

# **Groundwater Training Course**

**SOPAC, April 2005**

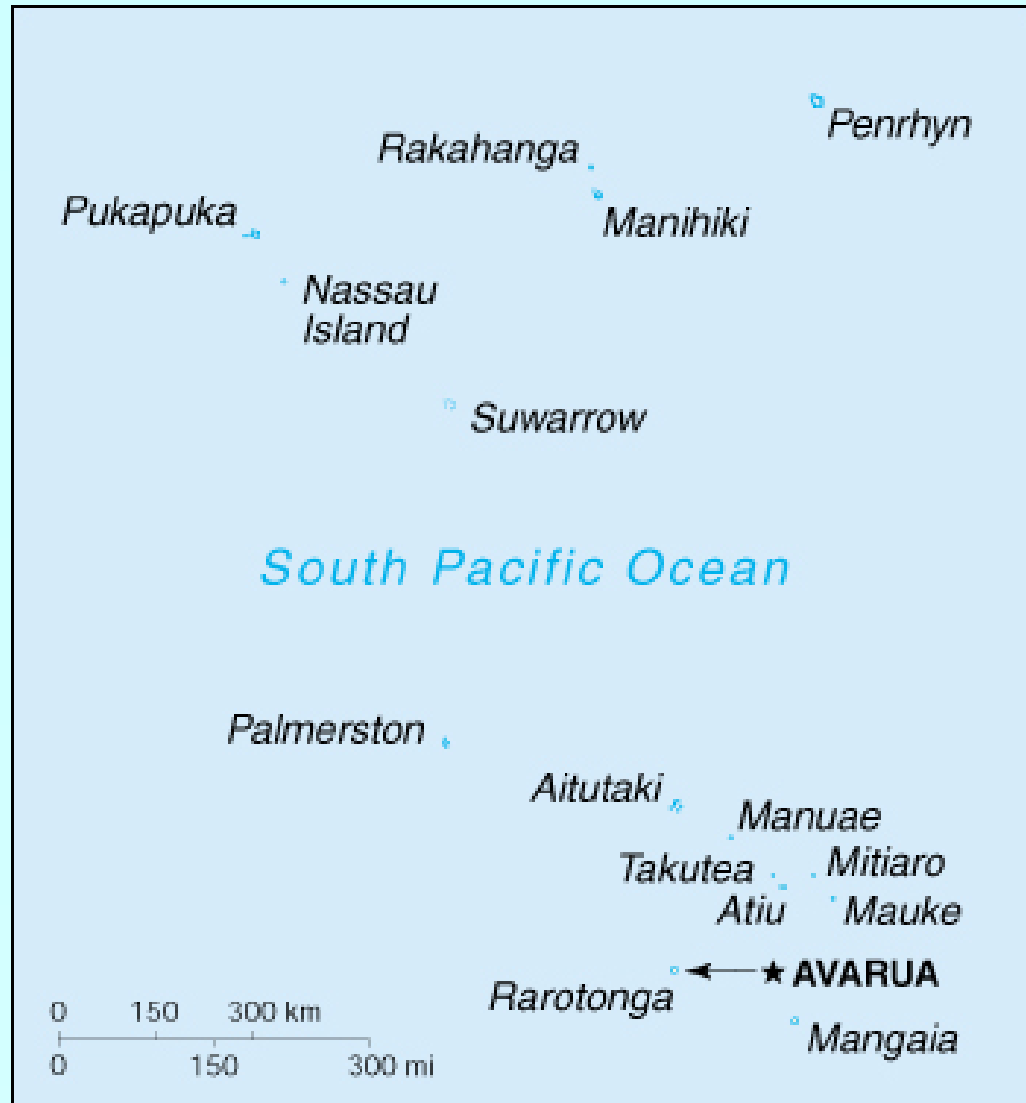
## **Borehole Monitoring Case Studies**

# Examples

- ◆ Pukapuka, Cook Islands
- ◆ Tarawa, Kiribati

# Example 1

## Pukapuka, Cook Islands



# Pukapuka

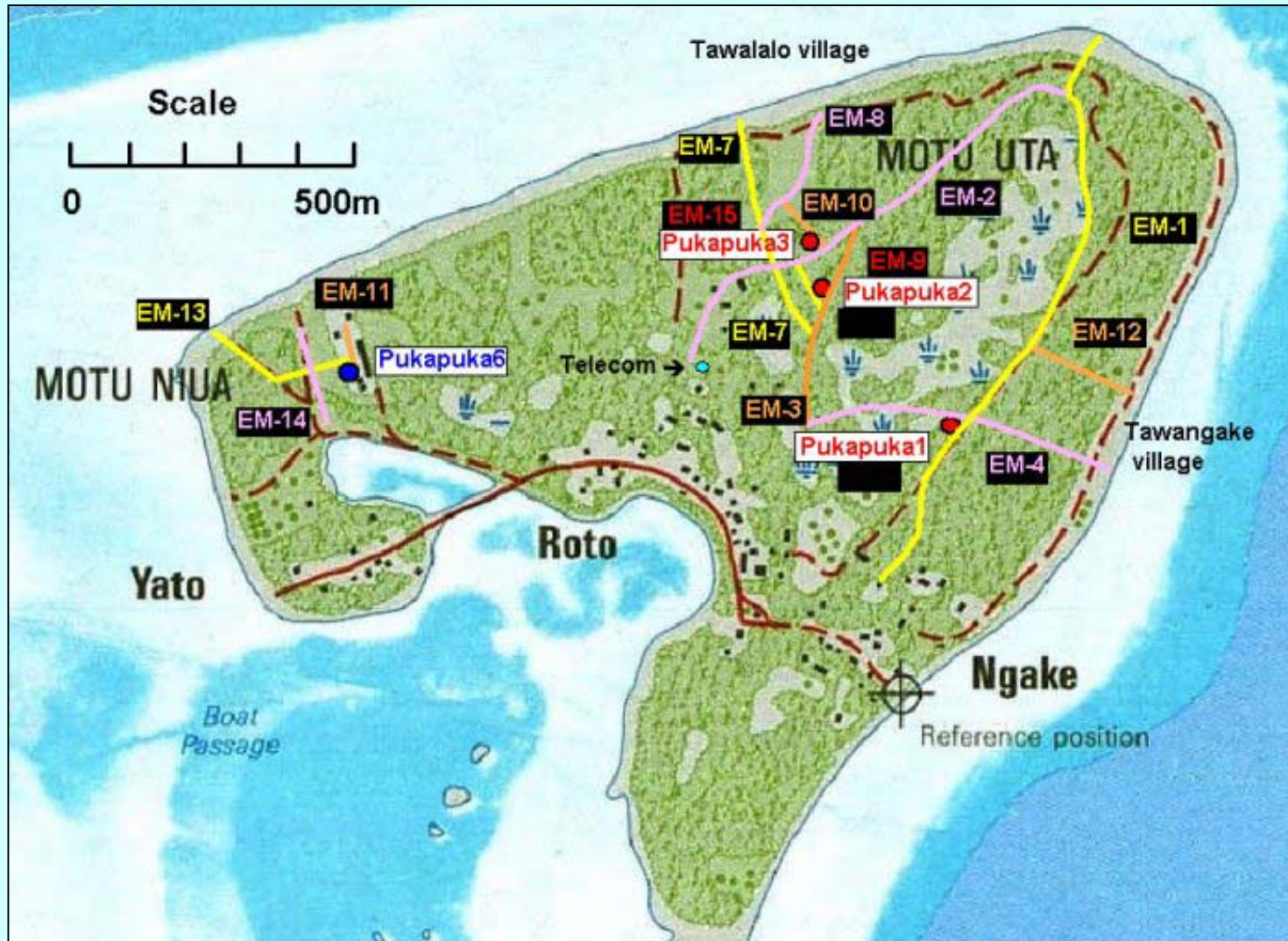


## Summary Statistics

- **Type : atoll (with 3 islands)**
- **Total land area: 3.8 km<sup>2</sup>**
