A - 7 GROUNDWATER DEVELOPMENT PROPOSAL

A-7-1 Well Yield

Based on specific capacity obtained by the exploratory and existing wells, optimum well yield for respective hydrogeological units is evaluated as following Table A-7-1. Table shows that specific capacity is applied for a calculation of well yield. Depth of proposed well is optimally determined based on results of the borehole loggings and geologic well logs from the exploratory wells of the Study and RDD. The optimum well yield is finally calculated based on the standard well specifications that includes screen with 20 m and drawdown with 10 m in minimum.

(1) Well Yield of Lake Manyara Beds

The Lake Manyara Beds overlying the Basement occurs in the southern part of the Study Area. Four villages; Oltukai, Mswakini, Naitolia and Makuyuni; are located on the Beds. In Table A-7-2, Naitolia and Oltukai village are excluded due to low potential and inferiority water quality in high electrical conductance. The possible well yield by one production well in Makuyuni and Mswakini are calculated at 135 and 144 m^3/day by 10 hours pumping duration.

(2) Well Yield in Colluvial Beds

A large scale colluvial beds is underlain in Monduli Juu Caldera. The possible well yield by one production well in Emaireti village is calculated at 36 m^3/day by 10 hours pumping duration.

(3) Well Yield in Younger Extrusive

Three major volcanic mountains is underlain by the Younger Extrusive. It is unclear geologic boundary to the Plateau Lava in northern edge of the Ardai and Eluanata Basins. Exploratory well, EX-11 in Tarosero was initially programed in the younger extrusive, but it encountered dry caves in cavern lava, so that encountered volcanic rocks is probably belong the Plateau Lava.

(4) Well Yield in Plateau Lava

Groundwater potential in this volcanic rocks vary in place and lithology. One of major problem for the development, especially rural area, is deeper static water

level which couldn't rift by a manual pump. A possible well yield by one production well in/near Meserani Bwawani is calculated at 24 m^3/day by 10 hours pumping time.

(5) Well Yield in Basement Rocks

The potential in basement rocks vary in thickness of weathered part of the basement. A possible well yield by one production well in Naitolia, east of Lake Manyara Beds is calculated at 12 m^3/day by 10 hours pumping time.

(6) Well Yield in Engare Volcanic Rocks near Arusha Airport

Seven existing well data were collected to evaluate well yield (see Table A-6-2, Data Summary of Exploratory Wells in Engare Olmotoni). An averaged possible well yield by one production well in Engare Olmotoni, north of Arusha Airport is calculated at 630 m^3/day by 10 hours pumping time.

A-7-2 Groundwater Development Plan

(1) Groundwater Supply Planning Criteria

Basic idea of groundwater development criteria of the Study is as follows:

<Rural Water Supply>

- Point sources by borehole shall be allocated to rural communities
- Pumping system shall be by manual pump if static water level is above 30 mbgs, otherwise power generating system shall be equipped, but discussion is required for affordability of operation and maintenance cost.
- Although 30 ℓ /person of water demand is recommended by ARWMP, it shall be modified by well yield and pumping capacity. Minimum water demand should be 10 ℓ /person which recommended by WHO
- Distance to a source from village shall be located based on source potential.
- Source quality shall meet the health standard
- Borehole shall be primarily allocated on public compound, such as school, health spot, village office, etc.

<Monduli Town>

- Groundwater sources shall be of supplemental and conjunctive sources

for existing system

- Total well yield by multi-borehole shall be fulfilled water demand of 30 ℓ /person for the projected population.

A-7-3 Implementation of Groundwater Supply Scheme

(1) Production Well

Table A-7-2, summarizes well yield for potential villages and Monduli Town which are Monduli, Makuyuni, Naitolia, Mswakini, Emaireti and Engare Olmotoni. The last one is located out of the Study Area, but it would be of an alternative well field for Monduli Town.

Number of required wells to meet water demand for each proposed village and town is tabulated in Table A-7-2.

