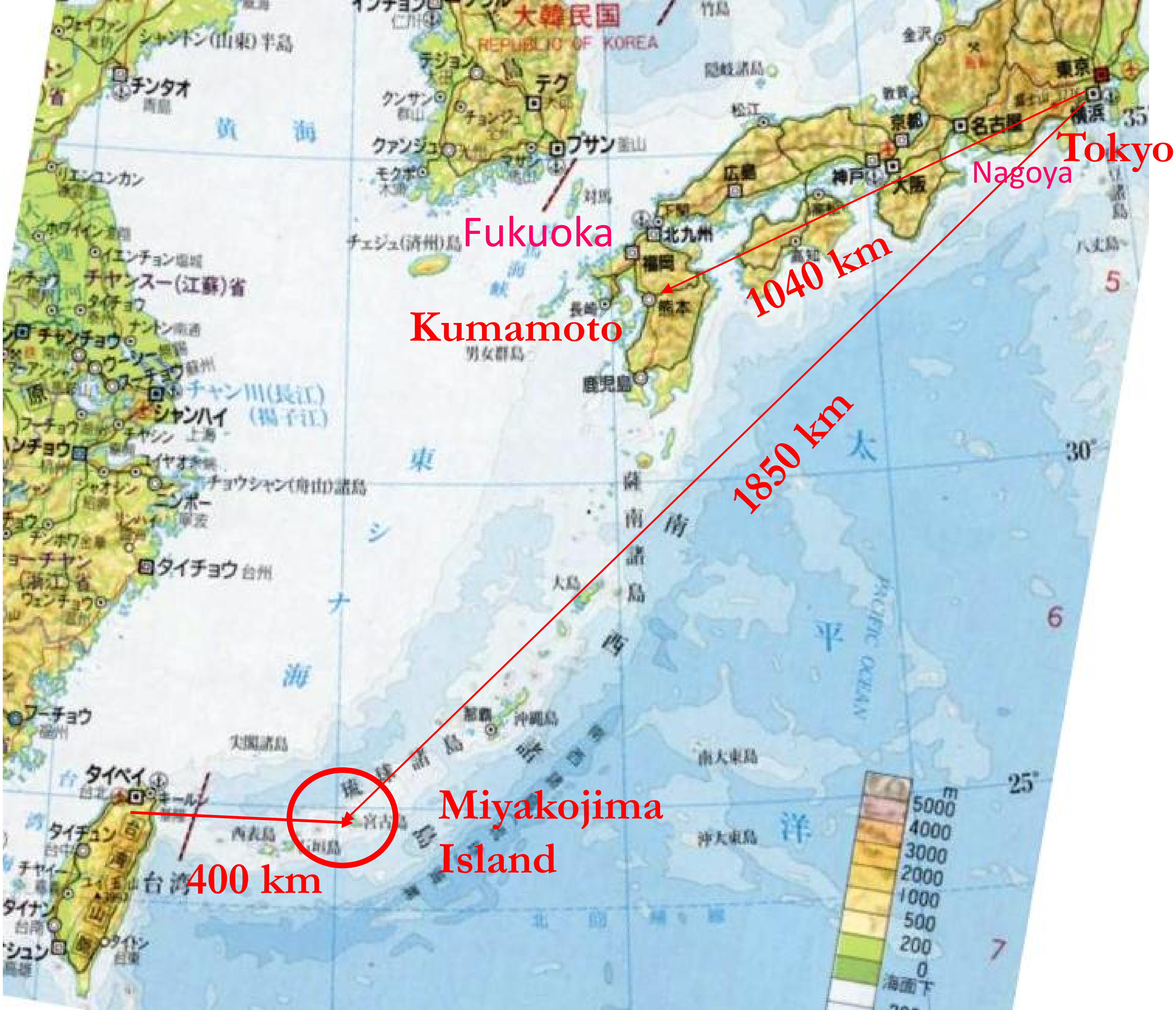
Groundwater management in the Kumamoto area

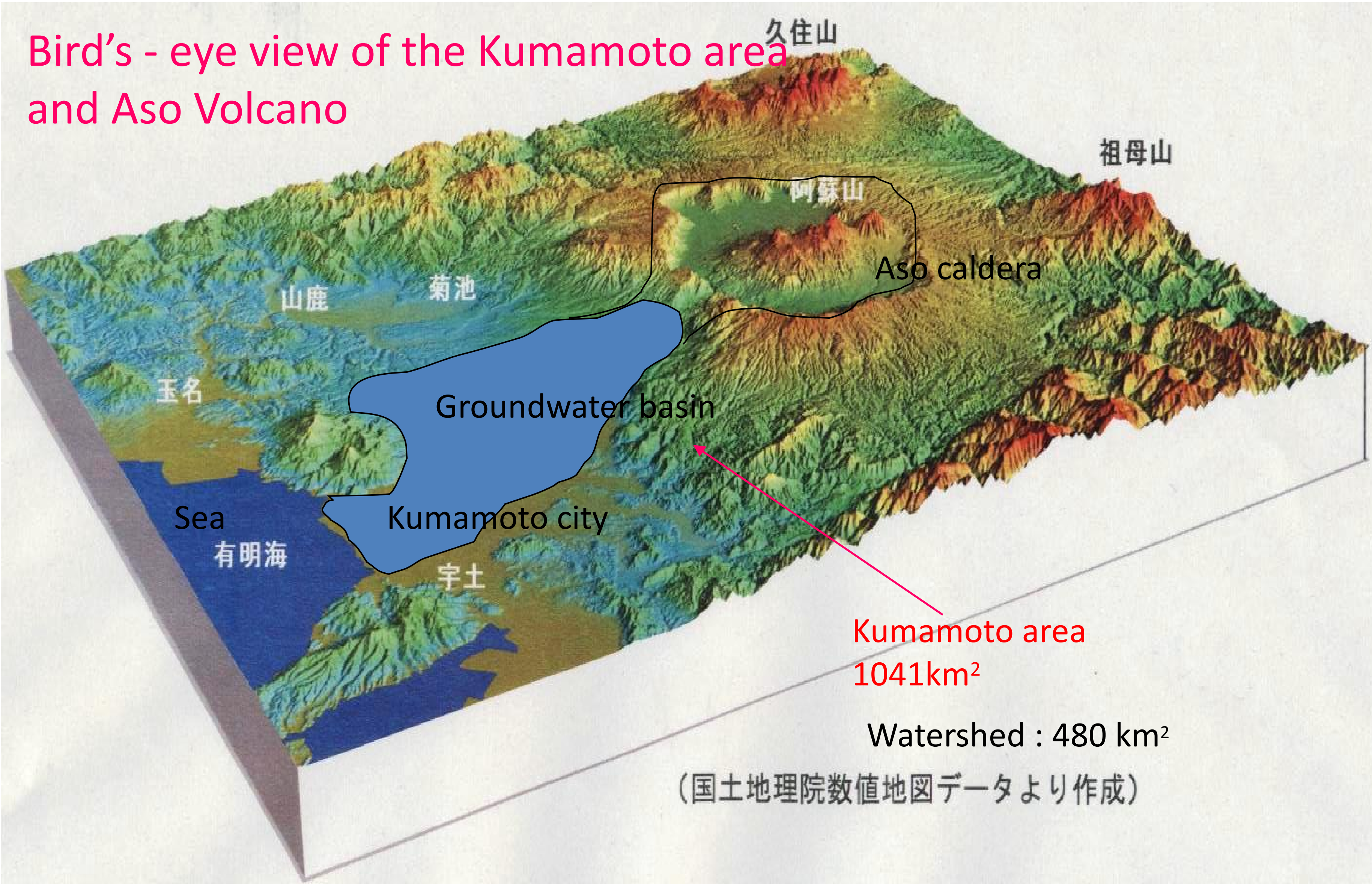
Suizenji Park, Spring water

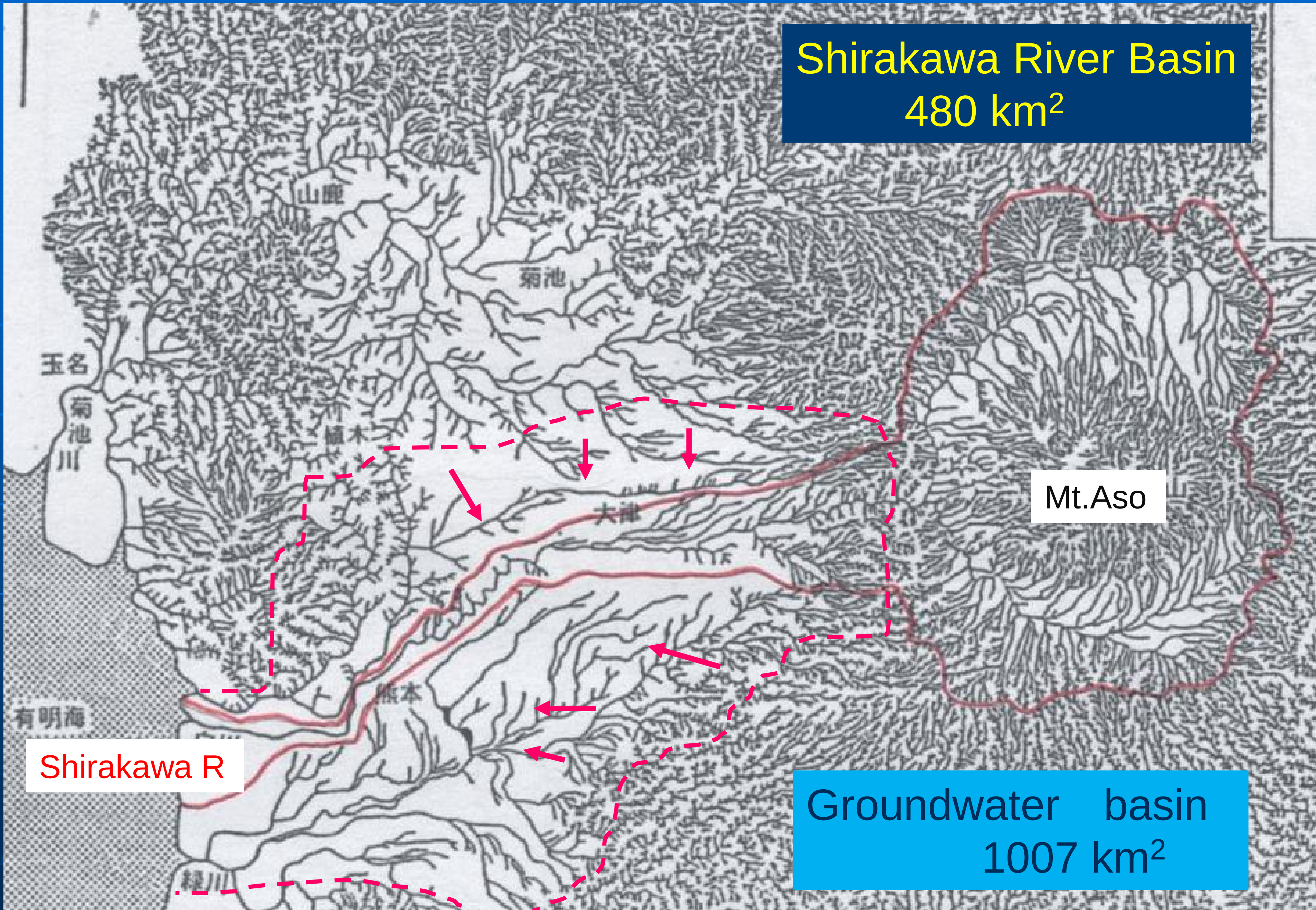

大韓民国
REPUBLIC OF KOREA
Tokyo
Nagoya
Fukuoka
Kumamoto
1040 km
1850 km
Miyakojima
Island
400 km
PACIFIC OCEAN
30°
25°
5000
4000
3000
2000
1000
500
200
0


Orono-shima
Yamaguchi
Heigun-jima
Fukuoka
Madara-shima
Taka-shima
Ikitsuki-shima
Hirado-shima
shima
Saga
Oita
Kuro-shima
jima
Matsu-shima
Nagasaki
Kumamoto
Okino-sh
Miyazaki
Kami-koshiki-shima
Shimo-koshiki-shima
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Kagoshima
©2006 Google
Pointer 32°54'11.62" N 130°54'21.58" E elev 1331 ft Streaming |||||||||| 100% Eye alt 173.00 mi

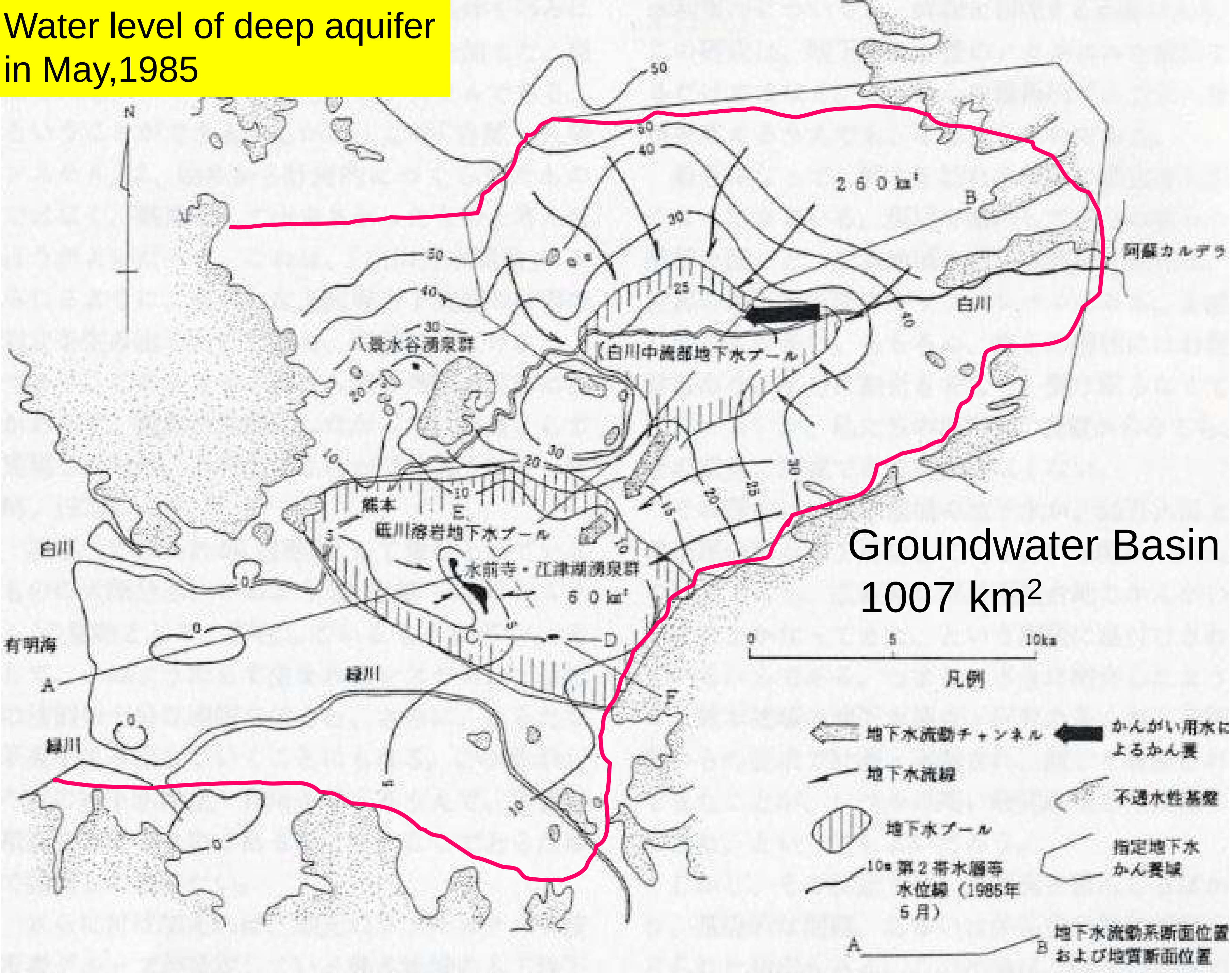
37km
Mt. Aso
Kumamoto
Airport
Matsubase
Kumamoto
© 2006 Europa Technologies
Image © 2006 TerraMetrics
Google
Pointer 32°50'56.45" N 130°51'58.00" E elev 411 ft
Streaming |||||||||| 100%
Eye alt 33.78 mi