- **Lagoon area: 10 km<sup>2</sup>**
- **Max elevation: 6m**
- **Annual rainfall:**
  - Average = 2,845 mm
  - Max = 3,940 mm
  - Min = 1,812 mm
- **Affected by cyclones (e.g. major damage in Feb 2005 due to Cyclone Percy)**
- **Population: approx. 650**

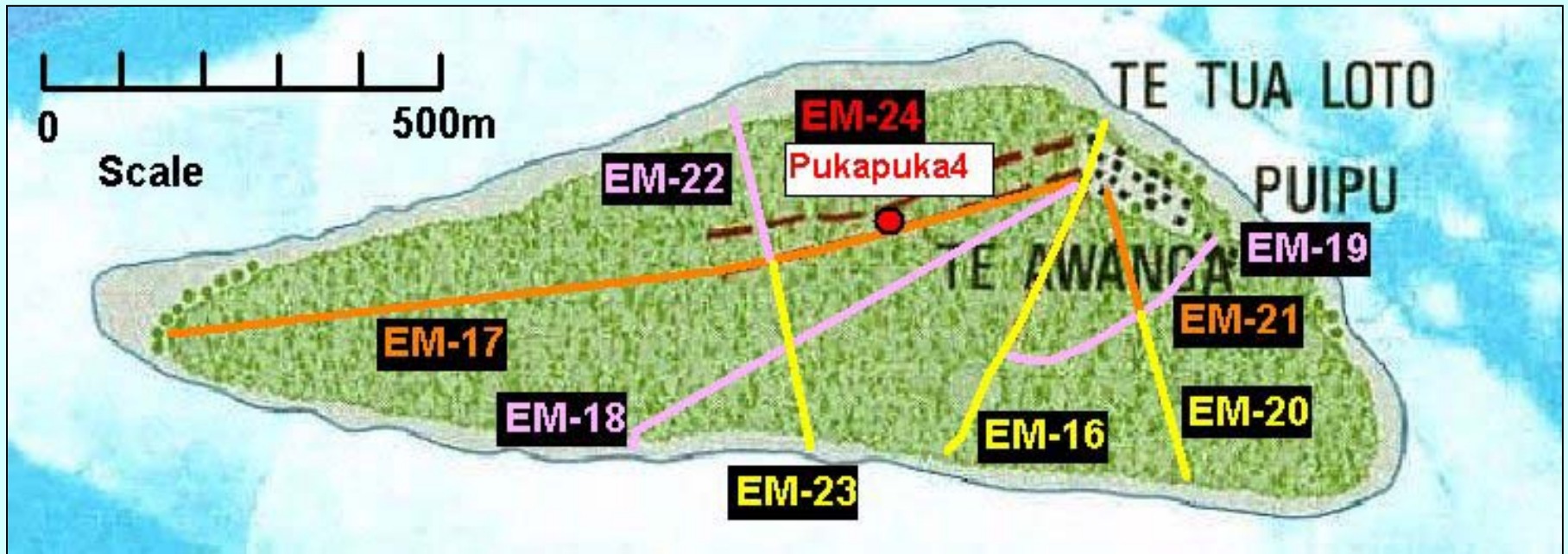
# Pukapuka

Boreholes Pukapuka1 to Pukapuka3 on Wale (main island)