- Monduli Town -

Table shows that Monduli Town requires two (2) boreholes in Engare Olmotoni well field for total population in year of 2014 (see Figure A-7-1 Proposed Production Well Site in Engare Olmotoni).

- Emaireti, Monduli Juu -

For Emaireti in Monduli Juu requires three (3) boreholes for water demand of 10 ℓ /cap. and nine (9) boreholes for water demand of 30 ℓ /cap. Although the exploratory well, EX-7 can be converted to a production well, one more well shall be located in the caldera to meet water demand of 10 ℓ /cap. On the basis of groundwater recharge capacity, second production well shall be located in lower part of EX-7, near the existing reservoir (see Figure A-7-2, Proposed production well sites in Monduli Juu).

- Mswakini -

An existing well is under operating for Phosphate Factory in Minjingu, but no outlet for villagers of Mswakini from this well. One production well shall be allocated to villagers in near village center. Proposed well site shows in Figure A-7-3, Proposed Well Site for Mswakini.

- Makuyuni -

Two production wells are operating for potable use of Makuyuni village. Makuyuni is only one village equipping power driven pumping facilities and distributing water by pipe. Pumps and distribution pipes were installed on 1950.

Two existing diesel driven pumps and distribution pipe shall be replaced to new pumps and distribution pipes.

(2) Pumping Facilities

Although manual pump is recommendable for rural water supply because of affordability of operation and maintenance cost, static water level in proposed villages indicate more than 30 mbgs which wouldn't meet operation of manual pumps.

Diesel driven power pumps should be installed in the production wells, however, electrical interruption must be taken into consideration to meet the demand.

The specification of pumps is summarized in Table A-7-3, Summary of Pump Specifications.

A-7-4 Design of Production Well

(1) Depth and Diameter

The well design is the process of specifying the physical material, dimensions and water requirement for a well. An possible yield can be determined by the specific capacity and/or transmissivity in relation to screenable length of aquifers. It is essential to construct production well by proper drilling technique and optimal locating of well screen.

The diameter must be chosen to satisfy water requirement. In this connection, the entrance velocity of water into screen is calculated based on each pumping discharge. Results indicates that the velocities in well diameter of 150 mm and 250 mm are 0.1 cm/sec. and 0.4 cm/sec. respectively (see Table A-7-4). It has been proposed based on field experience and laboratory test that an average entrance velocity of water to avoid sand extraction should not exceed 3.0 cm/sec. (Driscoll, 1987).

Taking this results into consideration, entrance velocity into screen for proposed area is calculated as follows:

Calculated entrance velocity is within the limitation of 3.0 cm/sec.

(2) Well Drilling Method

Selection of drilling method depends on the geologic conditions. The air percussion drilling method is proper technique in hard compacted volcanic area, however the Ardai basin and Engare Olmotoni are underlain by pyroclastic rocks with cavern rocks above water level. So that the rotary drilling with mud circulation is more safety in the most proposed area. Taking the regional geological conditions into consideration, most economical method should be taken into the project drilling.

(3) Material of Casing and Screen

Standard design procedures involve choosing the casing diameter and material, estimating well depth, selecting the length, diameter, and material for the screen, determining the screen slot size, and choosing completion method. Regarding to the material of casing and screen, assessment of water quality is essential to prevent corrosion and incrusting. The general idea of a combination of chemical items and limit of concentration which will causes corrosion and incrusting is listed as Table A-7-5.

Table shows that quality problems arises in Mswakini village where concentration of Mn exceed the in crusting limitation.

It is advisable to use FRP casing if Fe and Mn concentration exceed the limitation.