Bird’s-eye view of Kumamoto Groundwater basin
（ Kumamoto Municipal Water Bureau ）




Shirakawa River Basin
480 km²
Mt.Aso
Shirakawa R
Groundwater basin
1007 km²
山鹿
菊池
玉名
菊池川
植木
大津
熊本
有明海
緑川

Water level of deep aquifer in May,1985



Groundwater Basin
1007 km^2

Groundwater management in the Kumamoto area Southwest Japan

- Groundwater basin (1007 km^2) covers 13 administrative divisions.
- They concluded the basic agreement to preserve groundwater in the area. This is an epoch-making event.
- From Mt. Aso to Ariake Bay, water cycle & balance are clearly evaluated by simulation model study and well monitored in terms of water level, spring discharge and water quality.
- Groundwater abstraction : 186.2 million m^3/year (510,000 m^3/day, 2006)
- 976,000 people, for urban, agriculture and industrial activity
- Domestic water (320,000 m^3/day) is dependent on groundwater by 100%. Clean water, just chlorine added.
- Alternative water source (surface water) unavailable
- After the target for preservation of groundwater is shown to the public, the program has progressed up to the present.

Procedure for groundwater basin management

① *Research stage* : to set up objectives, such as understanding of the status of groundwater problems and determination of permissible yield (critical water level)

② *Observation stage* ; to monitor whether the permissible level has been accomplished or not

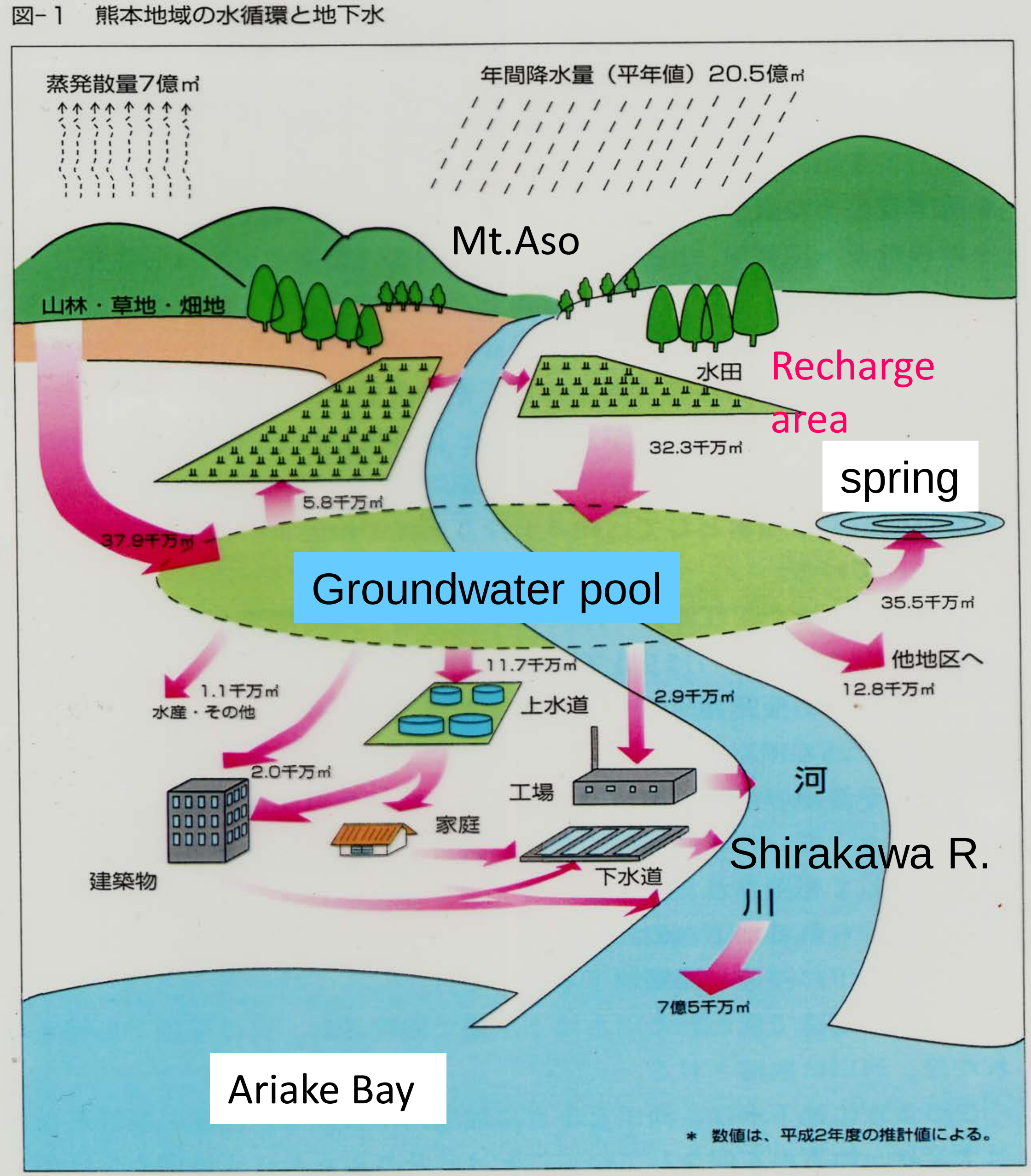
③ *Management stage* ; to practice the original function of groundwater basin management , including the intensive promotion so as to save groundwater use

In three stages, such facilities as observation wells, data base, simulation system are required.

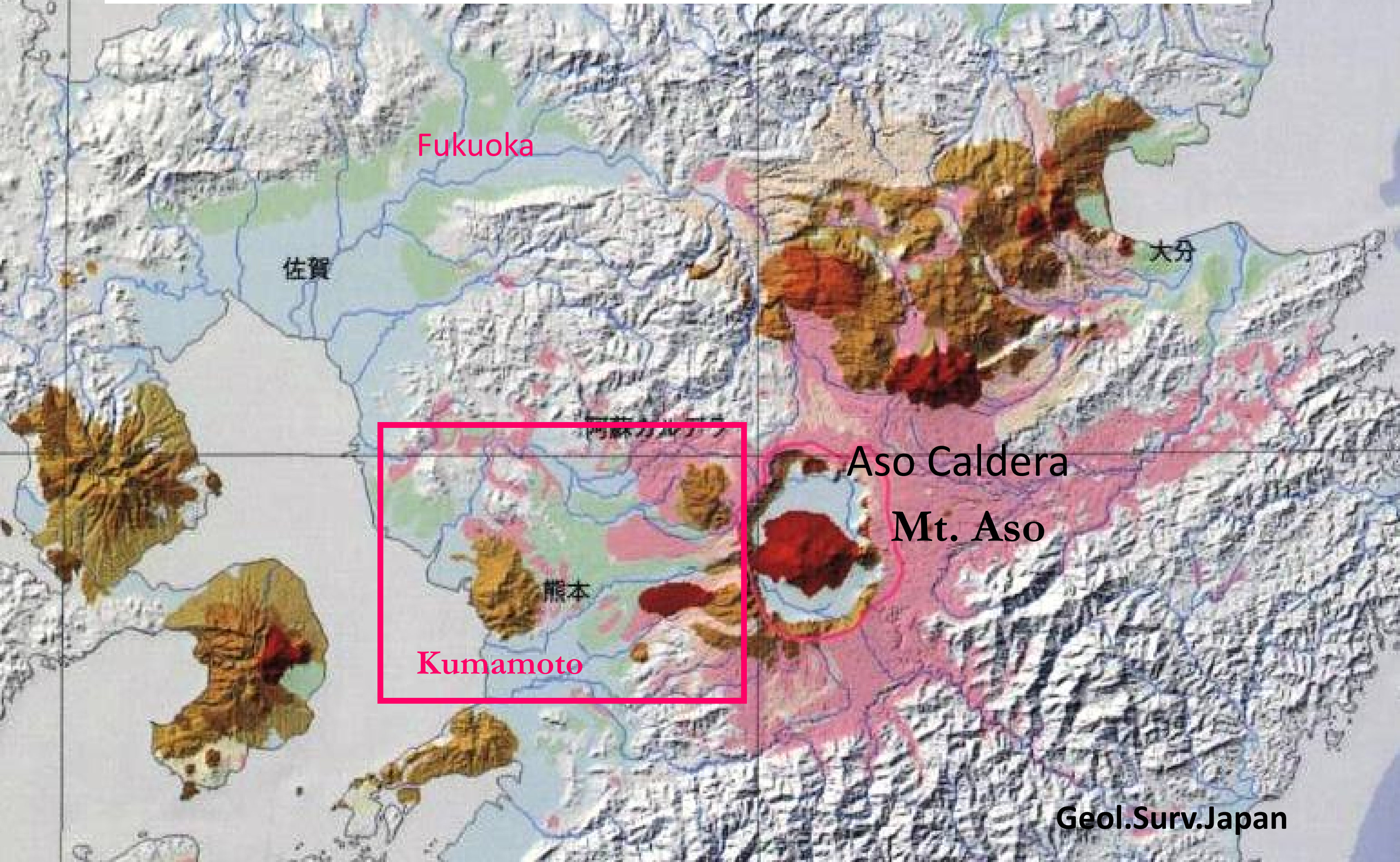
In the early part of the research stage, the plan is constructed, including cost estimate.

- Whole view of hydrologic cycle of the Kumamoto area

- Groundwater basin management in Kumamoto area
- From Mt. Aso to Ariake Bay
- Water cycle & balance are clearly evaluated by simulation model
- Preservation target is shown



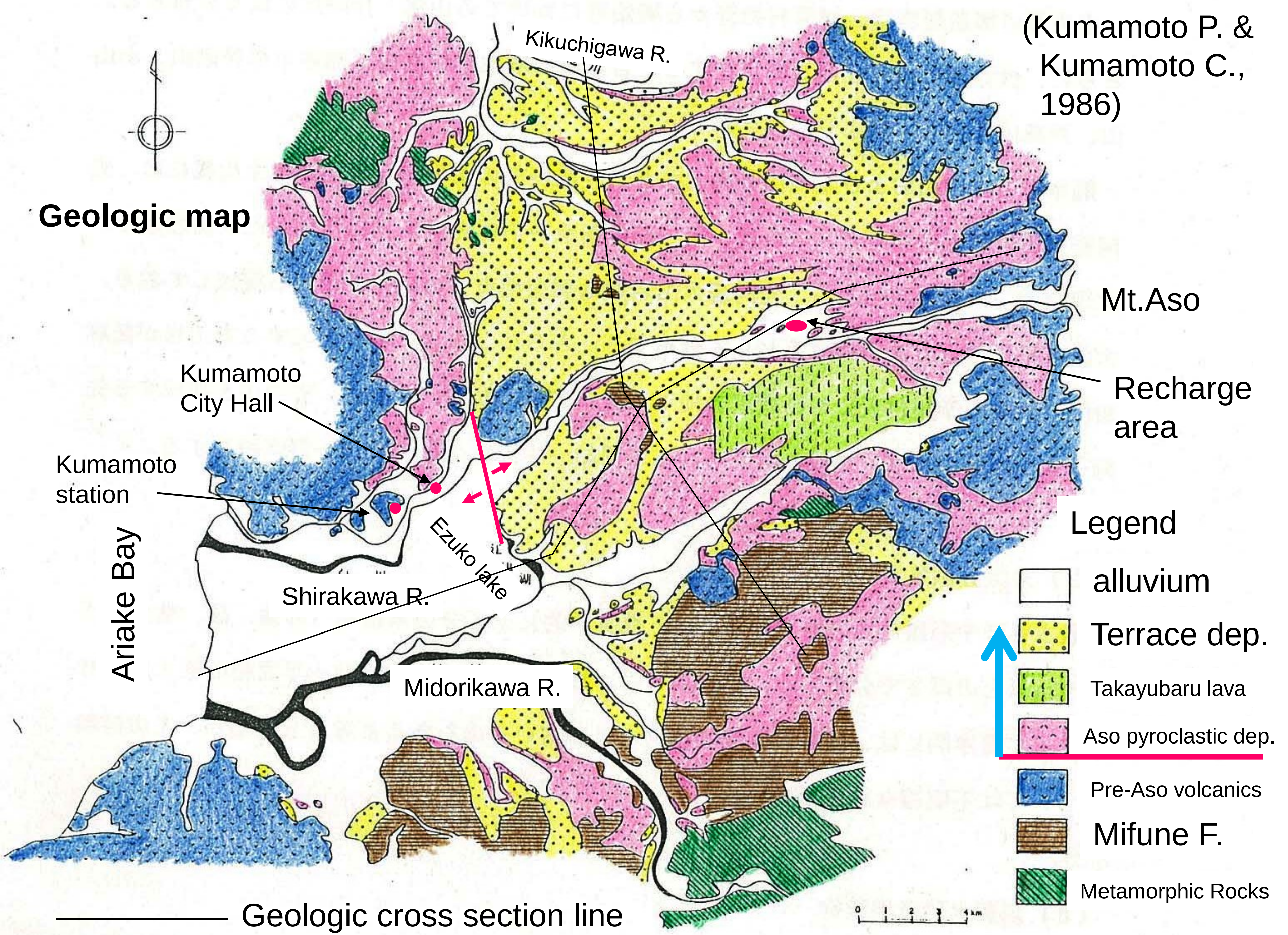
Volcanic rocks in Northern Kyushu
（ Pliocene ~ Recent ）



