

TRAVEL REPORT FORM

출장보고서

결 재	사원	부서장	부서장	원장
	07/25	07/25	07/25	07/25
협 조	전인자	문상원	김형진	정홍상
	선임연구 원	팀장		
	07/25	07/25		
	윤선권	조재필		

I. Reporter 보고자

Department 소속	Position 직위(직급)	Name 성명	Travel Date 날짜	Note 비고
응용사업팀	선임연구원	윤선권	7/3(월)- 7/13(목)	통가 누쿠알로파
대외협력실	사원	전인자	7/3(월)- 7/13(목)	통가 누쿠알로파

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

- 지하수 자동관측 장비 설치(3곳) 및 기존 자동관측 장비 설치지점 점검
- 실시간 지하수 자동관측 서버시스템 보완·구축, 운영테스트
- 2017년도 프로젝트 관련 정부 관계자 중간협의, 자동관측 장비 및 지하수자원 통합관리 시스템 운영 피드백 논의
- 중력식 막여과장치를 이용한 지하수/빗물 수질 Test 및 지하수 취약지역 수질 샘플링, 지역주민 설문조사 및 정부관계자 인터뷰
- 지하수 관리방안, 지하수 모델링 등 실무자 워크숍 추진 및 사용자 교육 등

2. Relevance to APEC Climate Center's Activities 결론 및 소감

- (붙임1) 통가 출장보고서 및 (붙임2) 발표자료 첨부파일 참고

III. References 참고사항

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

1. Presented and Collected Materials 주요 수집자료

2. Suggestions and Remarks 건의사항

통가 수자원 프로젝트 출장 보고서

[2017. 7. 24.(월) 응용사업팀/대외협력실]

I. 출장 개요

- 과 업 명 : 통가 물부족 대응을 위한 기후정보 활용 스마트 지하수 관리 시스템 개발(*"Development of smart water management system using climate information in response to shortage of water in the Kingdom of Tonga"*)
- 출장목적
 - 지하수 자동관측 장비 설치(3곳) 및 기존 자동관측 장비 설치지점 점검
 - 실시간 지하수 자동관측 서버시스템 보완·구축, 운영테스트
 - 2017년도 프로젝트 관련 정부 관계자 중간협의, 자동관측 장비 및 지하수자원 통합관리 시스템 운영 피드백 논의
 - 중력식 막여과장치를 이용한 지하수/빗물 수질 Test 및 지하수 취약지역 수질 샘플링, 지역주민 설문조사 및 정부관계자 인터뷰
 - 지하수 관리방안, 지하수 모델링 등 실무자 워크숍 추진 및 사용자 교육 등
- 출장기간 : 2017. 7.3.(월)-13.(목) <10박11일>
- 출장자(2인) : 윤선권 선임연구원, 전인자 사원 / 외부: 하이드로넷(2인)
- 출장관련 주요내용

분야	담당자	기간	방문목적	주요활동
수자원 (지하수)	윤선권 전인자 및 현지 담당자	2017. 7.3.(월) - 13.(목)	• 프로젝트 진행 사항 협의 (MLSNR) • 지하수 자동관측 장비 설치 및 세부조사 • 실무자 워크숍 및 사용자 교육	- 활동내용 • SMB 3곳의 지하수 자동관측 시스템 구축 및 서버시스템 설치 • Technical 워크숍 진행(지하수 관리, 데이터 로거, 모니터링 서버, 모델링 결과분석 등 세부교육 진행 및 피드백 취합·논의) • 자료확보 : 수자원 자료 검토 및 추가 확보(수온, 강수, 염도 등 세부 자료) • 현지조사 : 지하수 취약지역 세부조사 및 수질 샘플 테스트

Ⅲ. 주요활동 내용

1. 지하수 자동관측 장비 설치(3곳) 및 기존 자동관측 장비 설치지점 점검

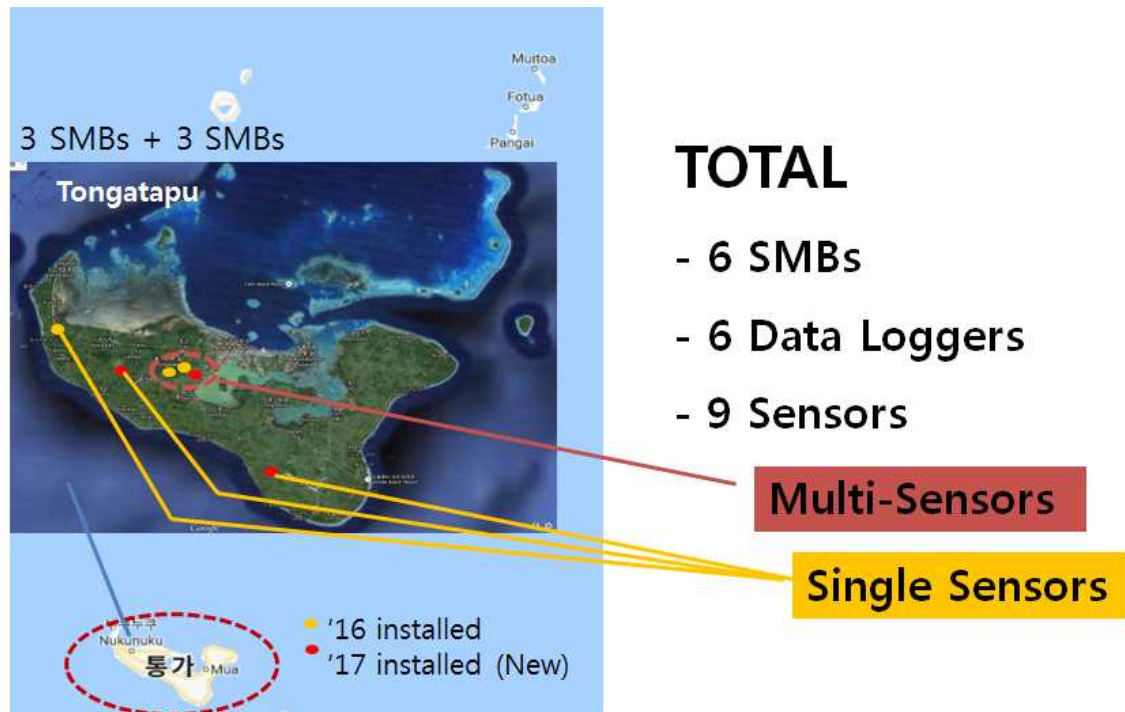
- 기존 자동관측 장비 3곳 현장점검 및 펌웨어 업데이트

SMB02	SMB13	SMB15
beside pump station 105	Next to pump station 313	Middle of Hihifo well field
		
Tube No.3/No.4	Tube No.3/No.4	Tube No.2
+676-841-5229	+676-841-5231	+676-841-5230
설치 관정 : #1 No 3 : #2 No 4 케이블 길이: #1 16.5m : #2 22.5m	설치 관정 : #1 No 3 : #2 No 4 케이블 길이: #1 30m : #2 26.8m	설치 관정 : No 2 케이블 길이: 17m

- 신규 자동관측 장비 3곳 설치, 통신확인 및 원격서버데이터 전송확인

SMB01	SMB08	SMB09
south side of track	Houma, Vaea Road	Toloa-End of Airport Runway
		
Tube No.2/No.3	Tube No.5	Tube No.4
+676-884-8617	+676-884-8618	+676-884-8619
설치 관정 : #1 No 2 : #2 No 3 케이블 길이: #1 19.79m : #2 14.70m	설치 관정 : No 5 케이블 길이: 19m	설치 관정 : No 4 케이블 길이: 38m

- 아래 그림은 지하수 실시간 자동 관측 지점 위치도를 나타내고 있음.
노란색 지점은 '16년도에 설치한 지점 3곳의 위치정보이며, 빨간색 지점은 '17년도에 신규로 설치한 지점 3곳의 위치정보임.



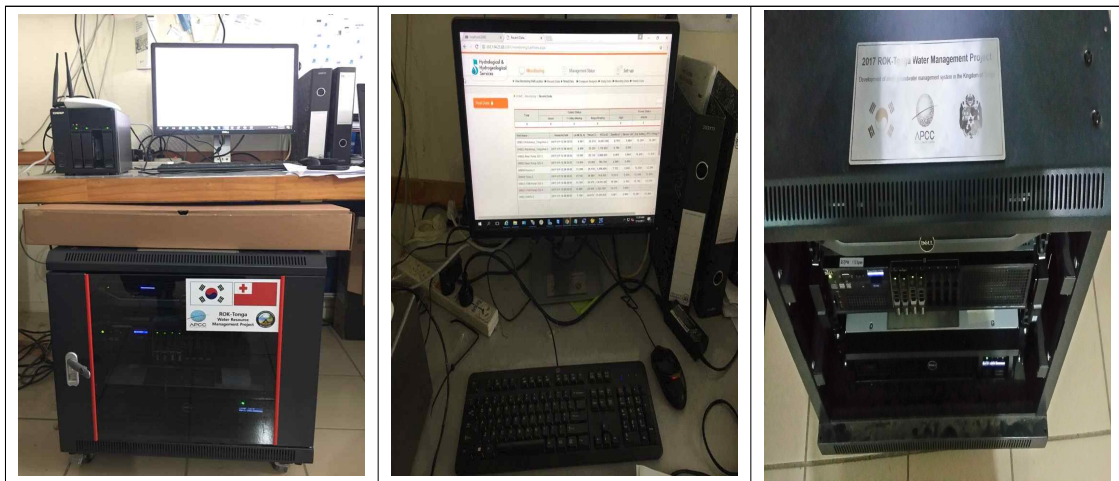
- 총 6개의 SMB(Salinity Monitoring Borehole)지점에 6개의 Data Logger와 9개의 Sensor가 설치되었으며, Tongatapu 섬의 Nukualo'fa Urban 지역으로 물을 공급하는 Production Well이 존재하는 Mataki 'eua/Tongamai Well Field에는 Multi-Sensor(다중심도 센서)를 설치하였음.

2. 실시간 지하수 자동관측 서버시스템 보완·구축, 운영테스트

- 신규서버설치 : 기존 서버1대에서 서비스호스팅, 데이터수집, 데이터베이스 등의 역할을 했던 것을 신규로 Hosting서버를 구축하여 호스팅 및 데이터수집 기능을 처리. 기존에 구축된 서버는 데이터베이스기능만 처리하도록 하여 서버간 기능을 나누어서 재 구축함
- 설치서버 계정정보

시스템	아이디	비밀번호	IP
Windows Server 2012 R2	Administrator	!123qwe	192.168.0.6
Microsoft SQL Server 2014	UGMS	123qwe!@#QWE	
Windows Server 2014 R2	Administrator	tonga1!	192.168.0.8

- 서버시스템 설치사진



- UPS 신규설치 : 통가 전산실의 구조상 전력단전이 자주 발생하여 서버의 고장 및 서비스 중단의 사고가 발생하여 신규로 UPS 설치
- IP 및 포트 확정
 - 외부 NAT IP : 202.134.25.68
 - 내부IP : Hosting Server(192.168.0.8)/Database Server(192.168.0.6)
 - 사용 중인 포트 현황

사용포트	목적
2080 (192.168.0.6)	메인 모니터링 시스템 구축예정
2081 (192.168.0.6)	데이터계측 모니터링 시스템 구축 (이번에 구축)
2082 (192.168.0.6)	내부 API용 포트
5012 (192.168.0.6)	Aqua Server 데이터 수신서버 프로그램 (계측장비와 통신)
1433 (192.168.0.8)	MS-SQL서버 사용

- 통가 기상청(Tonga Meteorological Service, TMS) 데이터베이스 연계(ToCSA) : APEC 기후센터에서 개발하여 통가 기상청에 구축한 ToCSA시스템에 의한 계절예측 및 단기, 장기 예측강우를 지하수 모델링에 사용하기 위하여, 데이터베이스의 연계에 필요한 작업(고정 IP 접속 및 Port Forwarding 등)을 수행함
- 통가 기상청 홈페이지: 202.43.10.46
- ToCSA시스템 홈페이지: met.gov.to:2016 (<http://met.gov.to:2016/index.do>)
- 외부 NAT IP: 202.43.10.46
- 내부 IP: 192.168.36.9
- 데이터베이스 포트: 3306
- Database: APEC2016
- ID: tocsa
- PW: tonga123\$

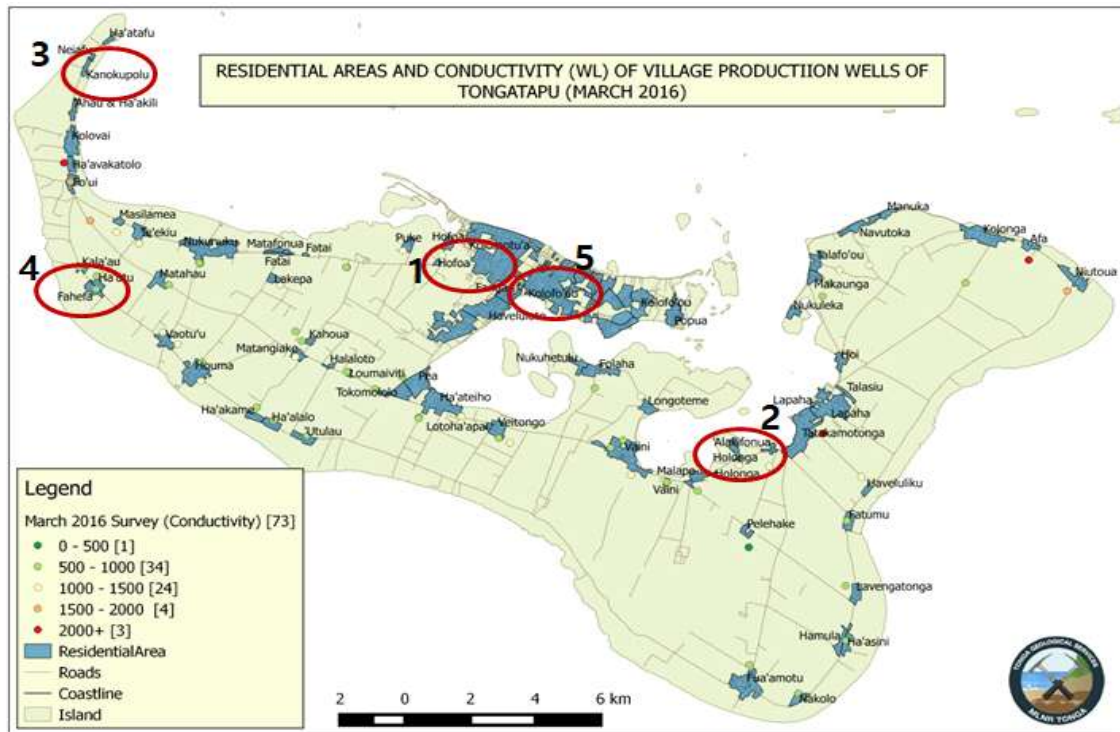
3. 2017년도 프로젝트 관련 정부 관계자 중간협의, 자동관측 장비 및 지하수자원 통합관리 시스템 운영 피드백 논의, 지하수 관리방안, 지하수 모델링 등 실무자 워크숍 추진 및 사용자 교육

- 통가 정부(Ministry of Lands, Survey and Natural Resources, MLSNR) 프로젝트 담당자와 실시간 지하수 모니터링 시스템 구축, 지하수세부조사 및 모델링, 기후변화 및 물수요 예측 관련 프로젝트 세부사항을 논의함
- 각 SMB 지점에 설치된 Data Logger는 GSM 모뎀 방식의 원격통신을 통하여, 서버로 지하수 관측정보를 실시간 전송하는 시스템임. 따라서 Data 전송을 위한 통신비용이 발생하게 되며, 프로젝트 결과물의 지속적인 활용을 위해 추후 통가 정부가 데이터로거의 데이터 통신비용을 지원하기로 함
- Technical Workshop을 통하여 기존에 구축한 통가 지하수 모델링 시스템(Tonga Groundwater Flow Model, ToGFlow), 통가 지하수자원 통합관리 시스템(Tonga Groundwater Information System, ToGWIS)의 사용자 교육을 실시하였음

- 또한, 매 3개월 마다 수동(Manual)으로 측정하고 있는 지하수관측정보를 지하수자원 통합관리 시스템(ToGWIS)을 통하여 Upload 시키며, 관리하는 방안을 교육하였으며, 현지 실무자의 Feedback을 받아 향후에 시스템을 더욱 개선시켜 나갈 예정임
- 통가 정부는 본 프로젝트를 통해 궁극적으로 지하수 모델링을 기반으로 하여 주민들에게 지하수활용 정보를 제공하고자 함(음용수, 가정용수 등 정보제공)
- 지하수자원 통합관리 시스템 사용자 교육 및 피드백 논의를 통해 사용자 친화적인 시스템 수립 및 추가 업데이트 사항 확정
 - 수동 모니터링 데이터 입력
 - User 등록 섹션 세분화
 - 리포팅 기능 관련 논의(포맷 등)
 - 해상도 조절 및 맵 하위카테고리 설정(SMB, TBU 등)
 - 통가 정부에 필요한 데이터 요청
- Technical Workshop 장면 및 이번에 설치한 지하수 자동관측 장비 앞에서의 단체사진



4. 중력식 막여과장치를 이용한 지하수/빗물 수질 Test 및 지하수 취약지역 수질 샘플링
 - 아래 5개 지역(도심 2곳, 농촌 3곳)의 지하수/빗물 수질분석을 위한 샘플링 실시(무균채수병 1L×20병)



- 통가타푸섬에서 샘플링한 물은 GIST(Gwangju Institute of Science and Technology) 김경웅 교수 연구팀에 수질 분석의뢰 하였으며, 최종 분석결과는 APCC와 통가 국토부에 공유 예정
- 추후 수자원의 수량·수질을 통합관리 프로젝트 프로포절 작성을 위한 수원국의 Supporting 레터 작성을 요청하였으며, KOICA OAD사업 발굴 등에 활용 예정
- 마을 상수도 채수장면 및 무균채수병(1L×20병) 샘플링 결과



5. 지역주민 설문조사 및 정부관계자 인터뷰

- 5개 지역(도심 2곳, 농촌3곳: 위 그림 참조)의 지역주민을 직접 만나 가뭄(물 부족)경험, 정부의 가뭄대책 등과 관련하여 인터뷰 설문 실시하여 통가타푸섬의 가뭄관련 현황조사 및 대책 수립 필요성 파악(붙임 #1 참조)
- 지역주민이 가뭄(물 부족)에 적절히 대처하기 위해 정부에서 필요한 사항(Village Well 확장, Pipe Line System 개선, Rainwater Tank 확충, 적절한 가뭄예측 시스템 구축 등)이 무엇인지 주민 설문조사를 통하여 파악하고 우선순위를 결정하고자 함
- 통가의 수자원관리 관계자(통가 기상청, 통가 물위원회, 통가 국토부 수자원부, 통가국립재난관리사무소) 인터뷰를 통해 정부의 가뭄모니터링 현황조사, 대책 수립 필요성 파악, 자료수집
- SPI(Standardized Precipitation Index), PDSI(Palma Drought Severity Index)등 가뭄지수를 이용한 가뭄모니터링을 실시하고 있는지? 정부의 가뭄대책은 무엇인지? 지하수를 가뭄에 활용하고 있는지? 가뭄예측을 실시하고 지하수자원 예측 시스템을 구축한다면 각 정부기관에 어떠한 도움이 될 것인지? 등의 인터뷰실시(붙임 #2 참조)

- 통가 지역주민 설문조사 장면



III. 주요일정

Date	Time	Task	Location	Note
2017-07-03 (Mon)/ 07-04 (Tue)		Busan → Incheon → Auckland → Nukualofa		
2017-07-05 (Wed)	AM	Mid-term workshop (Status check up, etc) Feedback from MLSNR Finalization on site selection Discussion on project request letter Site Visit	MLSNR office	
	PM	Data sim preparation Installation of data loggers	Field	
2017-07-06 (Thu)	AM/P M	Installation of data loggers (cont.) server installation install UPS Pilot test for data logger and server	Field MLSNR office	
2017-07-07 (Fri)	AM/P M	Monitoring installed data loggers Monitoring newly installed data loggers Monitoring server and data status	MLSNR office	
2017-07-08 (Sat)	AM/P M	Data loggers installation (cont.)		
2017-07-09 (Sun)	AM/P M	Visit Tonga Met. Service for data connection		
2017-07-10 (Mon)	AM PM	Training on use of data loggers, data analysis, modeling, etc. Training on server, website, etc. Water quality sample testing	MLSNR office Field	
2017-07-11 (Tue)	AM PM	Water quality testing on sites Survey and interview on water usage, drought monitoring, etc.	Field	
2017-07-12(We d)/07-13(Thur)		Nukualofa → Auckland → Incheon → Busan		

- 붙임#1: 지역주민 설문조사내용(50명)

Questionnaire for Village Survey↵

This survey is a part of project 'Development of smart groundwater management system using climate information in response to shortage of water' in cooperation with the Ministry of Lands, Survey, Natural Resources of Tonga and the APEC Climate Center, South Korea. The survey is for research use only to understand citizen's experience and expectation to drought. Your answer will be confidential. Thank you for your kind cooperation. ↵

↵

1. Have you experienced drought? If yes, go to 1-1). If no, go to 3. ↵

- 1) When was it?↵

- 2) How significant the effect was? Please describe. ↵

- ↵

- ↵

- ↵

2. Do you think your government responds appropriately in case of water shortage during dry season? If so, what did they do for you?↵

↵

↵

↵

↵

3. Are you familiar with your government's drought response discipline? If so, what are they? ↵

↵

↵

↵

4. What do you expect your government to do in facing water shortage? (eg. expand the number of village wells, improve pipeline system, build more rain water tank, Establish system for drought forecast, etc.)↵

↵

↵

↵

- 붙임#2: 정부관계자 인터뷰내용(10명)

Interview Questionnaire for Government↵

This interview is a part of project 'Development of smart groundwater management system using climate information in response to shortage of water' in cooperation with the Ministry of Lands, Survey, Natural Resources of Tonga and the APEC Climate Center, South Korea. Your response is for research use only to better understand how your government manages drought. Thank you for your kind cooperation. ↵

↵

1. Do you monitor drought? If so, what kind of methods do you use(eg. Drought indices such as SPI(Standardized Precipitation Index) and PDSI (Palma Drought Severity Index)?↵

↵

↵

↵

↵

↵

2. Do you have drought measures? If so, can you explain them?↵

↵

↵

↵

↵

↵

3. What kind of information is necessary in establishing drought measures such as precipitation or groundwater data? ↵

↵

↵

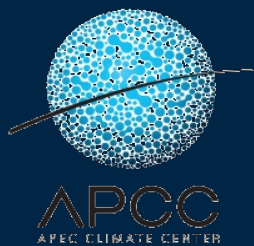
↵

↵

↵

4. Do you think drought forecast, using prediction of precipitation and groundwater is helpful for you to respond to drought?↵

↵



*2017 APCC-Tonga Agri-Water Project
Mid-term presentation*

Development of smart water management system using climate information in response to shortage of water in the Kingdom of Tonga

July 5, 2017

Sunkwon Yoon, Ph.D.

