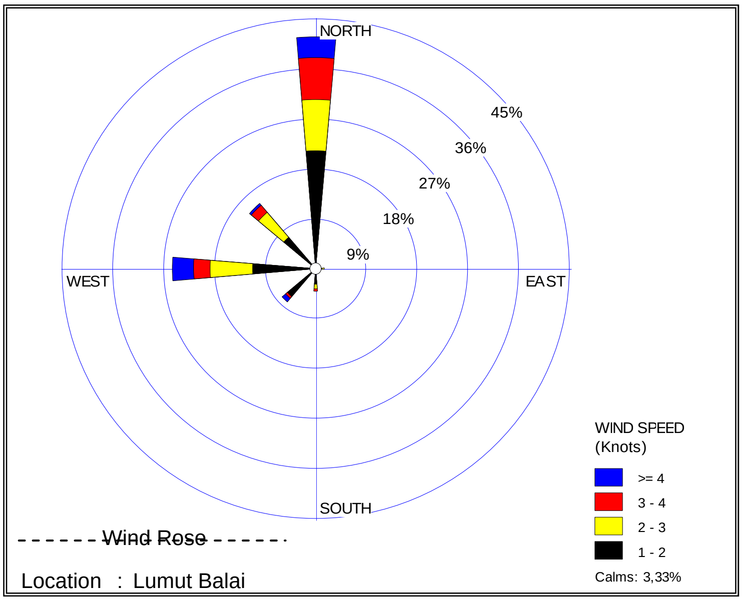


Fig. 6.1-9 Wind rose for the period September 24 –October 4 in Lumut Balai

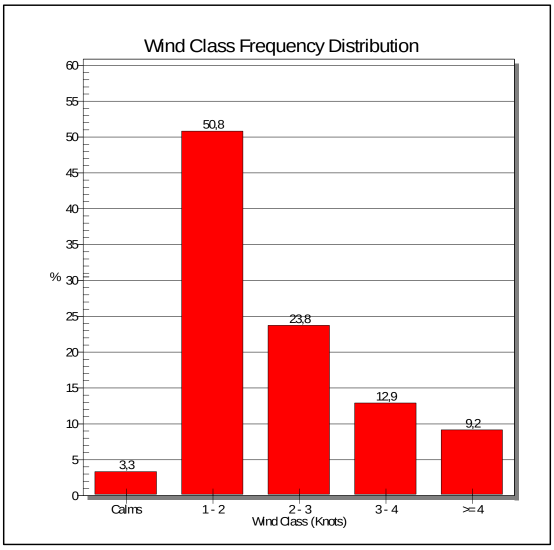


Fig. 6.1-10 Distribution of Wind Class Frequency from September 24 to October 4 in Lumut Balai

Table 6.1-3 Frequency and percentage of maximum wind in September – November, 2005-2009

Wind Direction	0 – 5 Knot		5 – 10 Knot		10 – 15 knot		15 – 20 knot		≥ 20 knot		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
N	-	-	-	-	-	-	-	-	-	-	-	-
NE	-	-	-	-	-	-	-	-	-	-	-	-
E	-	-	1	6.67	5	33.33	-	-	1	6.67	7	46.67
SE	-	-	-	-	2	13.33	1	6.67	1	6.67	4	26.67
S	-	-	-	-	-	-	-	-	-	-	-	-
SW	-	-	-	-	-	-	-	-	1	6.67	1	6.67
W	-	-	-	-	-	-	-	-	-	-	-	-
NW	-	-	1	6.67	-	-	-	-	2	13.33	3	20.00
Total	-	-	2	13.33	7	46.67	1	6.67	5	33.33	15	100

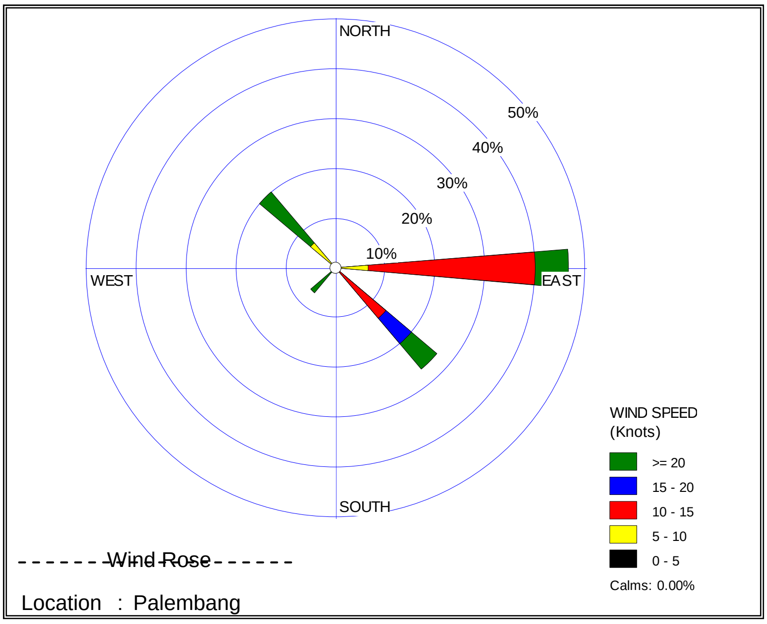


Fig. 6.1-10b Windrose of September – November, 2005-2009 in Palembang and its surrounding

(ix) Ambient Air Quality and Noise Levels

NO_2 content in the air comes from the burning of nitrogen and results in measurements of NO_2 over the entire location ranging from 6.19 to 16.44 μg/Nm^3, which is still within air quality standards. SO_2 content over the entire activity location is around 82.40 – 146.08 μg/Nm^3 and is still within air quality standards. CO content in the study location comes from emissions from the equipment used and emissions from motor vehicles and the burning of firewood. CO content in the entire location ranges from 15.27 to 74.25 μg/Nm^3 and is within the quality standards. HC content is 1.02 to 1.25 μg/Nm^3. TSP content is from 8.80 to 21.33 μg/Nm^3.