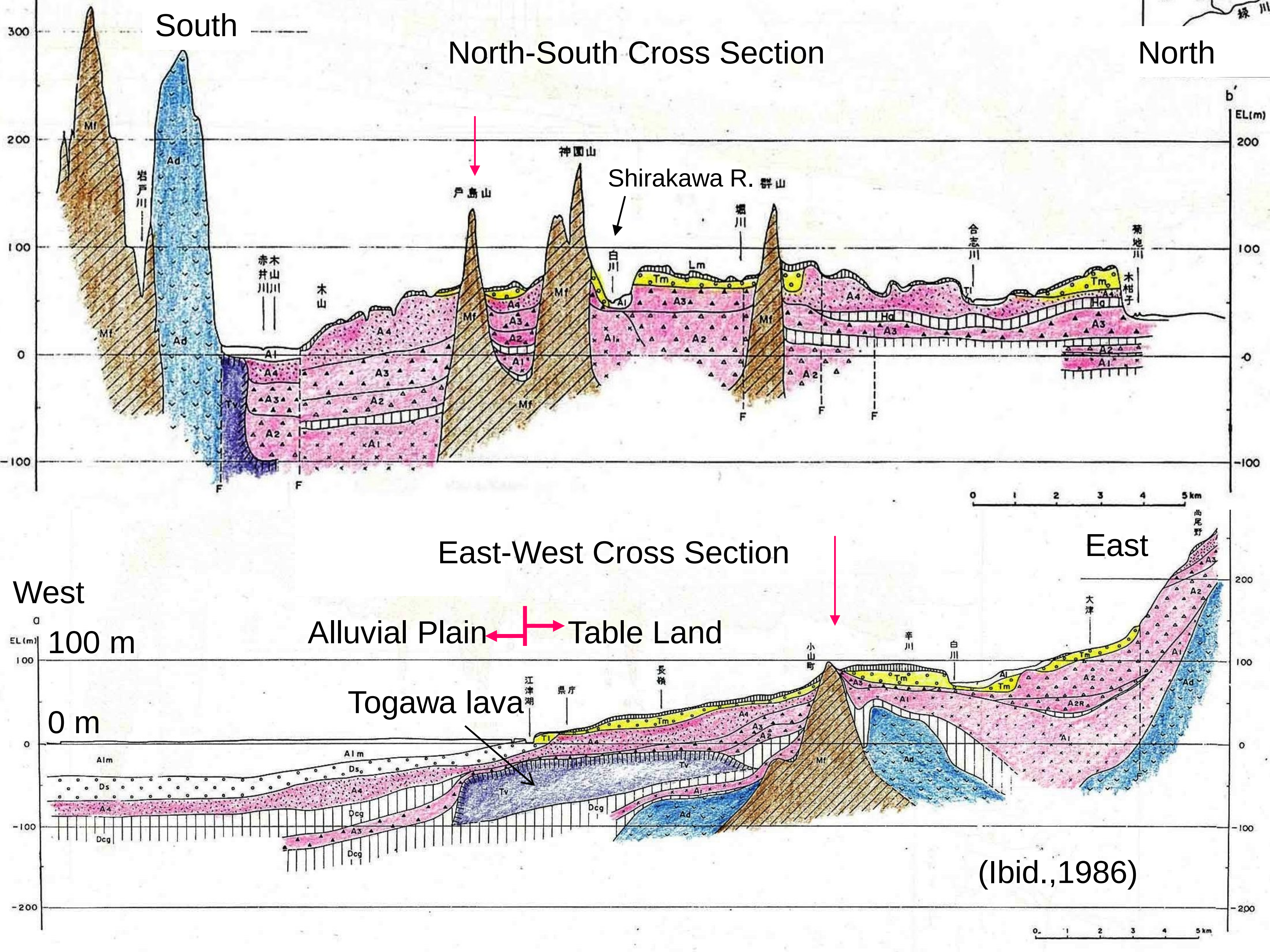
Geologic Succession of Aso Area

(Hase et al.,1998;Furukawa et al.2000)

Geologic age		Geologic Name	Radio Active (YBP) (* 1000)	Thickness (m)
Holocene		Ariake clay Bed	ca. 9	24-32
Pleistocene	Upper	Shimabarakaiwan Bed	18	6+
		Hodakubo/Takuma Gravel Bed	—	15-20
		Aso 4 WT	80-90	6-20
		Miyuki Bed	—	20-30
		Aso 3 WT	120-130	8-20
	Middle	Togawa lava flow	ca. 150	60
		Aso 2 WT	—	—
		Aso2/1 inter Bed	—	35-135
		Aso 1 WT	250-280	10
		Suizenji Bed	ca. 300+	35+
Lower Pleist. ～Pliocene		Pre-Aso Volcanic Rocks	—	—
Upper Cretaceous		Mifune Group	>65,000	—
Pre-Cretaceous		Metamorphic rocks	—	—



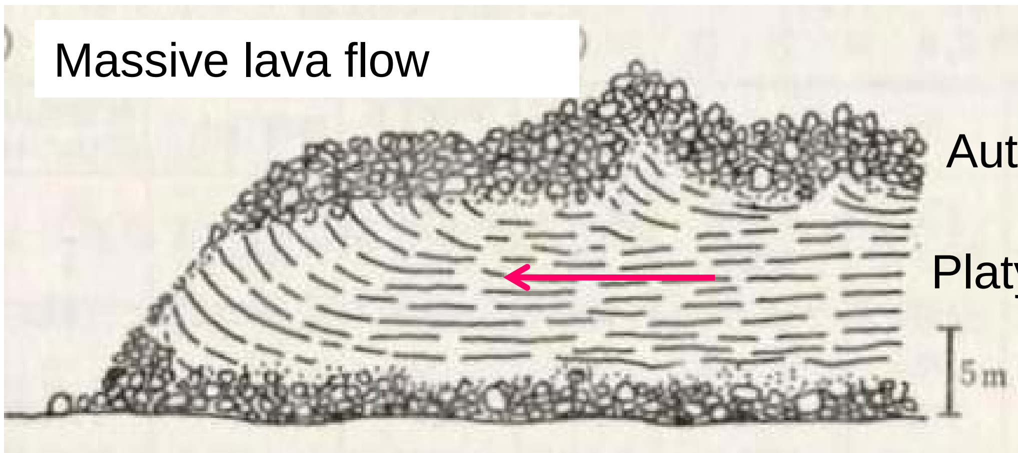
(Kumamoto P. & Kumamoto C., 1986)
Geologic map
Kikuchigawa R.
Mt.Aso
Recharge area
Kumamoto City Hall
Kumamoto station
Ezuko lake
Shirakawa R.
Ariake Bay
Midorikawa R.
Legend
alluvium
Terrace dep.
Takayubaru lava
Aso pyroclastic dep.
Pre-Aso volcanics
Mifune F.
Metamorphic Rocks
Geologic cross section line
0 1 2 3 4 km


South
North-South Cross Section
North
Shirakawa R.
East-West Cross Section
East
West
100 m
0 m
Alluvial Plain
Table Land
Togawa lava
(Ibid.,1986)

Boring core of Togawa lava flow, Good aquifer
ca.25m – ca.98m (ca. 70m thick)

(Hakenomiya Water Museum)

Massive lava flow

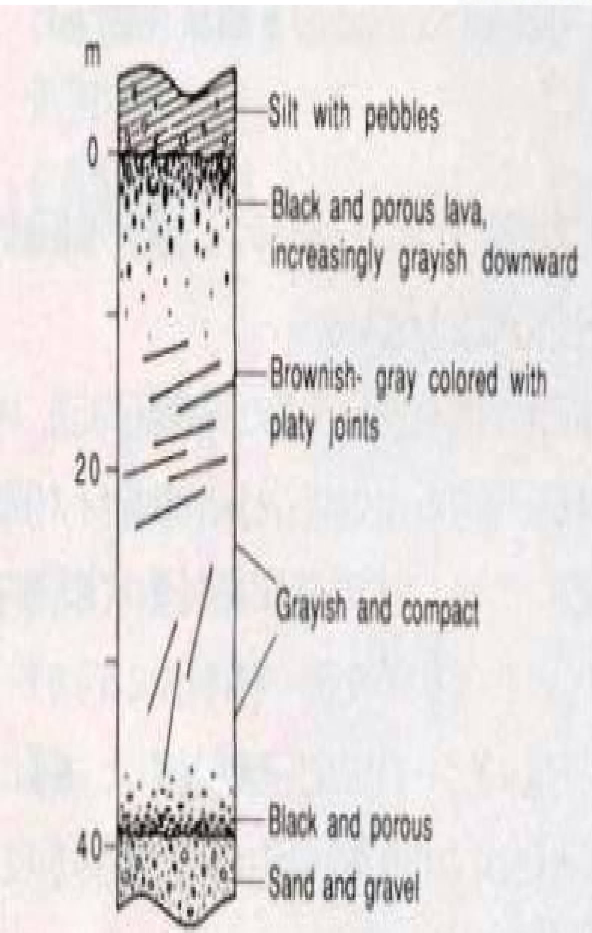


Auto-brecciated (clinker) and vesicular

Platy joint

(Macdonard,1972)

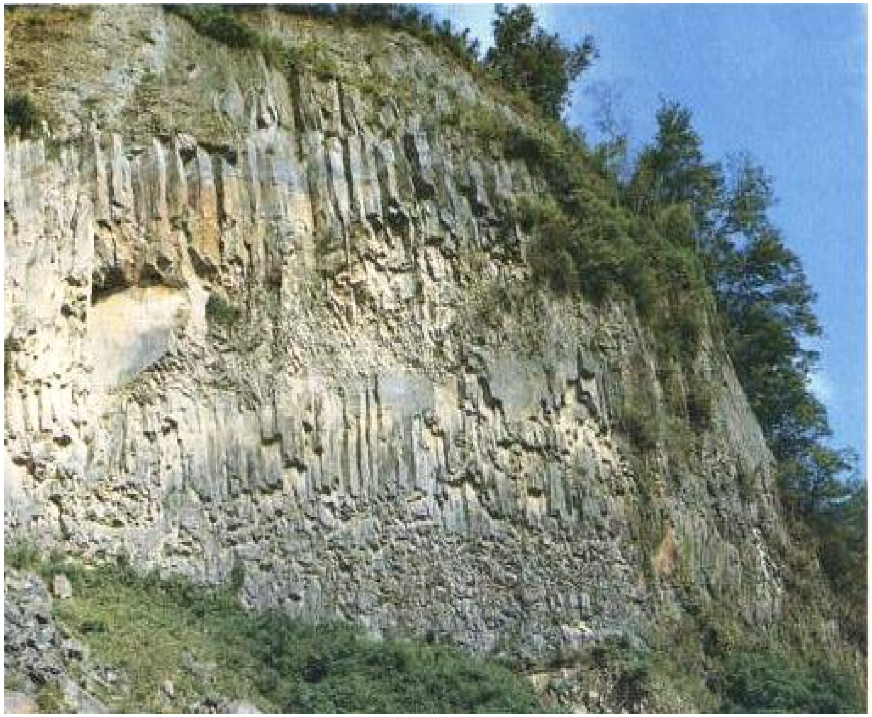
Close-up of drilled core of Togawa lava flow (porous, good aquifer)



Typical lithologic cross section （Morishita,1992)

(Kumamoto City)

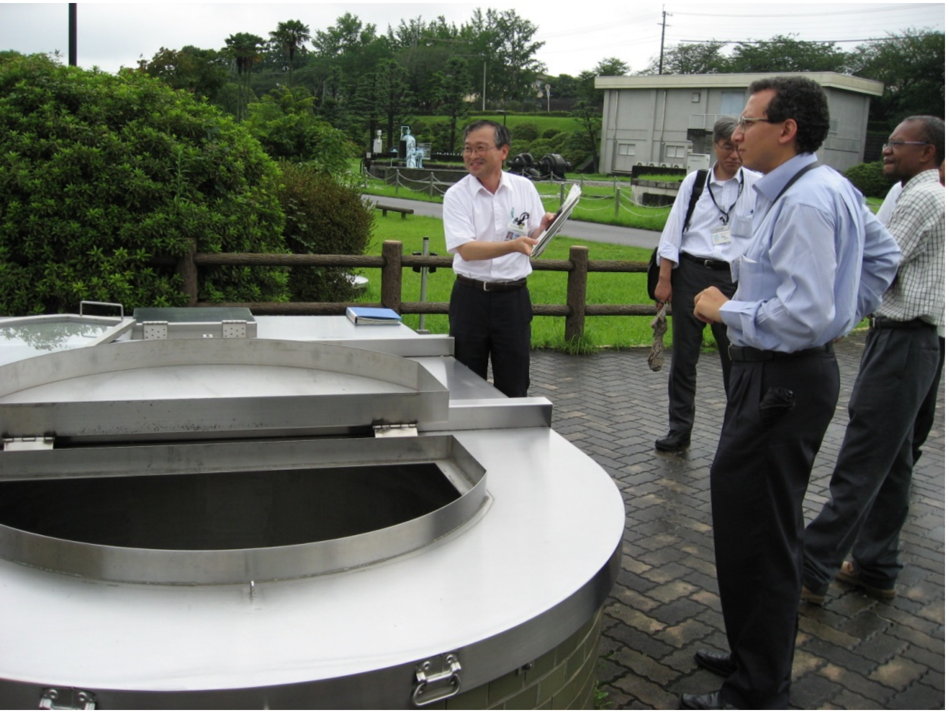
Outcrop of Aso Welded Tuff



(Nature of Japan, Heibonsya)