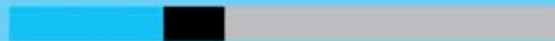
Contents

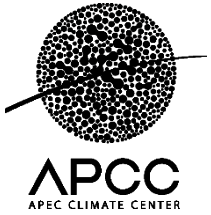
- **Project Outline**
- **Project Contents**
 - Climate
 - Water
 - Agriculture
- **Timeline**



I

Project Outline



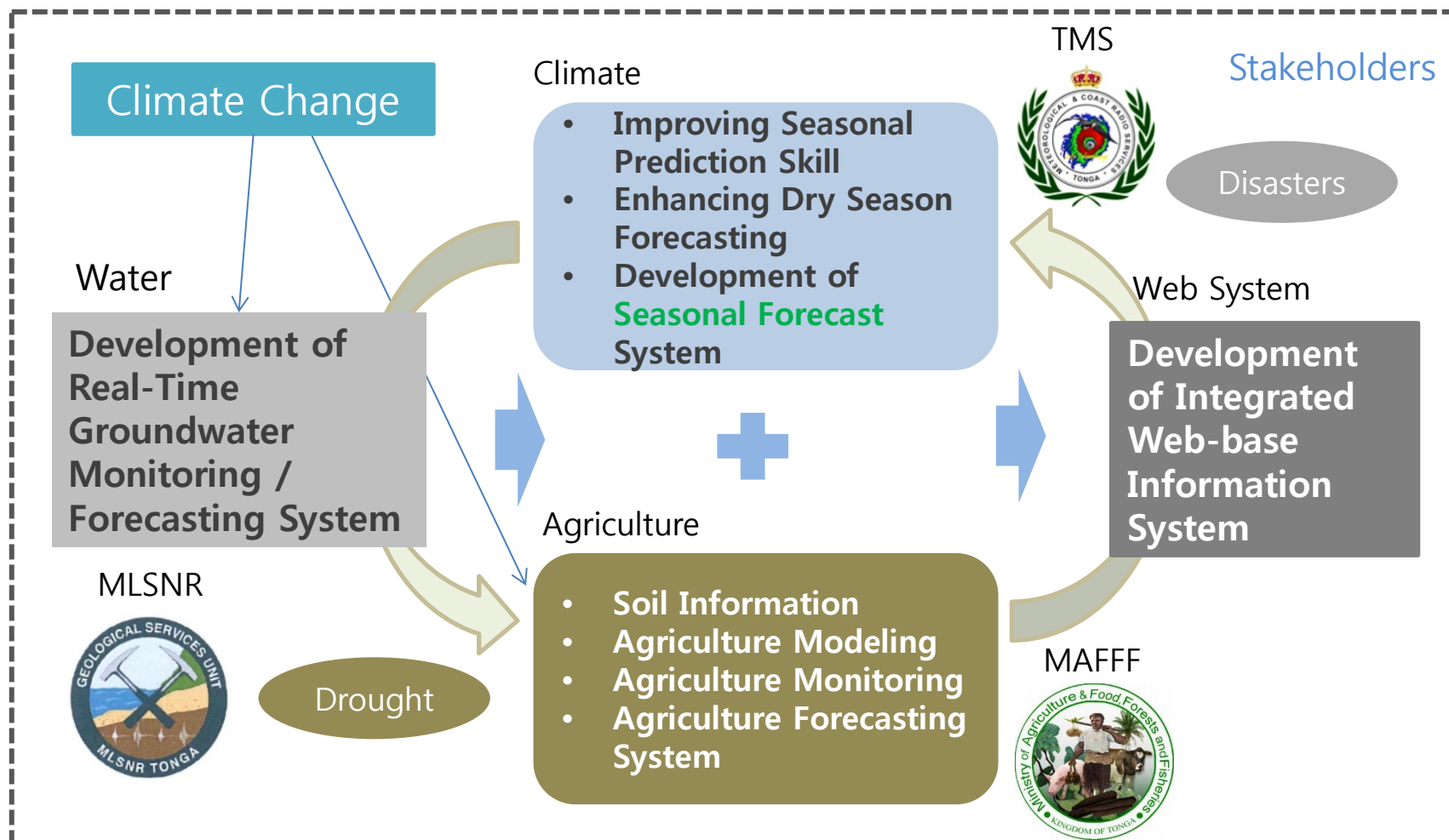


Project Background

- ❑ The Kingdom of Tonga face diverse and difficult water challenges
- ❑ For example, the supply and demand of water resource in Tonga is regionally biased and the quantity and quality of it are at high risk due to the pollution and depletion of surface water as well as seawater intrusion
- ❑ These facts affect Tonga, putting it in a very vulnerable status in obtaining sustainable water resources
- ❑ By developing climate-smart groundwater information system for water resources, Tongan community members and decision makers will be better understanding and implementation for sustainable water use and management

Tonga Agri-Water Project Design

APCC-Tonga Agri-Water Project



Tonga Water Project Work Sharing

Main Activities (2017년)

A. Climate

- CMIP5기후변화 시나리오/APCC MME계절예측 자료 분석 및 처리
- rcmip5/sforecast package를 이용한 상세화 자료 생산 및 처리
- 수문/농업 활용 및 Web시스템 연동을 위한 기후자료처리 및 분석

B. Water

- 계절예측 자료 기반 지하수자원의 계절예측 및 평가 기술 개발(Prototype)
- 지하수자원 기후변화영향평가 및 기후 위험관리 기술개발
- Web기반 통합 물관리 시스템 구축 및 현지화 방안 마련

C. Agriculture

- 토양수분함량 모니터링 시스템 구축 및 기후예측정보 활용 기술개발
- 지하수함량 예측정보와 연계한 농경지 스마트 물관리 방법 개발(Prototype)
- ToCSA(Tonga Climate Service for Agriculture)를 활용한 농업 데이터 구축

Success Indicators

- 연구원(정, 조)
- rcmip5/sforecast (@Dr. Jaepil Cho)

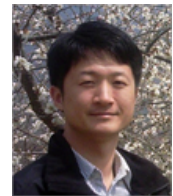


Co-PI: 윤선권 박사

위탁



PI: 신용희 박사

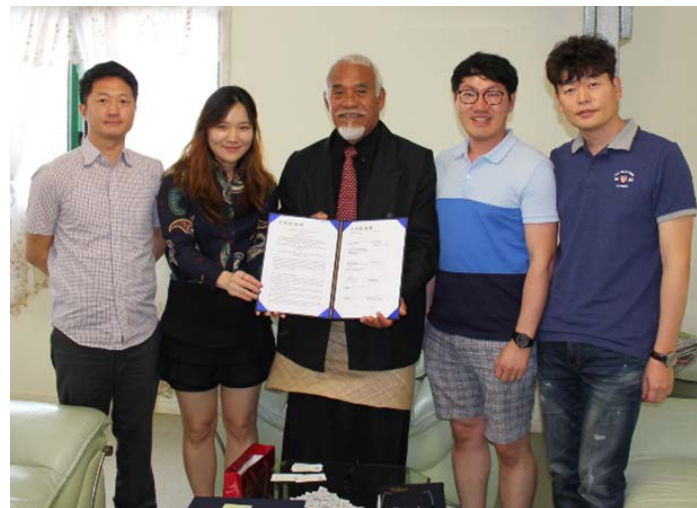


김광형 박사

Tonga Agri-Water Project MOU



Agri-Water Project MOU
(2017~2018, 2-year Project)



Tonga Agri-Water Project Workshop

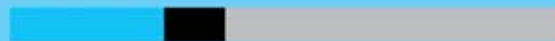
Photos from the Joint Workshop at TANOVA Hotel in TONGA



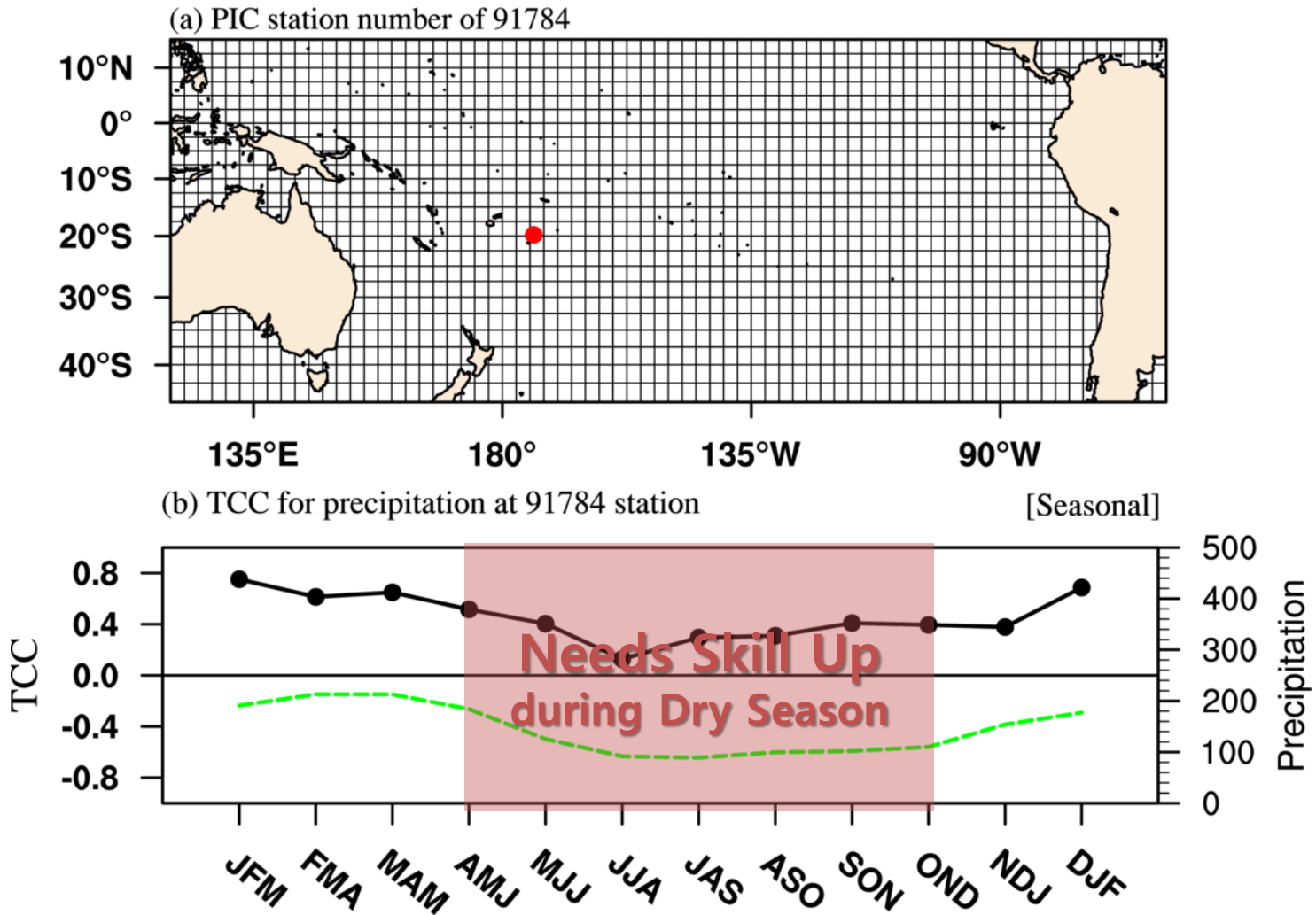
On March 2017.

Climate

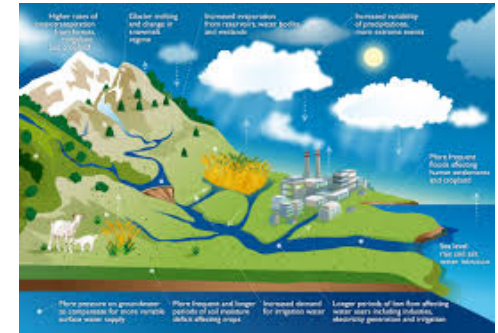
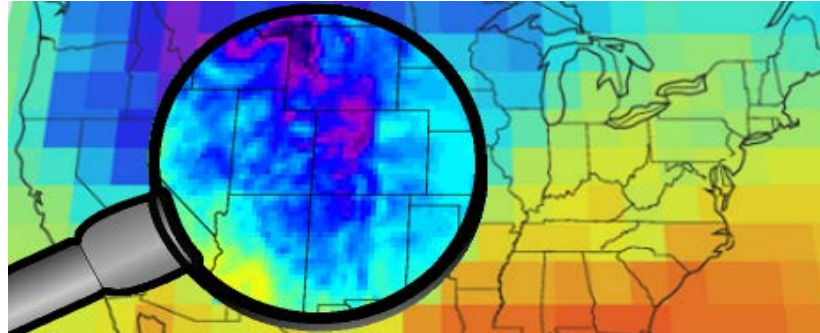
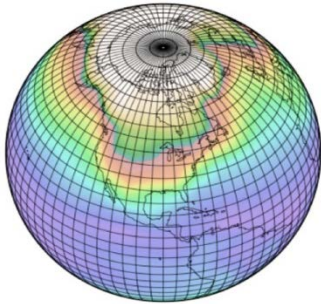
II Seasonal Forecasting



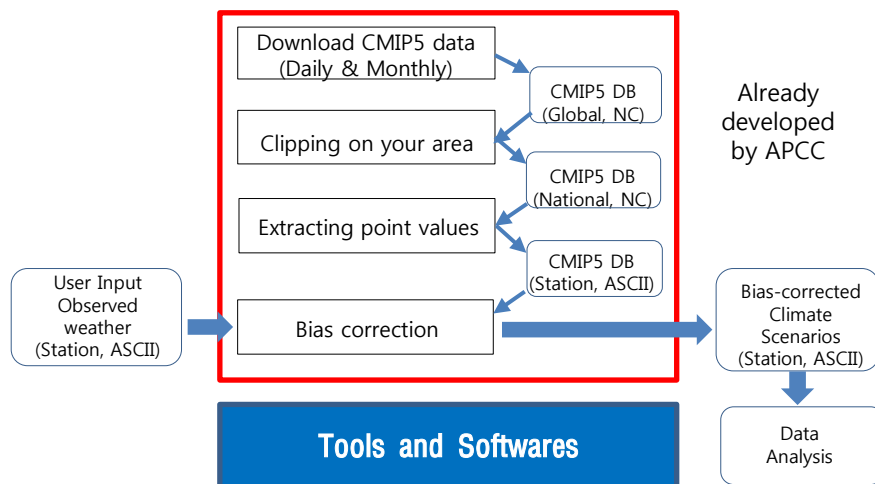
Seasonal Forecast Skill (@ PIC Project in APCC)



Statistical Downscaling (@ Dr. Jaepil Cho)



- Downscaling of Climate Change Scenarios using **rcmip5** package
- Downscaling of Seasonal Forecast using **sforecast** package

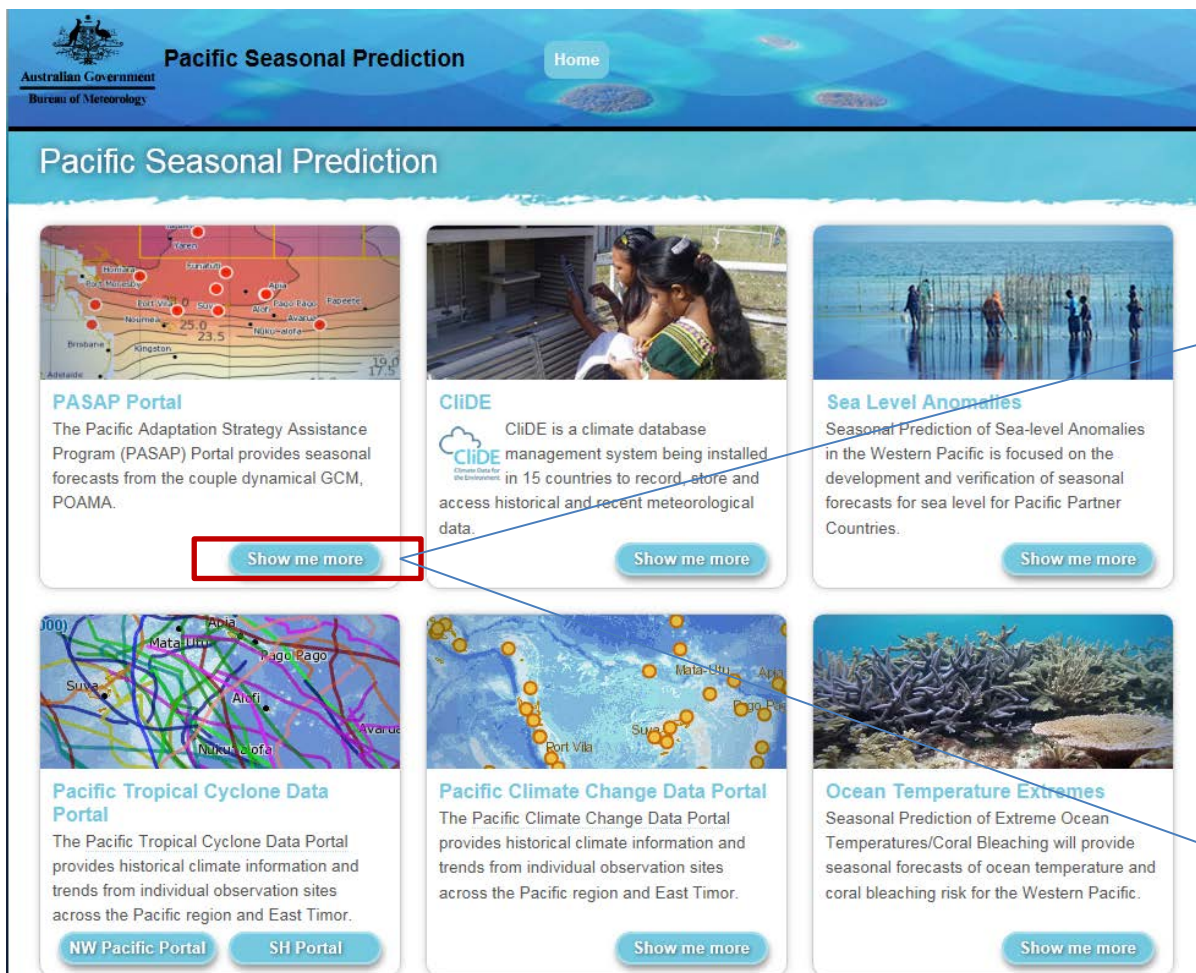


- Temporal downscaling

```

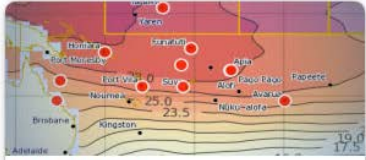
sforecast_real_time_run.R
Source on Save
Run
Source
1 # Setting working environment
2 EnvList = Set.Working.Environment (basedir="D:/APCC_TP_SDM_Aug2016/2Cho/SForecast",
3 prjname = "Vietnam", envfile = "Vietnam.txt")
4 # Update required climate information
5 Update.Climate.Information (EnvList, updatemode = T)
6
7 # Real-time forecast
8 Run.RealTime.Forecast.Model (EnvList, fiyearmon = "2016-07")
9
10 # Temporal downscaling
11 Daily.Hourly.Sampling (EnvList, fiyearmon = "2016-06", smplmoncnt=3)
  
```

Station Outlook (@ Pacific Seasonal Prediction)



Pacific Seasonal Prediction
Home

Pacific Seasonal Prediction



PASAP Portal
The Pacific Adaptation Strategy Assistance Program (PASAP) Portal provides seasonal forecasts from the couple dynamical GCM, POAMA.

Show me more



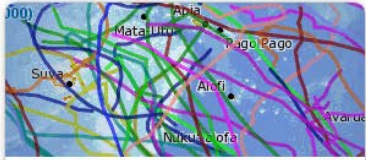
CLiDE
CLiDE is a climate database management system being installed in 15 countries to record, store and access historical and recent meteorological data.

Show me more



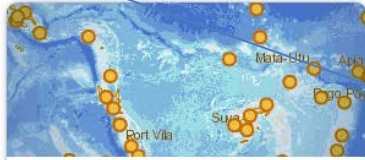
Sea Level Anomalies
Seasonal Prediction of Sea-level Anomalies in the Western Pacific is focused on the development and verification of seasonal forecasts for sea level for Pacific Partner Countries.

Show me more



Pacific Tropical Cyclone Data Portal
The Pacific Tropical Cyclone Data Portal provides historical climate information and trends from individual observation sites across the Pacific region and East Timor.

NW Pacific Portal SH Portal



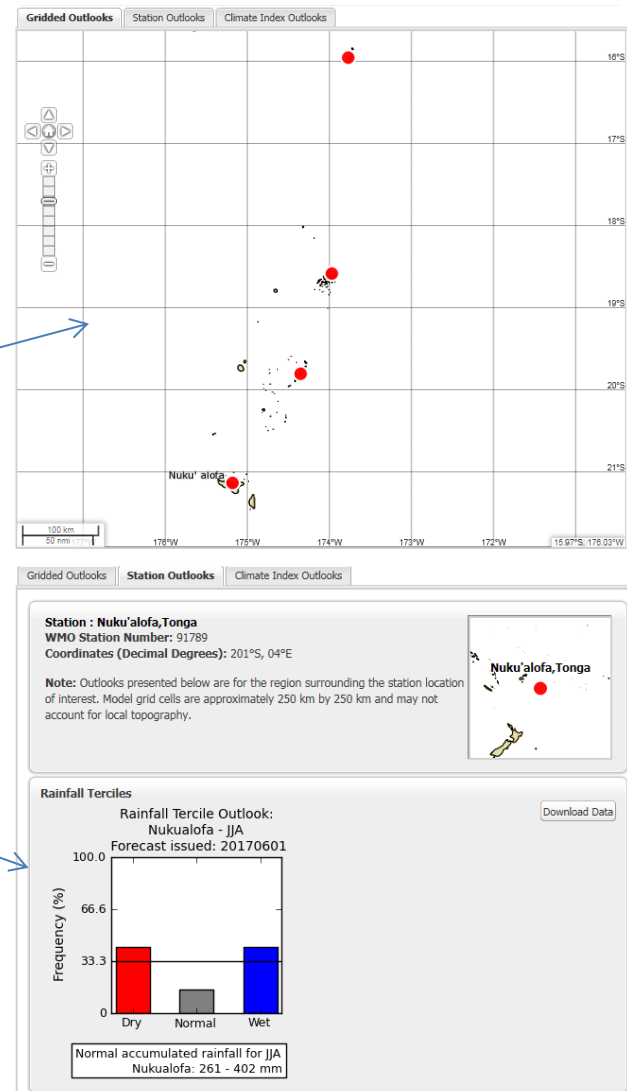
Pacific Climate Change Data Portal
The Pacific Climate Change Data Portal provides historical climate information and trends from individual observation sites across the Pacific region and East Timor.

Show me more



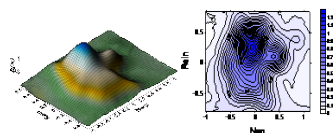
Ocean Temperature Extremes
Seasonal Prediction of Extreme Ocean Temperatures/Coral Bleaching will provide seasonal forecasts of ocean temperature and coral bleaching risk for the Western Pacific.