Measurement of noise levels was done in six locations by PGE for the EIA report, with results ranging from 48.2 to 54.2 dB.

The Environmental Quality Standards that are used are based on South Sumatra Governor's Regulation Number 17 of 2005 on Ambient Air Quality Standards and Noise Quality Standards. The results of measurements yield data that is within these quality standards (shown in Table 6.1-4).

Table 6.1-4 Analysis Results for Ambient Air Quality and Noise Levels

No	Parameter	Location					EQS)*
		U1	U2	U3	U4	U5	
1	Temperature ºC	25,8	25,0	25,0	26,1	26,2	-
2	NO_2 (μg/Nm^3/hour)	14,50	16,44	14,65	6,19	6,23	400
3	SO_2 (μg/Nm^3/hour)	101,02	126,10	120,08	91,67	90,02	900
4	CO (μg/Nm^3/hour)	15,27	18,27	15,20	46,83	44,23	30.000
5	HC (μg/Nm^3/hour)	1,12	1,12	1,10	1,25	1,02	160
6	TSP (μg/Nm^3/24 hour)	11,49	9,49	8,80	21,33	22,30	230
7	H_2S (μg/Nm^3/hour)	TTD	TTD	TTD	TTD	TTD	-
8	Noise	51,0	54,2	54,0	50,2	48,2	55

Source: PGE EIA report (2008)

Details:
U1 : Geothermal Power Plant Site
U2 : Well Drilling Site LB-01
U3 : Well Drilling Site LB-02
U4 : Population Settlement of Penindaian Village
U5 : Population Settlement of Babatan Village

*) Environmental Quality Standards: Regulation of Governor of South Sumatra Number 17 Year 2005

(x) H_2S Quality

Hydrogen Sulfide (H_2S) is a gas with a characteristic smell that is very toxic. At a concentration of 16-32 mg/m^3 it causes eye irritation, and at a concentration of 2,250 mg/m^3 for 15-30 minutes it may cause death. Though this H_2S can be identified through its specific smell, at lethal concentrations its smell disappears and it is therefore difficult to identify. This gas is also responsible for damage to zinc and other metals around the geothermal project since the gas is very corrosive.

Measurements of H_2S concentration in the air were carried out in 5 locations, namely near the crater, the road (entrance of settlements), and settlement areas (3 locations). These measurements were carried out within a 24-hour period. The results can be seen in Table 6.1-5.

Table 6.1-5 Result of H_2S Analysis

NO.	PARAMETER	QUALITY STANDARD *)	UNIT	RESULTS				
				H_2S-1	H_2S-2	H_2S-3	H_2S-4	H_2S-5
1	Hydrogen Sulfide (H2S)	0,02	ppm	< 0,003900	< 0,003900	< 0,003900	< 0,003900	< 0,003900

Source: This study

Remarks*) = KEP.50/MENLH/XI/1996 on Smell Level Standard

H_2S-1 = H_2S near crater S. 04° 11' 27,8" E. 103° 38' 18,8"

H_2S-2 = H_2S near settlement S. 04° 09' 58,1" E. 103° 38' 35,8"

H_2S-3 = H_2S at settlement S. 04° 09' 58,1" E. 103° 38' 35,8"

H_2S-4 = H_2S at settlement S. 04° 09' 58,1" E. 103° 38' 35,8"

H_2S-5 = H_2S at settlement S. 04° 09' 58,1" E. 103° 38' 35,8"

The table shows that the H_2S concentration in the measurement locations is lower than the detection limit and is far below the environmental quality standard threshold laid out in the Decree of Minister of Environment No: KEP.50/MENLH/XI/1996 on Smell Level Standard. This conclusion is also strengthened by anecdotal reports from individuals that there is no H_2S smell either in the daytime or at night.