Table A - 7 - 1 EVALUATION OF WELL YIELD FOR DEVELOPMENT PLAN

Formation /Village	Proposed Well Depth (m)	Aquifer Thickness (m)	S.W.L (mbgs)	Specific Capacity (l/min/m)	Possible Drawdown (m)	Well Yield (l/min)	Well Yield (m^3/d)	Evaluated Wells	Major Constraint
Lake Manyara Beds									
Makuyuni	100	20	30	15	15	225	135	10/52,23/68	none
Mswakini	120	50	30	12	20	240	144	110/79,82/79 74/79	E.C.=1,400 μS/cm Fluorite=9.54 mg/l(limit.=8.0)
Colluvial Beds									
Emaireti	150	25	75	6	10	60	36	EX-7, 107/79 87/79	Small recharge area
Younger Extrusive									
Monduli Town	100	20	30	4	10	40	24	3/36	
Basement									
Naitolia	200	20	30	2	10	20	12	54/55	Deep SWL & low potential
Engare Volcanics									
Engare Olmotoni	150	25	40	70	15	1,050	630	75/76,70/77 37/80,47/80 79/80,96/80	Densely drilled production wells for private estates

Remark : Well yield in m^3/d is calculated based on 10 hrs pumping per day

Table A-7-2 SUMMARY OF GROUNDWATER IMPLEMENTATION SCHEME

Name of Town /Village	Population 1994 2014	Source Demand (m3/day)	Name of Well Field	Well Yield (m3/day)	Possible Population to Meet Demand			Required Nos of Well to Meet Demand on 2014		
					10 l/cap	20 l/cap	30 l/cap	10 l/cap	20 l/cap	30 l/cap
Monduli Urban	18,210	-	Monduli	24			800			
		-								
	34,864	1,046	Engare Olmotoni	630			21,000			1.7
Emaireti	4,674	102	Monduli Juu	36	3,600	1,800	1,200	2.8	5.7	8.5
		205			0	0	0			
	10,241	307		0	0	0	0			
Mswakini	2,391	58	Mswakini	144	14,400	7,200	4,800	0.4	0.7	1.1
		105			0	0	0			
	5,239	157		0	0	0	0			
Makuyuni	3,604	45	Makuyuni	135	13,500	6,750	4,500	0.3	0.6	0.9
		83								
	4,134	124			0	0	0			
Naitolia	1,259	16	Basement	12	1,200	600	400	1.2	2.4	3.6
		29								
	1,444	43								

Remark : Source demand is based on 10, 20 and 30 lit/cap, showing upper, middle and lower figures
Well yield is calculated based on 10 hrs pumping duration per day

Table A - 7 - 3 SUMMARY OF PUMP SPECIFICATION

Name of Village/town	Well Design		Well Data			Pump Specification		
	Depth	Diameter (mm)	SWL (mbgs)	Yield (m^3/hr)	Drawdown (m)	TDH (m)	Q (m^3/hr)	Power (kw)
Makuyuni	100	150	30	14	15	55	17	6
Mswakini	120	150	30	15	20	60	18	7
Emaireti / Enguil	150	150	75	4	10	95	5	3
Engare Olmotoni	150	250	40	63	15	65	76	33

Remark : TDH = Total dynamic head → SWL + Drawdown + Height ofTank(10 m)

Q = Yield x 1.2

Table A-7-4 ENTRANCE VELOCITY BY DISCHARGE

Proposed Area	Discharge (m³/hr)	Screen Diameter (mm)	Entrance Velocity (cm/sec.)
Emaireti	5	150 mm	0.1
Mswakini, Makuyuni	15	150 mm	0.2
Engare Olmotoni	65	250 mm	0.4