Show me more

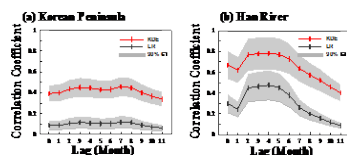


1 Mutual Information

J-PDF using Kernel



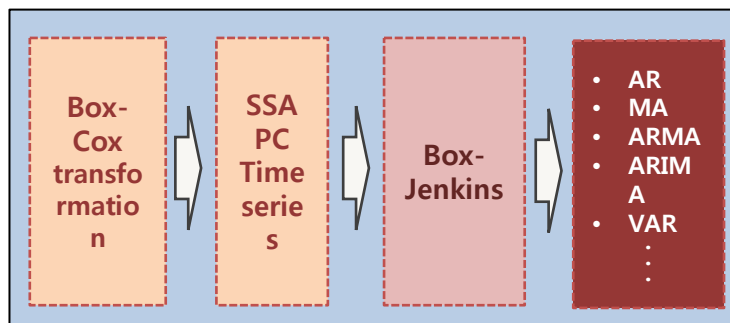
Lag Time Correlations



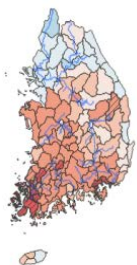
2 Original data

- ① Rainfall
- ② Nino 3.4
- ③ N_{CT} index
- ④ N_{WP} index

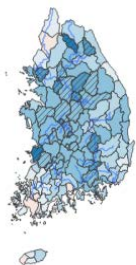
3 Statistical time series forecasting model



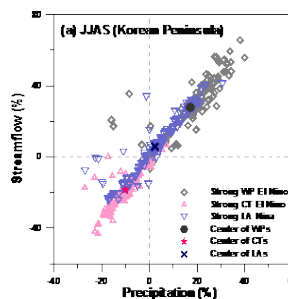
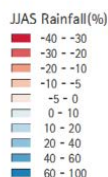
(a) CT El Nino years



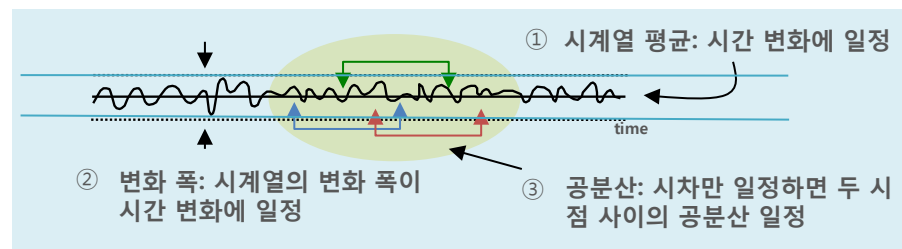
(b) WP El Nino years



(c) La Nina years

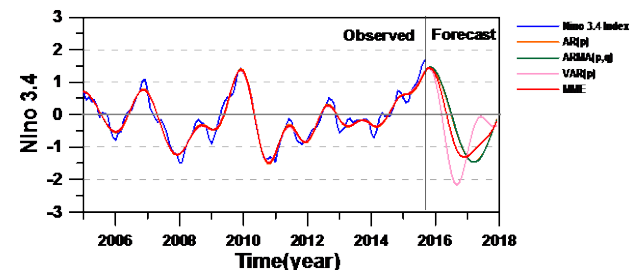
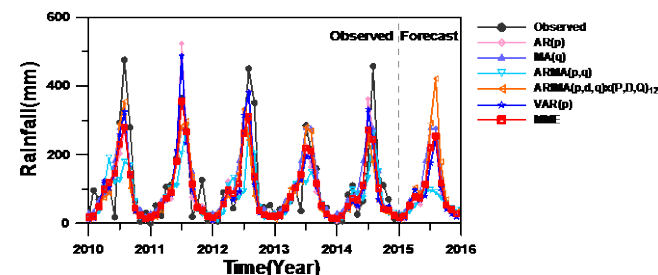


* Time Series Stationary Process



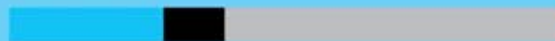
4 Monthly Forecasting

Rainfall, ENSO, APCC MME Forecast



Water

III Water Resources Forecasting and Risk Assessment



Status of Tonga and its Water Resources

Source: (<http://www.pacificwater.org/pages.cfm/country-information/tonga.html>)

Tonga

Home > Country Information > Tonga

Geography

Total Area	748 km ²
Land	718 km ²
Water	30 km ²
Highest Elevation	1,033 m

Land Use

Arable	20%
Perm. Crop	14.67%
Other	65.33% (2005)

People

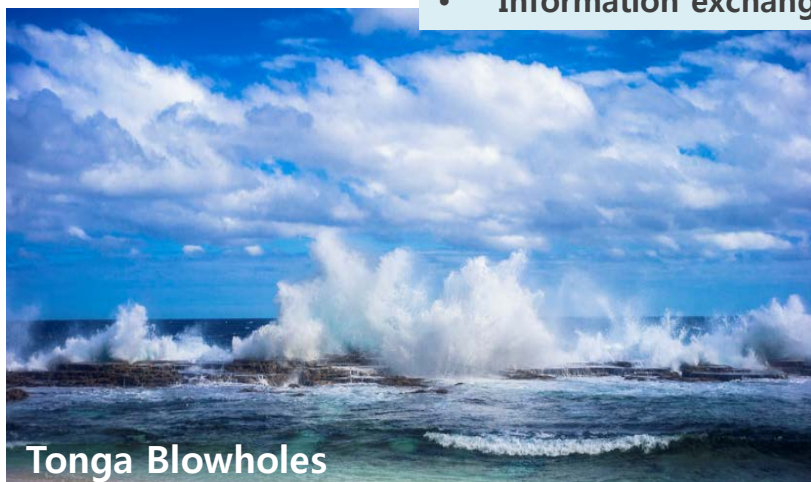
Population	116,921 (July 2007 est.)
Population Growth Rate	1.847% (July 2007 est.)

Economy

GDP per capita (PPP)	\$2,200 (2005 est.)
----------------------	---------------------

Water Statistics

Avg Rainfall	Varies from north to south of Tonga with an estimated average of 2500 mm per annum
--------------	--

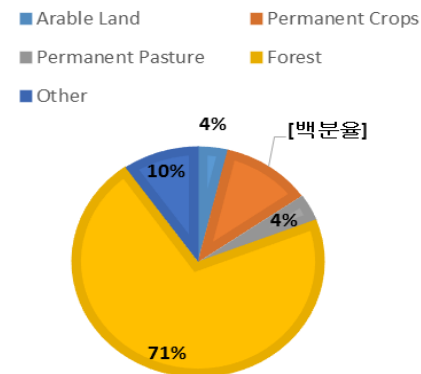


Tonga Blowholes

Problems with Water Resources

- Wastewater management and pollution control
- Information exchanges on water resources

LAND USE



Source of Water	Drinking water coverage estimates					
	Urban (%)		Rural (%)		Total (%)	
	1990	2015	1990	2015	1990	2015
Piped onto premises	--	73	--	80	--	78
Other improved source	97	100	99	100	99	100
Other unimproved	3	0	1	0	1	0
Surface water	--	0	--	0	--	0

Water Project Overview



❖ Project Outline

- Title : Water Resources Forecasting and Risk Assessment in the Kingdom of Tonga
- Partner country : Kingdom of TONGA
- Period : Jan. 2017 ~ Dec. 2017 (12 months)
- Potential Participants : APCC, Dong-a Univ., Hydronet(Univ. of Seoul)

❖ Technical Road Map (TRM)

1st (2016-year)

Installing, GW Modeling, and Web GIS-based Monitoring System



2nd (2017-year)

Extending Web-based System and Developing GW Seasonal Forecasting System



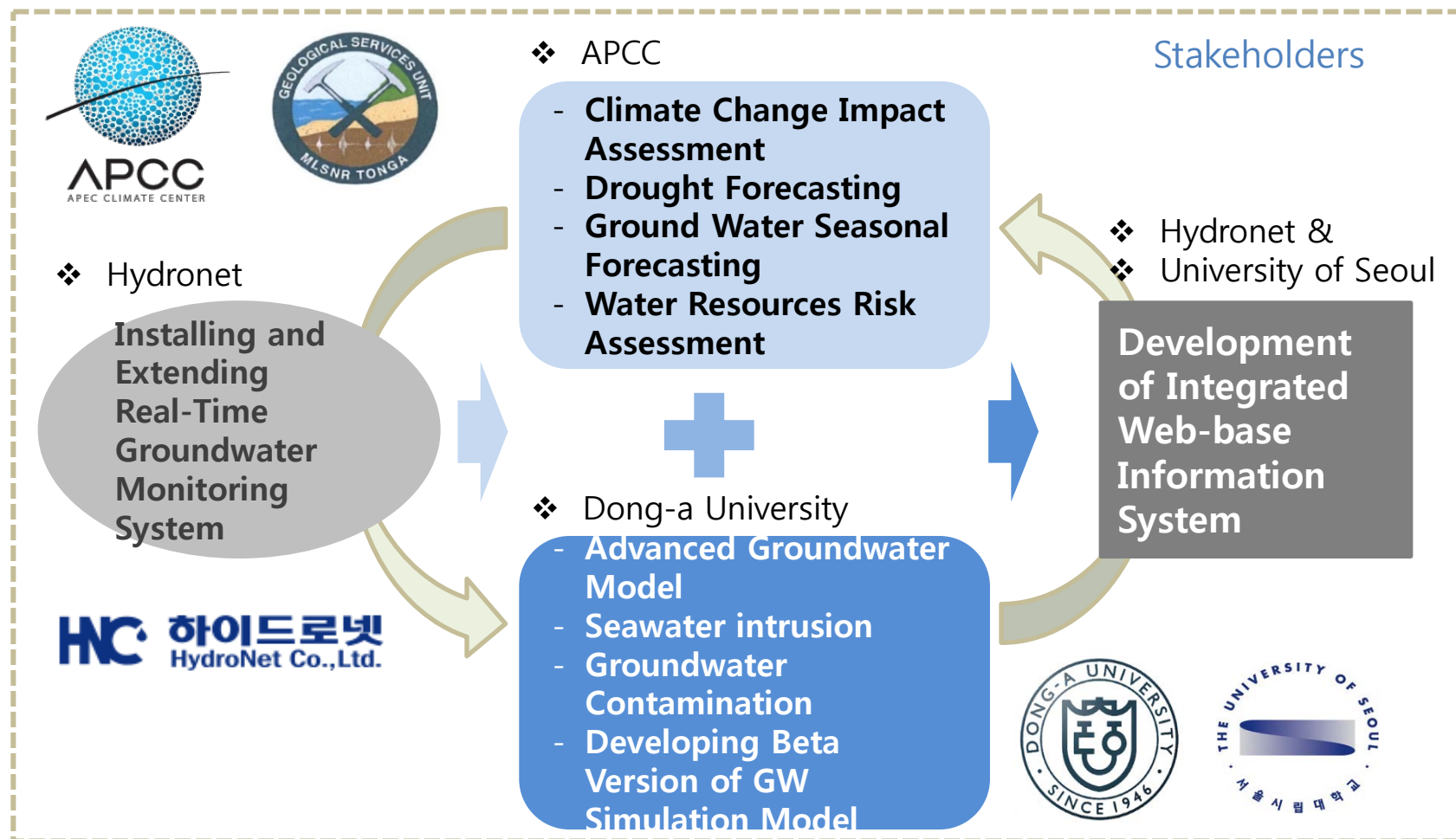
3rd (2018-year)

Development of Smart Tonga Water Information System & Funding from KOICA



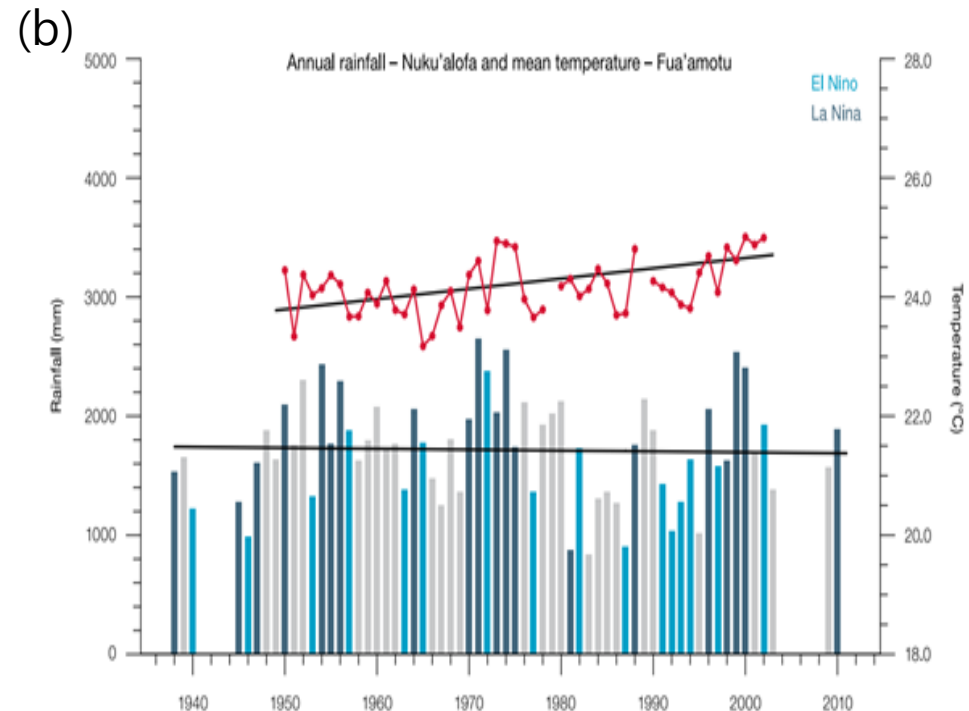
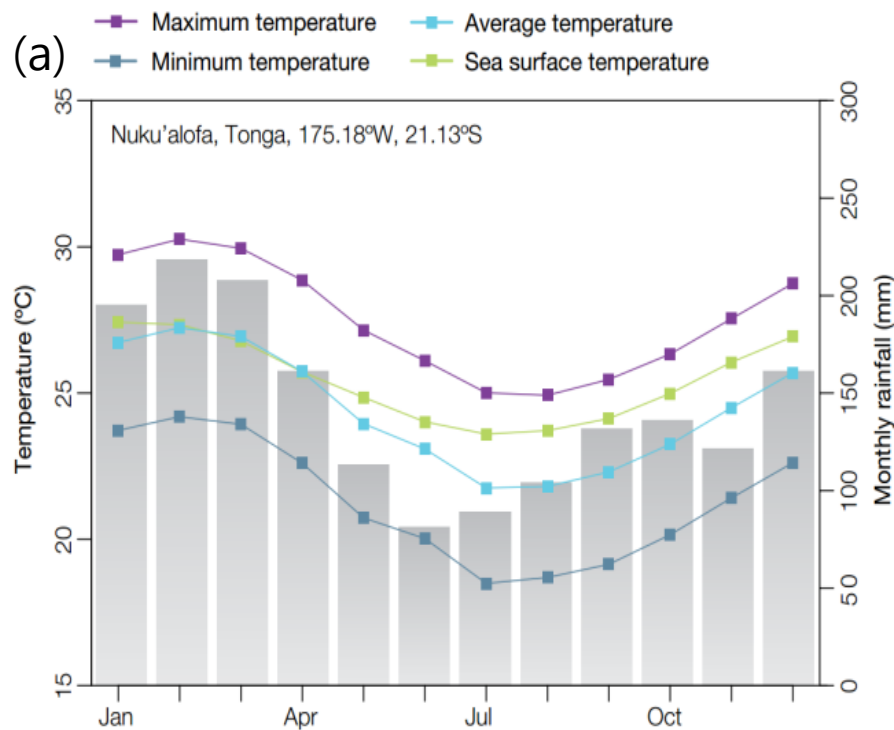
2017 Tonga Water Project Design

APCC+Tonga MLSNR(Ministry of Lands, Survey and Natural Resources)



Climate: Historical Observed Data

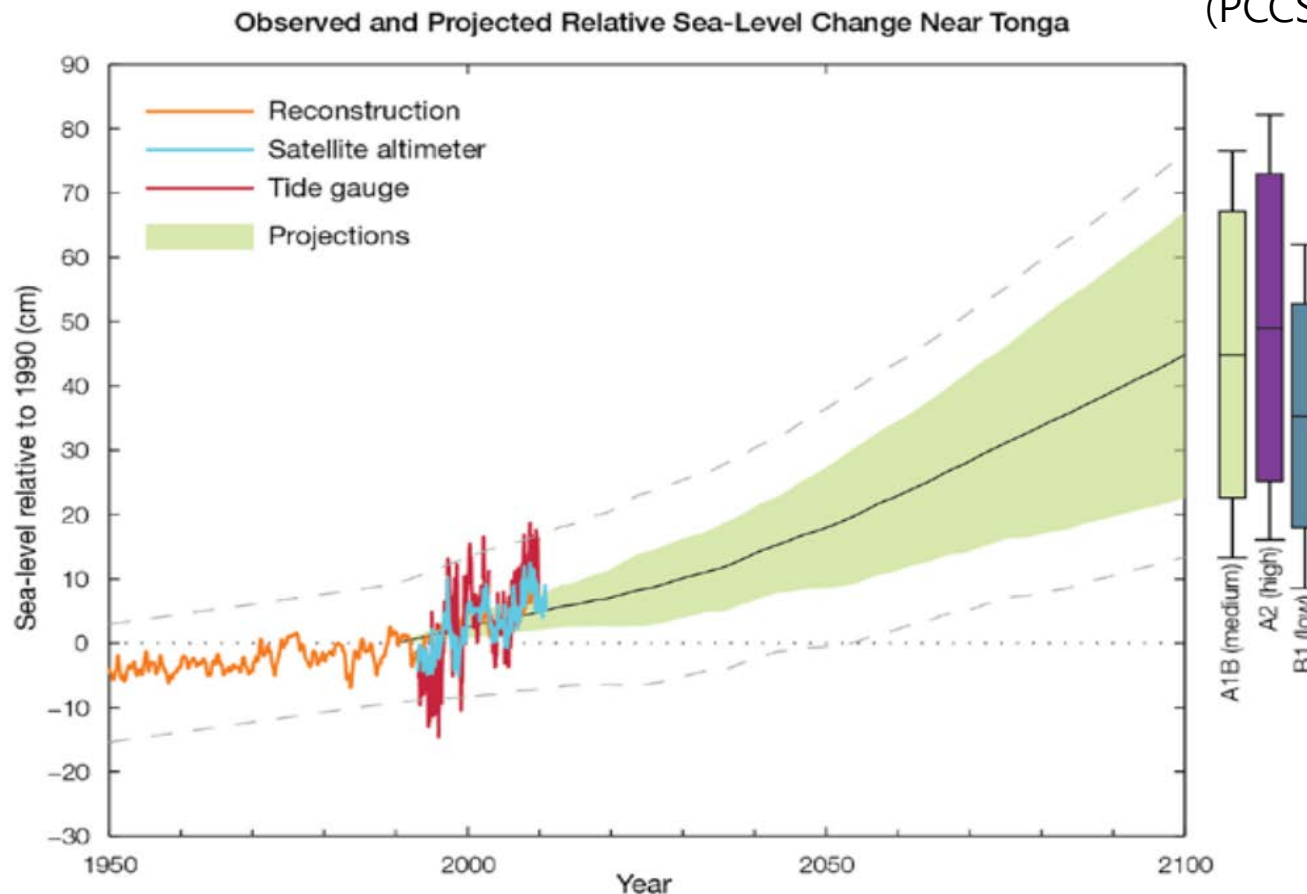
(a) Shows seasonal variability of rainfall and temperature, and (b) shows variation of annual rainfall and temperature during El Niño and La Niña in Tongatapu. (PCCSP, 2014)

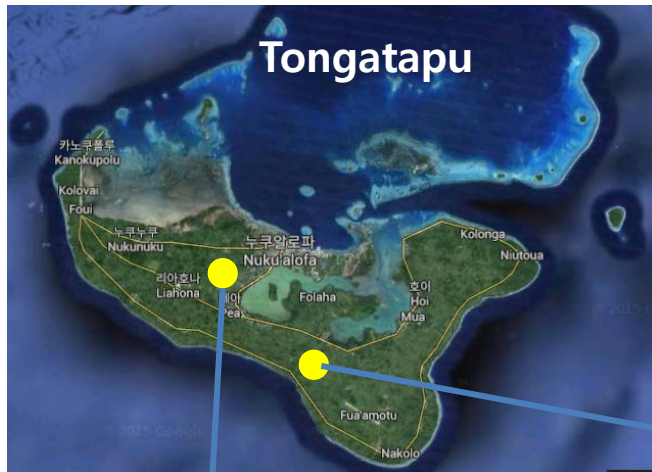


Sea Level Rise under Climate Change

Observed and Projected relative sea level change

(PCCSP, 2014)





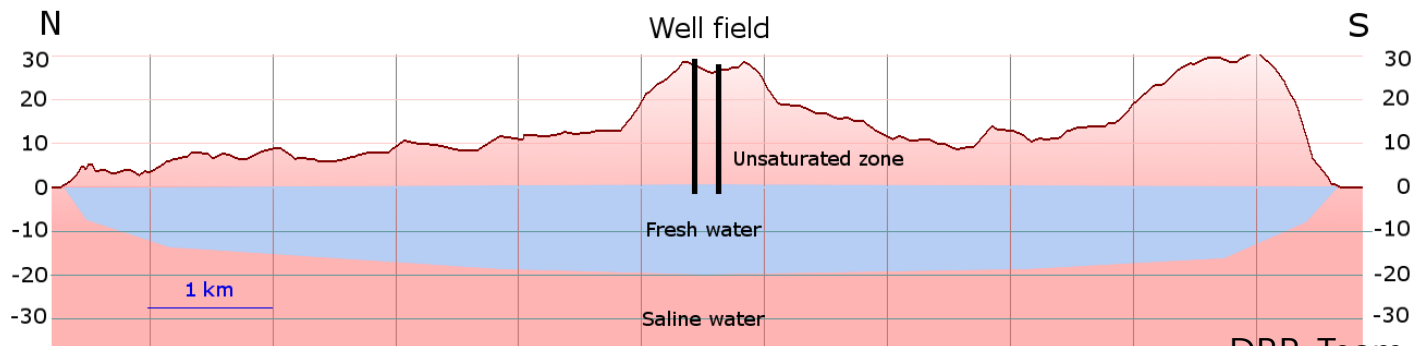
Picture of the exposed limestone aquifer in a quarry 5 km south-east of the Matakī'eua well field