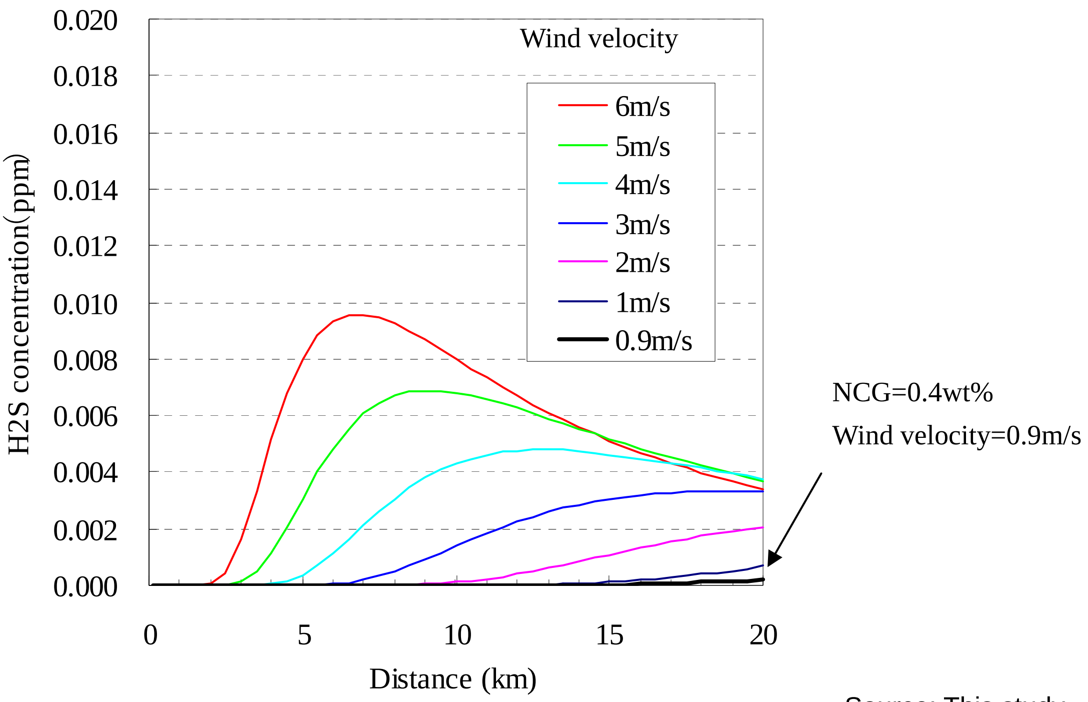
(xi) H_2S dispersion calculation

Predicted H_2S emissions from the power plant after the beginning of commercial operation were calculated. Parameters are shown in Table 6.1-6. For the noncondensable gas (NCG) concentration, a value of 0.4 wt% of geothermal fluid has been obtained for LMB 1-5. But it's only one data point and cannot be assumed to represent an average. So a value of NCG=1.0 wt% was used to prevent underestimation for this calculation in the same way as for plant design. And also wind velocity was assumed to be from 1 to 6 m/s, though it's only 1.75knot (0.90 m/s) on average in the field. The calculation results are shown in Fig. 6.1-11. Only the bold black line in Fig. 6.1-11 was calculated with the actual NCG concentration of 0.4 wt% (LMB 1-5) and wind velocity of 0.90 m/s for reference. The maximum concentration at the surface will be 0.0096 ppm even when the wind velocity is 6 m/s (Fig. 6.1-11) and is lower than the odor standard concentration of 0.02ppm. 0.001ppm is calculated for NCG=0.4wt% (LMB1-5) and wind velocity=0.90m/s for reference. The emission concentration (NCG=1.0wt%) is 10.2ppm and 15.4mg/m^3, lower than the standard 25ppm and 35 mg/m^3. (4.06ppm and 6.2 mg/m^3 each, when NCG=0.4wt%.) So the environmental impact concerning odor will be really small.

Table 6.1-6 Parameters for H_2S dispersion calculation

Items	unit	Value
Plume rise formula	-	Bosanquet-I
Diffusion equation	-	Sutton,Plum
Atmospheric temperature	℃	21.0
Wind velocity at 10m from ground	m/s	1.0～6.0
Rate of change of potential temperature with height	℃/m	0.0033
Amount of discharging gas	m^3/s	4,000
Temperature of discharging gas	℃	32.6
Diameter of cooling tower	m	9.0
NCG in steam (same as plant assuming)	wt%	1.0
Ditto (LMB 1-5)	wt%	0.4
H_2S in NCG (LMB 1-5)	wt%	2.4
Amount of discharging H_2S gas	m^3/s	0.016

Source: This study



Source: This study

Fig. 6.1-11 Calculated H_2S concentration in the air

(xii) Intensity of Noise and Vibration

Noise is unintended sound or voice that affects health, convenience, and can lead to deafness. It is necessary to establish the level of noise in the area affected by the geothermal power plant development plan in Penindaian. For that reason noise measurements were carried out for 24 hours in 5 measurement locations. Results of the measurements can be seen in Table 6.1-7.

Table 6.1-7 Results of Noise Measurements

NO.	LOCATION	RESULTS *)		
		L_SdB(A)	L_MdB(A)	L_{SM}dB(A)
N1	Location Site (near Office)	42.0	38.5	41.1
N2	Near Crater	54.8	55.1	54.9
N3	Protected Forest 1	41.1	38.7	40.1
N4	Protected Forest 2	35.9	37.7	37.2
N5	Simpang Tiga	44.4	47.8	45.8

Source: This study

Remarks:
- L_S = Value of Leq in daytime (16 hours)
- L_M = Value of Leq at night (8 hours)
- L_{SM} = Value of Leq in the daytime and at night (24 hours)
- Value of L_{SM} which calculated compared to noise level applied with tolerance +3 dB(A)
- KEP. 48/MENLH/XI/1996 Appendix I, Quality Standard

Government and Public Facilities = 60 dB(A)
Office and Commercial = 65 dB(A)
Housing and Settlements = 55 dB(A)
Trade and Services = 70 dB(A)
Green Open Space = 50 dB(A)
Recreation = 70 dB(A)
Industry = 70 dB(A)

Based on the table, it can be concluded that noise levels in the measurement locations are still far below the environmental quality standards. Results of measurements in the location near the crater show the highest level of noise compared to other measurement locations, namely 54,9 dB(A), while the quality standard for green open space is 50 dB(A). It is presumed that the high noise level is caused by the noise of from the water in the crater.

Vibration was later measured in the same locations, and the results are presented inTable 6.1-8.