# Pukapuka

## Borehole Pukapuka4 on Motu Kotawa

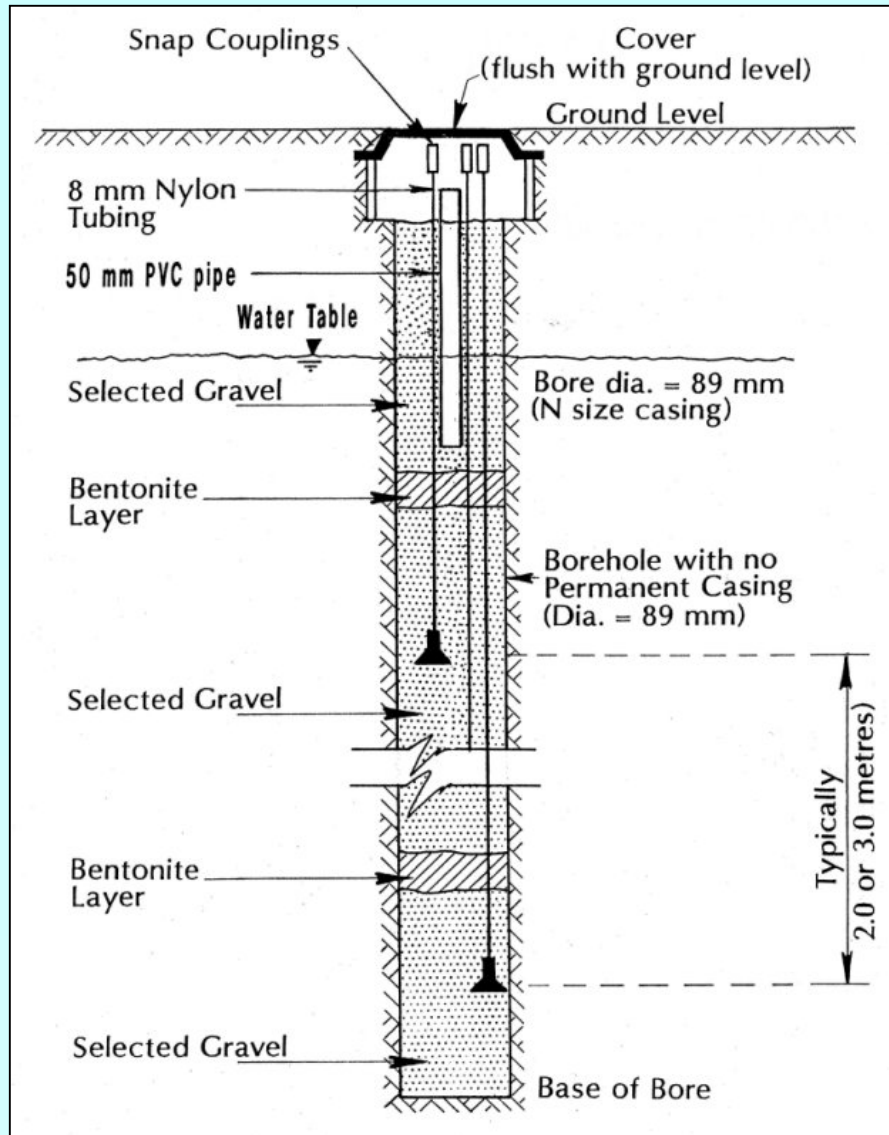


# Pukapuka

## Borehole Pukapuka5 on Motu Ko



# Borehole Type: multi-level tube system



# Pukapuka monitoring boreholes – summary details

Borehole Name	Borehole depth (mbgl)	Location	GPS Co-ordinates		Depth of PVC monitoring pipe and nylon tubes (mbgl)
			South	West	
Pukapuka1	13	Wale Island: east side of Ala Matua road at Te Welo (approx 220m north of power station)	10° 51' 6.2"	165° 50' 15.4"	3.0 (PVC pipe)
					4.5 (Tube A)
					6.0 (Tube B)
					8.0 (Tube C)
					9.5 (Tube D)
					12.5 (Tube E)
Pukapuka2	10	Wale Island: west side of Ala Matua road (inside) at Tukungawau	10° 50' 58.9"	165° 50' 21.8"	2.7 (PVC pipe)
					4.0 (Tube 1)
					6.0 (Tube 2)
					8.0 (Tube 3)
					9.5 (Tube 4)
Pukapuka3	18.5	Wale Island: west side of Ala Matua road (outside) at Te Ala o Maina	10° 50' 55.4"	165° 50' 21.7"	3.0 (PVC pipe)
					4.5 (Tube 1)
					6.0 (Tube 2)
					7.5 (Tube 3)
					9.0 (Tube 4)
					13.0 (Tube 5)
Pukapuka4	12	Motu Kotawa: north side of Timoti's road approx. 220m west of turnoff from Ala Ote Oro Avalu	10° 53' 33.8"	165° 52' 13.2"	2.1 (PVC pipe)
					3.5 (Tube 1)
					5.0 (Tube 2)
					6.0 (Tube 3)
					9.0 (Tube 4)
					11.9 (Tube 5)
Pukapuka5	22	Motu Kotawa: south side of Tiara's road at intersection with Ala Takapini (approx 250m east of Catholic	10° 54' 37.0"	165° 50' 5.1"	3.0 (PVC pipe)
					6.0 (Tube 1)
					9.0 (Tube 2)
					12.0 (Tube 3)
					15.0 (Tube 4)
					18.0 (Tube 5)
					21.0 (Tube 6)

# Borehole monitoring sheet for boreholes Pukapuka1 to Pukapuka3

**Borehole: Pukapuka1**

Area: **Motu Uta (Roto reserve)**

Location: **East side of Alamatua road at Te Welo (approx 220m north of power station)**

Drilled: **Feb-04**

Depth of PVC pipe below ground level (m): **0.05 (approx)**

Name(s) of monitoring person(s):

Date	Time	Monitor		Conductivity (EC) readings		
		Location	Depth (m)	1	2	3
		Water table below top of PVC pipe				
		Base of PVC pipe	3.0			
		Tube A	4.5			
		Tube B	6.0			
		Tube C	8.0			
		Tube D	9.5			
		Tube E	12.5			

**Borehole: Pukapuka2**

Area: **Motu Uta (Roto reserve)**

Location: **West side of Alamatua road (inside) at Tukungawau**

Drilled: **Feb-04**

Depth of PVC pipe below ground level (m): **0.05 (approx)**

Name(s) of monitoring person(s):

Date	Time	Monitor		Conductivity (EC) readings		
		Location	Depth (m)	1	2	3
		Water table below top of PVC pipe				
		Base of PVC pipe	2.7			
		Tube 1	4.0			
		Tube 2	6.0			
		Tube 3	8.0			
		Tube 4	9.5			

**Borehole: Pukapuka3**

Area: **Motu Uta (Roto reserve)**

Location: **West side of Alamatua road (outside) at Te Ala o Maina**

Drilled: **Feb-04**

Depth of PVC pipe below ground level (m): **0.05 (approx)**

Name(s) of monitoring person(s):

Date	Time	Monitor		Conductivity (EC) readings		
		Location	Depth (m)	1	2	3
		Water table below top of PVC pipe				
		Base of PVC pipe	3.0			
		Tube 1	4.5			
		Tube 2	6.0			
		Tube 3	7.5			
		Tube 4	9.0			
		Tube 5	13.0			
		Tube 6	18.0			