Soil mantle of variable thickness developed in volcanic ash deposits

Underground Water

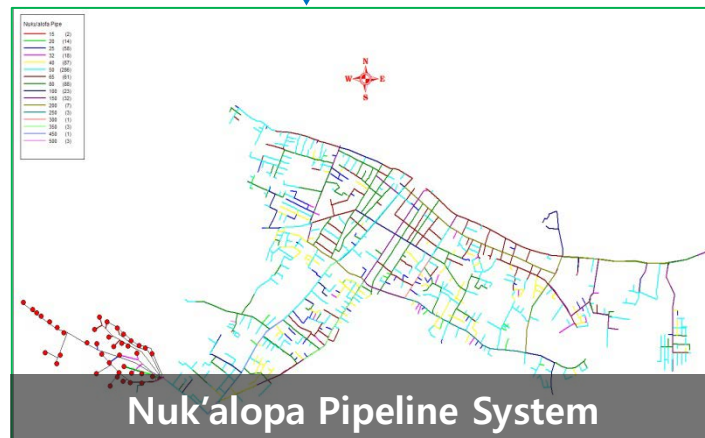
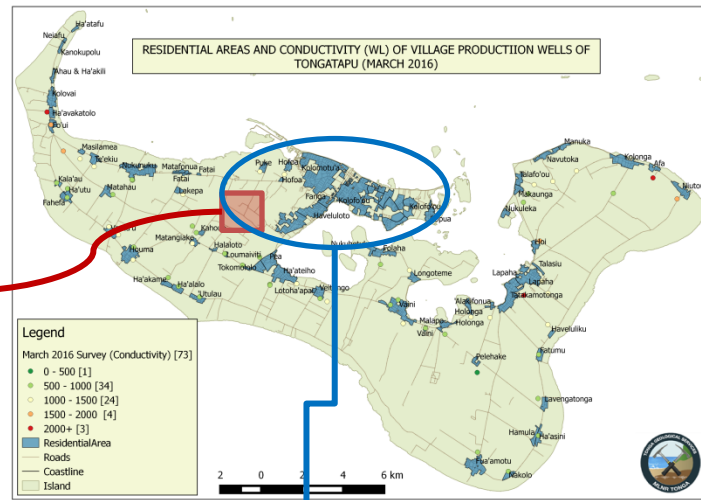


Location of a North-South elevation profile through the Matakī'eua public water supply well field area



Tonga Urban & Rural Water Distribution System

Urban

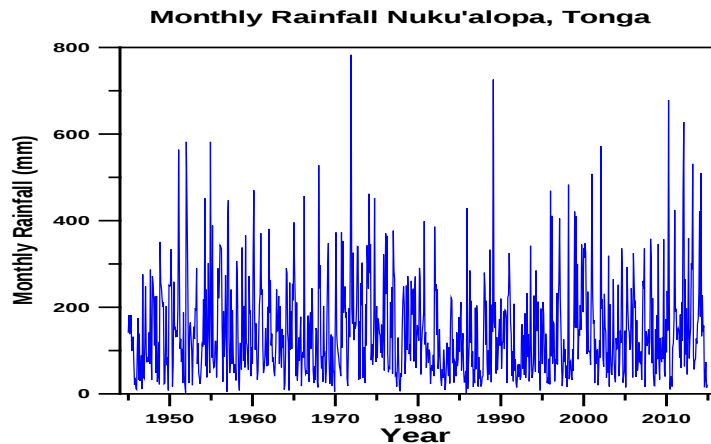


Rural

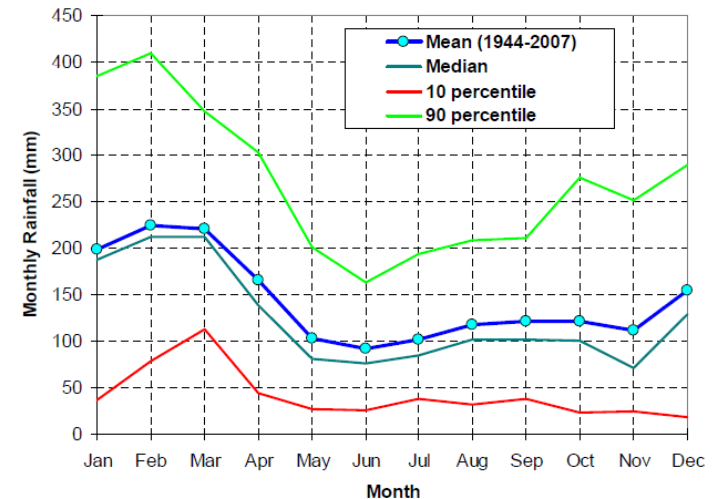


Rainfall Pattern in Tongatapu

➤ Monthly Rainfall in Tonga



Seasonal Rainfall Patterns, Tongatapu, Tonga

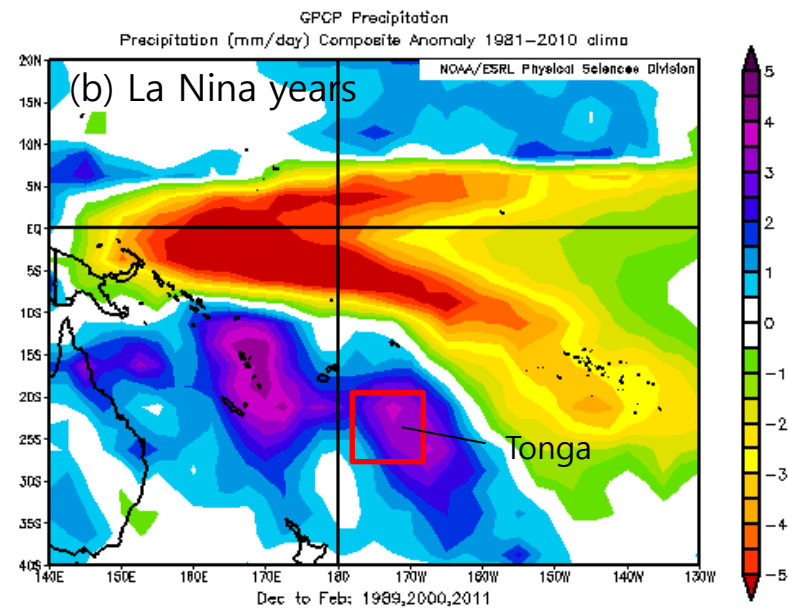
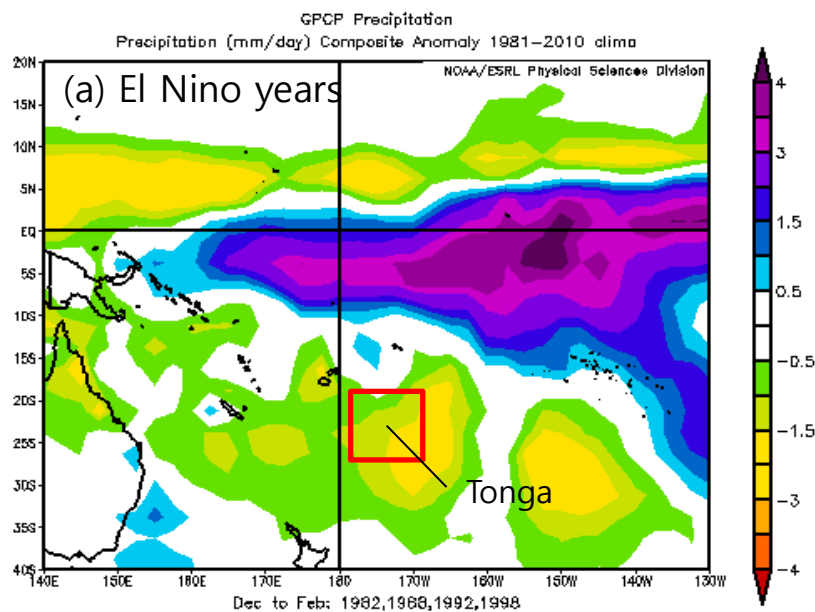


Meteorological Stations in Tonga

Stations	Latitude	Longitude	Station Elevation (m)	Adress
Niuafo'ou (3088)	-15.57	-175.6	60	Niuafo'ou
Niuatoputapu (3089)	-15.93	-173.77	2	Niuatoputapu
Vava'u (3091)	-18.58	-173.97	9	Vava'u
Ha'apai (3092)	-19.8	-174.35	4	Ha'apai
Nuku'alofa (3098)	-21.13	-175.18	2	Nuku'alofa, Tongatapu
Fua'amotu (3097)	-21.25	-175.14	38	Fua'amotu, Tongatapu

GPCP Precipitation in Tonga

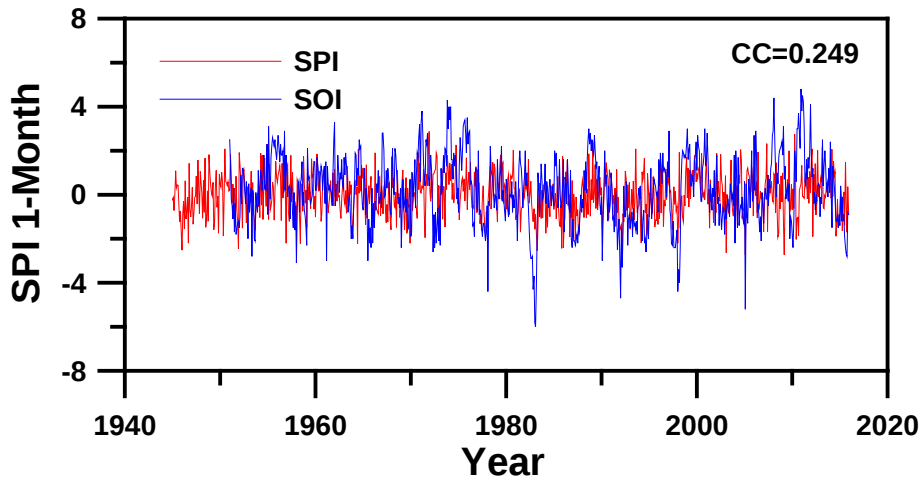
➤ ENSO teleconnection



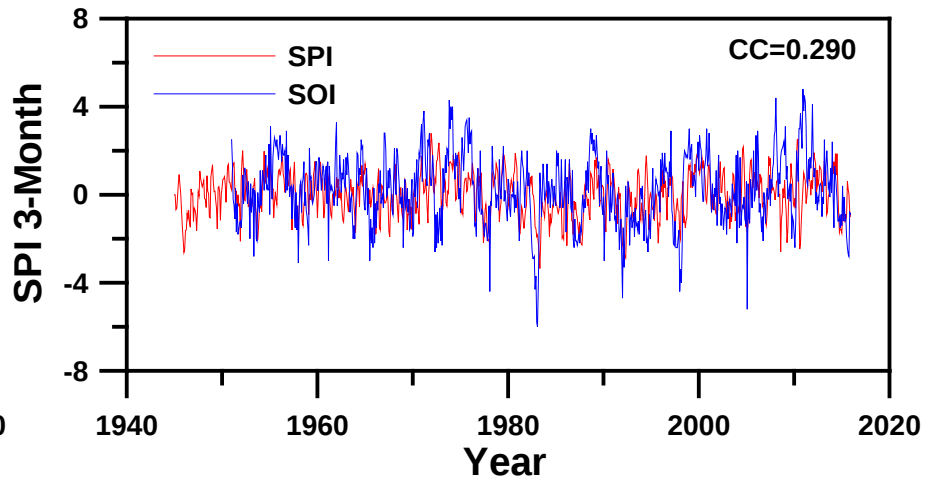
SPI Drought

➤ SPI (Standardized Precipitation Index)

Nuku'alopa (Station #3098), Tonga



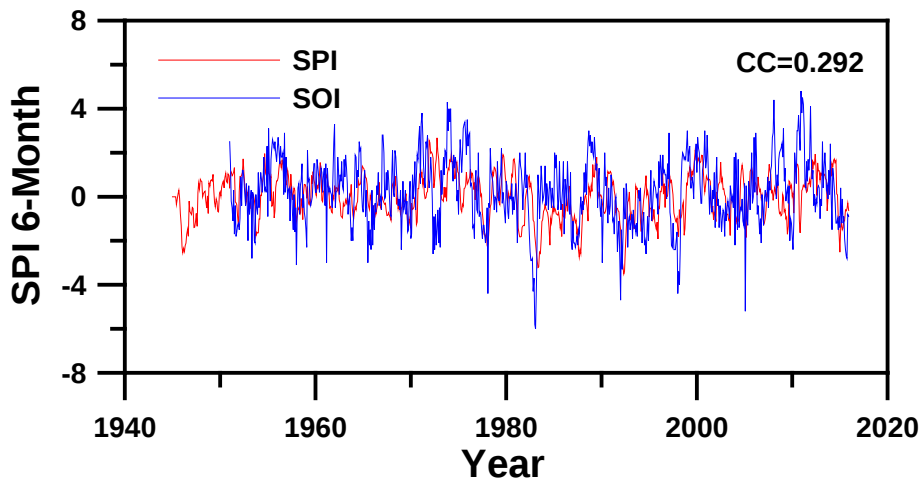
Nuku'alopa (Station #3098), Tonga



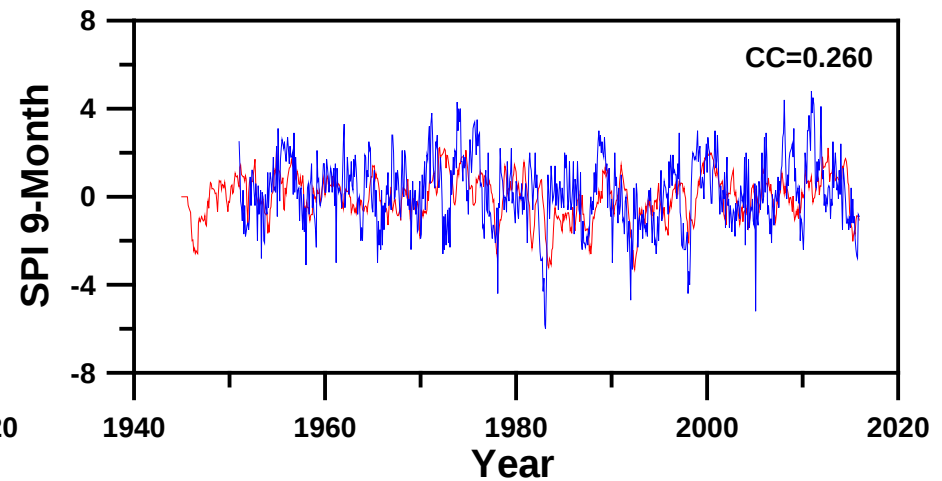
SPI Drought

➤ SPI (Standardized Precipitation Index)

Nuku'alopa (Station #3098), Tonga



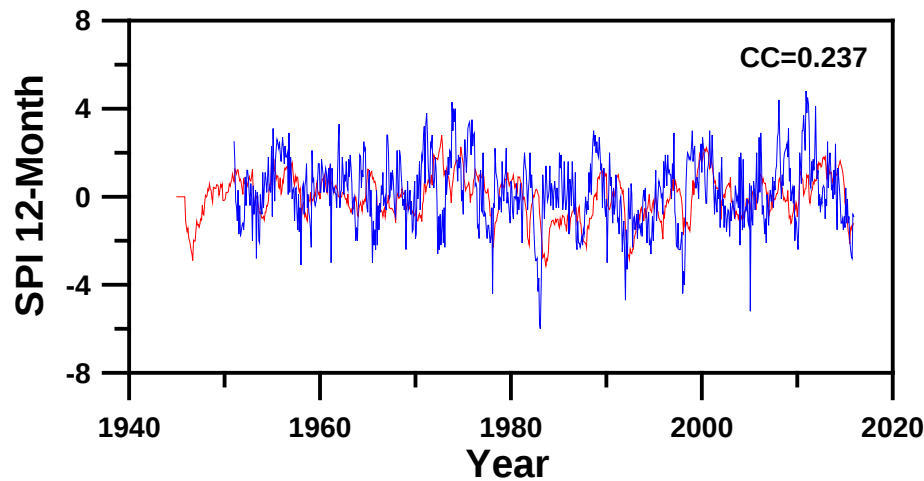
Nuku'alopa (Station #3098), Tonga



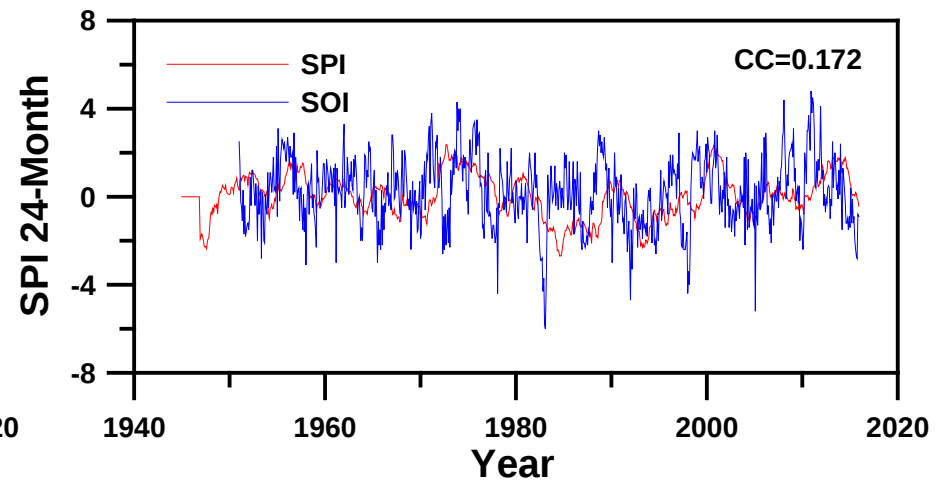
SPI Drought

➤ SPI (Standardized Precipitation Index)

Nuku'alopa (Station #3098), Tonga

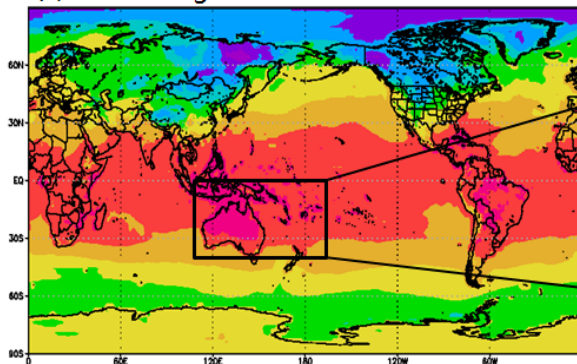


Nuku'alopa (Station #3098), Tonga

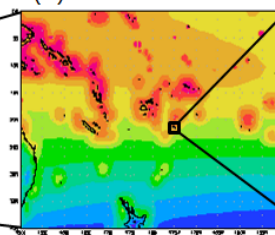


Climate Change in Tongatapu

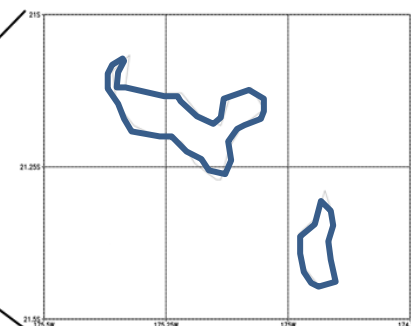
(a) Global region



(b) Pacific Islands



(c) Tonga region

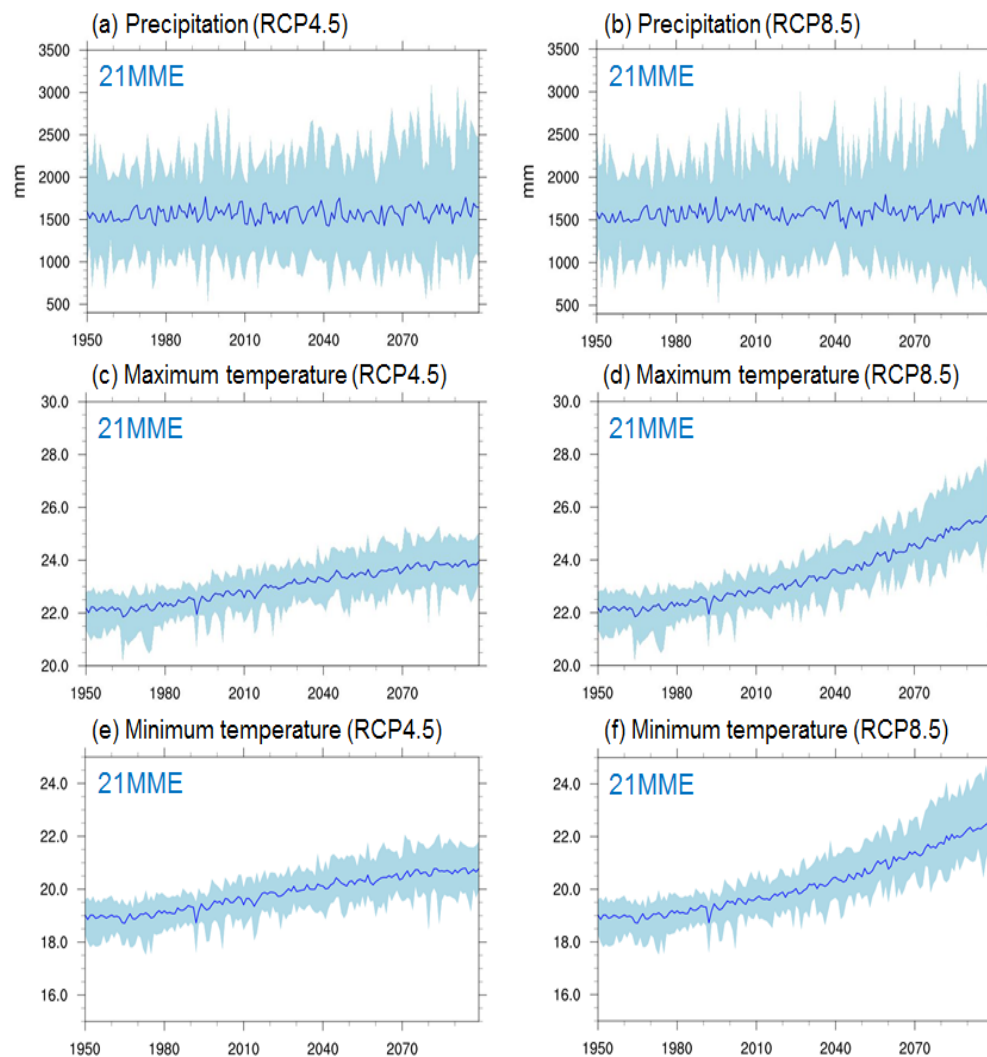


25kmX25km Grid Matrix

No.	Model Name	No.	Model Name
1	ACCESS1-0	12	INMCM4
2	BCC-CSM1-1	13	IPSL-CM5A-LR
3	BNU-ESM	14	IPSL-CM5A-MR
4	CanESM2	15	MIROC-ESM
5	CCSM4	16	MIROC-ESM-CHEM
6	CESM1-BGC	17	MIROC5
7	CNRM-CM5	18	MPI-ESM-LR
8	CSIRO-MK3-6-0	19	MPI-ESM-MR
9	GFDL-CM3	20	MRI-CGCM3
10	GFDL-ESM2G	21	NorESM1-M
11	GFDL-ESM2M		

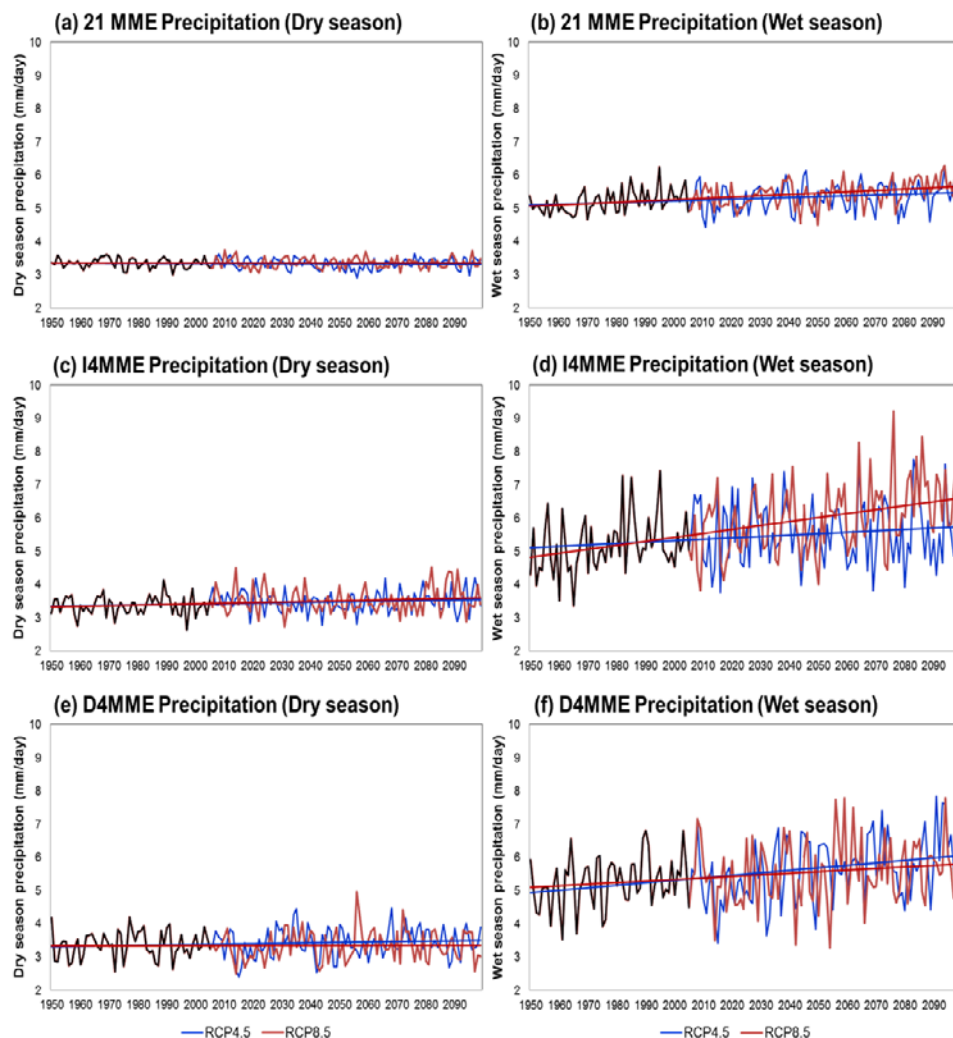
Climate Change in Tongatapu

Time series of (a, b) precipitation, (c, d) maximum and (e, f) minimum temperature during historical and RCP 4.5 (left panels) and RCP 8.5 (right panels). Blue solid line is 21 MME(Multi-Model Ensemble) and shaded sky blue area is range from minimum to maximum among 21 models.