Table 6.1-8 Results of Vibration Measurements

NO.	LOCATION	RESULTS (mm/sec)
V1	Location Site (near Office)	0.1
V2	Near Crater	0.1
V3	Protected Forest 1	0.2
V4	Protected Forest 2	0.1
V5	Simpang Tiga	0.1

Source: This study

Clearly, the creeping velocity of vibration in the study locations is far below environmental quality standards laid out in the Decree of Minister of Environment (Kepmen LH) No. 49/MENLH/11/1996. The decree explains that the creeping velocity of vibration for the most sensitive buildings, such as for ancient buildings and ones of high historical value, should not greater than 2. Meanwhile the nearest buildings to the geothermal power plant location are family homes built of wood. The distance from the project location to the nearest settlement area is less than 3 km.

(xiii) Water Quality

The nearest waterways to the activity location area are Hangat River and Abang River, which are about 250 meters from the location. Based on data from the Water Resource Center (2006), the average river flow rate is 10.48 m^3/second. Water required for drilling will be recycled in order not to disrupt the river flow rate. The results of measurements of the momentary river flow rate of Abang River and Hangat River were 1.46 m^3/second and 0.073 m^3/second, respectively. These measurements were taken during the rainy season. There is little fluctuation in river flow rates between the rainy season and the dry season because the condition of the water catchment area is still good due to the protection of the upper part of the rivers as a conservation forest area. Sepanas River plays a significant role in the lives of the residents of Babatan Village and Penindaian Village because water from Sepanas River is used for bathing and washing, as a source of drinking water and for farming necessities.

Water pollution is defined as deviance of water characteristics from their normal condition, not in terms of the purity of the water. Results of laboratory analysis of river water around the activity location are shown in Table 6.1-9. These results were then compared to the quality standards that were established by the Regulation of the Governor of South Sumatra Number 16 Year 2005 on Allotment of Water and Water River Quality Standards.

The quality of the drinking water in the inhabitant wells located around the activity location is still in a good condition and all the value parameters are below the determined quality standards. The quality standards for well water is set in Regulation of Minister of Health Number 907 Year 2002 on Quality Standards of Drinking Water. Results of the laboratory analysis of the inhabitants' well water are shown in Table 6.1-10.

Table 6.1-9 Results of Water Quality Analysis

No	Parameter	Unit	Quality Standard *)	Results				
				WQ1	WQ2	WQ3	WQ4	WQ5
A.	***PHYSICAL***							
1	Temperature (at site)	Meter	Air ±5°C	24,0	24,0	24,0	25,0	24,0
2	Total Dissolved Solid (TDS)	-	2.000	25	22	24	55	18
3	Total Suspended Solid (TSS)	NTU	400	454	97	76	43	2100
B.	***CHEMICAL***							
1	pH (at site)	-	5 - 9	4,5	4,5	4,5	5,0	4,5
2	Mercury (Hg)	°/oo	0,005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005
3	Arsenic (As)	mg/l	1	<0,005	<0,005	<0,005	<0,005	<0,005
4	Boron (B)	mg/l	1	<0,01	<0,01	<0,01	<0,01	<0,01
5	Dissolved Oxygen (DO) (at site)	mg/l	0	5,8	5,8	5,6	6,2	5
6	Total Phosphate (PO_4)	mg/l	5	0,11	0,03	0,03	0,01	0,03
7	Cadmium (Cd)	mg/l	0,01	<0,003	<0,003	<0,003	<0,003	<0,003
8	Chromium VI (Cr^{6+})	mg/l	0,01	<0,01	<0,01	<0,01	<0,01	<0,01
9	Cobalt (Co)	mg/l	0,2	<0,02	<0,02	<0,02	<0,02	<0,02
10	Nitrate (NO_3-N)	mg/l	20	0,3	0,2	0,2	0,4	0,5
11	Selenium	mg/l	0,05	<0,002	<0,002	<0,002	<0,002	<0,002
12	Zinc (Zn)	mg/l	2	<0,01	<0,01	<0,01	<0,01	<0,01
13	Copper (Cu)	mg/l	0,2	<0,02	<0,02	<0,02	<0,02	<0,02
14	Lead (Pb)	mg/l	1	<0,01	<0,01	<0,01	<0,01	<0,01
15	BOD_5	mg/l	12	11	9	7	2	15
16	COD	mg/l	100	98	67	66	18	141
C.	***MICROBIOLOGY***							
1	Fecal Coliform	MPN/100ml	2000	90	40	230	40	2100
2	Total Coliform	MPN/100ml	10000	230	90	430	40	2400

Source: This study

Table 6.1-10 Results of Water Quality Analysis of Inhabitants' Wells

No	Parameter	Units	Location		EQS)*
			Inhabitant Well water of Penindaian Villege	Inhabitant Well water of Babatan Villege	
	I. Physics				
1	Odor	-	Normal	Normal	Normal
2	Temperature	ºC	27,6	27,0	Normal
3	Soluble Solid Substance	mg/l	56	54	1500
4	Turbidity	NTU Scale	21	23	25
5	Color	TCU Scale	36	36	50
	II. Chemistry				
1	Mercury (Hg)	mg/l	ud	ud	0,001
2	Arsenic (As)	mg/l	ud	ud	0,05
3	Iron (Fe)	mg/l	0,017	0,026	1,0
4	Fluoride (F)	mg/l	ud	ud	1,5
5	Cadmium (Cd)	mg/l	ud	ud	0,005
6	Hardness ($CaCO_3$)	mg/l	4,640	4,202	500
7	Chloride (Cl)	mg/l	2,826	2,814	600
8	Chromium (Cr^{6+})	mg/l	ud	ud	-
9	Manganese (Mn)	mg/l	ud	ud	0,5
10	Nitrate As N (NO_3)	mg/l	0,130	0,115	10
11	Nitrite As N (NO_2)	mg/l	0,050	0,017	1,0
12	pH	unit	6,55	6,58	6,0 – 9,0
13	Selenium (Se)	mg/l	ud	ud	0,01
14	Zinc (Zn)	mg/l	ud	ud	5
15	Cyanide (Cn)	mg/l	ud	ud	0,1
16	Sulfate (SO_4^{2-})	mg/l	8,0	7,9	400
17	Lead (Pb)	mg/l	ud	ud	0,05
18	Organic Substance (KMNO4)	mg/l	0,672	0,842	10
19	Ammonia ($NH^{3-}N$)	mg/l	ud	ud	0,5
20	Oil and Grease	µg/l	ud	ud	None
21	Total of Coliform	Amount per 100 ml	ud	ud	1000