Remark : Required velocity is based on 20 m screen length Screen opening is 12%

Table A-7-5 QUALITY LIMITATION FOR CORROSION AND INCRUSTING IN mg/ℓ

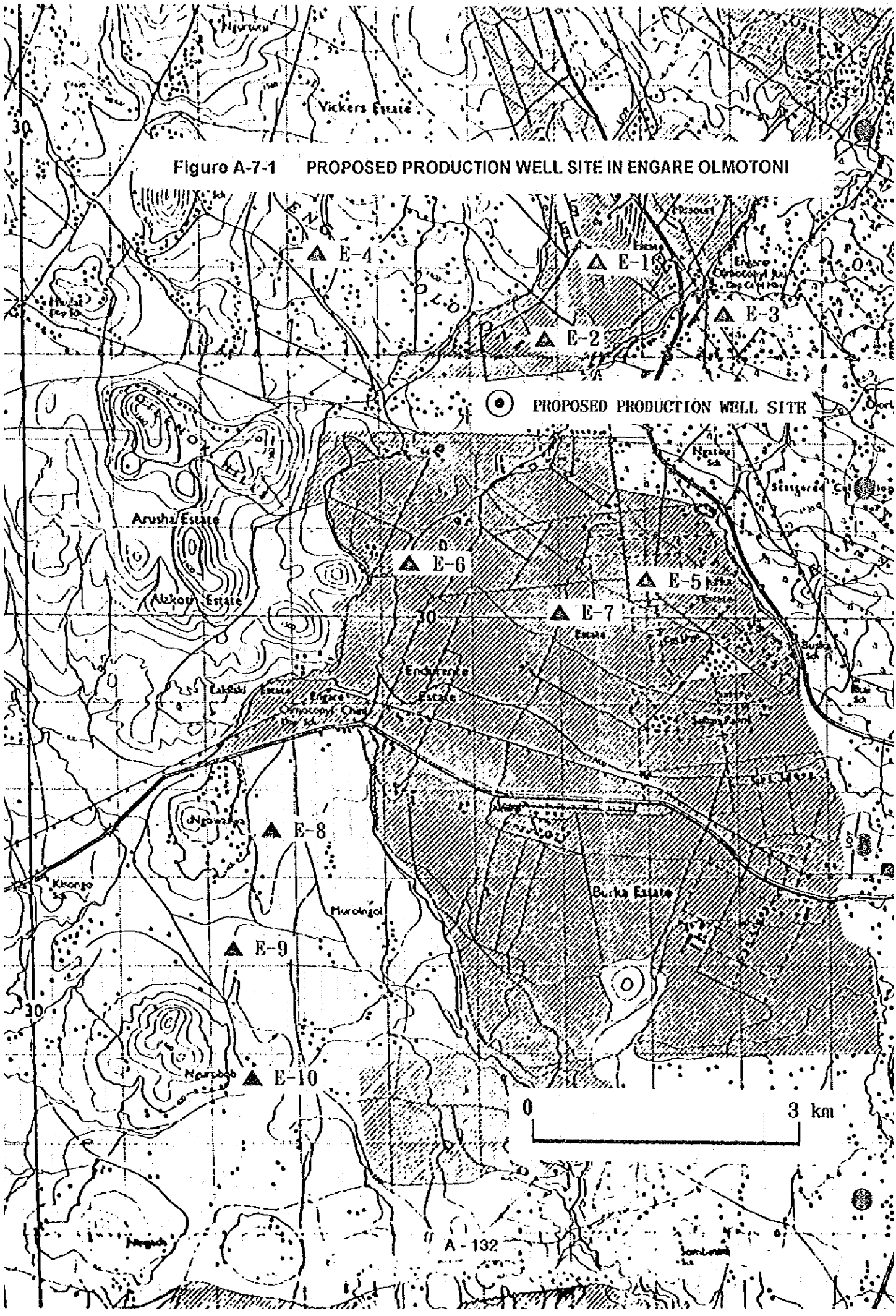
	pH	CO_2	Fe	Mn	Hard's	DO	TDS	Cl
Corrosion	7.0>	50<	-	-	-	2.0<	1,000>	500<
Incrusting	7.5<	-	0.5<	0.2<	300<	-	-	-