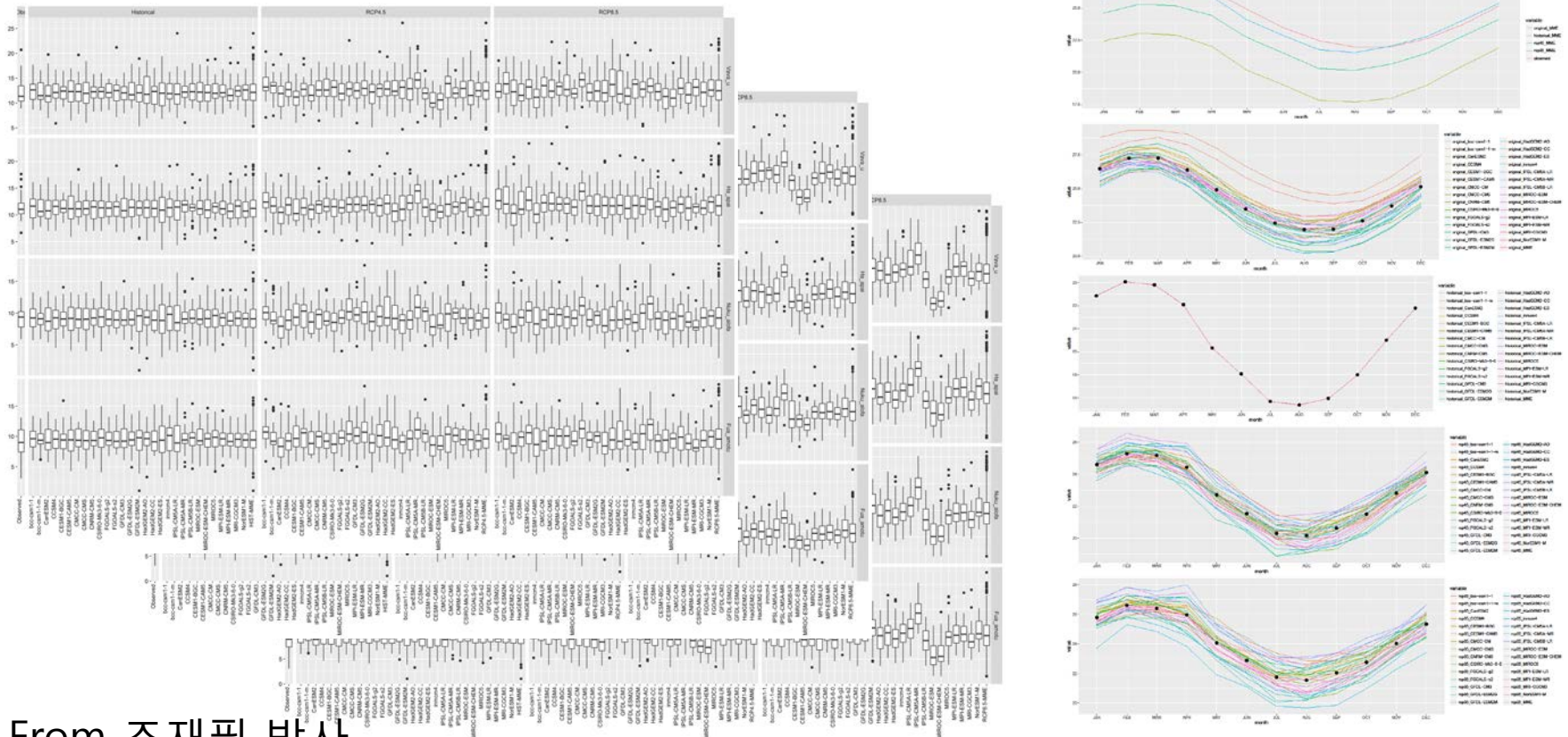
Climate Change in Tongatapu

Time series of precipitation of historical and RCP scenarios averaged among (a),(b) 21MME, (c),(d) I4MME and (e),(f) D4MME, respectively. Black solid line is historical variation, blue and red lines are for RCP 4.5 and 8.5 scenario.



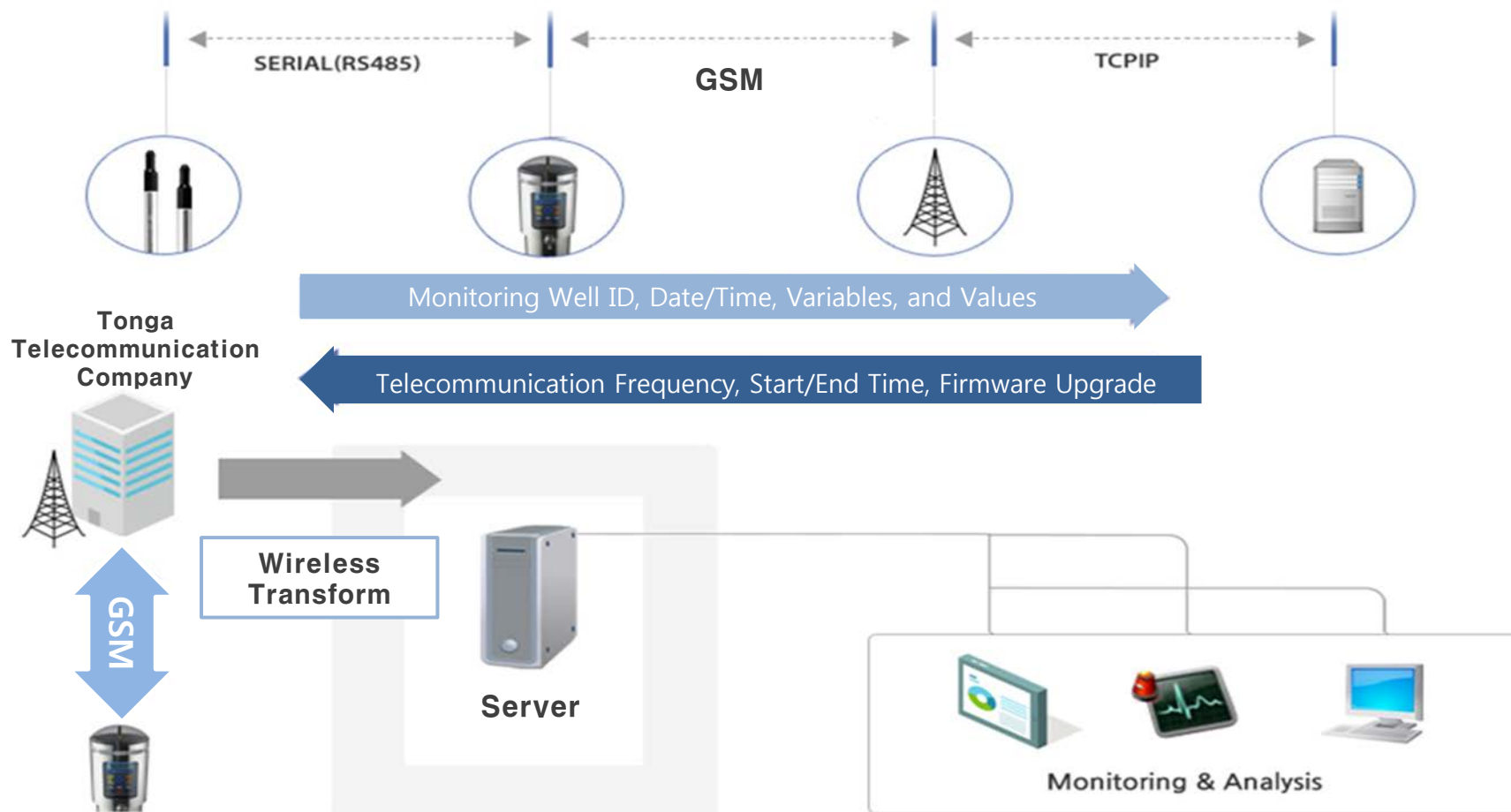
Downscaing in Tongatapu: *rcmip5*

- Index: 1Day Max, 80mm/d, JJAS, Max Dry Day, ONDJFMAM, P-Intensity
- Period: 2010-2039, 2010-2099, 2040-2069, 2050-2099
- 30 GCMs, 4 Stations



Real-Time Groundwater Monitoring System

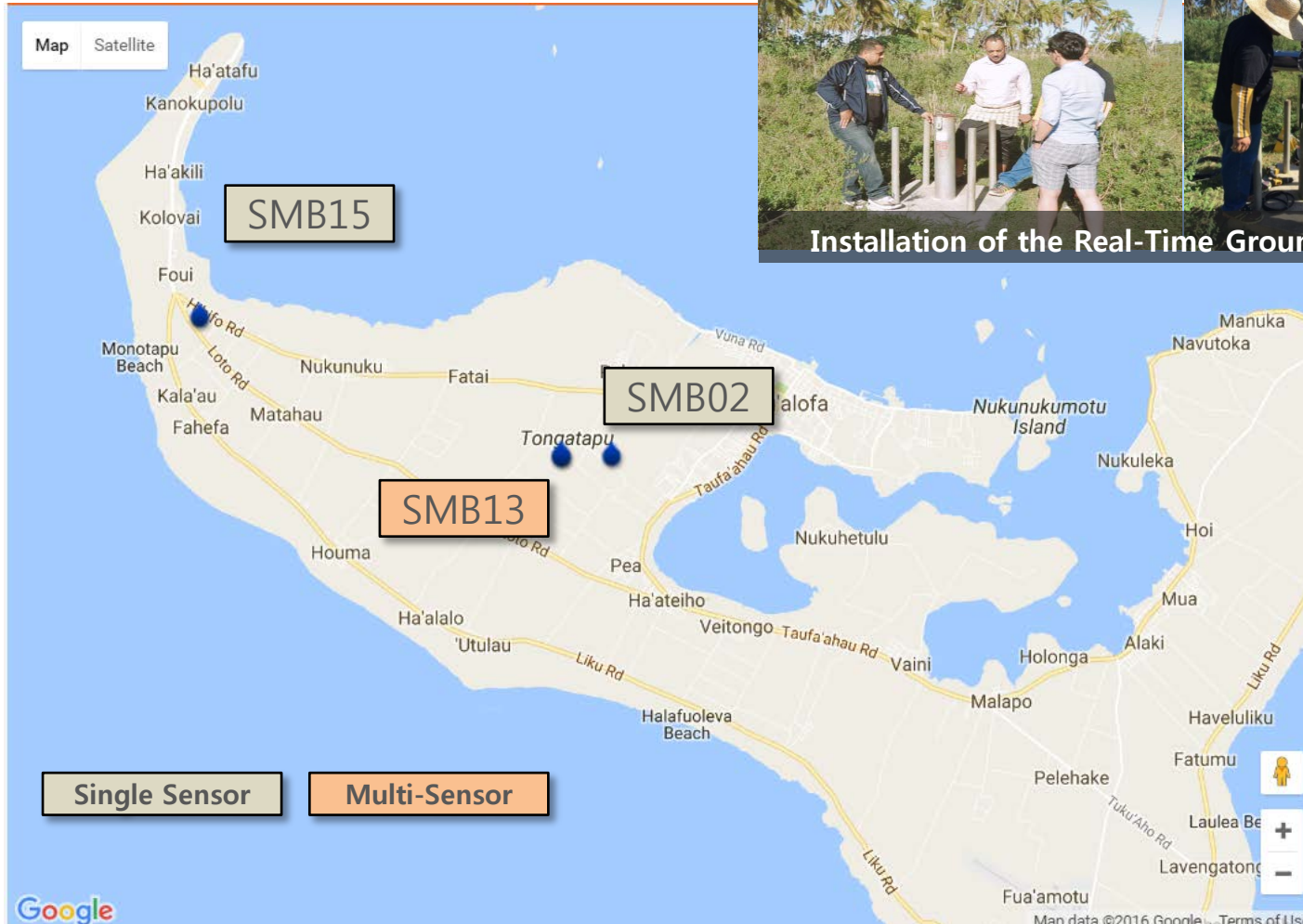
Wireless Telecommunication System for Real-Time Groundwater Monitor

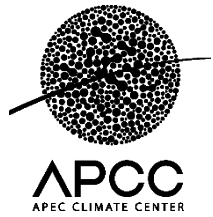




GW Monitoring System

Installed Groundwater Monitoring System

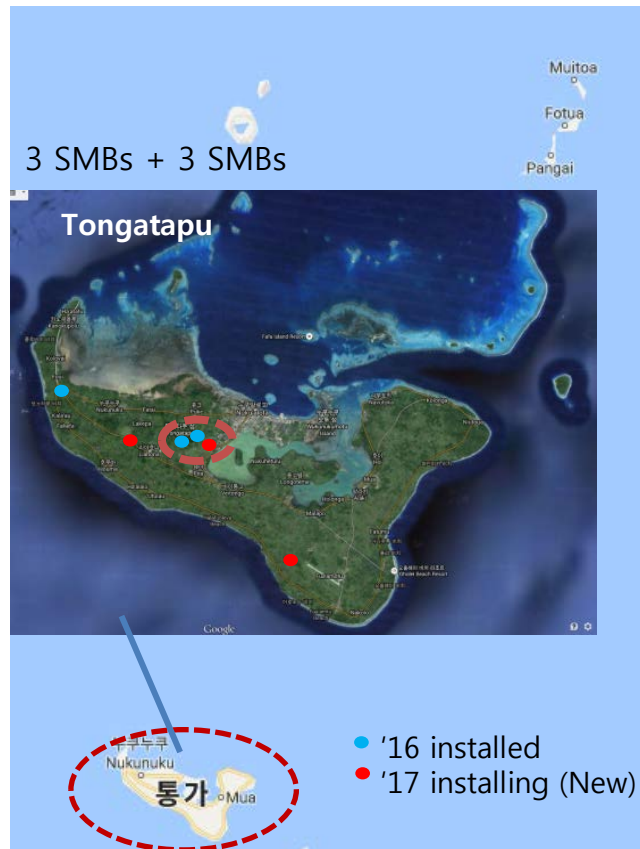




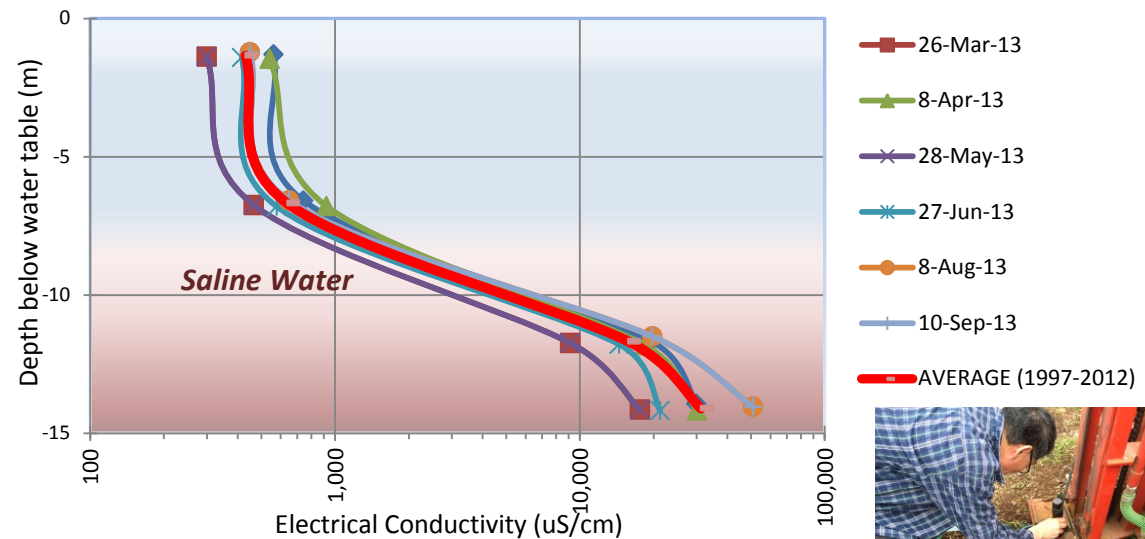
GW Monitoring System

Extending Groundwater Monitoring System

Data collection at SMB(Salinity Monitoring Borehole) locations and groundwater field survey in Tongatapu



SMB1 Monitoring Results



Real-Time Groundwater Monitoring System

Sensor



Water Level (depth),
Temperature, Electrical
Conductivity (EC), Flash
Memory (4Mbyte),
Internal Lithium Battery

Data Logger

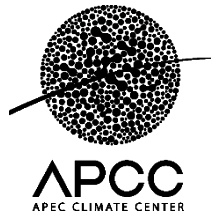


High performance, Low
Power Consumption, LCD
Monitoring System, and
Inner Battery (14.4V Lithium
19Ah)

STU-CAP



Solar Charging Device,
Wireless Communication,
Saving Space, and
Comport Install and
Maintain System