Source: PGE EIA report (2008)

Details:

*) Regulation of Minister of Health Number 907 Year 2002 on Quality Standards of Drinking Water

ud = undetected

(xiv) Biological conditions

1) Flora

The type of plant ecosystem found in the activity location is primary forest with the status of conservation forest area. In addition, there is also mixed plantation vegetation that is dominated by coffee, durian and bananas. Field observation indicates that the canopy of the primary forest is so dense that the forest floor tends to be humid and occupied by ferns and lianas. Many types of trees found in the primary forest have a high economic value, including trees used to produce lumber and medicines, among others: Shorea sp, Dipterocarpus sp, Pronema conescens, Bridelia monoica, Gluta renghas, Lanne grandis and so forth. The understory of the primary forest consists of grasses and lianas such as rattan and ferns. Because this area is a conservation area, there is no human intervention or activities on the part of local residents to exploit the woods. There is no special vegetation in this area that is protected by law.

2) Fauna

The types of fauna that are frequently found in the activity location vary widely and include amphibians, reptiles, aves, and mammals. The primary forest is the habitat, in which wildlife interacts to mate, reproduce and find food, care for their offspring and carry on other life activities. It is to be noted that everyone is prevented from using the nature preservation forest by Law No41/1999. The project site is not in the nature preservation forest but in the protected forest. Some of the fauna in the protected forest are rare species and are protected by the laws of the Republic of Indonesia; among these are cobras (*Manis javanica*), deer (*Cervus sp*), tapirs (*Tapirus indicus*), napus (*Tragulus napu*), tigers (*Panthera sumatrensis)*, leopards (*Neofelis sp*), clouded leopards (*Neofelis nebulosa*) and antelopes (*Cervulus sp*), as shown in Table 6.1-11. Detailed information concerning these species is attached in an appendix to this report. Accordingly, the protected forest area must really be managed carefully to minimize the impact on forest habitat and other species. Employees must be prevented from hunting wild animals, and safety patrols around the project site must be conducted.

Table 6.1-11 Protected Species at the Project Site

Latine Name	Common Name	Abundance Estimation	Regulation/Law	Description
Naja naja	Indian cobra	+++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	venomous elapid snakes that can expand the skin of the neck into a hood
Haliastur sp	Brahminy Kite(?)	++	1. Decision Letter Ministry of Agriculture No.421/Kpts/Um/8/1970 2. Government Regulation No. 7/1999	any of various large keen-sighted diurnal birds of prey noted for their broad wings and strong soaring flight
Gallus gallus	Red Junglefowl	+++	1. Decision Letter Ministry of Agriculture No.757/Kpts/Um/12/1979 2. Government Regulation No. 7/1999	a tropical member of the Pheasant family, often believed to be a direct ancestor of the domestic chicken
Manis javanica	Sunda Pangolin	++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	toothless mammal having a body covered with horny scales and a long snout for feeding on ants and termites
Tragulus javanicus	Java mouse deer	++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	very small hornless deer-like ruminant of tropical Asia
Hystrix sp	Porcupine	+++	1. Decision Letter Ministry of Agriculture No. 247/Kpts/Um/4/1979	large rodents with a coat of sharp spines, or quills, that defend them from predators. They are endemic
Cervus sp	Deer	++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	animals that have antlers. They are the fastest growing living tissue on earth. Antlers are usually only found on males
Tapirus indicus	Malayan tapir	++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	large inoffensive chiefly nocturnal ungulate of the tropics having a heavy body and fleshy snout
Tragulus napu	Greater mouse deer	++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	species of even-toed ungulate in the Tragulidae family
Panthera sumatre	Sumatran tiger	+	1. Decision Letter Ministry of Agriculture No.327/Kpts/Um/7/ 1972 2. Government Regulation No. 7/1999	member of the Felidae family; the largest of the four "big cats" in the genus Panthera
Neofelis sp	Common leopard	+++	1. Decision Letter Ministry of Agriculture No. 66/Kpts/Um/2/ 1973 2.Government Regulation No. 7/1999	the typical yellow cat with black spots
Neofelis nebulosa	Clouded leopard	+++	1. Decision Letter Ministry of Agriculture No. 66/Kpts/Um/2/ 1973 2.Government Regulation No. 7/1999	relatively medium-sized cat, 55 to 110 cm (2 ft to 3 ft 6 in) long and weighing between 15 and 23 kg (33 to 50 lb)
Helarctos sp	Malayan sun bear	++	1. Decision Letter Ministry of Agriculture No. 66/Kpts/Um/2/ 1973 2.Government Regulation No. 7/1999	(family Ursidae), stocky, bob-tailed MAMMAL with 5 clawed toes on each paw
Cervulus sp	Muntjac	++	1. Protection Regulation for Wild Animals 1931 2. Government Regulation No. 7/1999	hoofed animals with hollow horns. They live on grasslands, brush lands, and forests