Table A - 7 - 6 PROPOSED WATER SOURCES DEVELOPMENT PLAN

Name of Town /Village	Popula'n 1994 2014	Water Demand (m^3/day)	Existing Sources Type	*1)Supply (m^3/day)	Present Constraint	Development Plan Proposed Sources	Yield (m^3/day)
Monduli Town	18210 34851	1046	Army Pipe Kilimani & Rasharasha Sp.	*2) 45 130 20	Sources shortage	1)Drill New BH at Engare 2)Develop Spring at Mferegi 3)Construct new dam	630 270 776
Arkatan	1895 3786	114	Nanja Dam Nadosoito Dam Nongilili Dam Ardai Ranch Dam	26780 3620 3200 0	Turbitity Turbitity Turbitity Broken in Embankement	1)Control turbidity in existing dams and install handpump for drinking purpose	114
Emairete	4674 10241	307	Spring Mon. Juu Dam Soimineri Dam	6 2700 7700	Source short. Turbidity Turbidity	1)EX-7 install pump 2)Drill new BH w/pump 3)Improve turbidity in existing dams 4)Construct new dam	36 36 235 105
Enguik	4090 8961	269	Spring Emaireti Dam	66 510	Source short. Turbitity	1)Existing spring 2)Improve existing dams 3)Construct new dam	66 203 590
Lendikinya	2873 6295	189	Ardai Dam Spring Mrandawa Dam	0 - 150	Dam broken Source short. Turbitity	1)Improve existing dam 2)Construct new dams	90 99
Lepurko	3042 6665	200	Lepurko Dam KKitasho Dam	1690 400	Turbitity Turbitity	1)Improve existing dam 2)Construct new dams	150 50
Lolkisale	4397 9634	289	Spring-1 Spring 2	35 69	Source short. Source short.	1)Existing springs 2)Construct dams	101 185
Lossimingor	1720 3769	113	Essimingor Dam Rasha Rasha Dam	0 0	Dam broken Dam broken	1)Repair existing dam 2)Construct new dams	8 105
Makuyuni	3604 4134	124	BH-1 BH-2 Makuyuni Dam JKT Dam,1,2 Lemiyoni Dam	135 0 850 780 160	Pump old Pump broken Turbitity Turbitity Turbitity	1)Install new pumps in existing two pumps 2)Construct new dams 3)Improve existing dam	135
Naitolia	1259 1444	43	Naitolia Dam Nguvukazi Dam	230 15400	Turbitity Turbitity	1)Construct new dams	43
Mbuyuni	3700 8107	243	Mbuyuni Dam-1 Mbuyuni Dam-2	1020 130	Turbitity Turbitity	1)Construct new dams	243
Meserani Bwawani	1151 2517	76	Naalarami Dam Onjapatwa Dam Meserani Dam	970 60 0	Turbitity Turbitity Broken	1)Improve existing dam	76
Meserani Juu	2985 6540	196	TMA pipe Ngoi Kunien Dam	43 770	Source short. Turbitity	1)TMA pipe 2)Construct new dams	43 153
Moita Bwawani	3934 8619	259	Ndulele Dam Kilimatinde Dam	610 100	Turbidity Turbidity	1)Construct new dams	259
Moita Kiloreti	1685 3692	111	Ekivuk Dam Orngarwa Dam Emao Ekivuk Dam	1780 950 670	Turbidity Turbidity Turbidity	1)Construct new dams	111
Mswakini	2391 5239	157	MIPCO BH Dam	75 0	High Fluoride Broken	1)Drill two BH	157
Tukusi	1541 3376	101	Spring River	11 77	Source short. Source short.	1)Construct new dams	101
Oltukai	691 726	22	Dug Pit Dam	1 0	Source short. Embak. borken	1)Repair existing dam	22
Nengungu	1586 3036	91	TMA pipe Hamsini Dam Levi Dam	20 120 1010	Source short. Turbidity	1)TMA pipe 2)Construct new dam	20 71

Remark : Demand is based on 30 lit/day/cap., consumtion by livestosks is not counted
Current supply in river and spring is based on measured discharge on Sep., 1995
*1)Existing monthly source supply by dam is based on 30 % of storage capacity
*2) TMA agreed to supply 450 m^3/day to Monduli according to A Water Right