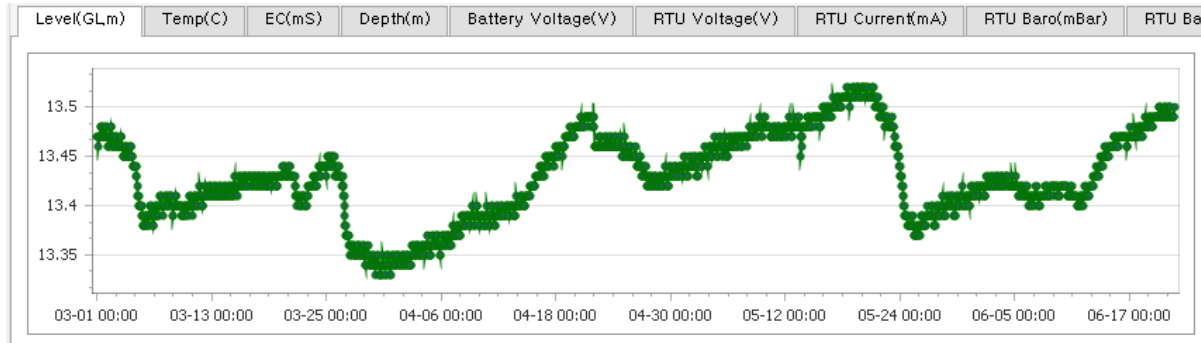


GW Monitoring System

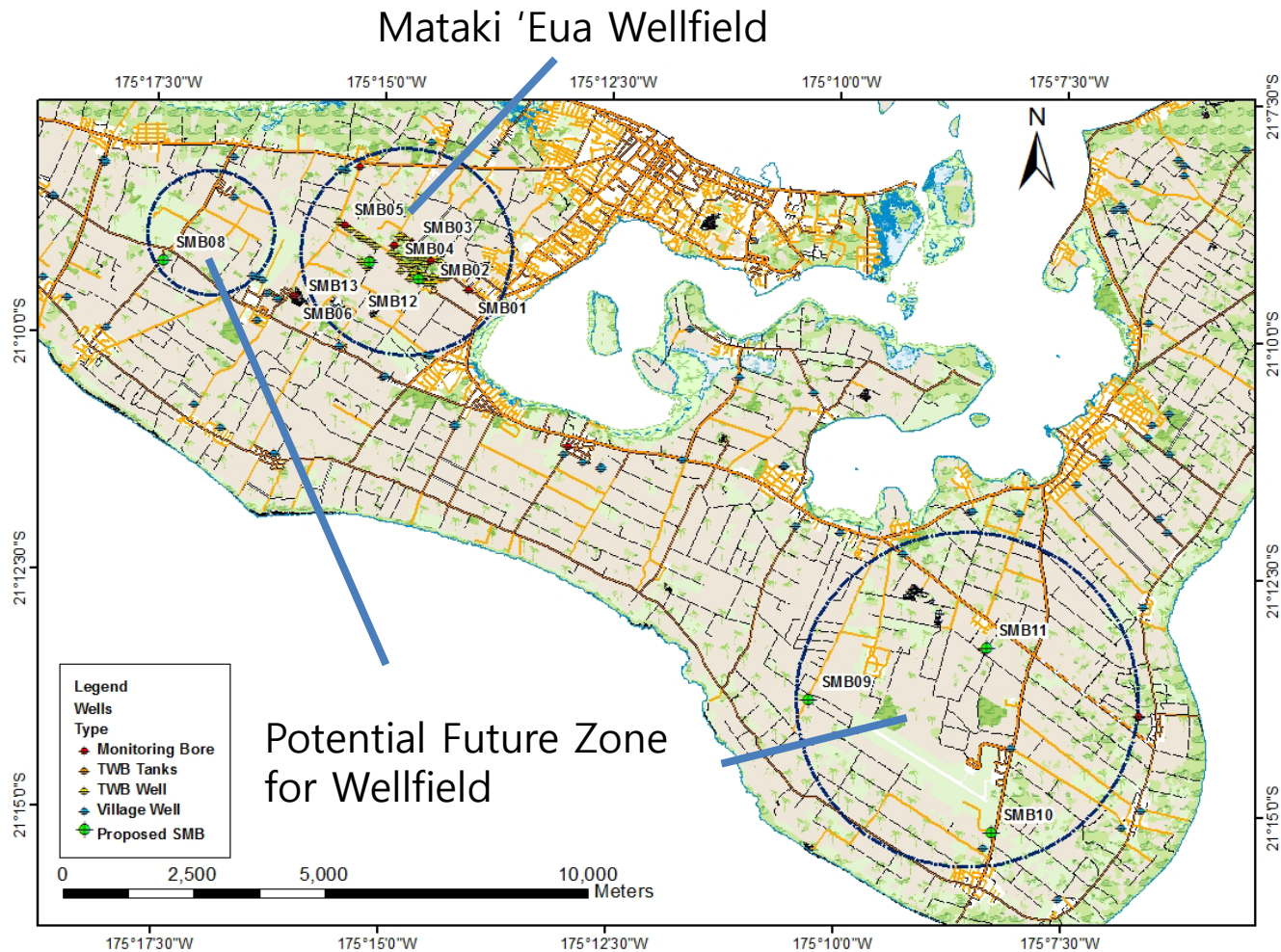
Real-Time Groundwater Monitoring System



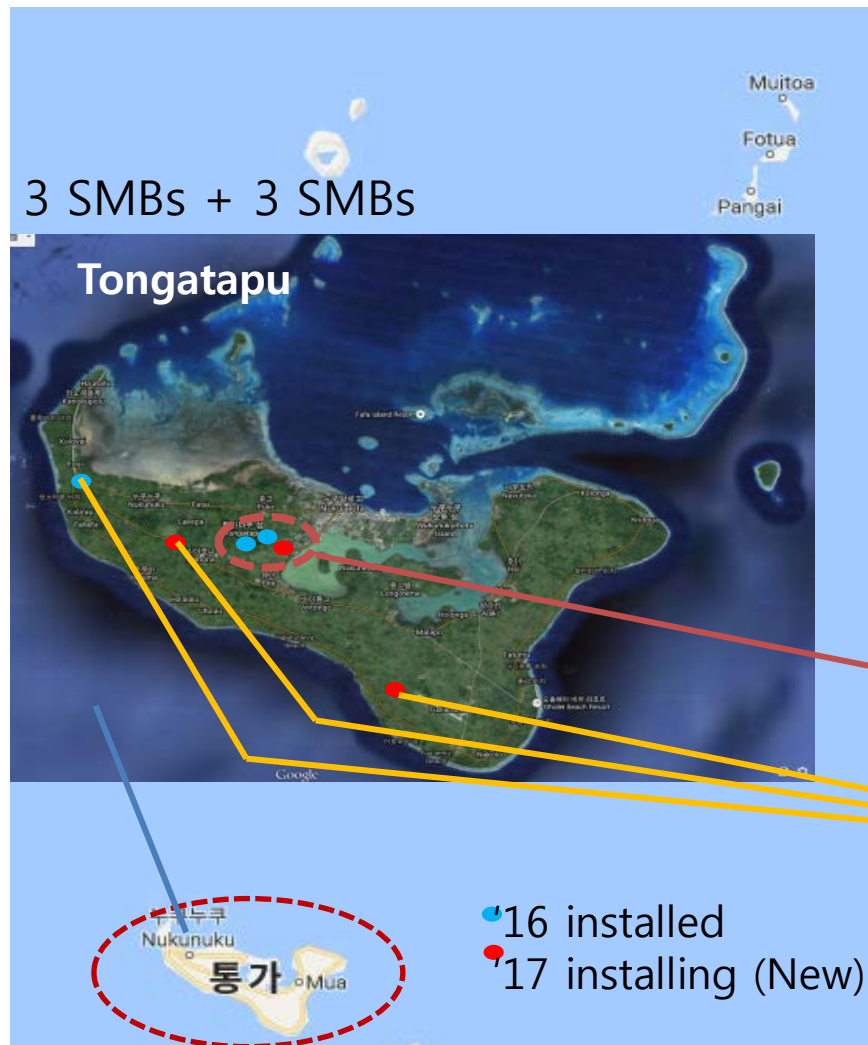
SMB02 Site



Potential Future Zone for Wellfield



Locations of Data Loggers and Sensors



TOTAL

- 6 SMBs
- 6 Data Loggers
- 9 Sensors

Multi-Sensors

Single Sensors

Real-Time Groundwater Monitoring System

Data Loggers installed in 2016

SMB 02	SMB 13	SMB 15
beside pump station 105, Mataki'eua	Next to pump station 313	Middle of Hihifo well field
		
Tube No. 3 / Tube No. 4	Tube No. 3 / Tube No.4	Tube No. 2

Tel. +676-841-5229

Tel. +676-841-5231

Tel. +676-841-5230

* In the middle of screen slot in each tube, the sensor is located.

Real-Time Groundwater Monitoring System

Data Loggers installed in 2017

SMB 01	SMB 08	SMB 09
South side of track between Matakieu and Fanga'uta Lagoon	Houma, Vaea Road	Toloa-End of Airport Runway
		
Tube No. 2 / Tube No. 3	Tube No. 5	Tube No. 4

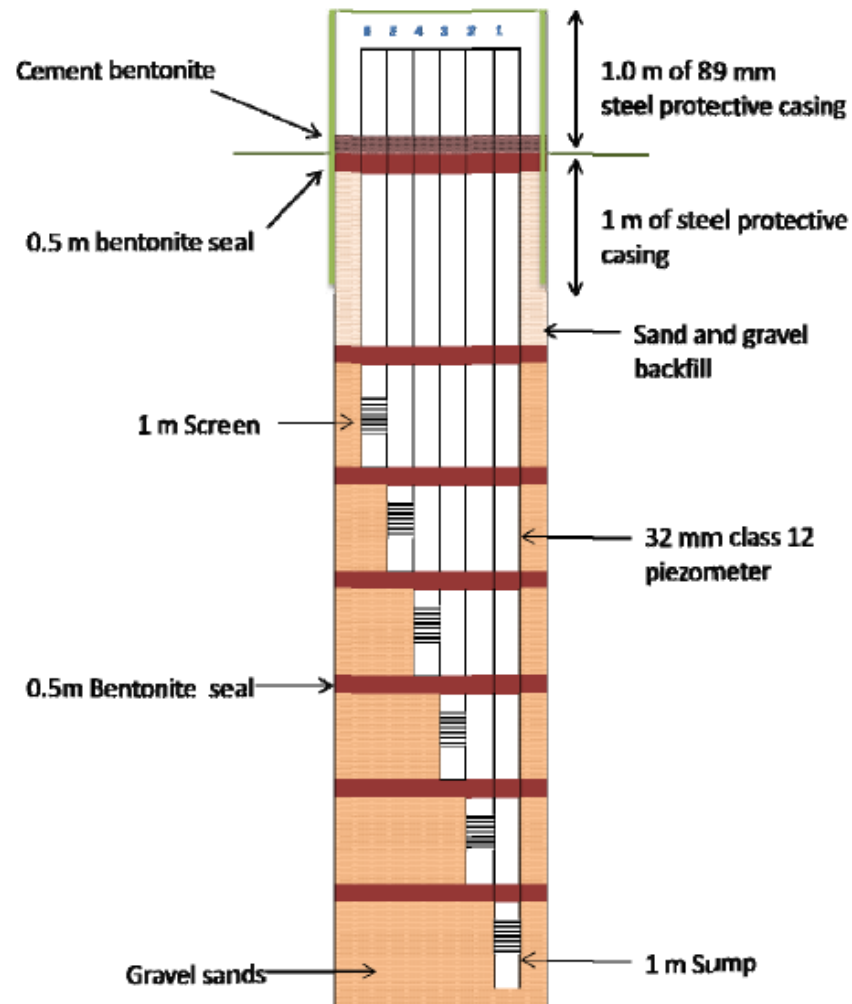
Tel. +676-884-8617

Tel. +676-884-8618

Tel. +676-884-8619

* In the middle of screen slot in each tube, the sensor is located.

Schematic View of the Multi-Nested Piezometer Design (Not to scale)



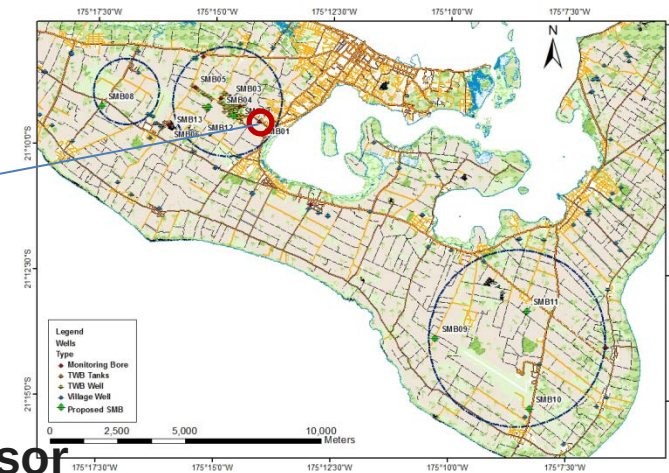


GW Monitoring System

Monitoring Site in the Wellfield : SMB01

Location: South side of track between Mataki'eua and Fanga'uta Lagoon

S: - 21.15387 W: - 175.24173



Multi-Sensor

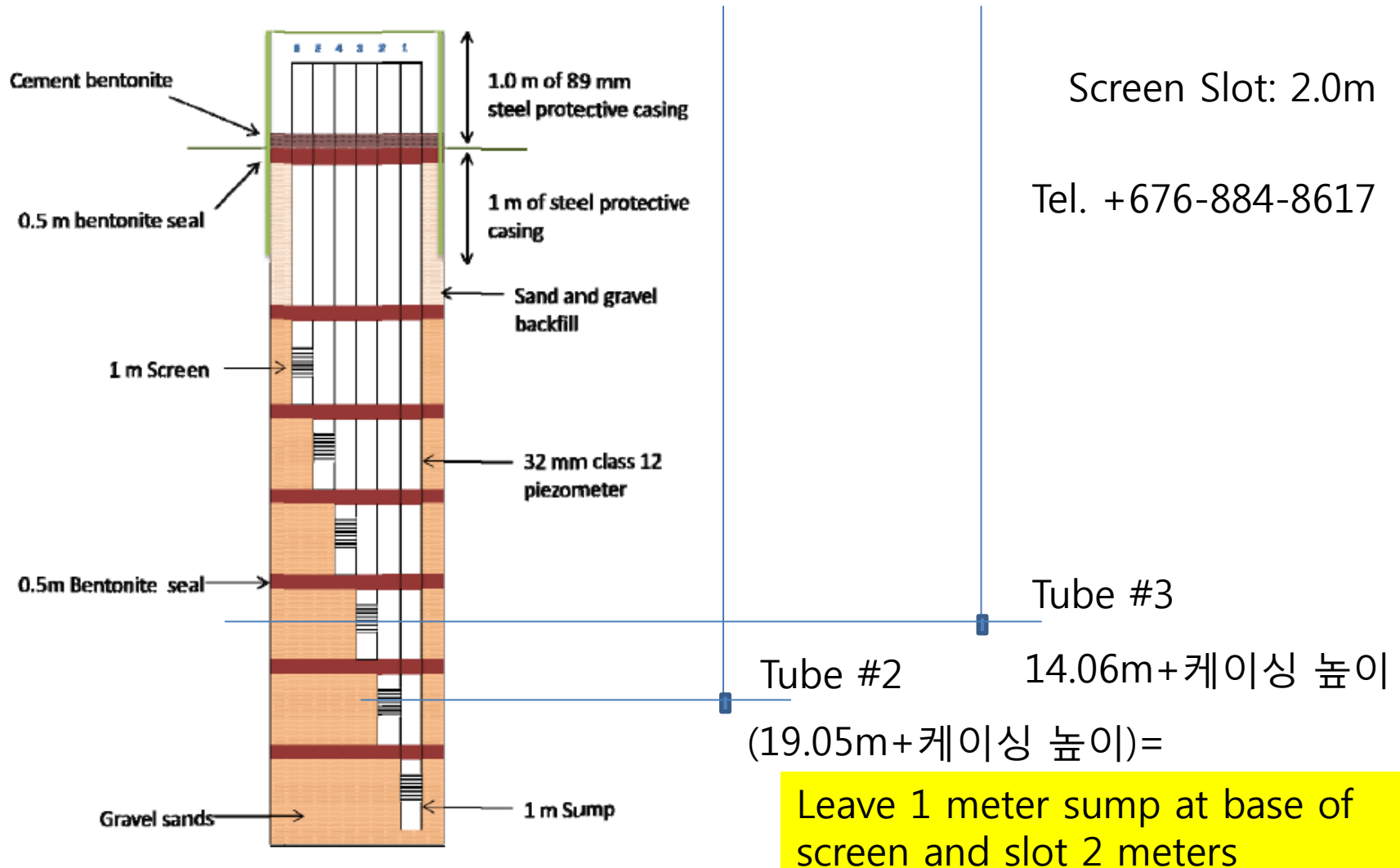


Recommend:
SMB01 is a potential site for multi-sensor monitoring.
Recommended the additional sensors in **Tube #2, Tube #3**

*Diameter: Outside casing (galvanize pipe) = 6 inches
Piezometers pressure pipe (PVC pipe) = 32 mm*

Location of sensors

SMB01



Monitoring Site in the Wellfield : SMB02

Location: beside pump station 105, Matakieu

S: - 21.15387 W: - 175.24173



Multi-Sensor

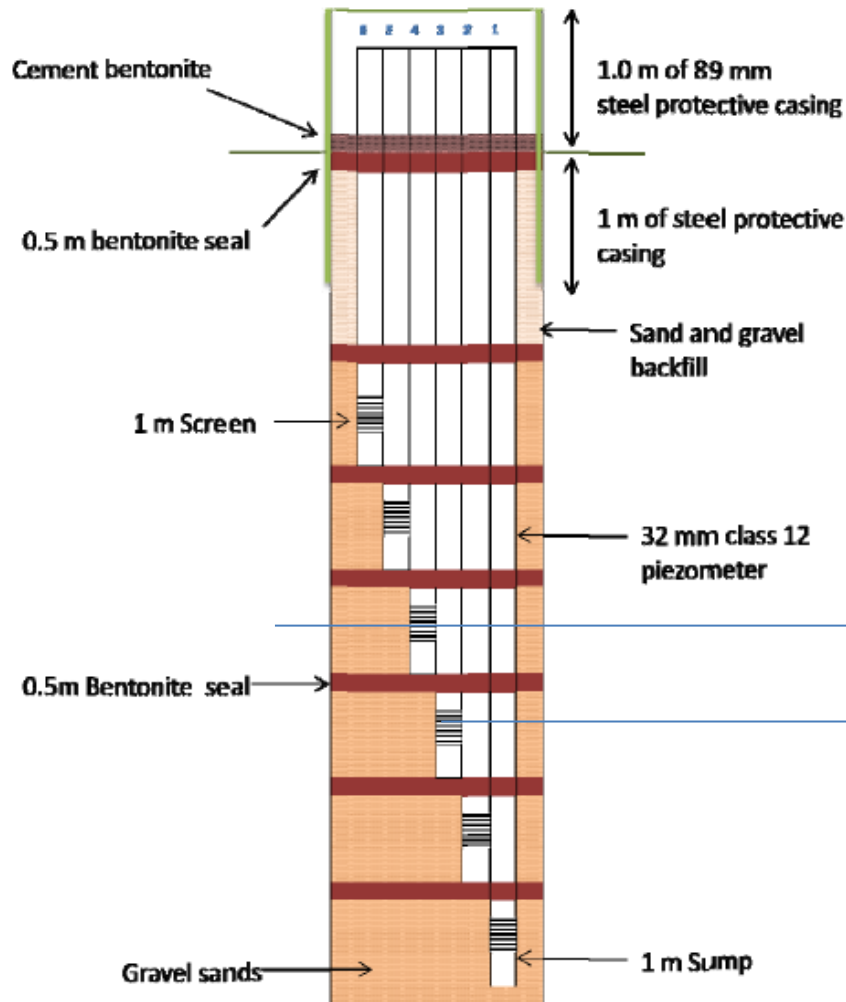


Recommend:
SMB02 is a potential site for multi-sensor monitoring.
Recommended the additional sensors in **Tube #3, Tube #4**

*Diameter: Outside casing (galvanize pipe) = 6 inches
Piezometers pressure pipe (PVC pipe) = 32 mm*

Location of sensors

SMB02



Screen Slot: 2.0m

Tel. +676-841-5229

Tube #4

Tube #3

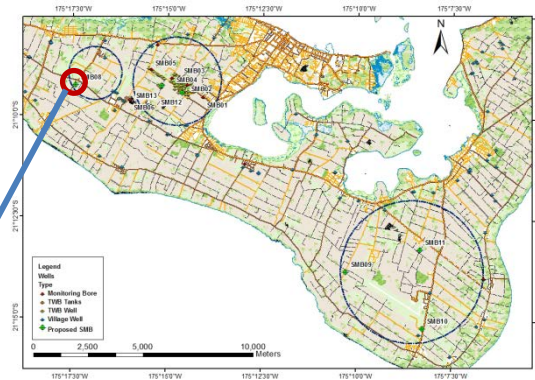
14.06m+케이싱 높이
(19.05m+케이싱 높이)=

Leave 1 meter sump at base of screen and slot 2 meters

Future Zone for Wellfield : SMB08

Location: Houma, Vaea Road

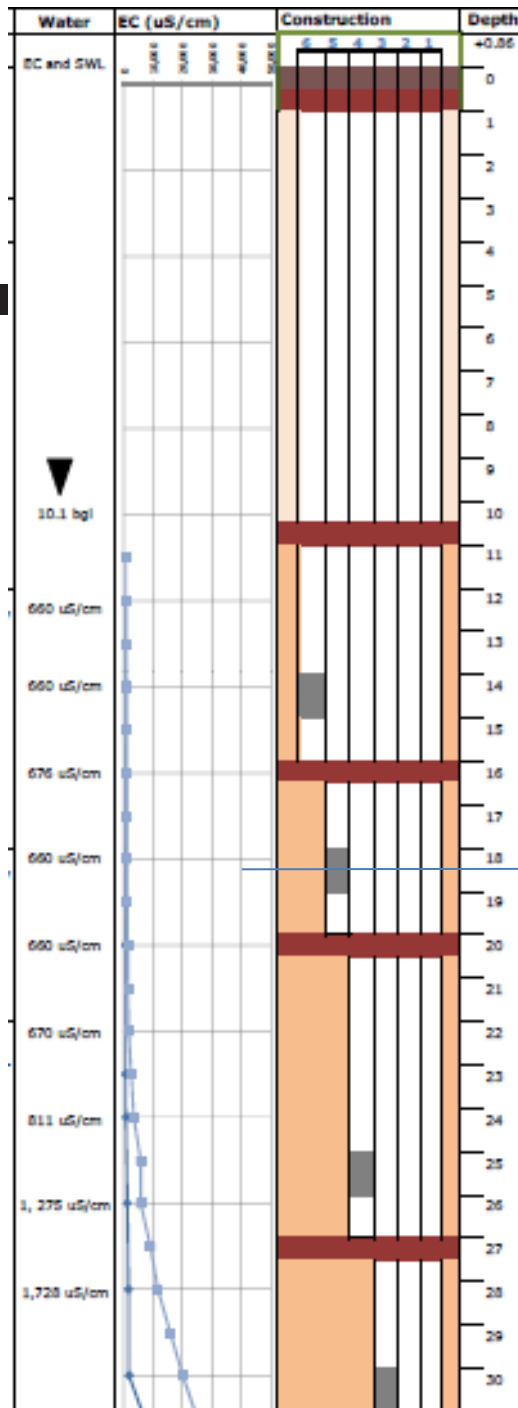
S: - 21.15424 W: - 175.25308



➡ Recommend:
Install a sensor
in **Tube #5**

Location of sensor is
18.5m + Casing (H)

*Diameter: Outside casing (galvanize pipe) = 6 inches
Piezometers pressure pipe (PVC pipe) = 32 mm*



Location of sensor

SMB08

Screen Slot: 1.0m

Tel. +676-884-8618

Tube #5

18.5m + Casing Height



GW Monitoring System

Future Zone for Wellfield : SMB09

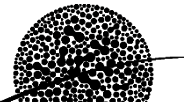
Location: Toloa-End of Airport Runway

S: - 21.22935 W: - 175.17130



➡ Recommend:
Install a sensor
in **Tube #4**

*Diameter: Outside casing (galvanize pipe) = 6 inches
Piezometers pressure pipe (PVC pipe) = 32 mm*



Location of sensor

Location: Tongatapu, Tonga		Program: SOPAC UN Envelope B	
Site: Toloa-End of Airport Runway		Start Date: 6/19/2012	
Borehole No: SMB09		Finish Date: 7/5/2012	
Driller: N.E.E.D.S, Naisa		Rig: Cable Tool	
Co-ordinates S: 21.22935		Drilling Method: Percussion	
W: 175.17130		Logger: Kate Hyland and Sione Nonu	

Depth	Lithology	Description	Water	EC (uS/cm)	Construction	Depth
28	Limestone	28-32m Limestone, Moderately Weathered, Cream and white with minor brown staining, low to medium strength, with Layers of Sand, white, coarse grained.	550 uS/cm	550	Casing	28
29						29
30						30
31						31
32						32
33	Limestone	32-36m Limestone, Slightly Weathered, Cream with minor brown staining, high strength, cemented and some crystallised Limestone, slightly vesicular	515 uS/cm	515	Casing	33
34						34
35						35
36	Limestone	36-38m Limestone, Slightly Weathered, Cream with minor brown staining, high strength, cemented and some crystallised limestone, slightly vesicular. with Layers of Sand, white, coarse grained	670 uS/cm	670	Casing	36
37						37
38	Limestone	38-44m Limestone, Moderately to Highly Weathered, Cream with brown staining, low to very low strength, slightly vesicular.	2,000 uS/cm	2,000	Casing	38
39						39
40						40
41	Gravelly Sand	41-42 Highly fractured zone with abundant sand lenses; GRAVELLY SANDs, white, medium to coarse grained.	40,000 uS/cm	40,000	Casing	41
42	Gravelly Sand					42
43	Limestone	44-46 m Limestone, Moderately Weathered, Cream with brown staining, very high strength, highly vesicular. Highly fractured zone.	42,000 uS/cm	42,000	Casing	43
44						44
45	Limestone	46-48 m Limestone, Moderately Weathered, Cream, medium strength, with Layers of Sand, white, coarse grained.			Casing	45
46						46
47						47
48						48

SMB09

Screen Slot: 1.0m

Tel. +676-884-8619

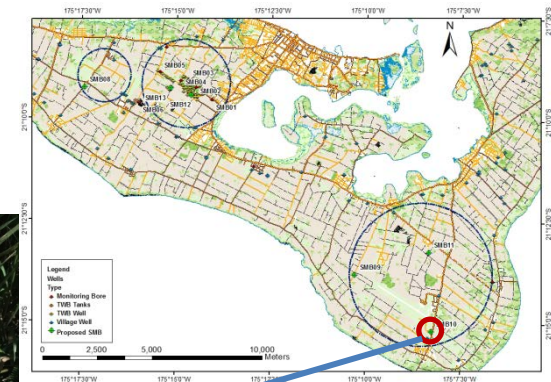
Tube #4

37.5m + Casing Height

Potential Future Zone for Wellfield : SMB10

Location: Fua'amotu

S: - 21.25284 W: - 175.13728



Recommend:
Install a sensor
in **Tube #4**

*Diameter: Outside casing (galvanize pipe) = 6 inches
Piezometers pressure pipe (PVC pipe) = 32 mm*