Columnar joints are developed, much effective porosity, good aquifer

Kengun Well Field

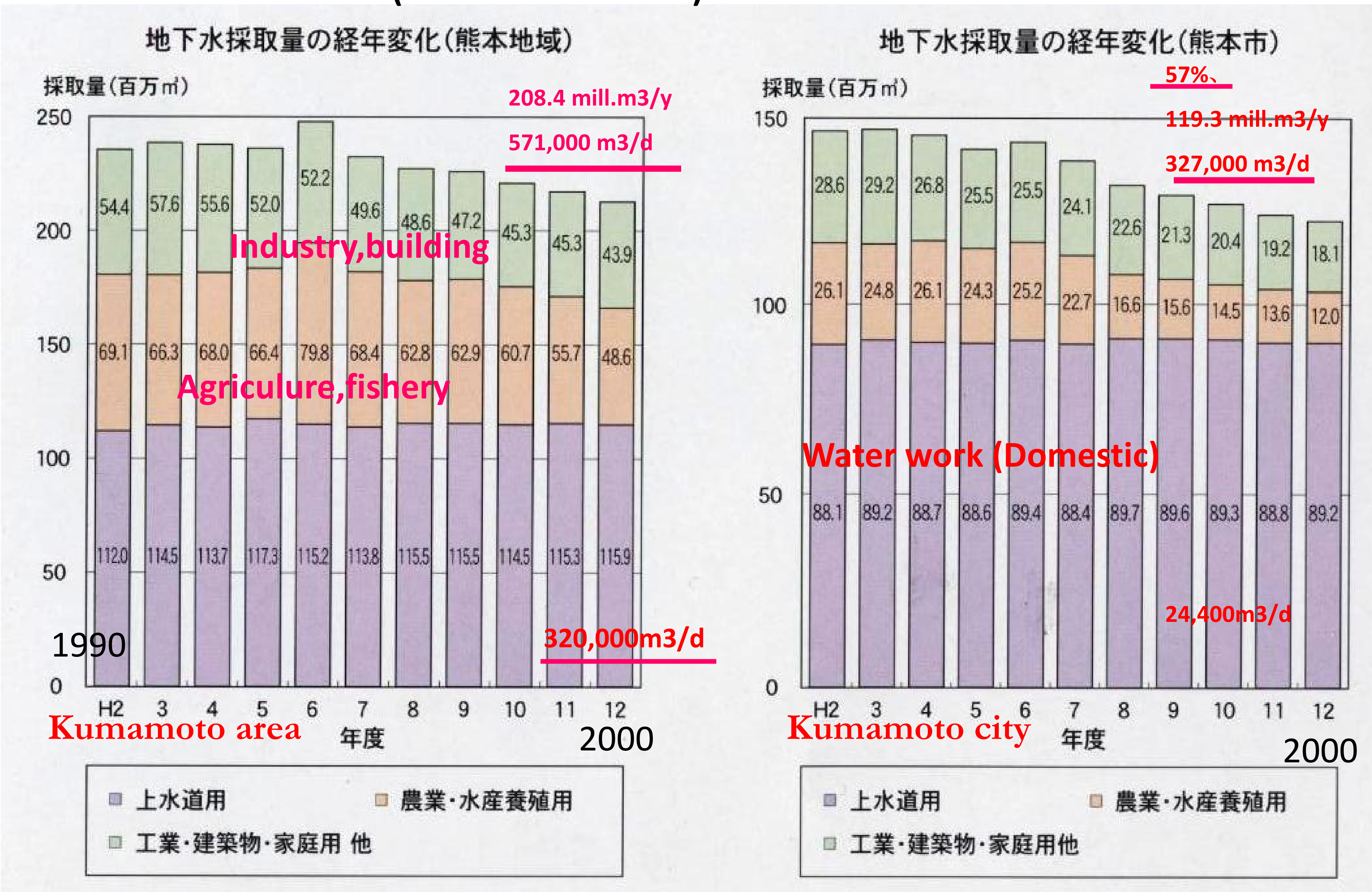



Kengun Well Field

Self-flowing Well at Kengun Well Field, (16,000 m^3/day)
Depth: 40m, diameter: 350-450mm

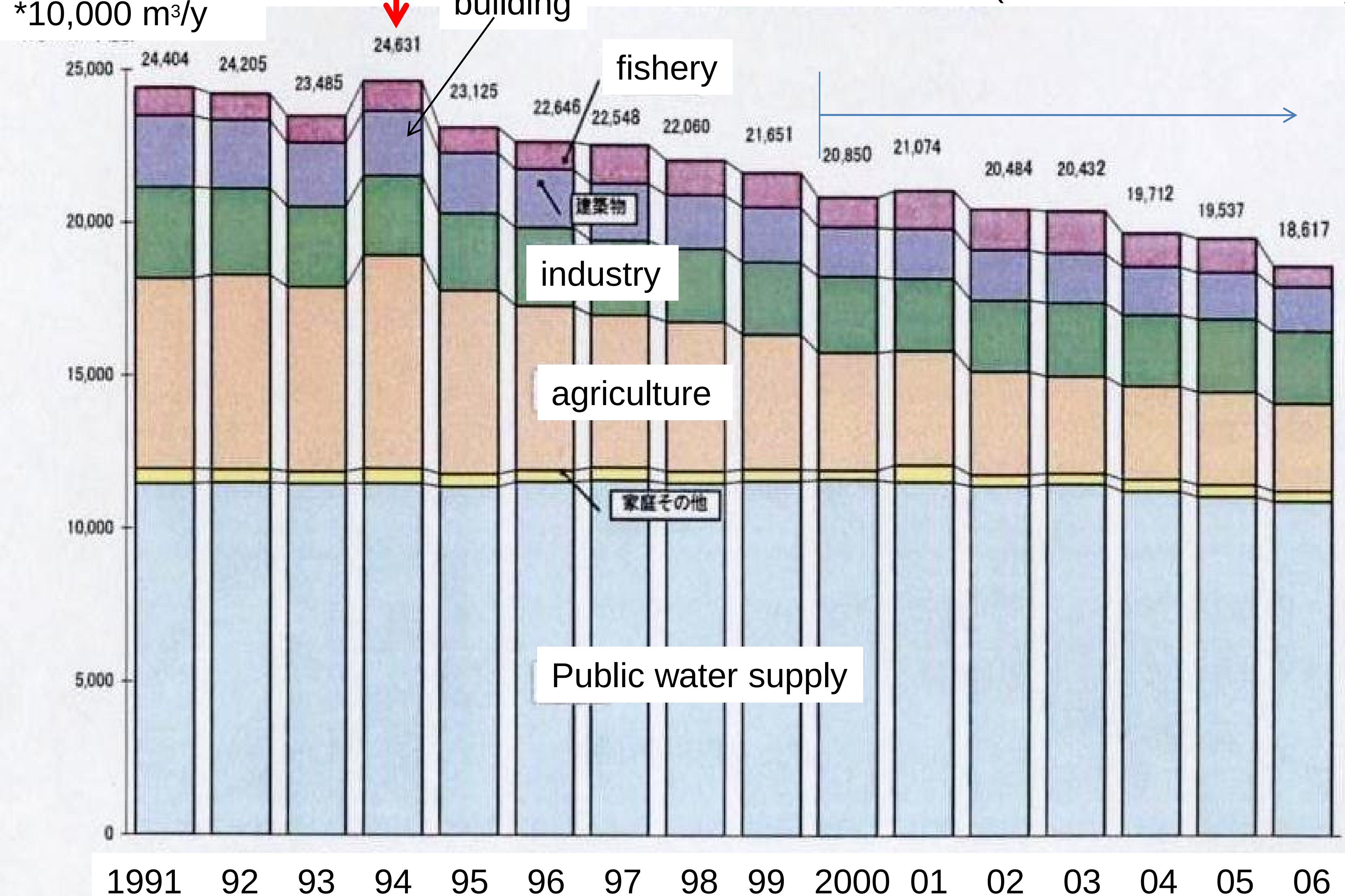
Annual change of groundwater pumpage in the Kumamoto area and city

(From 1990 to 2000)

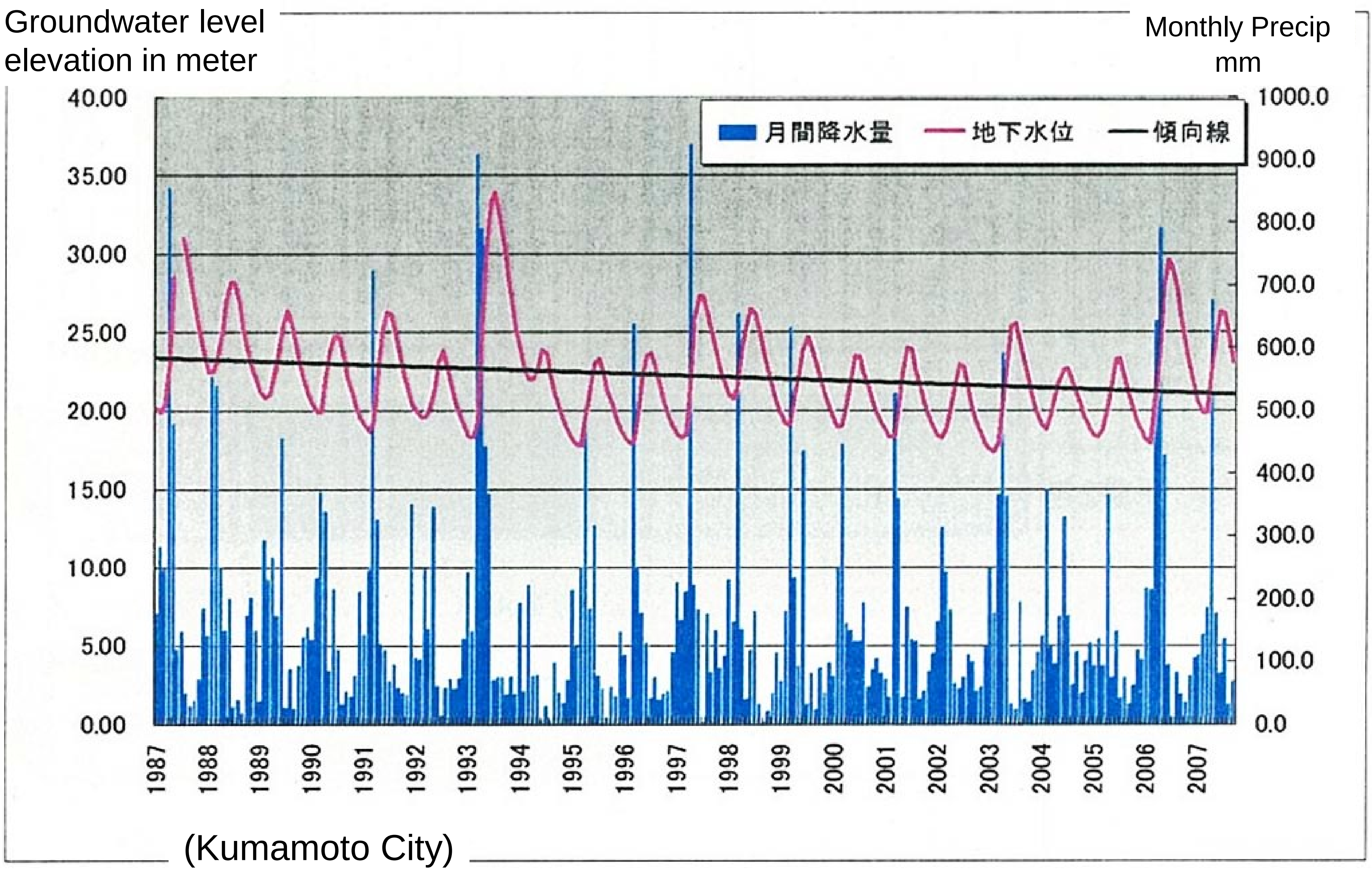


Pumpage of the Kumamoto area

(Kumamoto Pref. office)



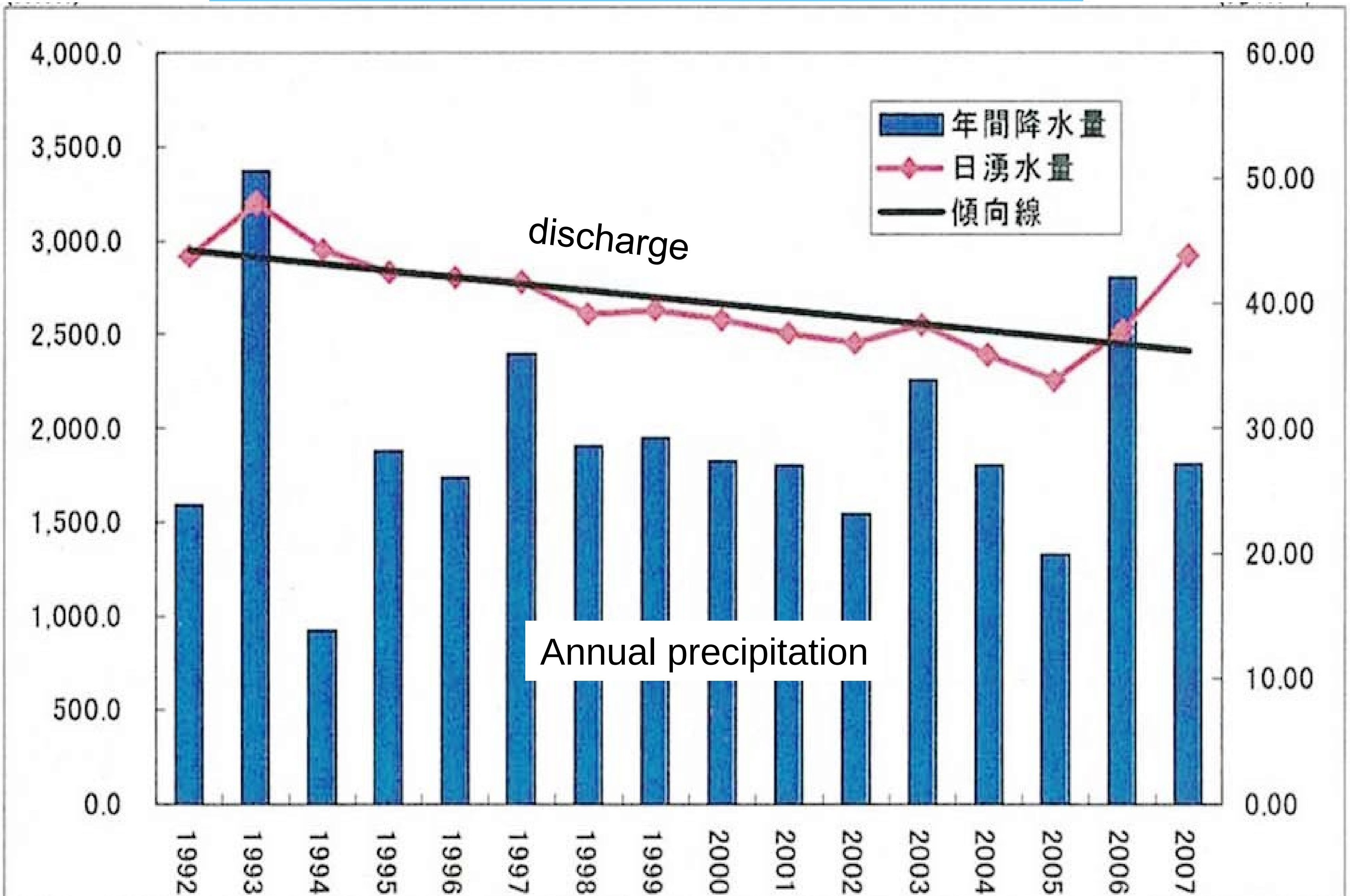
Monthly groundwater level （Toshima station in the middle of the basin）from 1987 to 2007