Added by JICA study team

(Source) PGE EIA report (2008) and JICA study team

3) Field survey

To confirm the real situation in the field of precious fauna and flora, an additional field survey was conducted.

i. Objective

The objective of the additional field survey for evaluation of the environmental impact on precious fauna and flora, which was already outlined on the basis of a literature investigation and hearings, is to confirm the actual living and breeding situations of these species on the site in the Lumut Balai geothermal development field. These results of the site survey should contribute to the environmental impact evaluation for those species and also to recommendations of plans to mitigate the anticipated impacts on these species.

ii. Methodology of the survey

The precious fauna and flora living and growing in the area which contains Lumut Balai geothermal development field should be delineated based on the EIA report of PGE, the relevant documents and information from the local residents. Then, in order to confirm the actual situation of living and breeding of the species which should be carefully considered among them, site surveys should be carried out to observe the animals themselves or traces of them such as hair, waste, tracks and trails, and to study their habitat. In addition, hearings should be conducted with participation of the local residents to collect relevant information required.

iii. Survey area

Field surveys were conducted mainly for the area of well pads, power plants and access roads (existing and planned) of Lumut Balai geothermal development field.

Survey tracks are shown as lines in Fig. 6-1.12. Light green color tracks are shown for the herpetofauna and fish, and orange color tracks are for aves and mammals, all near the well pads and power plant.

iv. Survey period

From February 3 to February 16, 2011

As shown in c. Natural Environment (i) Climate, it was a typical rainy season in Muara Enim.

v. Survey team

Since there are many kinds of fauna and flora in the Lumut Balai geothermal development field, it was necessary to enlist experts for each field to distinguish species. Therefore, the survey team consisted of six experts; a mammal expert, reptile expert, aves expert, aquatic biota expert, flora expert, and biology expert.

vi. Listed up categories of precious flora and fauna

In this survey, the species which are protected by Indonesian law/regulation were listed up.

Laws/Regulations used as references are:

- Law No. 5 / 1990 on Conservation of Biological Resources and Ecosystems;
- Government Regulation No. 7 of 1999 concerning the Preservation of Plants and Animals.
- Government Regulation No. 60 of 2007 on the Conservation of Fish Resources

vii. Survey results

Regarding precious fauna and flora, the existence of eight species of mammals, ten species of Aves and one species of flora were confirmed. Aves, mammals and flora are thought to be distributed all through the forest area in and around the Lumut Balai geothermal development field (Fig. 6.1-12). Results of the survey are summarized in Table 6.1-12.

viii. Discussion

a) Environmental assessment for precious flora and fauna potentially affected by the Lumut Balai geothermal power development

Land clearing in the area of Lumut Balai geothermal development field, of course, will have an impact either directly or indirectly on wildlife. The impact will occur in the form of habitat loss or habitat fragmentation.

But the habitat and breeding area of each precious species confirmed in this survey is not thought to be limited to the development field, but to be widely distributed in and around the development field. Therefore, the environmental impact on the precious flora and fauna will be small given the application of appropriate mitigation measures. General information about precious flora and fauna in and around the Lumut Balai geothermal power development area were obtained by this short-term field survey. Considering seasonal changes in situation of flora and fauna, it is desired that further impact assessment and considering about mitigation of preservation should be conducted after the survey about vegetation and ecological characteristic of each species as possible as they can.

b) Mitigation of impacts on precious flora and fauna in the Lumut Balai geothermal power development field

Based on the results of the environmental survey, the following mitigation of impacts on precious flora and fauna should be implemented.

- Preventing the clearing of land beyond what is absolutely necessary.
- Replanting the precious flora that is found in the development field
- Taking care to ensure water quality during construction work (sand basin, treatment for turbid water)
- Creation of habitat with vegetation harmonized with the environment (with plants found in the power plant site as far as possible)
- Road and site preparation that do not create turbid water (during construction and operation)
- Considering all the conditions, preserving animal trails by lifting up part of the pipeline or lowering the ground level, if necessary
- Patrolling to prevent hunting wild animals, and safety patrols around the project site