# Details of borehole monitoring sheet for borehole Pukapuka3

<b>Borehole: Pukapuka3</b>						
Area:		<b>Motu Uta (Roto reserve)</b>				
Location:		<b>West side of Alamatua road (outside) at Te Ala o Maina</b>				
Drilled:		<b>Feb-04</b>				
Depth of PVC pipe below ground level (m)		<b>0.05</b>	<b>(approx)</b>			
Name(s) of monitoring person(s):						
Date	Time	Monitor		Conductivity (EC) readings		
		Location	Depth (m)	1	2	3
		<b>Water table below top of PVC pipe</b>				
		<b>Base of PVC pipe</b>	<b>3.0</b>			
		<b>Tube 1</b>	<b>4.5</b>			
		<b>Tube 2</b>	<b>6.0</b>			
		<b>Tube 3</b>	<b>7.5</b>			
		<b>Tube 4</b>	<b>9.0</b>			
		<b>Tube 5</b>	<b>13.0</b>			
		<b>Tube 6</b>	<b>18.0</b>			

# Borehole monitoring data

## Salinity (EC), Pukapuka1, 2 and 3

### Feb 2004 – Jan 2005

Borehole	Depth	EC ( $\mu\text{S/cm}$ )									
	(mbgl)	Feb-04	Apr-04	May-04	Jul-04	Aug-04	Oct-04	Oct-Nov 04	Nov-04	Dec-04	Jan-05
Pukapuka1	Pipe	550									
	3	545	559	591	512	525	615	651	656	678	639
	4.5	680	604	588	564	561	619	619	651	382	641
	6	686	641	544	694	884	704	899	683	824	644
	8	1,576	1,305	2,630	4,570	7,140	8,160	9,480	10,500	8,840	8,230
	9.5	10,520	7,340	11,700	19,920	33,600	34,100	36,600	36,900	35,600	33,100
	12.5	45,700	50,700	50,400	50,700	52,200	59,900	58,900	57,900	52,800	52,200
Pukapuka2	Pipe	1,013									
	2.7	1022	866	845	804	1,085	768	937	611	1,218	1,178
	4	1,546	1,577	1,251	1,056	921	1,001	1,028	911	1,064	1,107
	6	5,770	4,640	5,320	7,190	8,190	8,760	9,400	8,810	8,390	7,600
	8	8,590	12,510	13,440	13,410	14,340	13,170	15,100	12,950	14,450	12,160
	9.5	10,270	12,860	13,480	14,020	14,680	14,770	15,930	12,850	16,030	12,800
Pukapuka3	Pipe										
	3		544	580	626	766		823	705	697	692
	4.5		533	560	631	576	689	700	524	667	699
	6	1,000	613	660	806	1,127	1,154	1,348	2,002	2,112	2,464
	7.5	7,690	3,760	6,200	8,740	10,590	11,230	12,050	12,370	12,000	9,890
	9		20,010	27,900	29,800	30,200	31,000	31,100	23,120	31,700	22,180
	13		21,000	28,000	30,000	30,400	31,500	31,700	31,600	32,000	23,640
18	23,700	20,730	28,200	30,400	30,600	32,300	31,700	31,200	33,400	30,100	

# Borehole monitoring data

## Water depth below top of pipe, Pukapuka1, 2 and 3

### Feb 2004 – Jan 2005

Borehole No.	1st round Just after drilling (Feb 2004)	2nd round (Apr 2004)	3rd round (May 2004)	4th round (Jul 2004)	5th round (Aug 2004)	6th round (Oct 2004)	7th round (O-N 2004)	8th round (Nov 2004)	9th round (Dec 2004)	10th round (Jan 2005)
Pukapuka1	1.85	1.85	1.85	1.95	1.85	2.05	2.05	1.95	1.95	1.85
Pukapuka2	1.25	1.25	1.25	1.35	1.25	1.35	1.35	1.35	1.35	1.05
Pukapuka3	1.53	1.75	1.75	1.75	1.65	1.85	1.75	1.45	1.95	1.55
Pukapuka4	1.13	1.05	1.05	1.35	1.05	1.35	1.25	1.15	0.85	0.95
Pukapuka5	2.08	2.25	2.25	2.35	2.75	2.45	2.25	2.45	2.65	1.95