Potential Future Zone for Wellfield : SMB11

Location: Pelehake, Next to Village Well

S: - 21.22086 W: - 175.13928



Recommend:
Install a sensor
in **Tube #3**



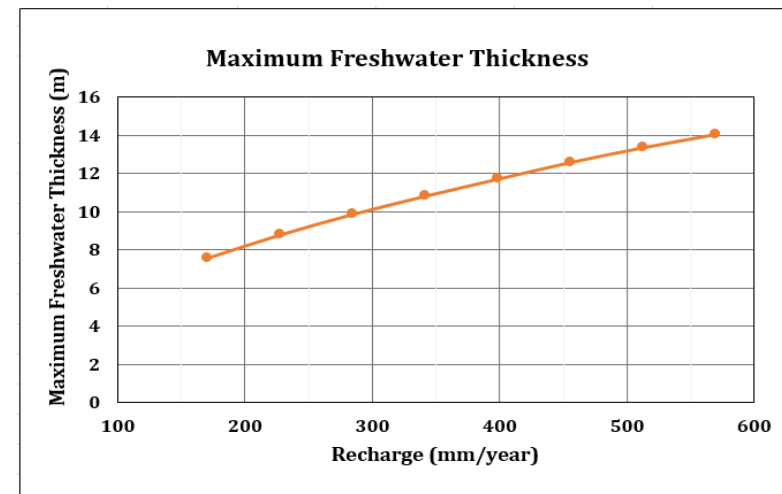
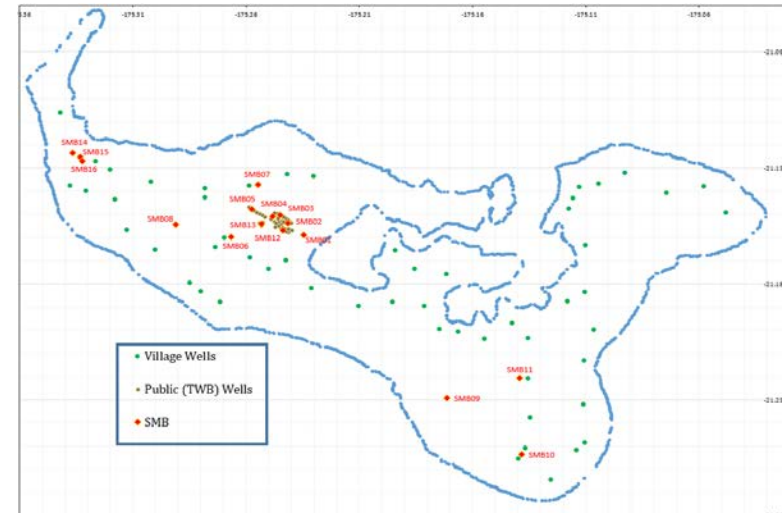
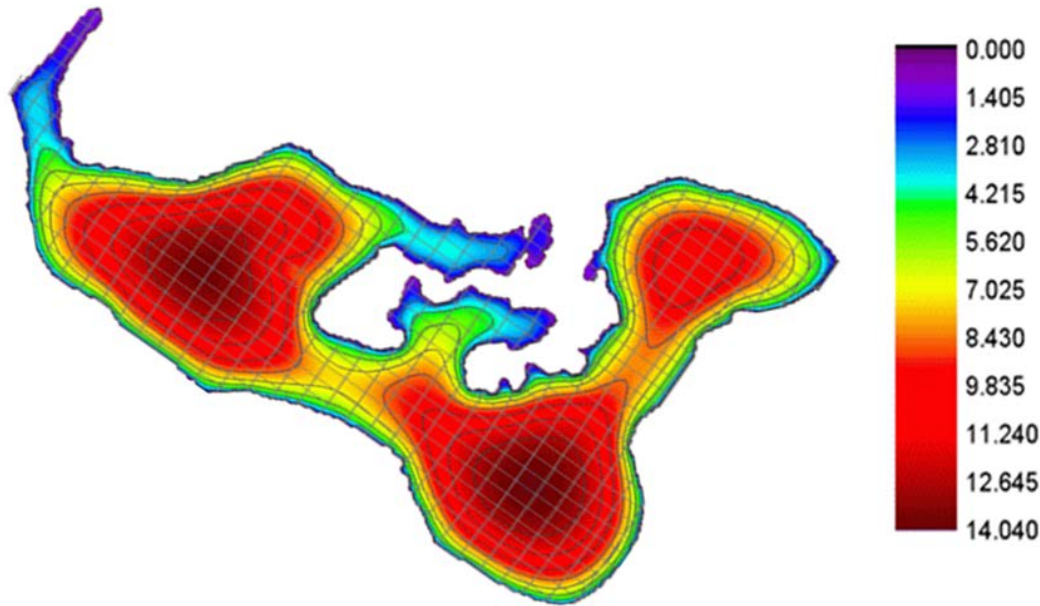
There is a pumping station
near the SMB11.

*Diameter: Outside casing (galvanize pipe) = 6 inches
Piezometers pressure pipe (PVC pipe) = 32 mm*

Tonga Groundwater Flow Model (ToGFlow)

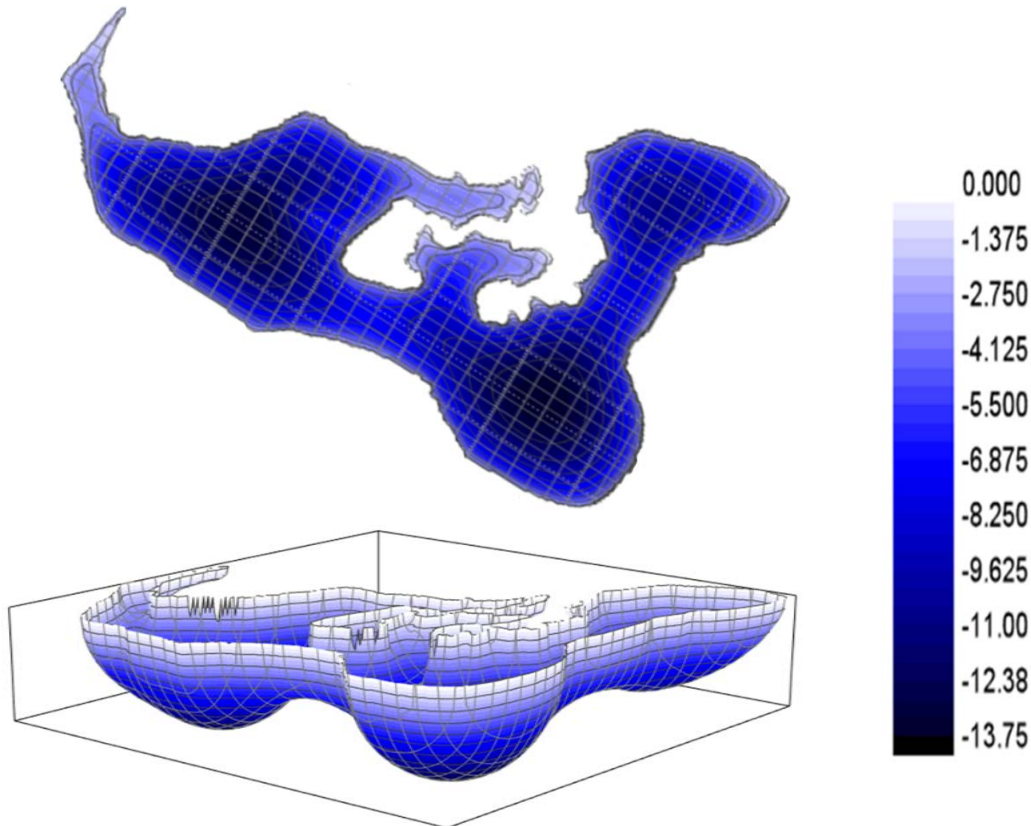
Steady state analysis results

➤ Freshwater Thickness (m)



Tonga Groundwater Flow Model (ToGFlow)

Freshwater –Saltwater Interface Elevations



Present Freshwater Resources in Tongatapu Island

**Average FW
Thickness
(m)**

8.42

**Maximum FW
Thickness
(m)**

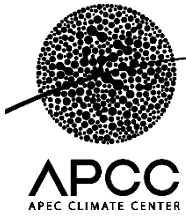
14.04

**Total Volume of
Usable FW
(m³)**

1,938,000

**Total Volume of
FW
(m³)**

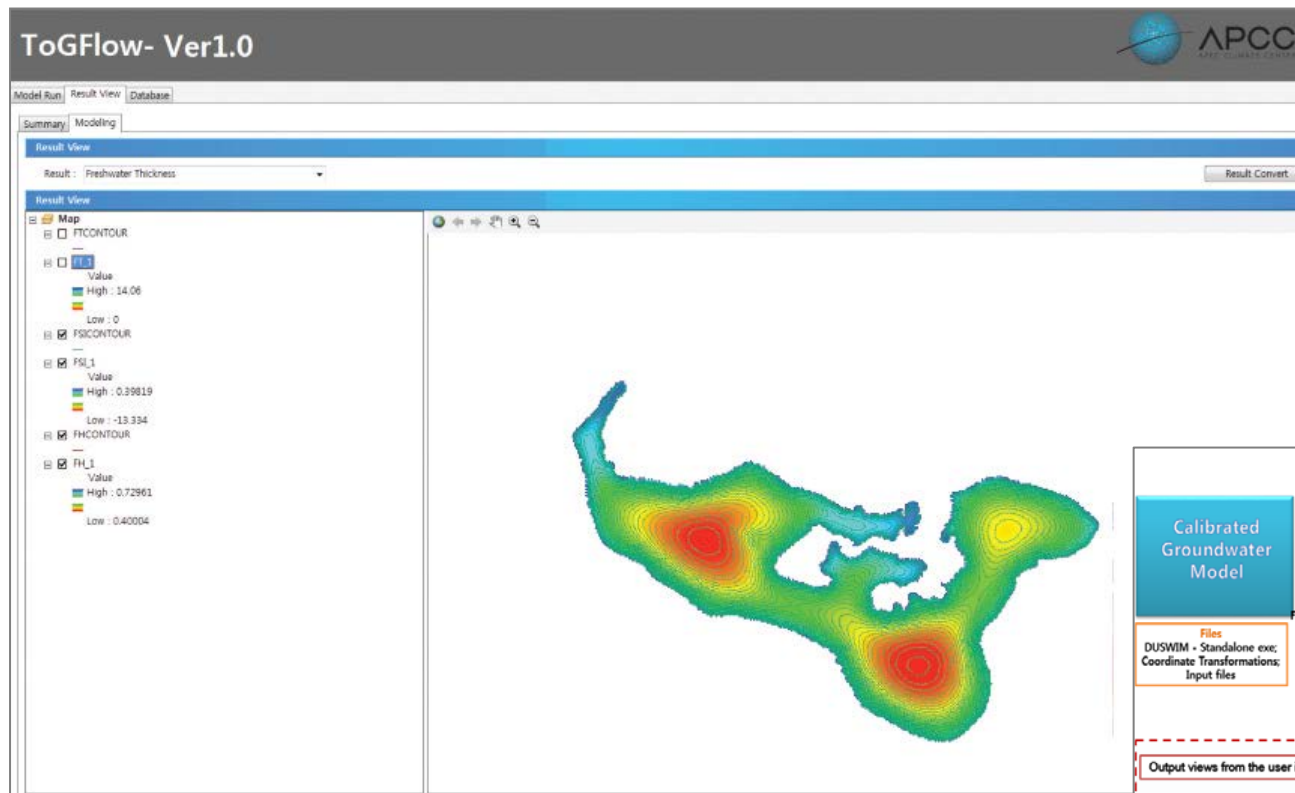
2,123,000



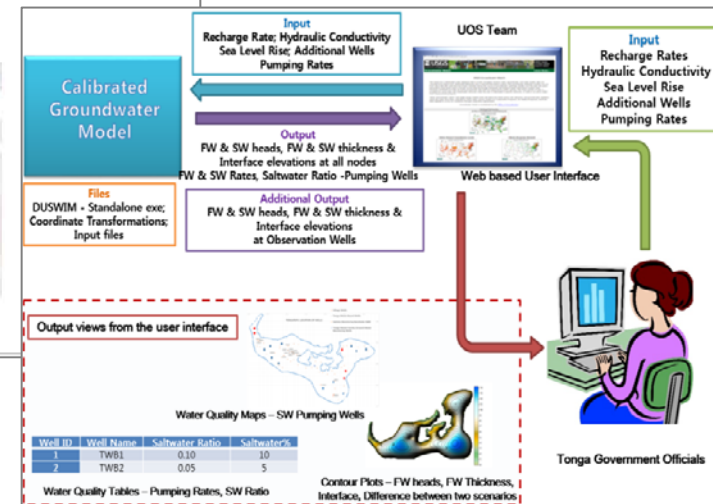
Tonga Groundwater Flow Model

Tonga Groundwater Flow Model (ToGFlow)

ToGFlow allows 'easy to run' by adjusting parameters and model simulation



Integrated system for web based groundwater modeling



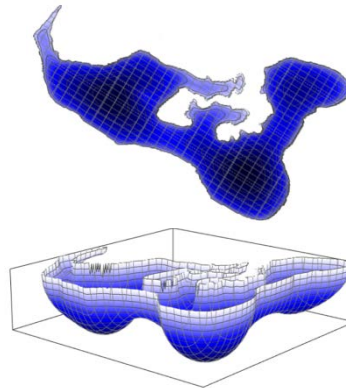


Web Based Groundwater Information System

Groundwater Information System (ToGWIS)



01 MONITORING

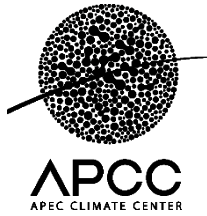


02 MODELING



03 MANAGEMENT

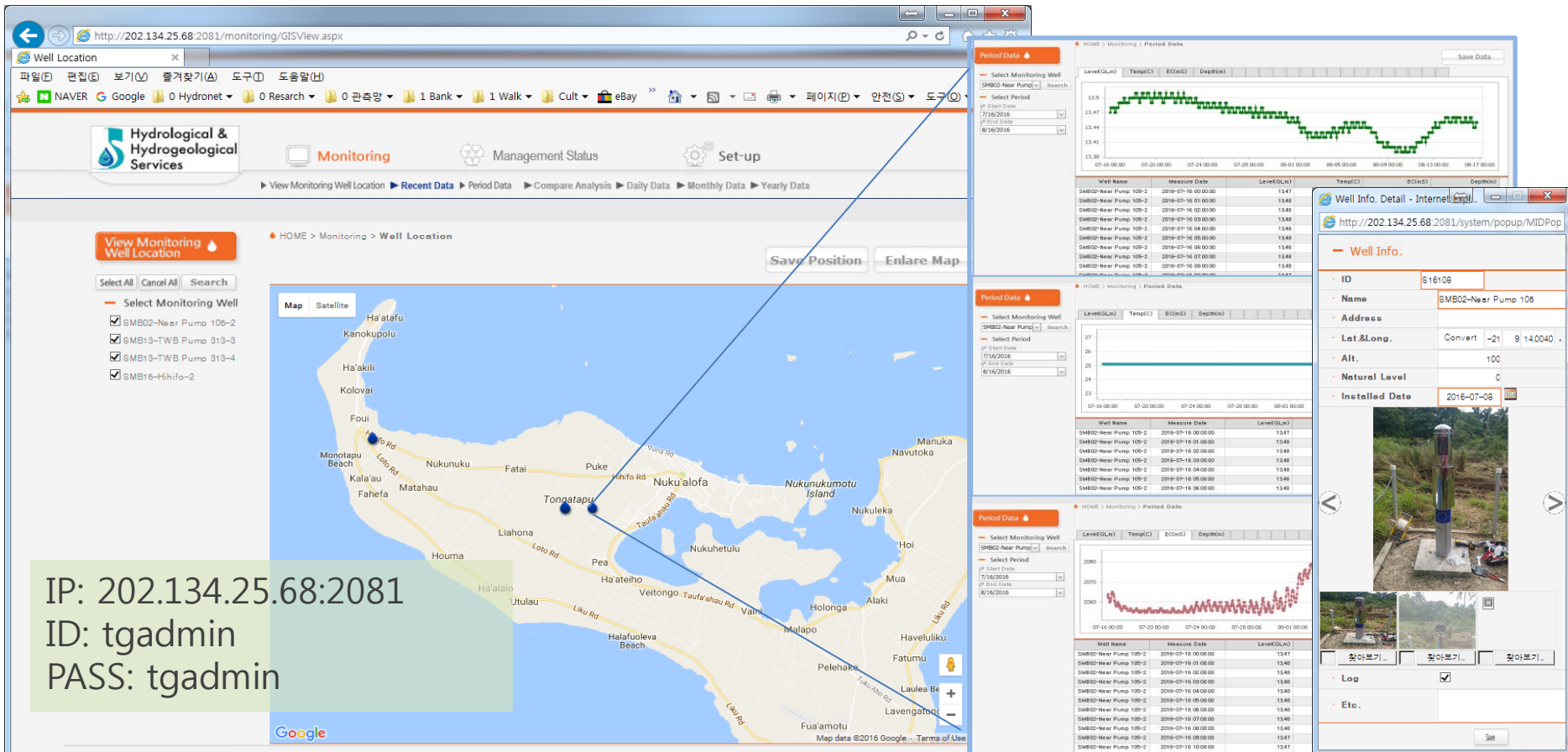
ONE STOP SOLUTION FOR GROUNDWATER MANAGEMENT

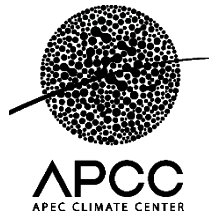


Web Based Groundwater Information System

Real-Time Groundwater Monitoring System

- Demonstration: Real-Time Groundwater Management System
- Observation Data: Level(GL.m), Temp(C), EC(mS), Depth(m)





Web Based Groundwater Information System

Groundwater Information System (ToGWIS)

Groundwater Management System in the Kingdom of Tonga

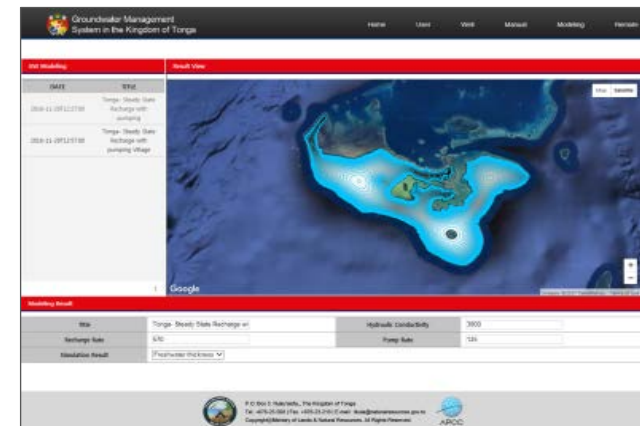
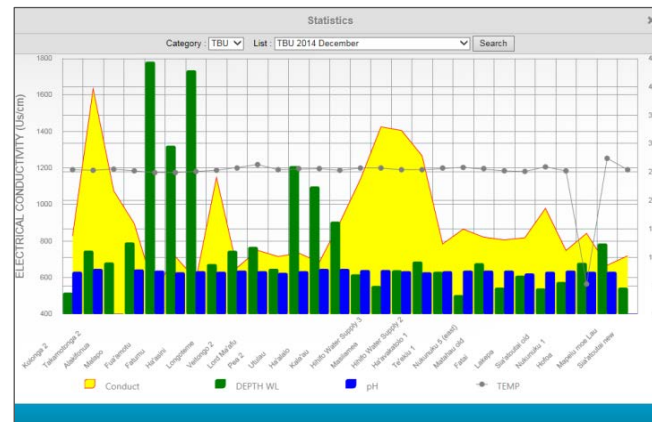
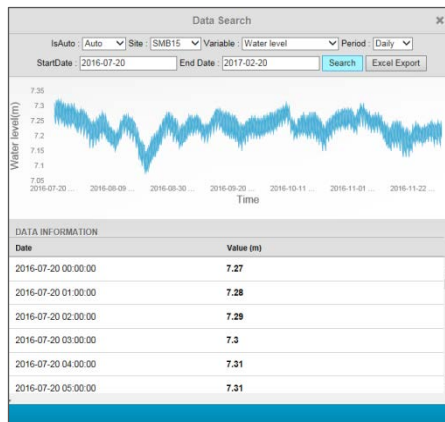
Please enter your ID and Password

- ID

- PASSWORD

☐ Save ID

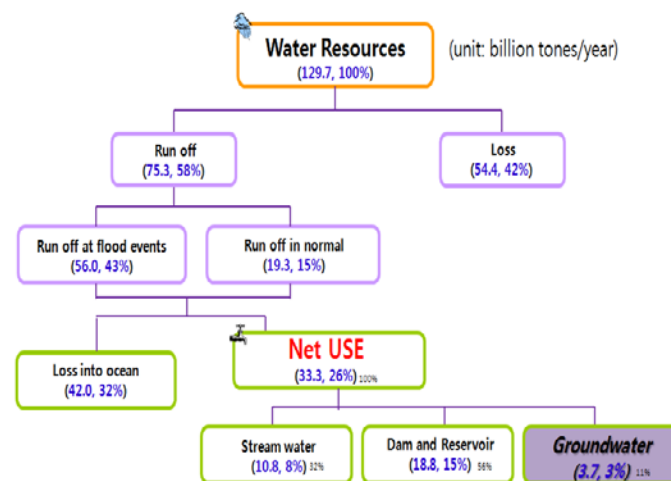
P.O. Box 5, Nuku'alofa, The Kingdom of Tonga
Tel: +676-25-508 | Fax: +676-25-216 | E-mail: Info@naturalresources.gov.tg
Copyright (Ministry of Lands & Natural Resources. All Rights Reserved)



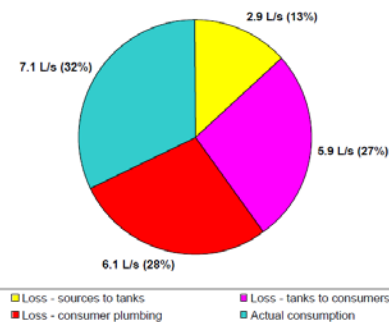
ToGWIS: <http://210.125.181.22/login>

Water Resources and Water Use Survey

- Target Areas: 5-Village (2-Urban/3-Rural)
- Survey: 50-Household
- Interview: Tonga MLSNR Office
- Contents:
 - Total Water Resources(Rainwater, Groundwater)
 - Total Water Use (Agricultural, Domestic, Industrial, Environmental)
 - Pattern of Water usage and Priority Items