Figure A-7-1 PROPOSED PRODUCTION WELL SITE IN ENGARE OLMOTONI



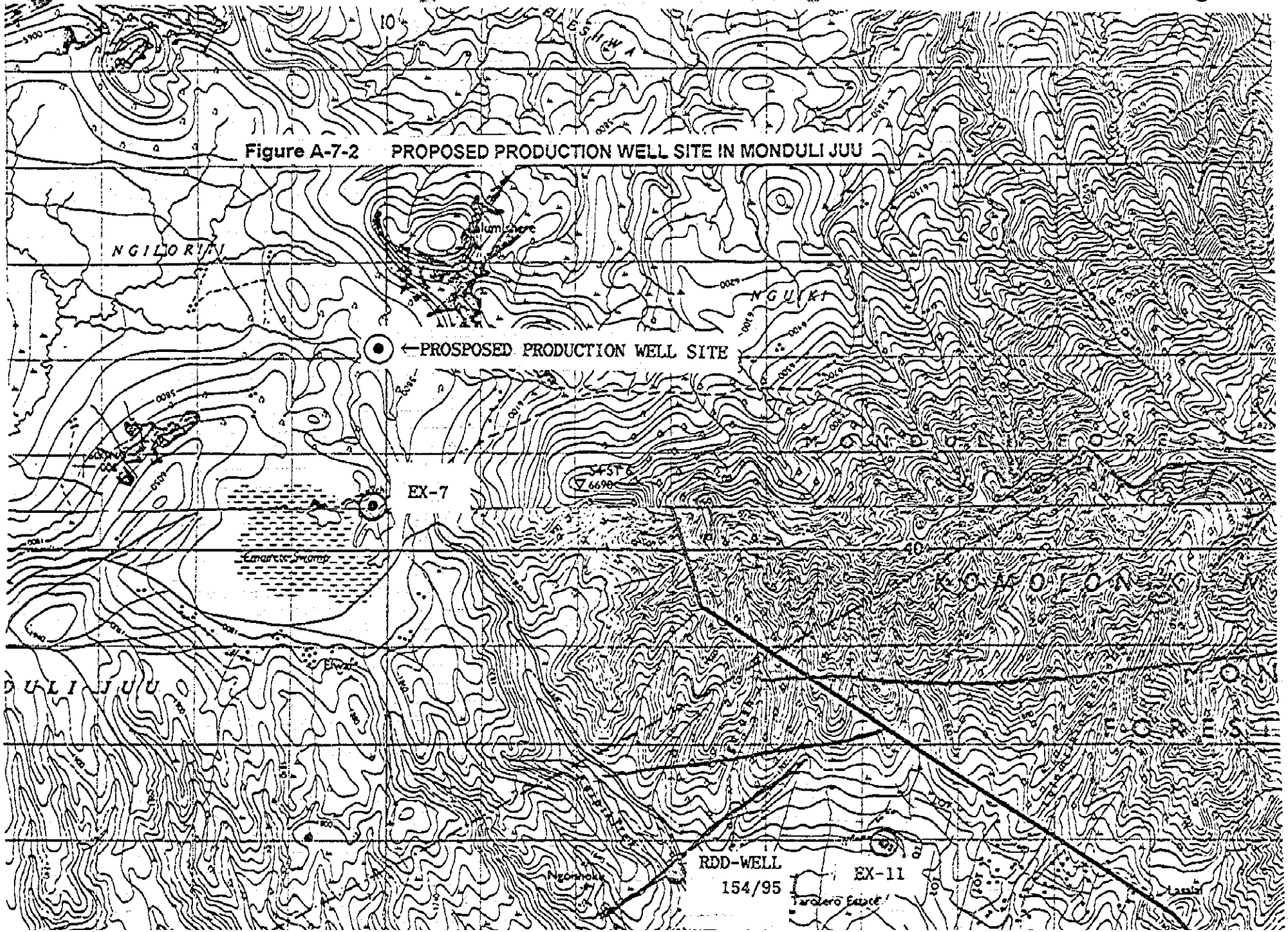


Figure A-7-2 PROPOSED PRODUCTION WELL SITE IN MONDULI JUU

Figure A-7-3 PROPOSED PRODUCTION WELL SITE IN MSWAKINI