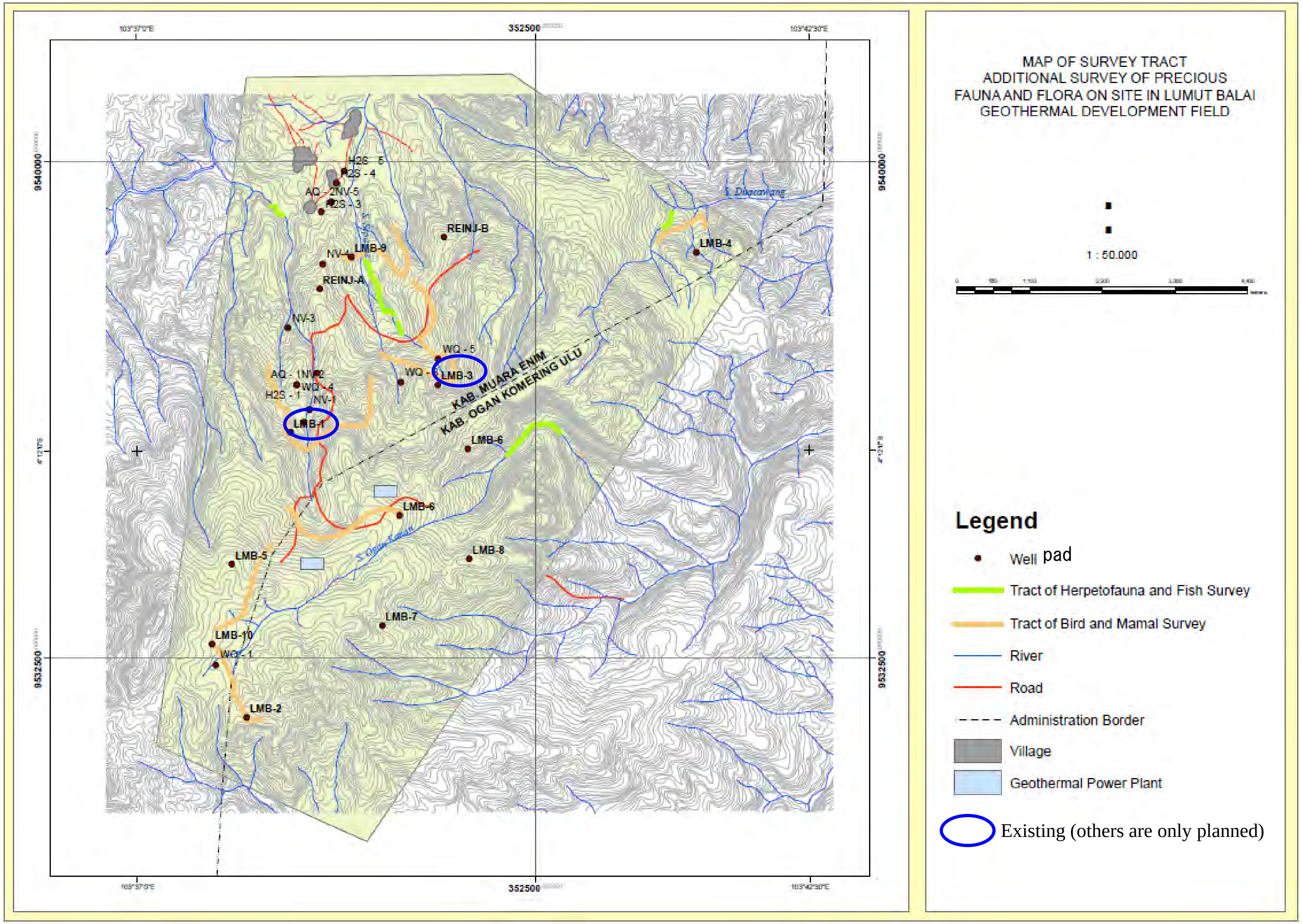
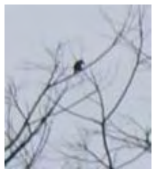
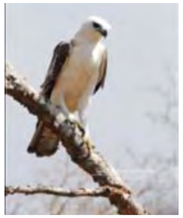
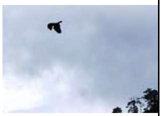


Fig. 6.1-12 Map of surveyed precious flora and fauna

Table 6.1-12 Precious fauna and flora confirmed of the existence in this survey

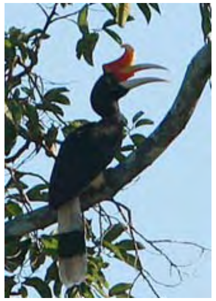
Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (track, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
AVES							
 Name : Plain sunbird (*Anthreptes simplex*) Local name : Burung madu polos IUCN: LC	In the course of survey at well pad LMB-4	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Cost of building green zone : 250 million Rp. **(0.027millionUS$)** • Sand basin should be tentatively prepared in civil work during construction
 Name : Collared kingfisher (*Todirhamphus chloris*) Local name : Cekakak sungai IUCN: LC	On the track of survey at well pads RenjA - RenjB	Sighting and call 	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
AVES							
 Name : Changeable hawk-eagle (*Spizaetus cirrhatus*) Local name : Elang brontok IUCN: LC	On the track of survey at the well pads RenjA - RenjB	Sighting 	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction
  Name : Black eagle (*Ictinaetus malayensis*) Local name : Elang hitam IUCN: LC	On the track of survey at well pads LMB 6 – LMB 7	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
AVES							
 Name : Crested serpent eagle (*Spilornis cheela*) Local name : Elang ular bido IUCN: LC	On the track of survey at well pad LMB 1	Sighting and call	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
 Name : Oriental pied hornbill (*Anthracoceros albirostris*) Local name : Kangkareng perut putih IUCN: LC	On the track of survey at well pad LMB 1	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
AVES							
 Name : Pied fantail (*Rhipidura javanica*) Local name : Kipasan belang IUCN: LC	On the track of survey at well pads LMB 2 – LMB 5	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction
 Name : Schneider's pitta (*Pitta schneideri*) Local name : Paok Schneider IUCN: VU	On the track of survey at well pad LMB 4	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
AVES							
 Name : Rhinoceros hornbill (Buceros rhinoceros) Local name : Rangkong badak IUCN: NT	On the track of survey at well pad LMB 3	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction
 Name : Rueck's blue-flycatcher (*Cyornis ruckii*) Local name : Sikatan aceh IUCN: CR	On the track of survey at well pad LMB 4	Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work.	• Included in the cost above • Sand basin should be tentatively prepared in civil work during construction