Discharge of spring water of Suizenji-Ezuko from 1992 to 2007

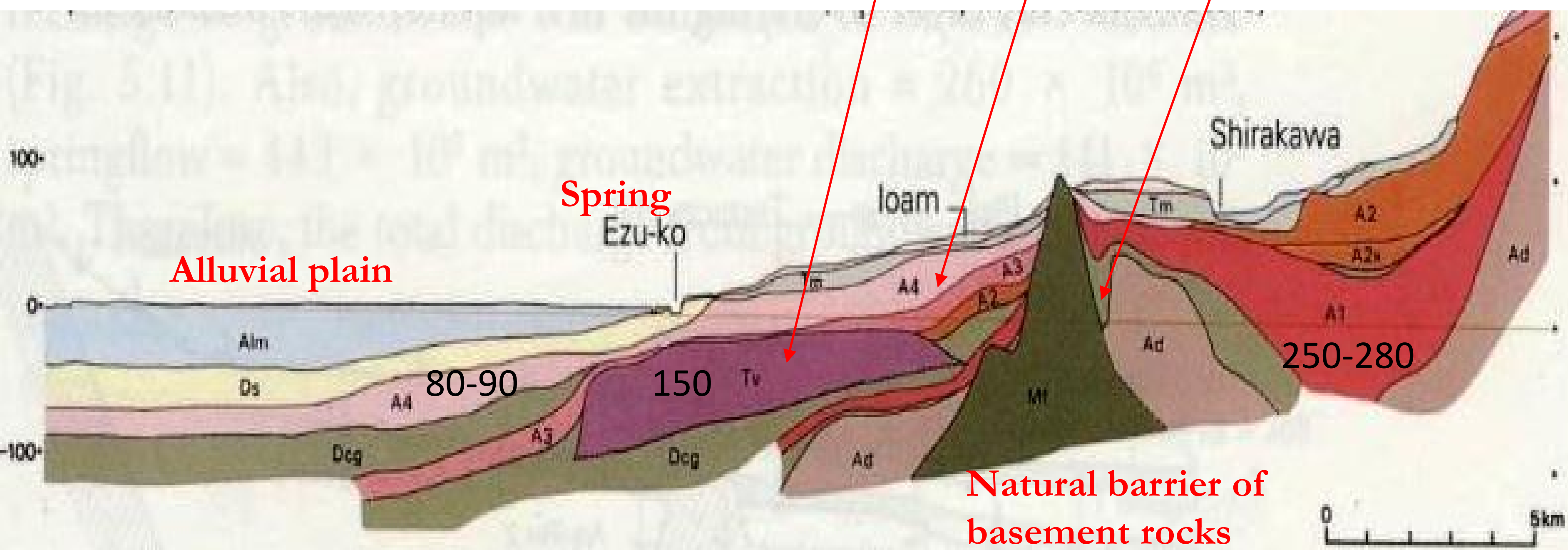
Annual precip.
mm

Daily discharge
*10,000 m^3



(Tokai University)

Geologic cross section in the west to east direction
groundwater is regulated by upper aquifer (pyroclastic flows),natural subsurface dam and lower aquifer (andesite lava flow)

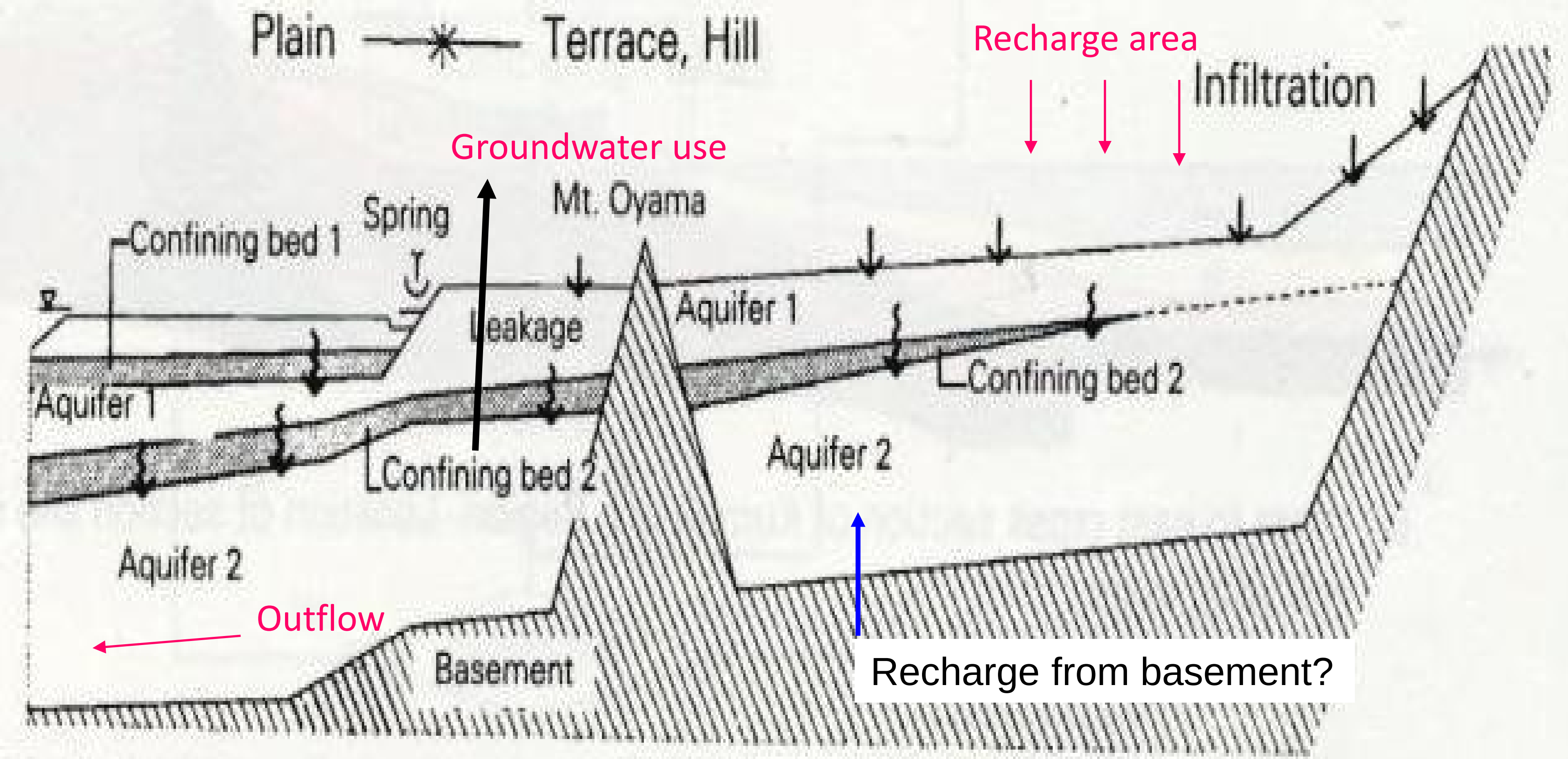


(e) West to east cross section of Kumamoto Region. Location of section line is indicated in (a).

Absolute age * 1000 years before present

(Urban Kubota)

Modeling of groundwater basins



Confining bed 1 : Ariake clay (alluvial)
Confining bed 2 : Hanabusa clay
Aquifer 1 : Takuma sandy gravel layer and Aso-4
Aquifer 2 : Aso-1 ~ 3 and Togawa lava

Outcome of simulation study of 2007 and forecast in 2024

(million m^3/year)

year		2007	2024	
hydrologic parameters		Case 1	Case 2	Case 3
inflow	recharge in table land	495.1	458.2	531.5
	recharge in mountains	100.4	100.0	100.1
	leakage from unconfined aquifer	4.8	4.9	4.6
	sub-total	600.4	563.2	636.2
outflow	groundwater abstraction	186.2	186.2	170.0
	spring discharge	342.6	297.3	370.6
	outflow to adjacent areas	93.6	80.5	93.8
	sub-total	622.6	564.0	634.4
water balance		-22.2	-0.8	1.8
precipitation at Kumamoto Observatory (mm/year)		1946.0	1946.0	1946.0

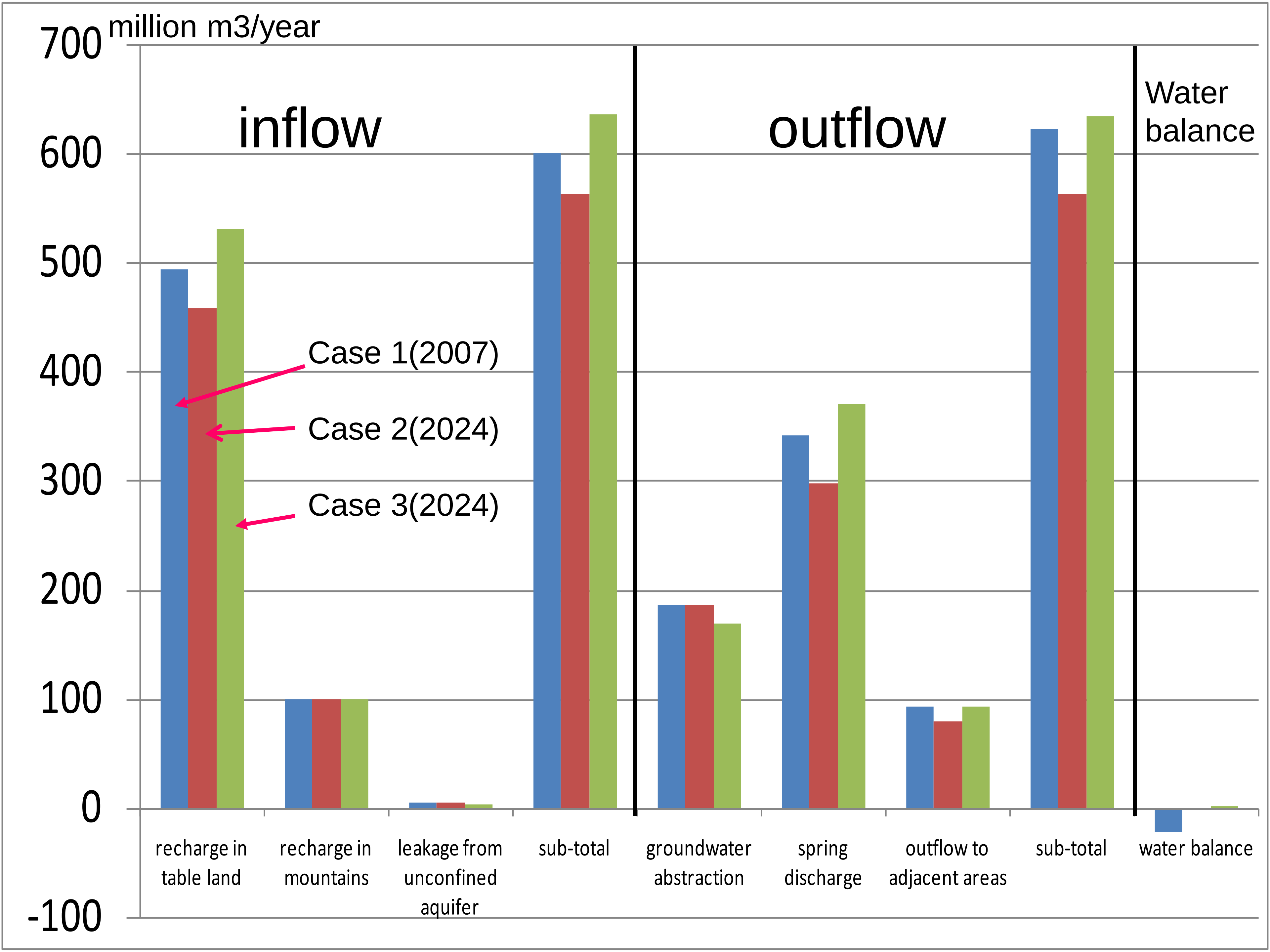
Case 1 : Present situation

Case 2 : Forecast conditions are as follows (if countermeasures are not achieved),

1) Rechargeable area will decrease according to average rate 1.12 km^2/year during 1990 to 2006. 2) Groundwater will be abstracted at the rate of 186.2 m^3/year(2006). 3) Precipitation will continue at the rate of average year of 1946 mm/year.

Case 3 : Forecast conditions are as follows (if countermeasures are achieved),

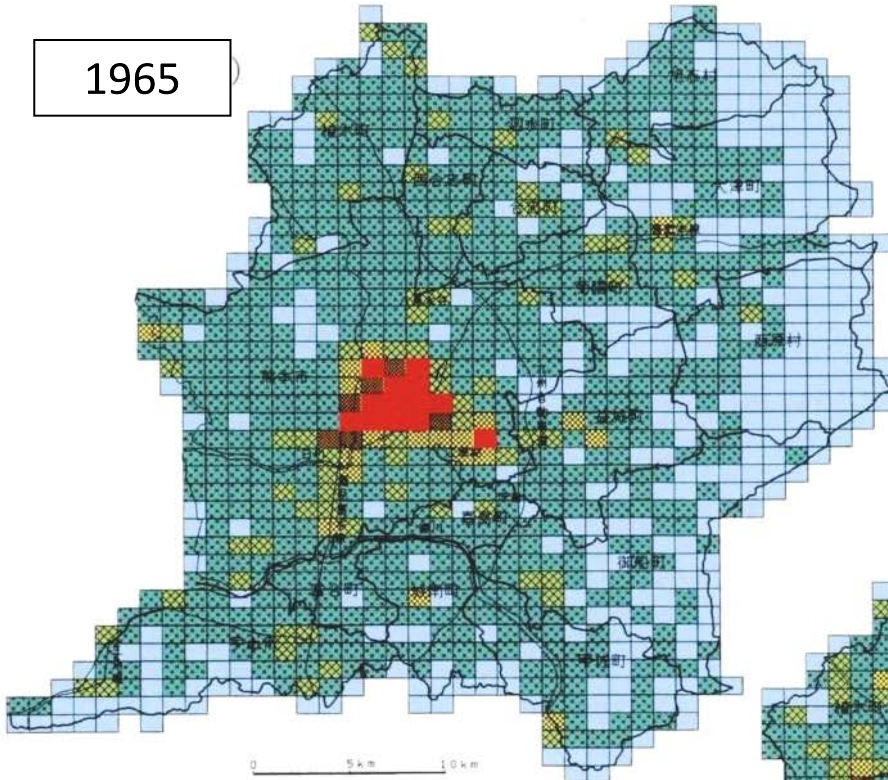
1) Artificial recharge will attain the final target of 73 million m^3. 2) Groundwater abstraction will save down to 170 million m^3 of upper limit.


million m3/year
700
600
500
400
300
200
100
0
-100
inflow
outflow
Water balance
Case 1(2007)
Case 2(2024)
Case 3(2024)
recharge in table land
recharge in mountains
leakage from unconfined aquifer
sub-total
groundwater abstraction
spring discharge
outflow to adjacent areas
sub-total
water balance