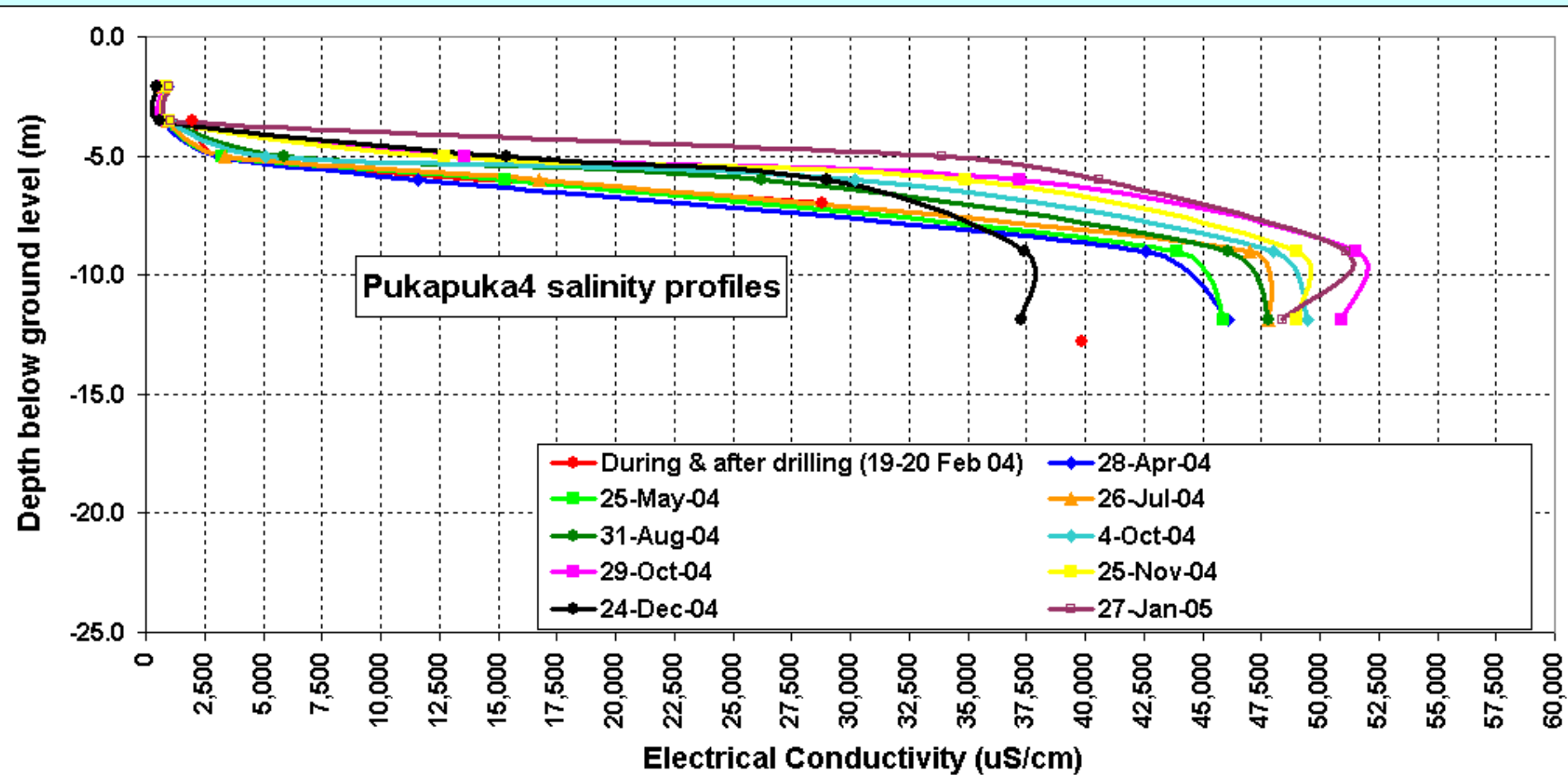
 Suspect values





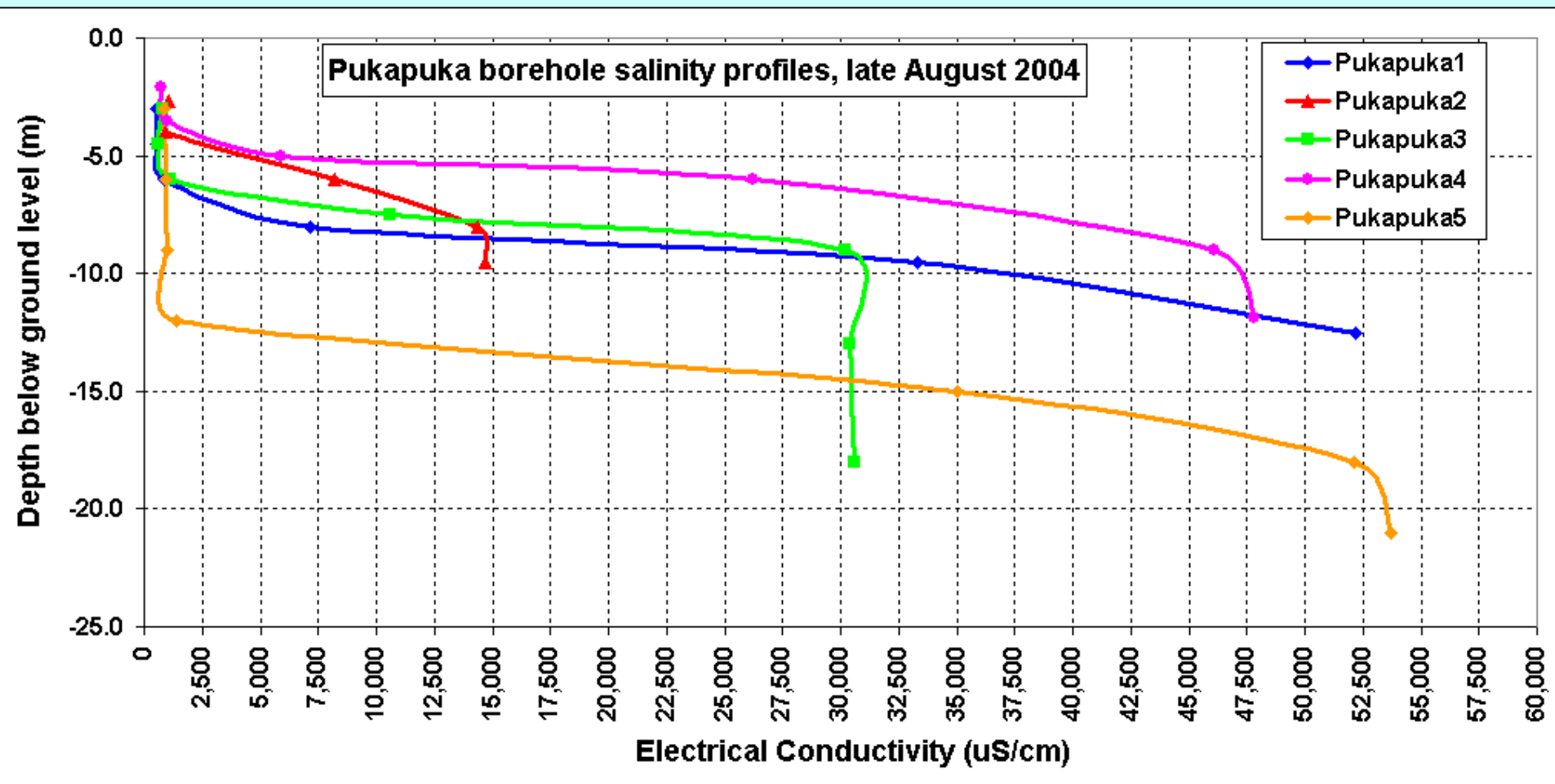


# Borehole Pukapuka4 – salinity profiles, Feb 2004 – Jan 2005

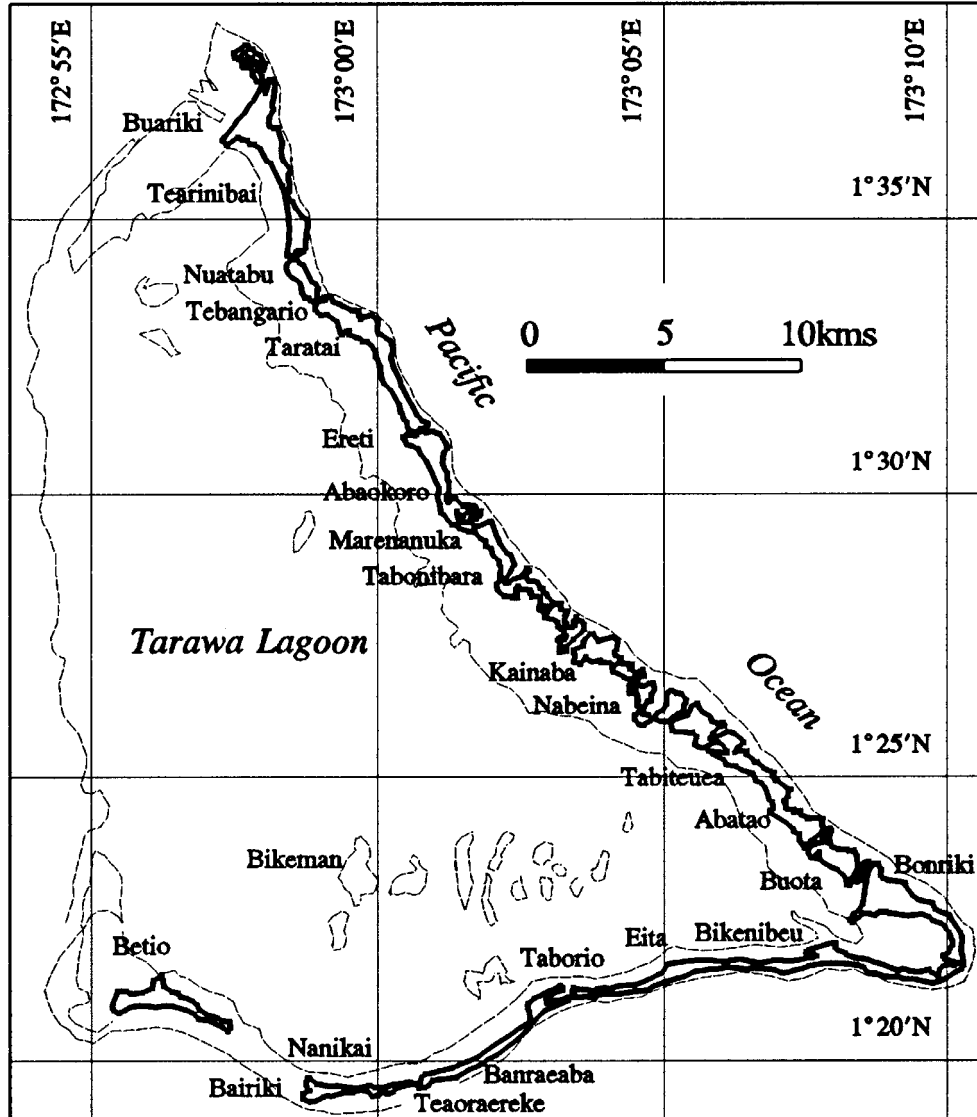




# Boreholes Pukapuka 1 to 5, salinity profiles for selected date (August 2004)



# Example 2, Tarawa, Kiribati



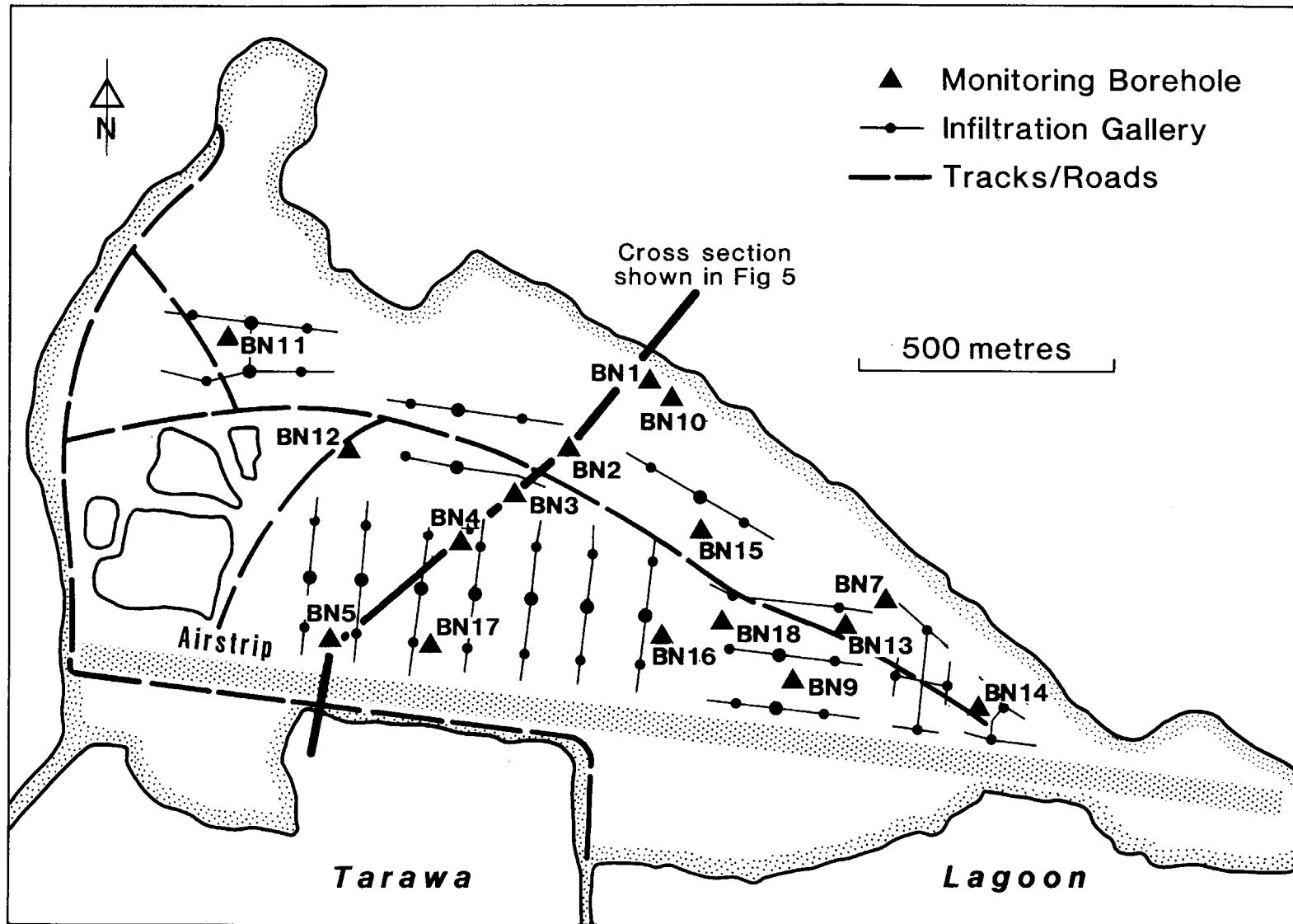
- Type : atoll (with many islands)
- Total land area: 31 km<sup>2</sup>
- Max elevation: 3 – 4 m
- Annual rainfall:
  - Average = 2,047 mm
  - Max = 4,250 mm
  - Min = 398 mm
- Rainfall is highly influenced by El Niño and La Niña episodes (causing high rainfall and droughts, respectively)
- Population: approx. 45,000