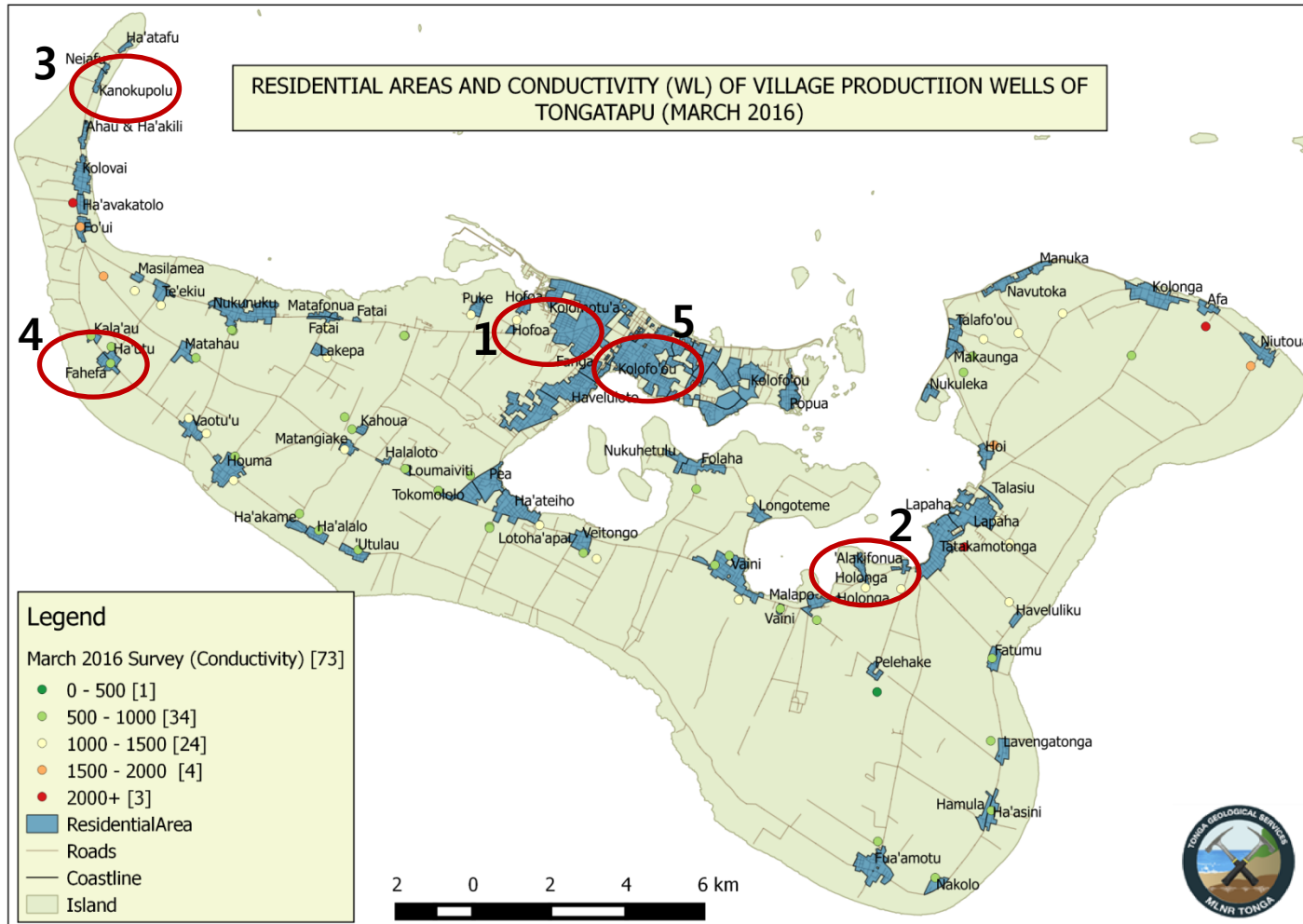


Distribution of the total supply from sources



Water Use / Demand Estimation

Water Resources and Water Use Survey



Urban: 1, 5

Rural: 2, 3, 4

Village Name

1. Tu'atakilangi
2. 'Alakifonua
3. Kanokupolu
4. Fahefa
5. Kolofo'eu

Water Resources and Water Use Survey

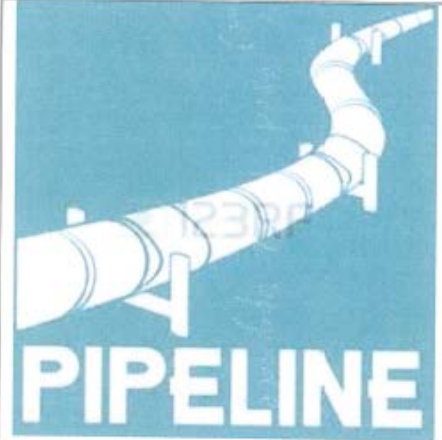
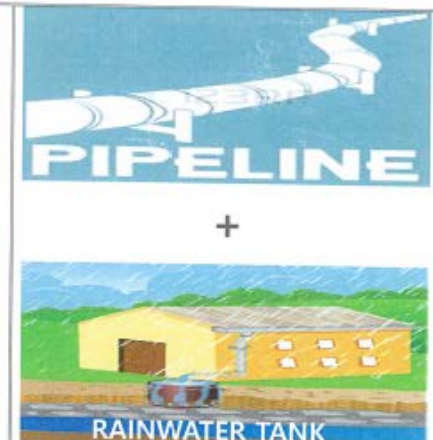
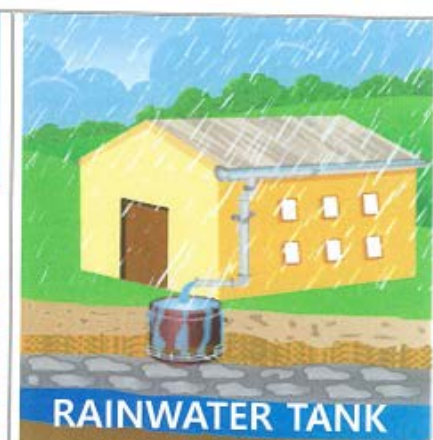
Example of survey result

Aleki Palu 



1. How to access water

Please tick ☒ whether you access water from pipeline, rainwater tank or both.

		
1) Pipeline	2) Both pipeline and Rainwater tank ☒	3) Rainwater Tank

Water Resources and Water Use Survey

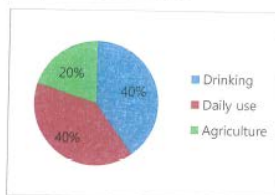
Example of survey result

2. How to use water

Please show the distribution of water usage

Example

[Water Usage]

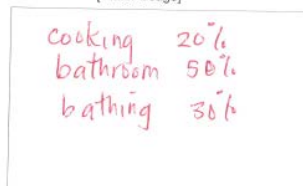


[How to Drink Water]

✓	Category
	1. Boiling water
	2. Purification Filter
	3. Without any purification

1) Groundwater usage

[Water Usage]

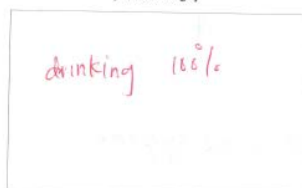


[How to Drink Water]

✓	Category
	1. Boiling water
	2. Purification Filter
	3. Without any purification

2) Rainwater usage

[Water Usage]



[How to Drink Water]

✓	Category
✓	1. Boiling water
	2. Purification Filter
	3. Without any purification

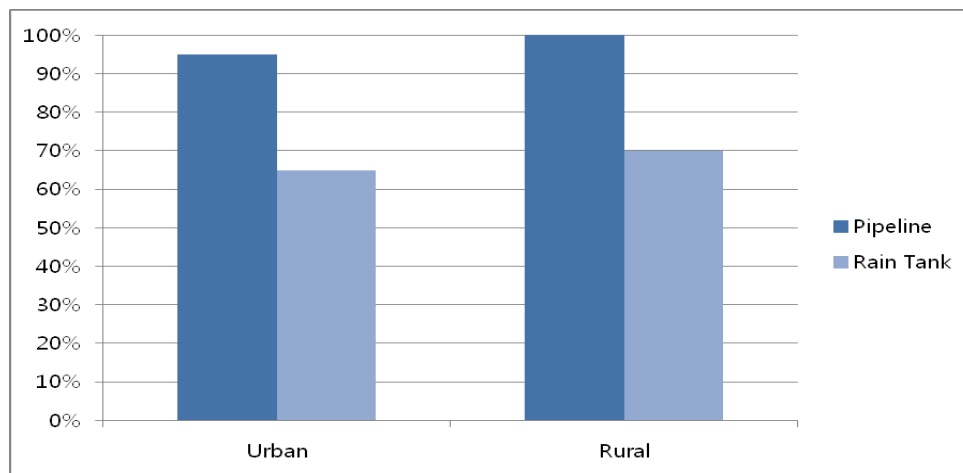
3. What can be improved in terms of water usage?

Please tick ✓ one you think it is the most priority to be improved in terms of water usage.

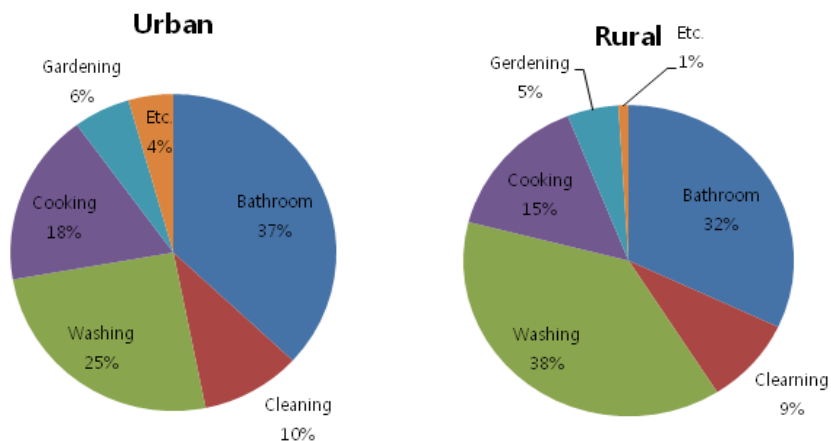
1) Not enough water  2	2) Low quality water  1
3) Expensive water bill  4	4) Expensive maintenance cost for water tank(well/filter)  3
5) Etc. (Please specify if any) water service need to be upgrade. (pipe system)	

Water Resources and Water Use Survey

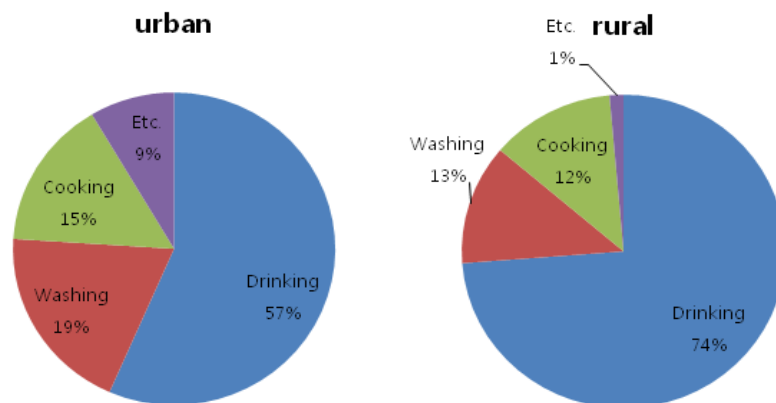
➤ Result of how water is accessed



➤ Result of groundwater usage



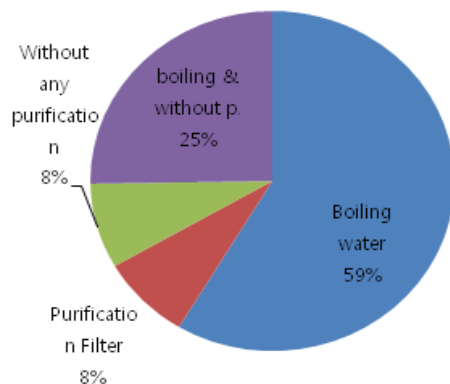
➤ Result of rain water usage



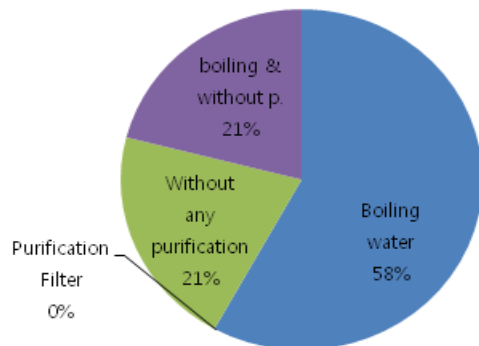
Water Resources and Water Use Survey

➤ Result of how to drink water safely

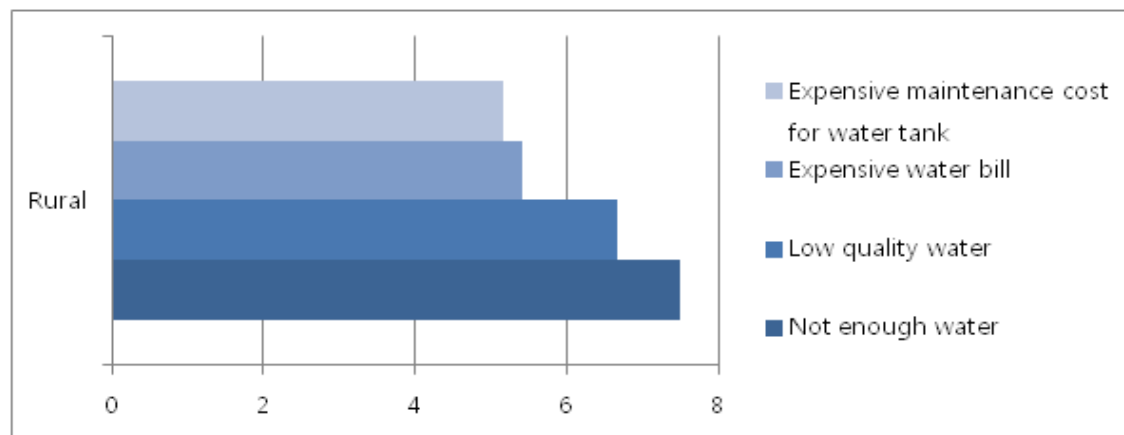
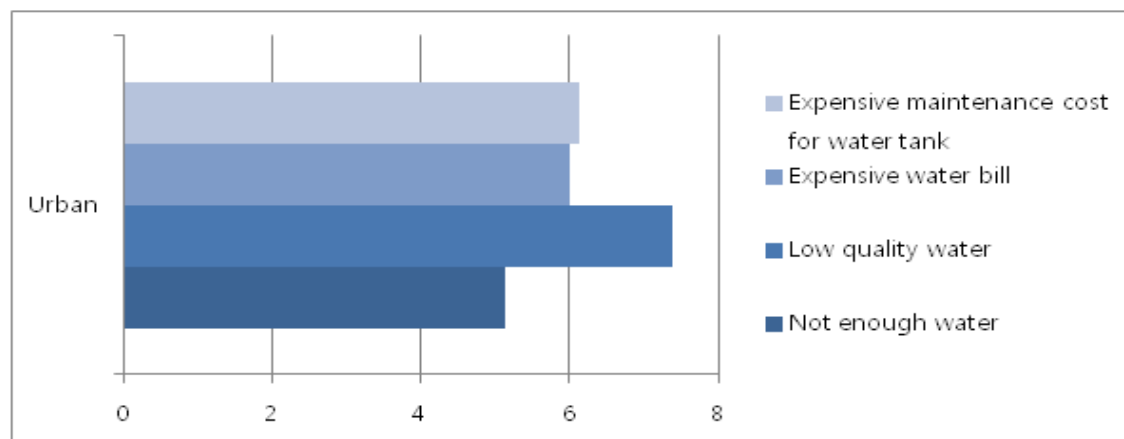
Urban



Rural



➤ Result of priority items to be address



Tongatapu Water Resources Risk Assessment



Long-Range Ground Water Resources Risk Matrix (Tongatapu)

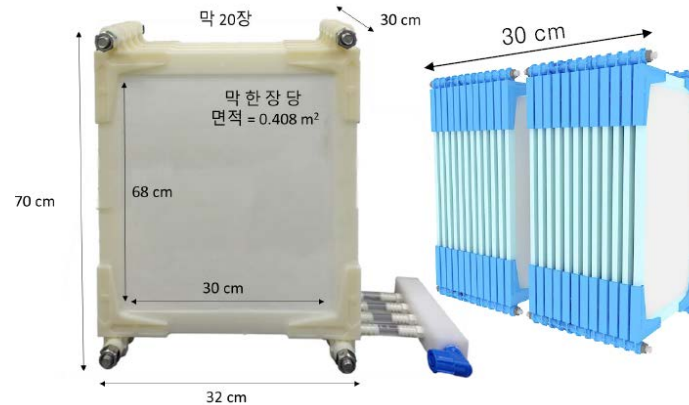
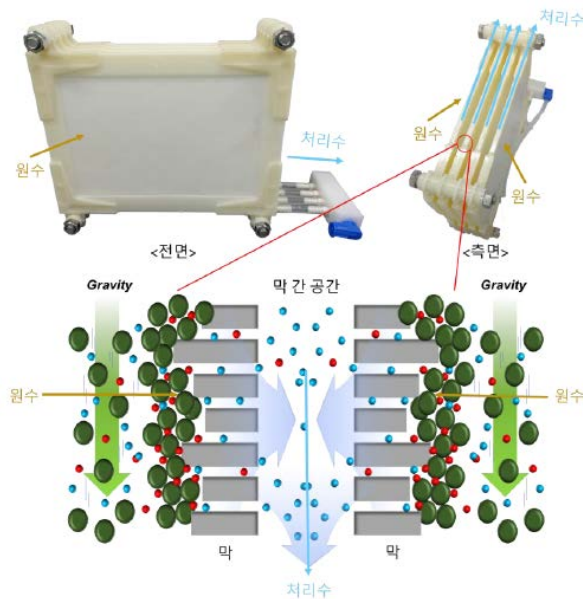
Likelihood	High				
	Medium		√		
	Low				
	Very Low				
		Minimal	Minor	Significant	Severe
		Potential Impacts			

Overall Water Risk

HIGH	
MEDIUM	
LOW	
VERY LOW	

Tongatapu Groundwater Quality Test

➤ 중력식 막여과 장치



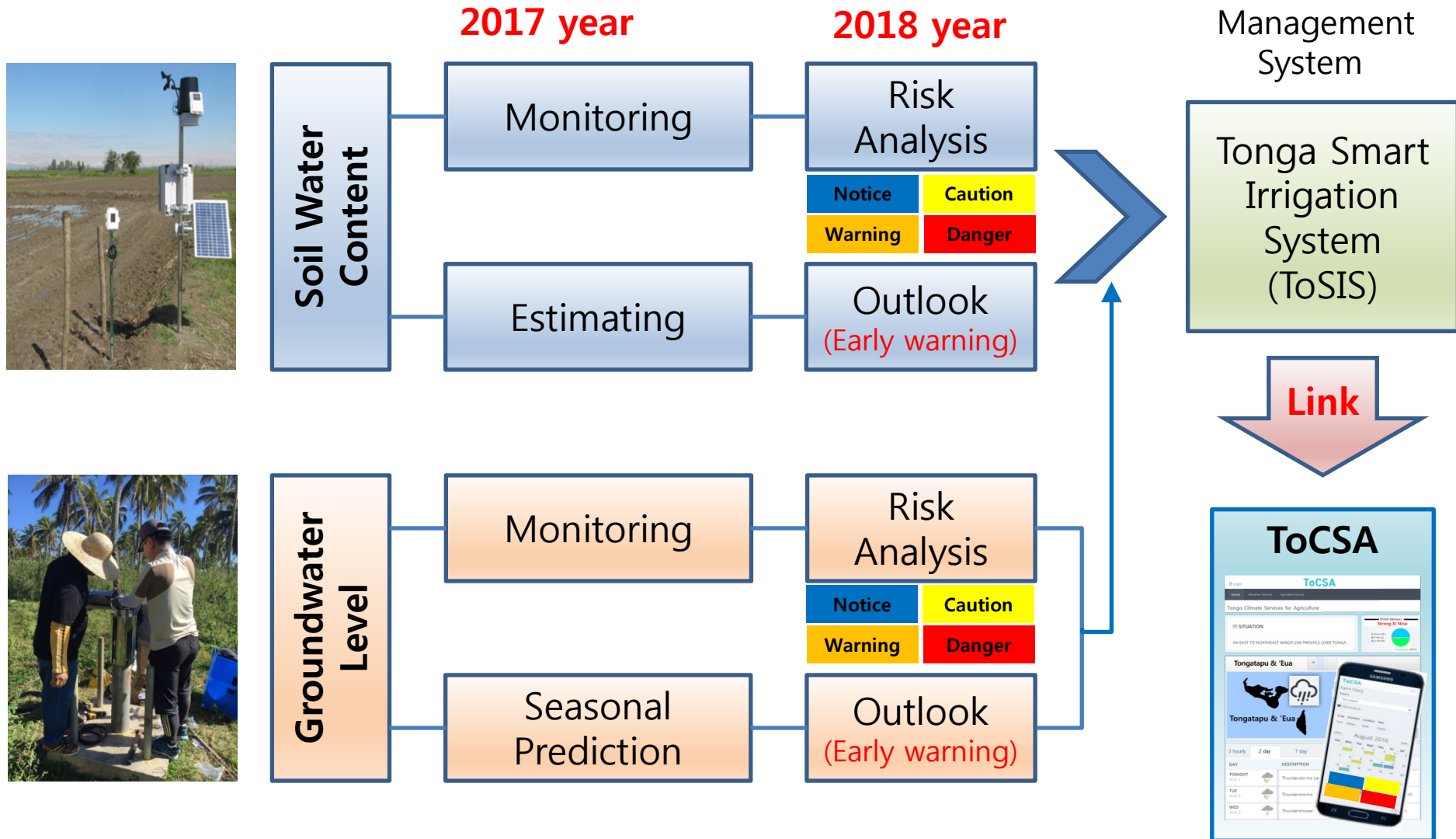
재질 : PVDF, 공극 $0.2 \mu\text{M}$ 막
면적 : $0.408 \times 20\text{장} = 8.16 \text{ m}^2$



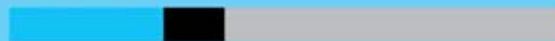
무균채수병 X 20개

취약지역 수질 Test 예정

Soil Moisture and Groundwater Monitoring / Forecasting System



IV Tonga Project Timeline



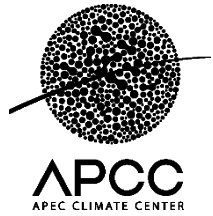
Project Main Activities and Timeline

핵심요소기술개발

실용화기술개발

Main Activities	2017				2018			
	1/4	2/4	3/4	4/4	1/4	2/4	3/4	4/4
1. 기후자료 수집 및 분석	완료		계속사업					
2. 기후자료의 통계적 상세화 처리		완료		계속사업				
3. 상세화 자료의 농업/수자원 활용 가공 처리		완료		계속사업				
4. 지하수자원 기후변화/계절예측 기술개발	완료		계속사업					
5. 지하수자원의 위험도 분석 기술개발			계속사업					
6. Web기반 지하수자원 정보 시스템 구축			계속사업					
7. 토양수분 함량 모니터링 기술 개발	완료		계속사업					
8. 토양수분 함량 예측시스템 개발			계속사업					
9. ToCSA를 활용한 농업 데이터 구축	완료		계속사업					
10. Web기반 농업수자원 관개정보 시스템 구축					계속사업			

 완료
 계속사업



Thank you for your attention!

Killer whale, Tonga

*Bridging the Gap Between Climate Science and Applications
to Smart water use in the Kingdom of Tonga*