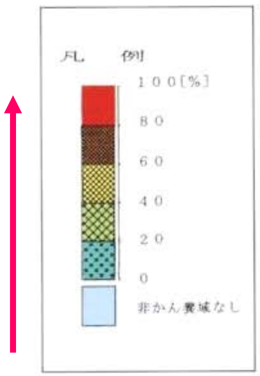
Decrease of rechargeable area

1 km grid resolution

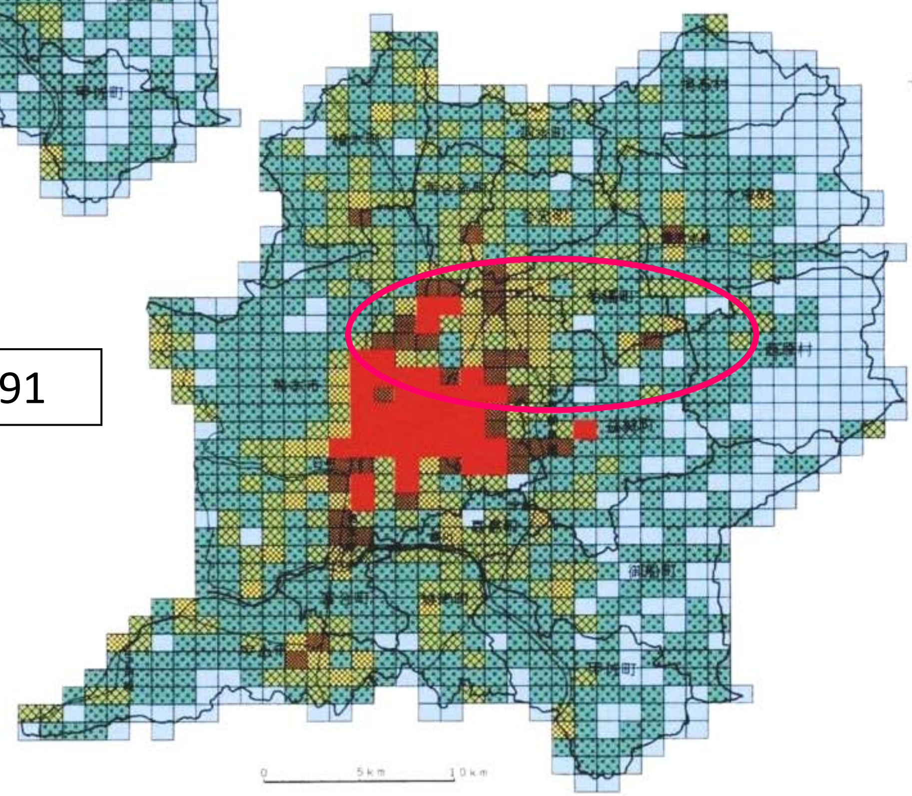
1965



Urbanization



1991



Rechargeable:
Paddy,vegetable field, forest,grass land

Non-rechargeable:
House,building, factory,pavement road

- Diagram showing the relation between time until 2010 and recharge of groundwater

  (million m^3/year)

- Recharge Quantity

  decreases in proportion to decrease of rechargeable area in the upstream

- Decease of recharge

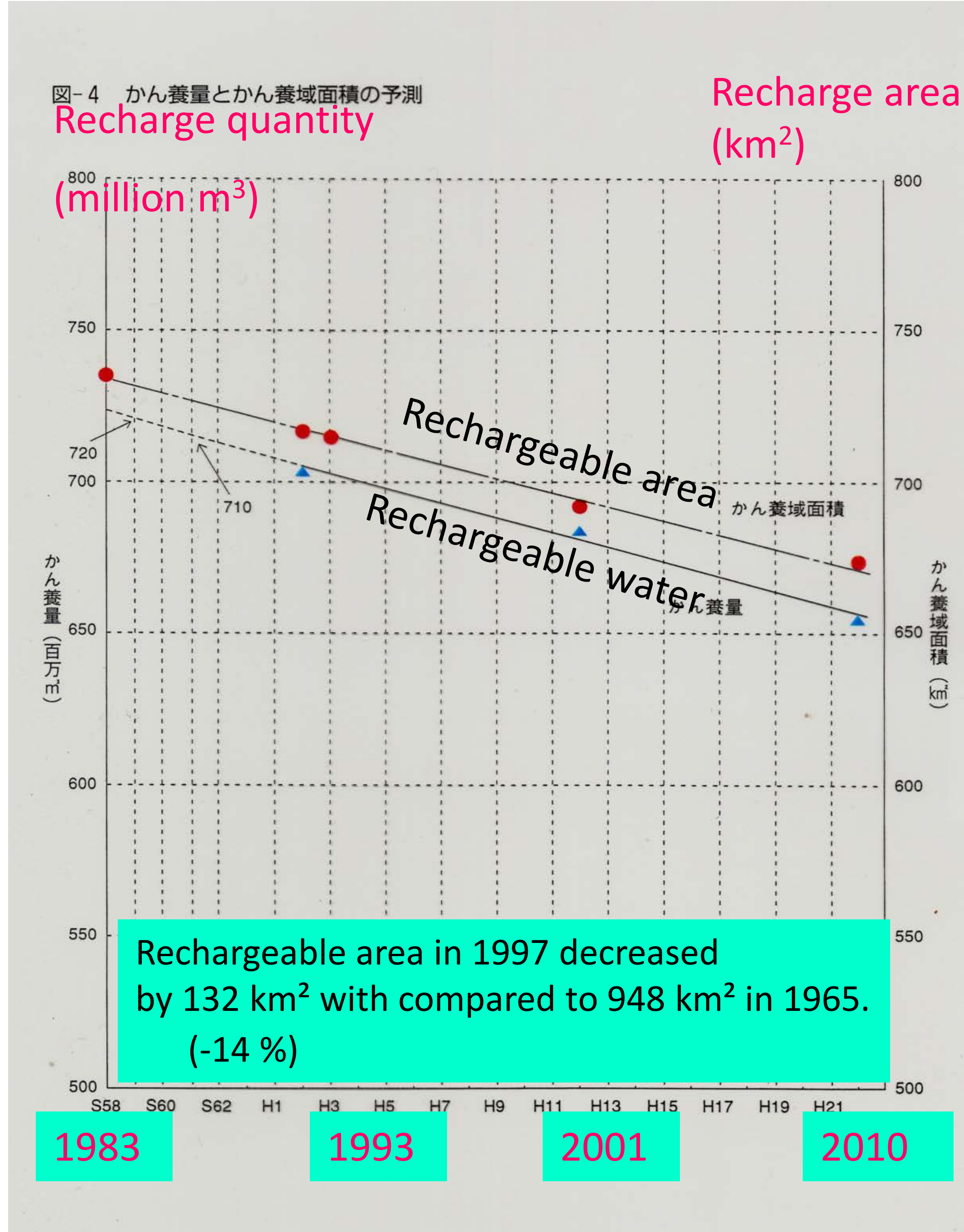
  area is caused by

  change of land use

  from paddy and grass land to others

  (residential, pavement,

  factories, green house etc.)



Where does decrease of infiltration go away? Let think from the viewpoints of water balance.