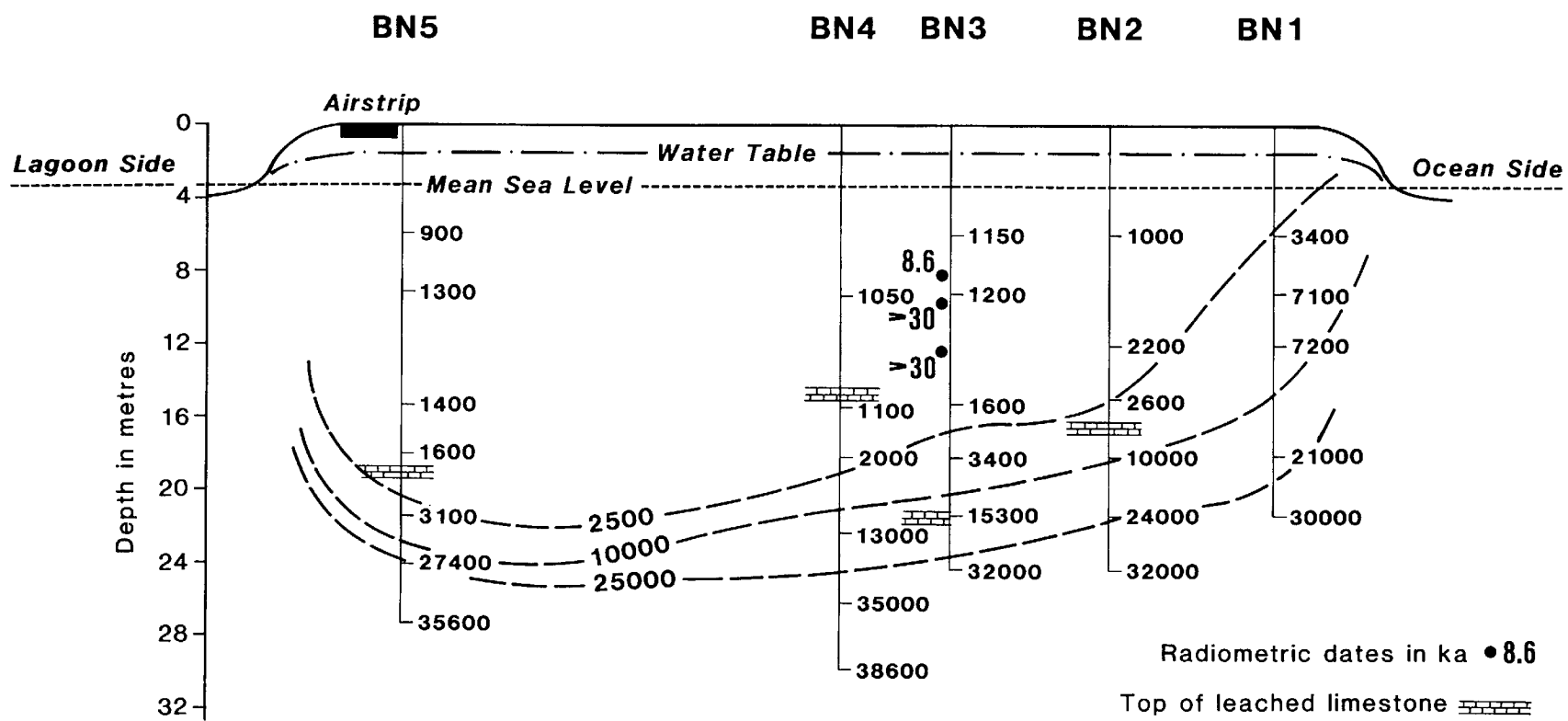
Focusing on the island of Bonriki in southeastern corner