Name of Observed Precious Species (Photo)	Item						
	servation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
MAMMALS							
 Name : Agile gibbon (*Hylobates agilis*) Local name : Siamang/Ungko IUCN: EN	On the track of survey at well pads • LMB 3; • LMB 2 – LMB 5; • LMB 6 – LMB 7; • LMB 1; • RenjA-RenjB	• Direct observation • Call	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, preserving the animals trails by lifting up the part of the pipeline or lowering the ground level, if necessary	• Included in the cost for aves • Sand basin should be tentatively prepared in civil work during construction • Operational cost of patrol =75 million Rp. per year(0.008MUS$) • Lifting up the part of pipeline or lowering the ground level =6.6 billion Rp.(0.73MUS$)
 Name : Barking deer (*Muntiacus muntjak*) Local name : Kijang IUCN: LC	On the track of survey at well pads • LMB 3; • LMB 2 – LMB 5; • LMB 6 – LMB 7	Footprints 	Brush/shrub	All the forest area in and around the LMB GPP field. Surrounding rivers near to LMB GPP where they seek drinking water	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
MAMMALS							
 Name : Malayan porcupine (*Hystrix brachyuran*) Local name : Landak IUCN: LC	On the track of survey at well pad LMB 1	• Nest • Information from local people 	Nest in the ground	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above
 Name : Malayan sunbear (*Helarctos malayanus*) Local name : Beruang IUCN: VU	On the track of survey at well pads • LMB 1; • RenjA-RenjB	Scratches and nest 	Trees and ground	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
MAMMALS							
 Name : Malayan pangolin (*Manis javanica*) Local name : Trenggiling IUCN: EN	On the track of survey at well pad LMB 3	Nest 	Nest in the ground	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above
 Name : Malayan tapir (*Tapirus indicus*) Local name : Tapir IUCN: EN	On the track of survey at well pad LMB 4	Footprint 	Brush/shrub	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
 Name : Bearcat (*Arctictis binturong*) Local name : Binturung IUCN: VU	On the track of survey at well pads • LMB 4; • LMB 6 – LMB 7	• Nest • Information from local people 	Brush/shrub	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above
 Name : Three-striped ground squirrel (*Lariscus insignis*) Local name : Bajing tanah bergaris tiga IUCN: LC	On the track of survey at well pads • LMB 4; • RenjA-RenjB	Direct watching/Sighting	Trees	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible. • Measures to preserve water quality during construction work. • Patrol for hunting • Considering all the conditions, keep the pathway by lifting up the part of pipeline or lowering the ground level, if necessary	Included in the cost above

Name of Observed Precious Species (Photo)	Item						
	Observation point	What Signature (foot print, spoor, hair, feather, egg etc)	Breeding place	Inhabited area (assumed inhabited area in and around the LMB GPP field)	Assumed degree of impact of development of LMB GPP	Necessary mitigation	Estimated cost for mitigation (for unit 1 - 4)
FLORA							
 Name : Nepenthes (*Nepenthes gynamphora*) Local name : Kantong semar IUCN: Not registered	On the track of survey at well pads • LMB 3; • LMB 4 • LMB 2 – LMB 5; • LMB 6 – LMB 7; • LMB 1; • RenjA-RenjB	Direct observation	On the ground	All the forest area in and around the LMB GPP field	• Little impact because there is a possibility that breeding and inhabited area is not limited to the development area, but widely distributed in the development field.	• Reducing the land clearing to the minimum possible.	Included in the cost above
							<Total> **Initial investment 0.75 MUS$** • Cost of build green zone 0.027 MUS$ • Lifting up the part of pipeline or lowering the ground level 0.73 MUS$ **O&M 0.008 MUS$ per year** • Operational cost of patrol

Listed in PGE's AMDAL

IUCN category

CR: Critically Endangered EN: Endangered

VU: Vulnerable NT: Near Threathened

LC: Least Concern

(Source) JICA study team

(xv) Evaluation based on the chemical data for geothermal fluid from LMB 1-5

Table 6.1-13 shows the chemical data for geothermal fluid from the LMB 1-5 production test in June 2010. The brine contains arsenic, but it will be reinjected into the reinjection well. Waste such as silica scale will not be formed from the brine because the reinjection temperature will be higher than the precipitation temperature. In case silica scale is formed, it will be buried in open areas (belonging to PERTAMINA) and covered with plastic to make it watertight. So there should be no environmental impacts. For H_2S, the calculated result using LMB 1-5 gas data shows no environmental impacts.

Table 6.1-13 Chemical analysis data for geothermal fluid from LMB 1-5

Item	Unit	Condensate	Brine
No. Lab		137	138
pH/Temp °C (25°C)		4.73	7.18
Electical Conductivity (25°C)	Mic/cm	30.3	28100
Total Dissolved Solids (TDS)	mg/l	16.075	10993.66
Natrium (Na^+)	mg/l	15.87	783.87
Kalium (K^+)	mg/l	<0.01	448.12
Calcium (Ca^{++})	mg/l	0.007	7.571
Magnesium (Mg^{++})	mg/l	0.018	0.572
Ammoniun ($NH4^+$)	mg/l	3.93	2.510
Lithium (Li^+)	mg/l	<0.0001	3.120
Besi Total (Fe)	mg/l	0.076	0.152
Fluor (F^-)	mg/l	0.10	2.320
Belerang ($S^=$)	mg/l	9.56	1.95
Bicarbonat (HCO_3)	mg/l	11.46	20.09
Clorida (Cl^-)	mg/l	<0.01	9751.63
Sulphat (SO_4^{--})	mg/l	0.15	196.33
Boron (B)	mg/l	0.85	78.76
Silika (SiO_2)	mg/l	1.7	663.25
Arsen (As^{+++})	mg/l	ttd	2.61
NON COND. GASES			
CO_2	M MOL/100MOL KOND	125.19	
H_2S	M MOL/100MOL KOND	5.21	
Gas Sisa	M MOL/100MOL KOND	56.08	
CO_2 / H_2S	MOL RATIO CO2/H2S	24.03	
Volume	%	0.19	
Weight	%	0.40	

Source: AECOM (2010)