Basic Formula $P-R-E-I=\varDelta S$

$R=P-E-I-\varDelta S$

P: Precipitation

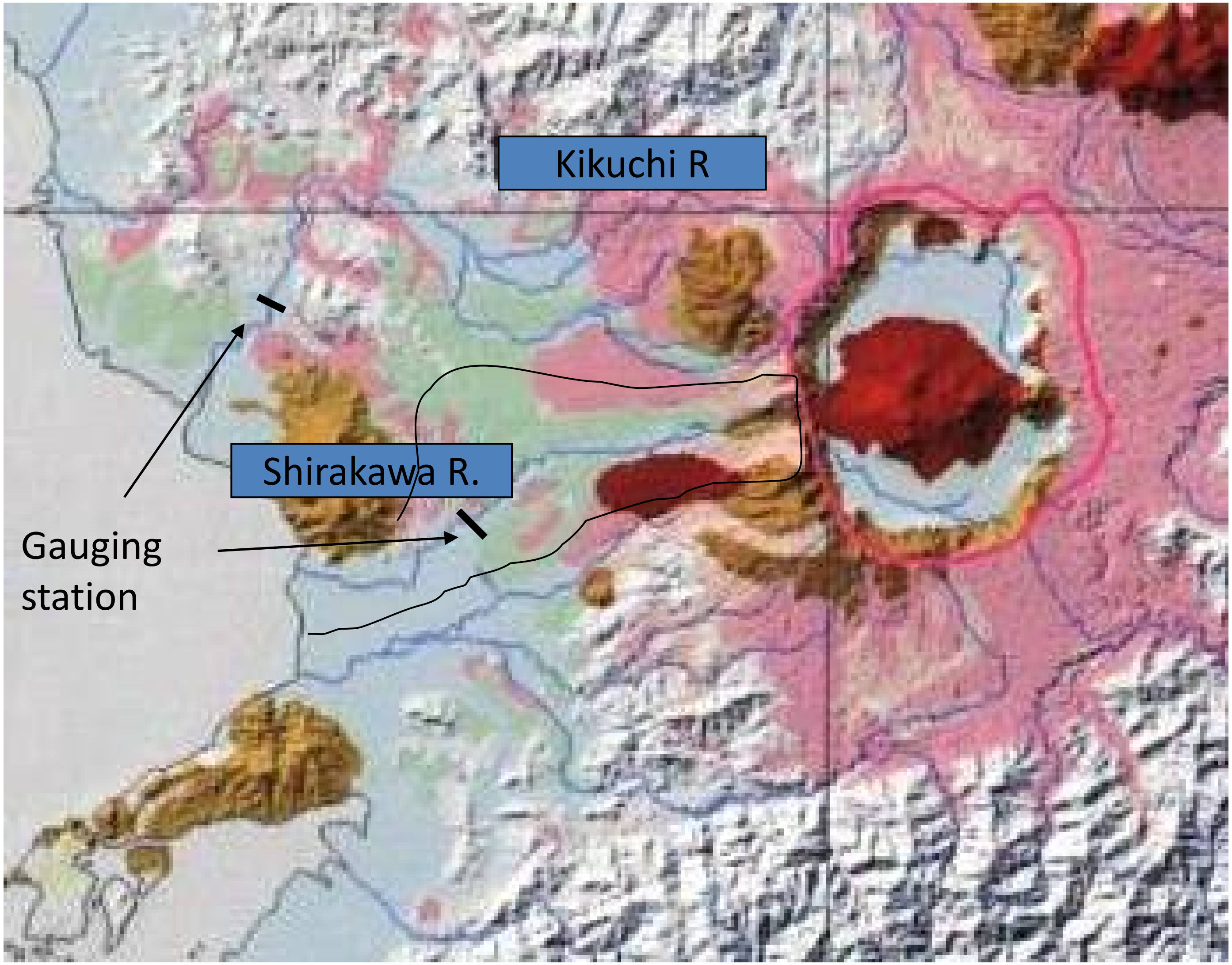
R: River Runoff

E: Evapotranspiration

I: Infiltration : underground for recharge

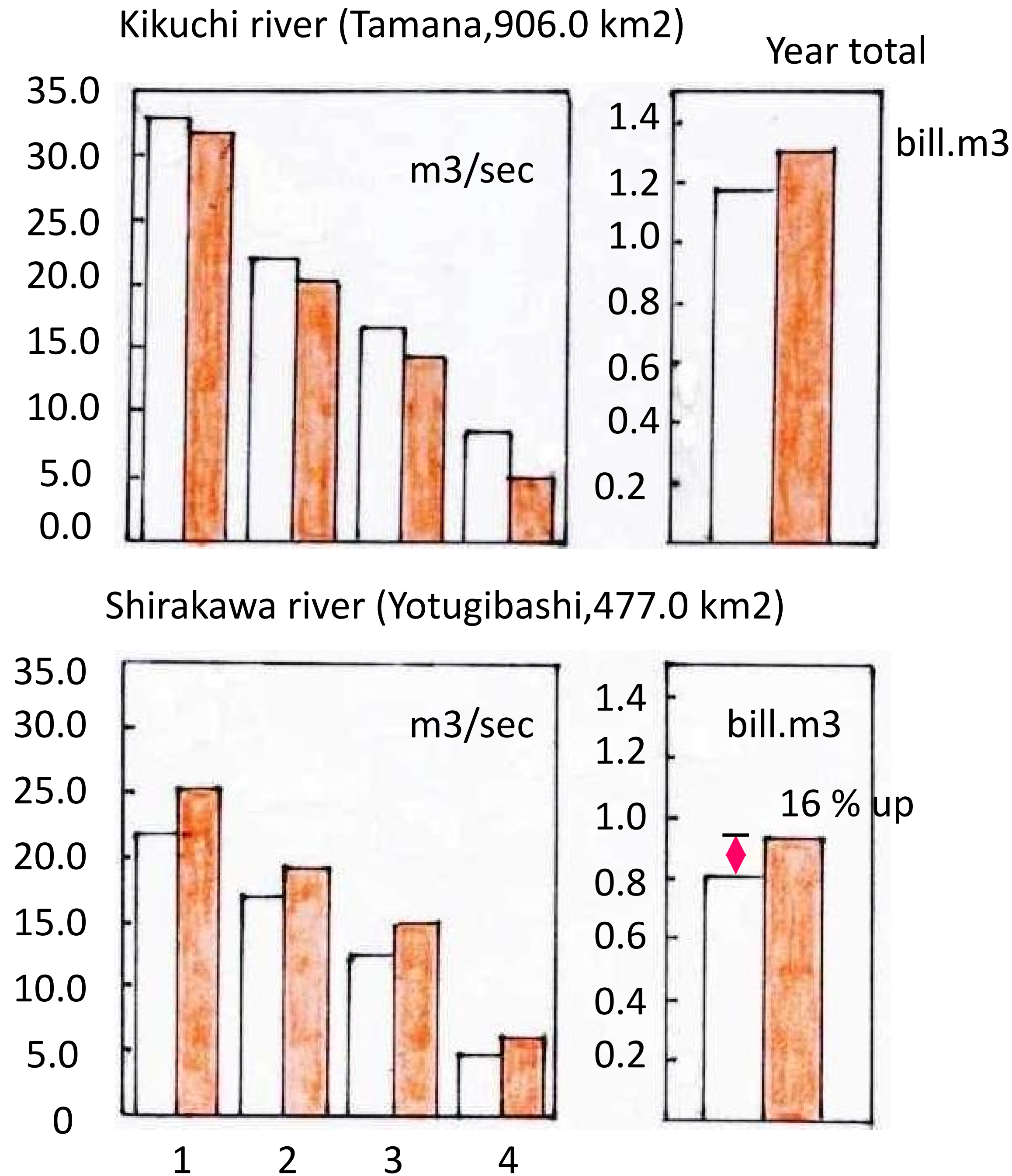
⊿S: Difference of groundwater storage

Location of two rivers



Change of river flow discharge in Kumamoto

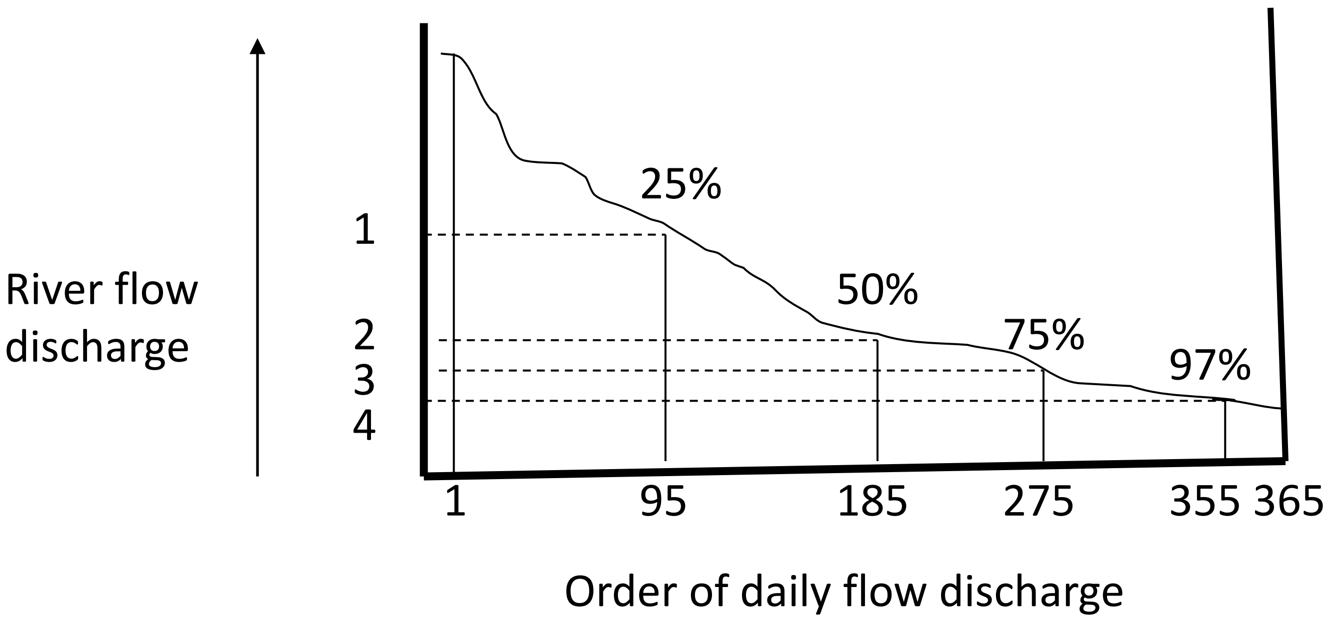
averages of
1955-1976
and
1977-1998



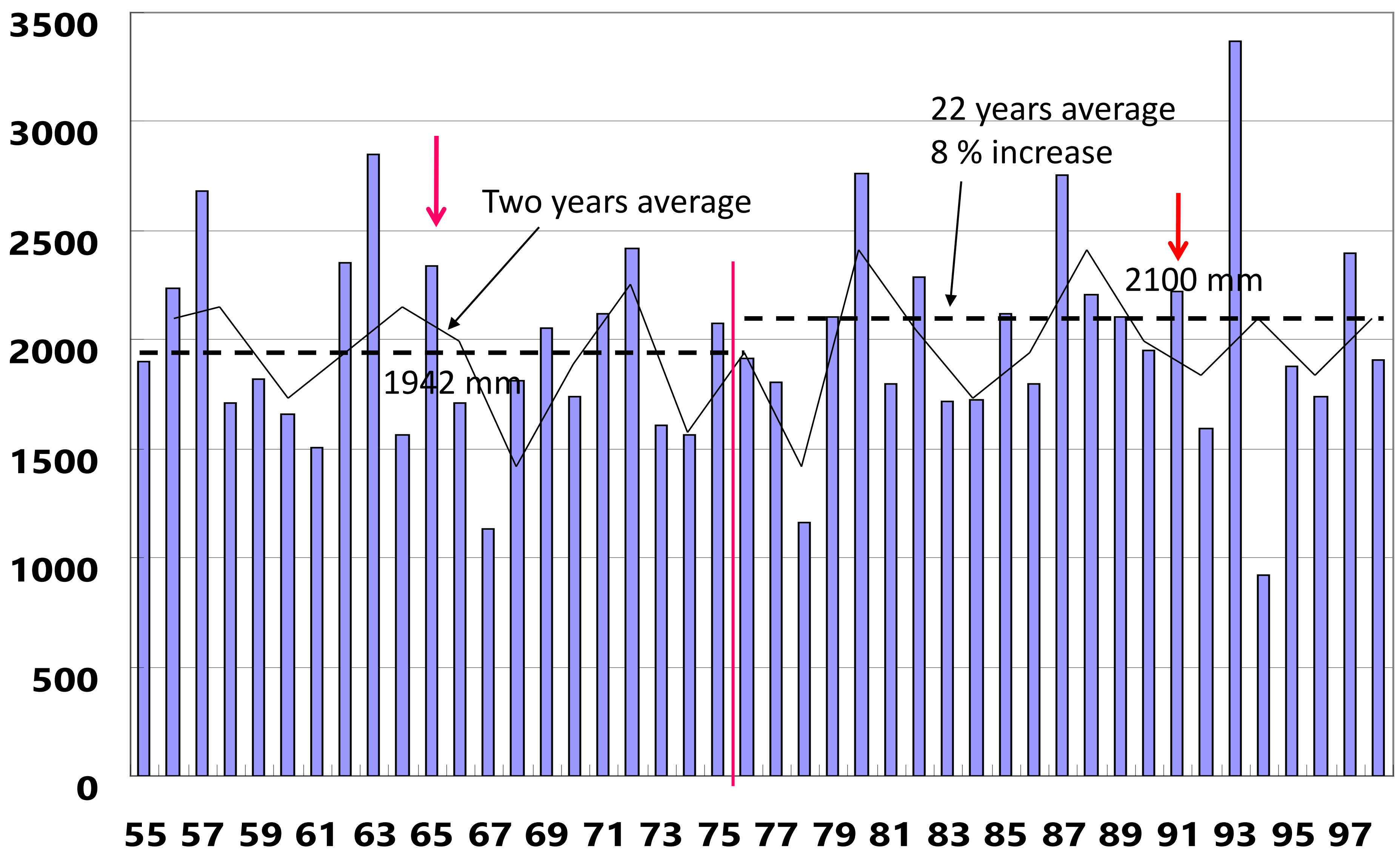
Definition of flow discharge

River flow

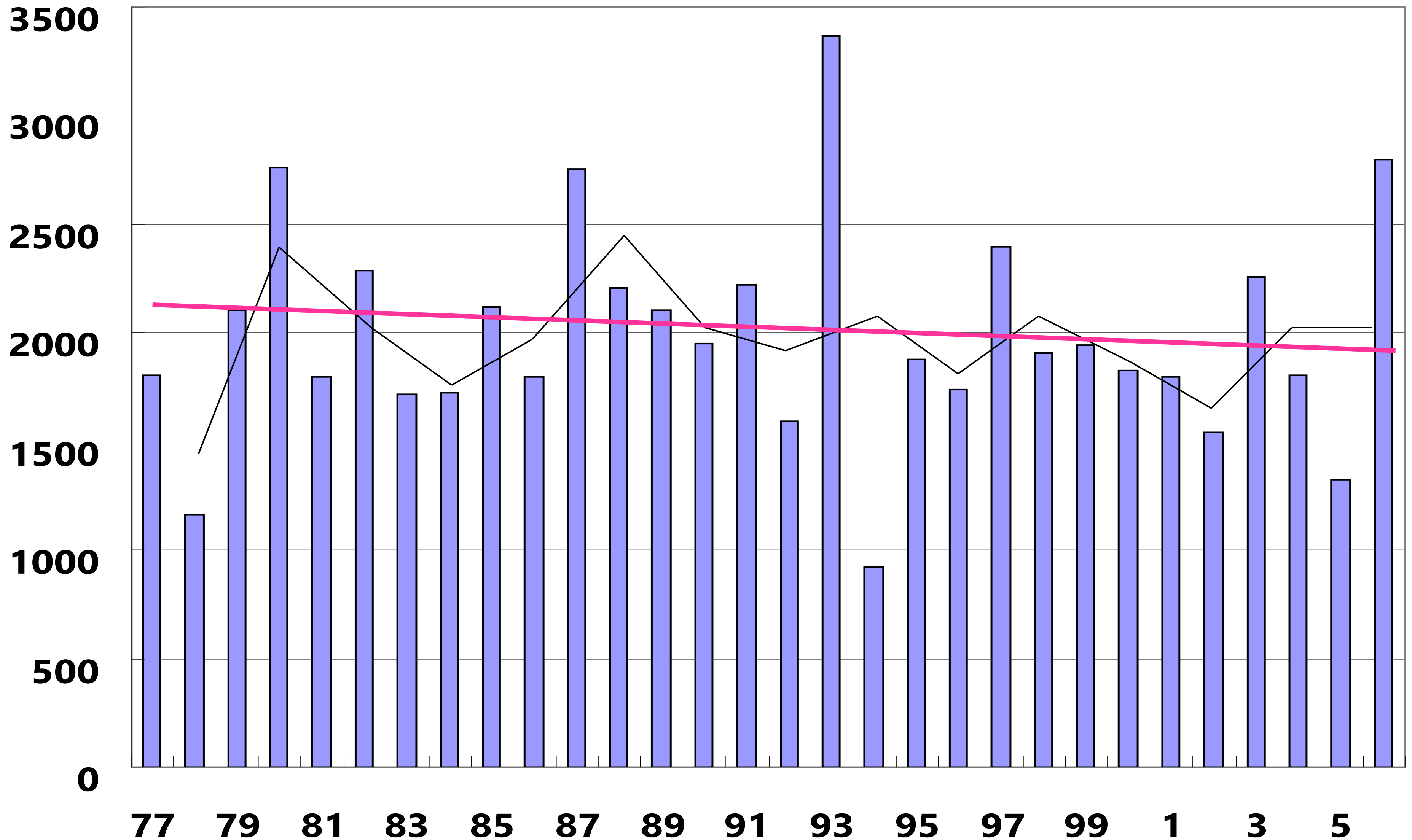
- 1: Wet discharge = 25％ exceedance for 95 days
- 2: Ordinary discharge = 50％ exceedance for 185 days
- 3: Low discharge = 75% exceedance for 275 days
- 4: Draught discharge = 97% exceedance for 355 days



Annual precipitation from 1955 to 1997 in Kumamoto (mm)



Annual precipitation from 1977 to 2006 (20 years) in Kumamoto city (mm)



Managing issues which the Kumamoto should solve in the near future are as follows,

- Water level declines for long term
- Spring discharge decreases for long term
- Rechargeable area in the middle to upstream decreases gradually
- 100% dependent upon groundwater
- No alternative water resources available
- Water use for domestic per capita is more than averages of other cities in Kyushu.
- Water quality deteriorated mainly originated from fertilizers, which are used for agriculture in suburb.
- Formulating of groundwater conservation plan（ Prefecture,City)
- Building-up of local governance system
- On a basis of monitoring, the managing policies and results are recommended to evaluate from viewpoint of PDCA (plan, do, check and act, ISO) cycle.

Principal target for groundwater preservation policy of Kumamoto area by Prefecture office（２００８）

Target parameter	Target year	Target value
Groundwater recharge	2024	73 million m^3
Groundwater abstraction	2024	170.0 million m^3 (0.47 million m^3/d.)
Decrease of Groundwater abstraction	2024	16 million m^3
Nitrate-N content	2024	all wells <10 mg/L

Preservation guideline of land use in view of groundwater recharge and its quality

<table>
<tr><th>Zone division</th><th>Area and land use</th><th>Guideline for preservation of recharge</th><th>Guideline for preservation of water quality</th></tr>
<tr><td>Ⅰ</td><td>・River terrace in the middle reach of Shirakawa river
・Irrigated paddy</td><td>1.New development is not invited in principle

2.In case of evelopment, rainfall infiltration is to equally be maintained</td><td rowspan="3">1. Hazardous substances to groundwater is kept away

2. In case of introducing and handling hazardous substances,

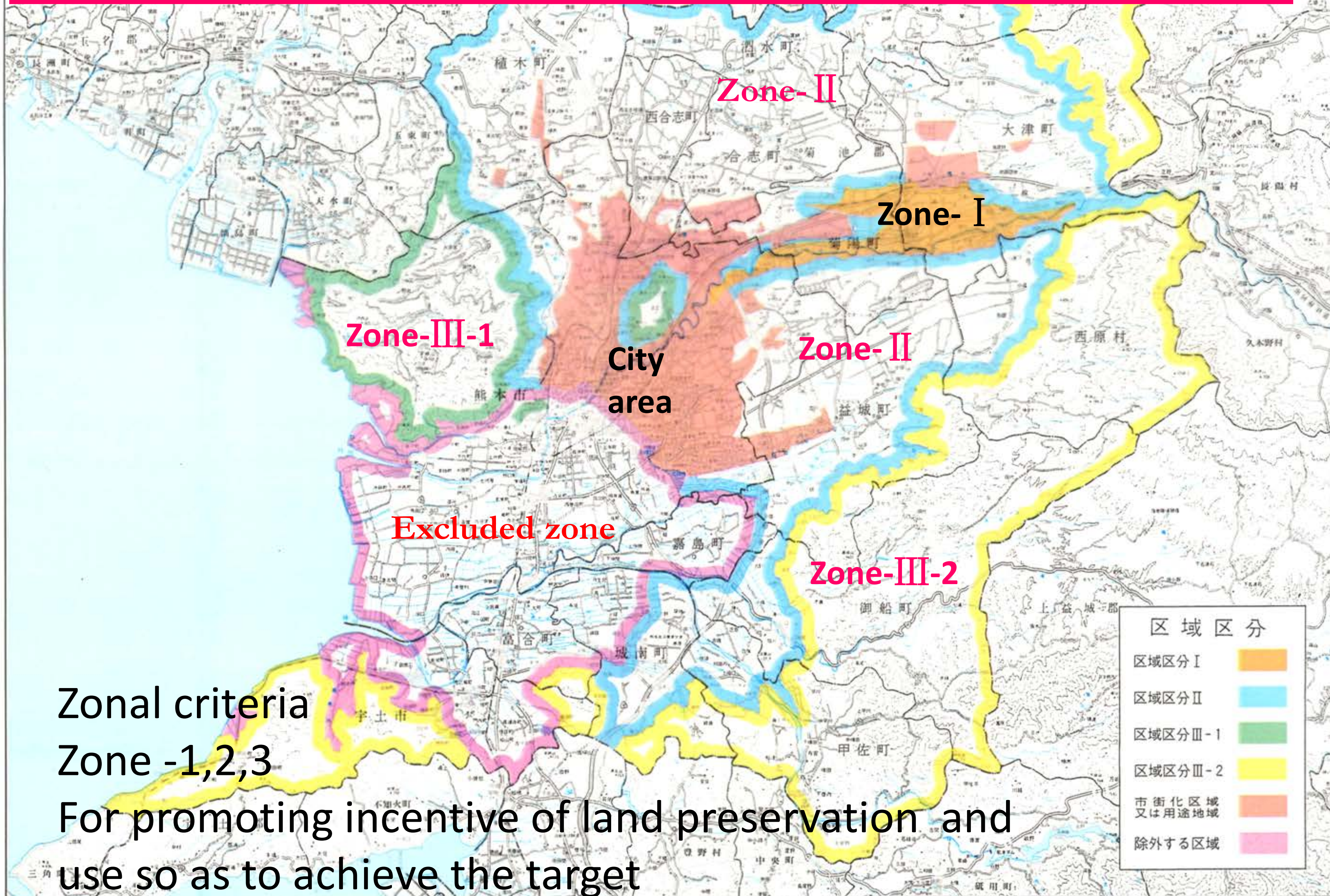
・Anti-shock structure against earthquake and facility is ensured
・Storage is minimized and dispersed
・Monitor and report soil and groundwater condition periodically</td></tr>
<tr><td>Ⅱ</td><td>1.High land, irrigated paddy

2.Forest and bare land in the foot.of Ueki high land and Kinpozan mountains

3 .Forest, grass land, vegetable field and irrigated paddy</td><td rowspan="2">1.In case of development, grass land is maintained as wide as possible

2.Rainfall infiltration facility is recommended to ensure groundwater recharge</td></tr>
<tr><td>Ⅲ</td><td>1. Grass land in the suburb of urban area
2. Mountains</td></tr>
</table>

Zone division for preservation of groundwater recharge area



Zonal criteria

Zone -1,2,3

For promoting incentive of land preservation and use so as to achieve the target

Principal target for groundwater preservation policy in 1st stage of Kumamoto City (2004)

Target parameter	Year & numerical target		2002 (base line)	
	Q'tity	Year	Q'tity	Year
Addition of groundwater recharge (*million m^3/y)	30	2008	—	2002
Decrease of groundwater pumpage (*million m^3/y)	4	2008	—	2002
Groundwater pumpage (* $million^3$/year)	113	2008	117	2002
Domestic water demand (ℓ/day/capita)	230	2008	254	2002

Kumamoto City is responsible for equality to abstraction ratio of 60% in the Kumamoto area, where the final target of recharge is set up 73 million m^3 in 2024.