**Bonriki**

# Bonriki – plan view showing galleries & selected boreholes



# Bonriki – cross section through lens showing contours of EC (salinity) at boreholes BN1 – BN5



Radiometric dates in ka • 8.6

Top of leached limestone

Borehole BN3 corresponds to borehole I on Fig.1

Isolines of electrical conductivity ( $\mu\text{mhos cm}^{-1}$ ) — 2500 —



# Bonriki – salinity variations, 1980-2004 at borehole BN1

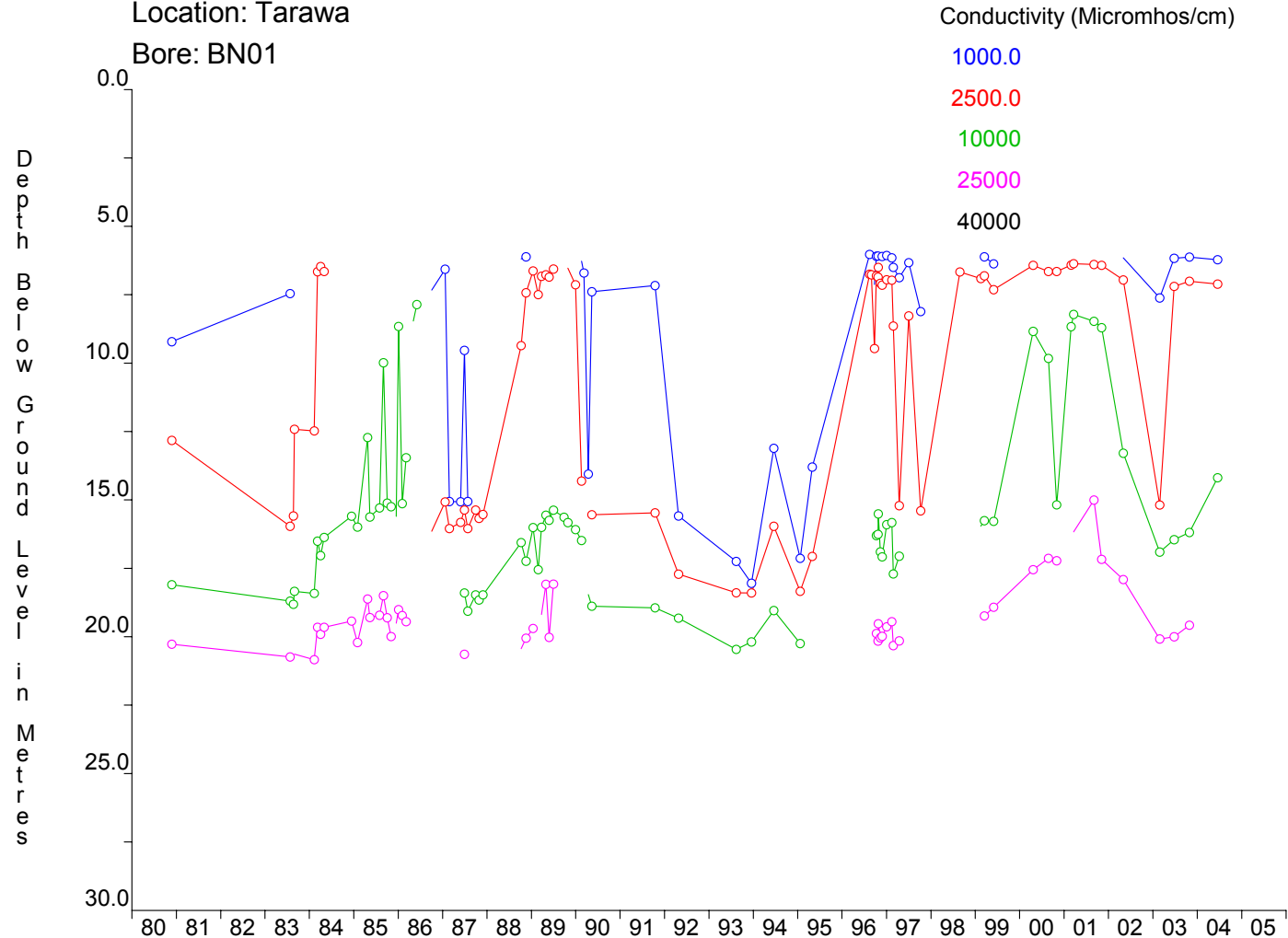
Data Output on 21/04/2005

## BOREHOLE MONITORING

Electrical Conductivity (25 deg. C.) against Time.

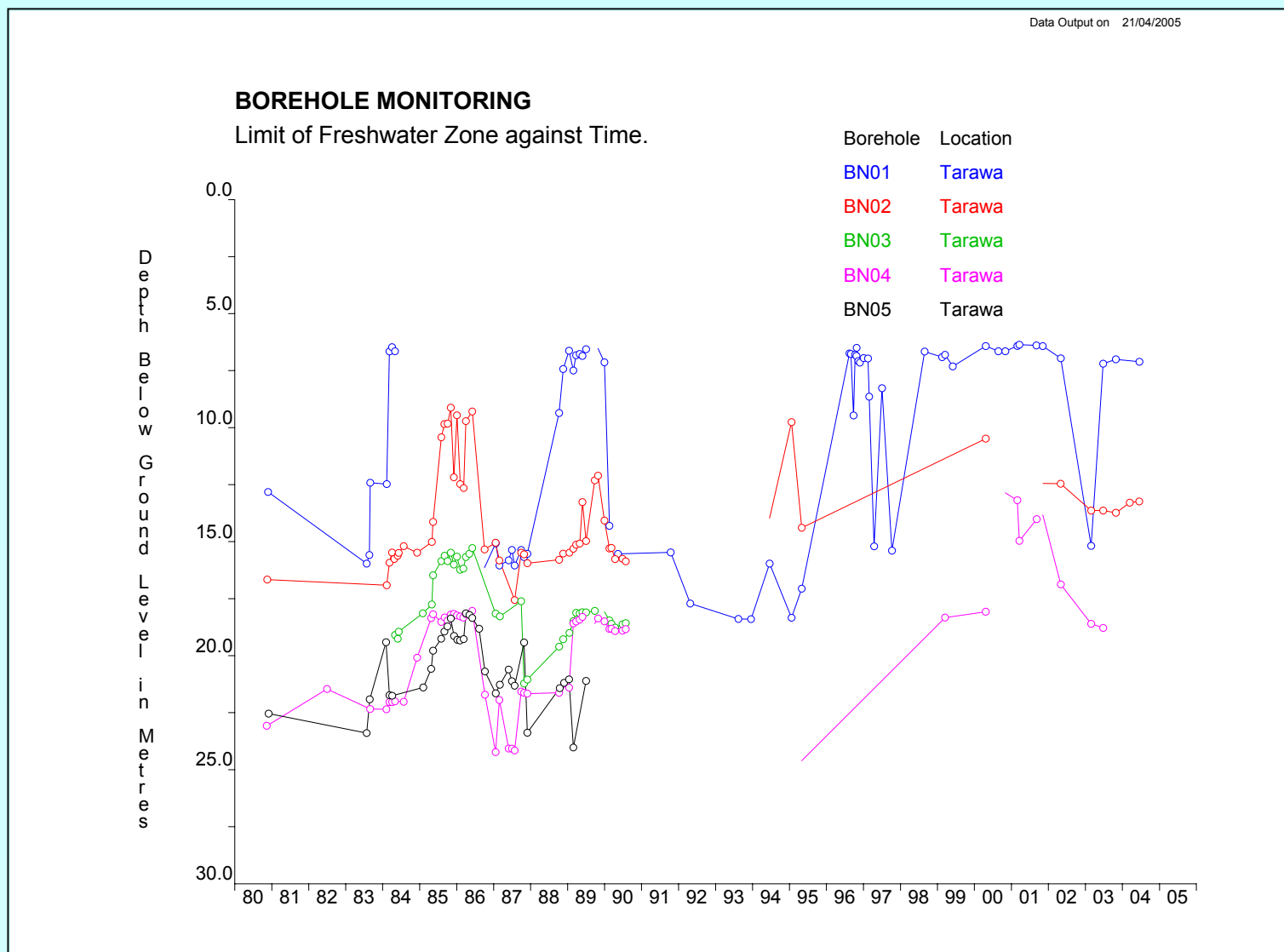
Location: Tarawa

Bore: BN01



**Note: The record from BN1 is one of the longest for Bonriki (and for any atoll island).**

# Bonriki – variations in freshwater zone base, 1980-2004 at boreholes BN1-BN5



**Notes: Some boreholes have been lost or damaged due to runway construction (BN5) or vandalism (BN3). BN2 and BN5 have been rehabilitated. BN1 is the only one not damaged.**