Principal target for groundwater preservation policy in 2nd stage of Kumamoto City (2009)

Target parameter	Target year Target value	Year Present value
Groundwater recharge	2013 30 million m^3	2007 12.23 million m^3
Decrease of groundwater abstraction	2013 4.8 million m^3 (104.68 million m^3)	2006 109.48 million m^3 (0.3 million m^3/d.)
Domestic water use/capita/day	2013 230 ℓ/capita/d.	2007 241ℓ/capita/d.
Nitrate-N content	2013 exceeding 10 mg/L < 5%	2007 19.6 % (22wells/ 112 wells)

Set-up of monitoring standard groundwater level for preservation policy

イ）基準地下水位

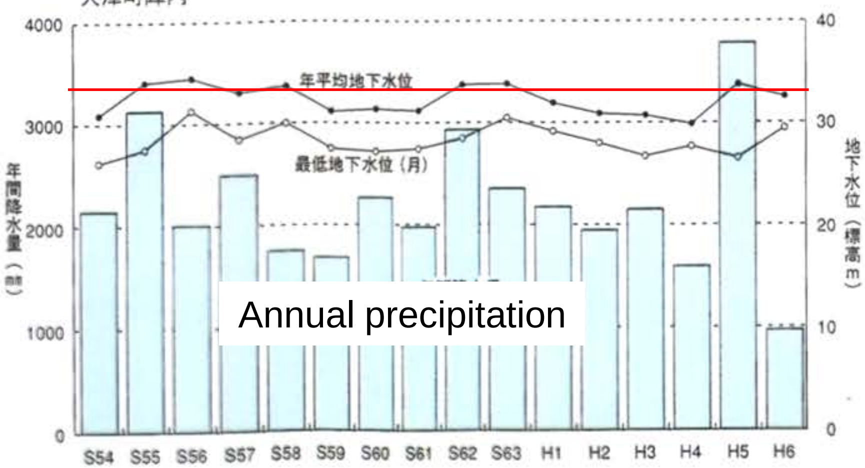
判定観測点の地下水位の近年の変動状況は、異常多雨の平成５年を除き、昭和62年から概ね低下傾向にある。昭和62年も年間降雨量が2,755㎜と多雨の年であったが、昭和59年から昭和61年の３年間の降雨量は平年程度であり、地下水位も安定していたことから、それぞれの判定地点での３年間（植木町大和は昭和60年から２年間）の平均水位を、維持することが望ましい基準地下水位と考える。（図－３参照）

表-８　基準地下水位

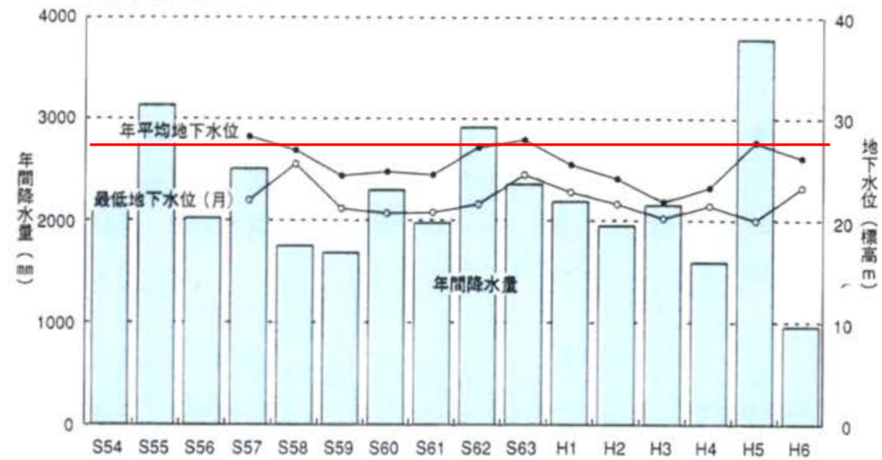
判定地点	基準地下水位(標高ｍ)
大　津　町　陣　内	31
菊　陽　町　辛　川	25
植　木　町　大　和	57

図-３　年間降水量と年平均地下水位の変動

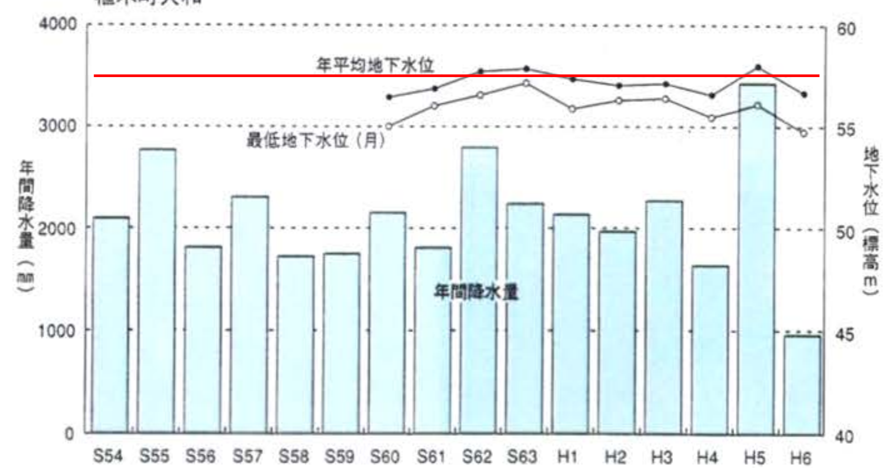
大津町陣内



菊陽町辛川



植木町大和



熊本日日新聞　平成16年(2004年)1月29日　木曜日

全国初…高まる期待

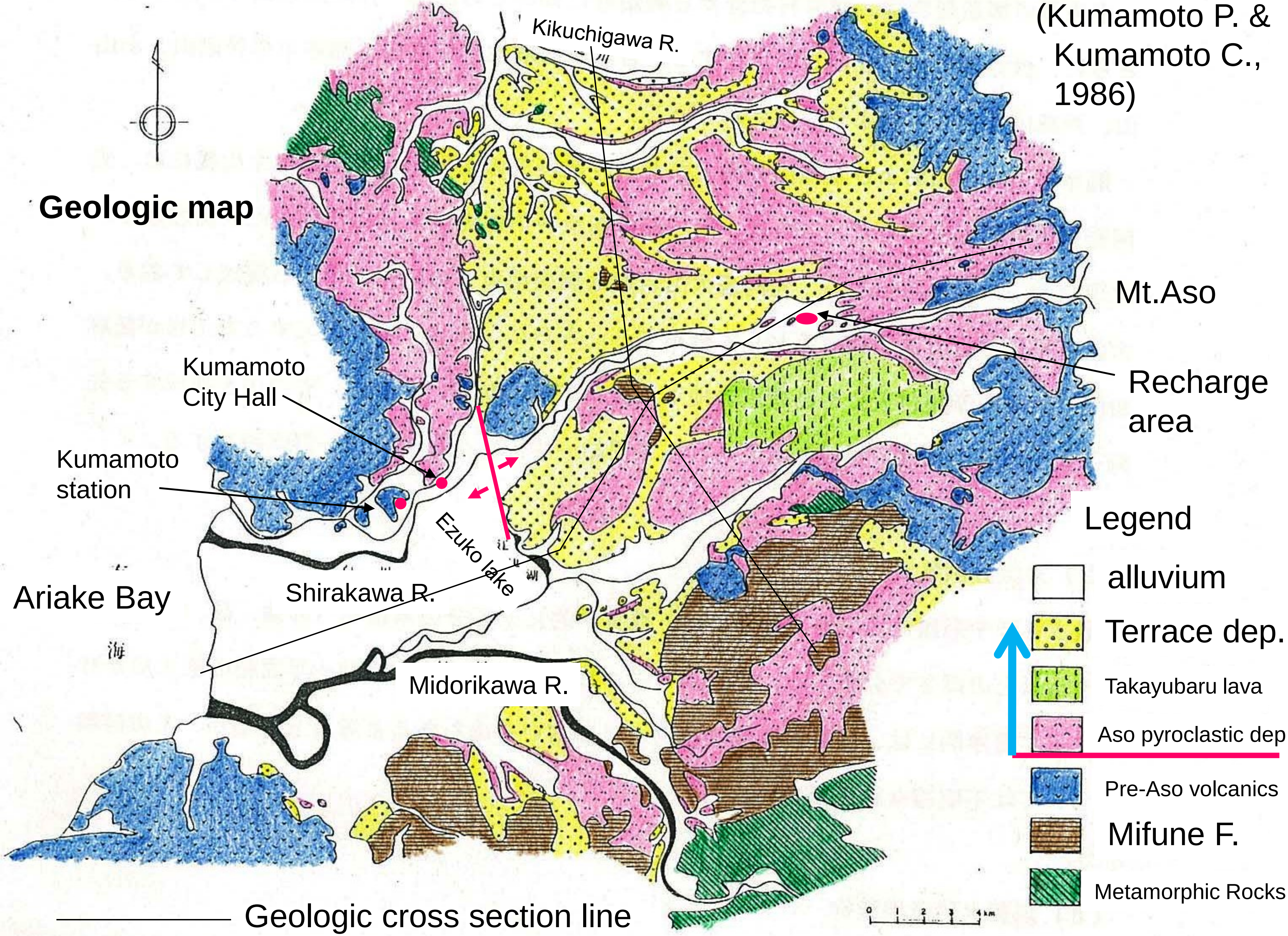
地下水保全へ熊本市、大津町、菊陽町が連携

熊本市は来年度から、全国に誇る地下水を次世代に継承するため、白川中流の涵養（かんよう）域に当たる菊池郡大津、菊陽両町の協力で、保全事業に乗り出す。両町の農家が協力、水田から転用した畑などに一定期間水を張ってもらうことで、五年後には涵養量の年間約三千万トン、5%近いアップを狙う。「市民の生命線」である地下水の保全に向け、自治体が広域連携する全国初の取り組みに、期待が高まっている。

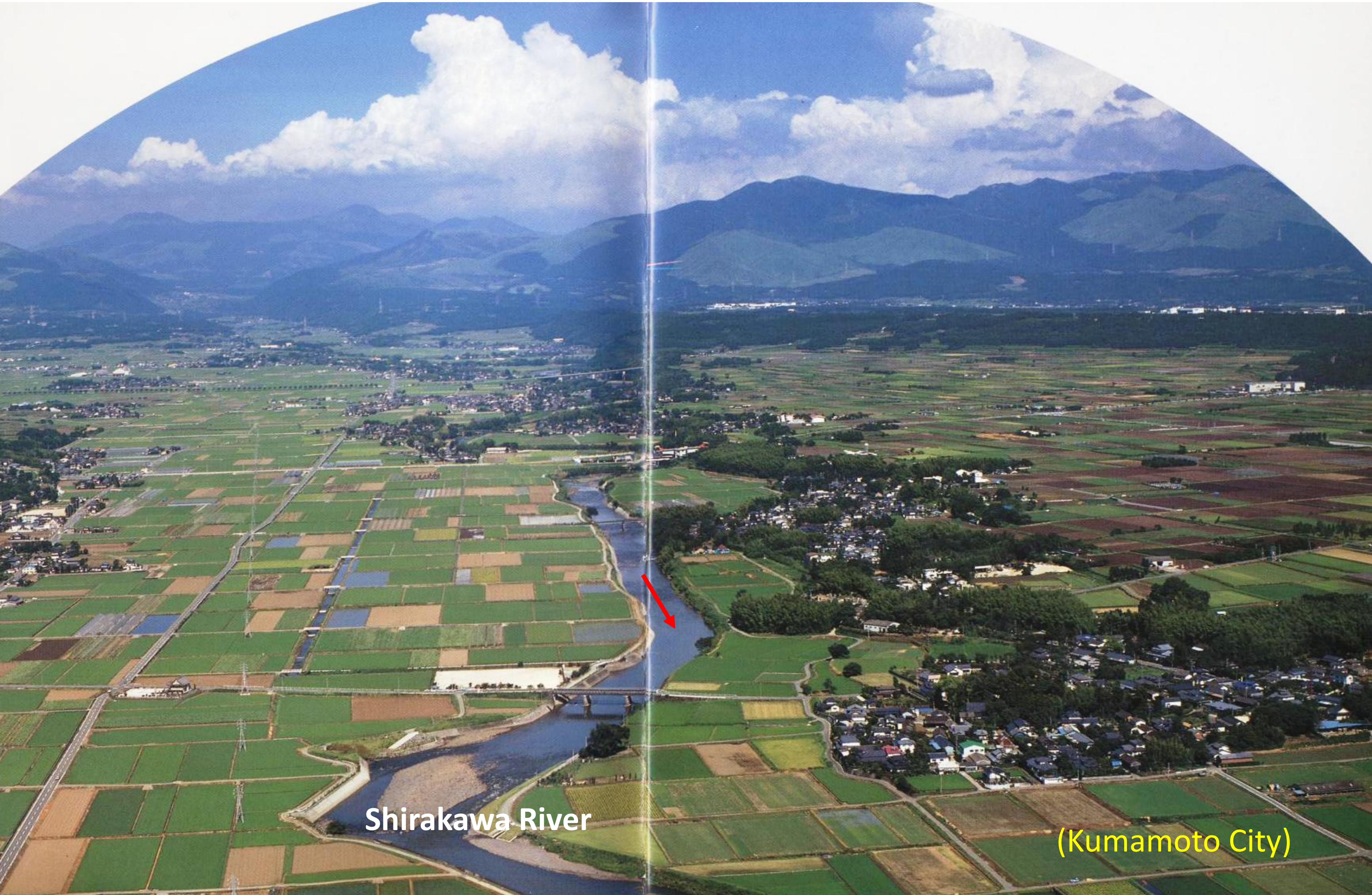
Towards the groundwater conservation, three local autonomies agreed to set up artificial recharge using paddy field in the upstream of the Kumamoto area. This is the first epoch-making case ever in Japan (Jan.2004).

同市は「地下水保全には白川中流域での涵養量アップが最も効果的」として畑での水張りに着目した。両町の水田面積は約千六百㌶だが、減反などで半分は野菜などの畑になっている。保全事業は、水田から転用されている畑に、五—十月のうち一—三カ月間、水を張ってもらう代わりに、助

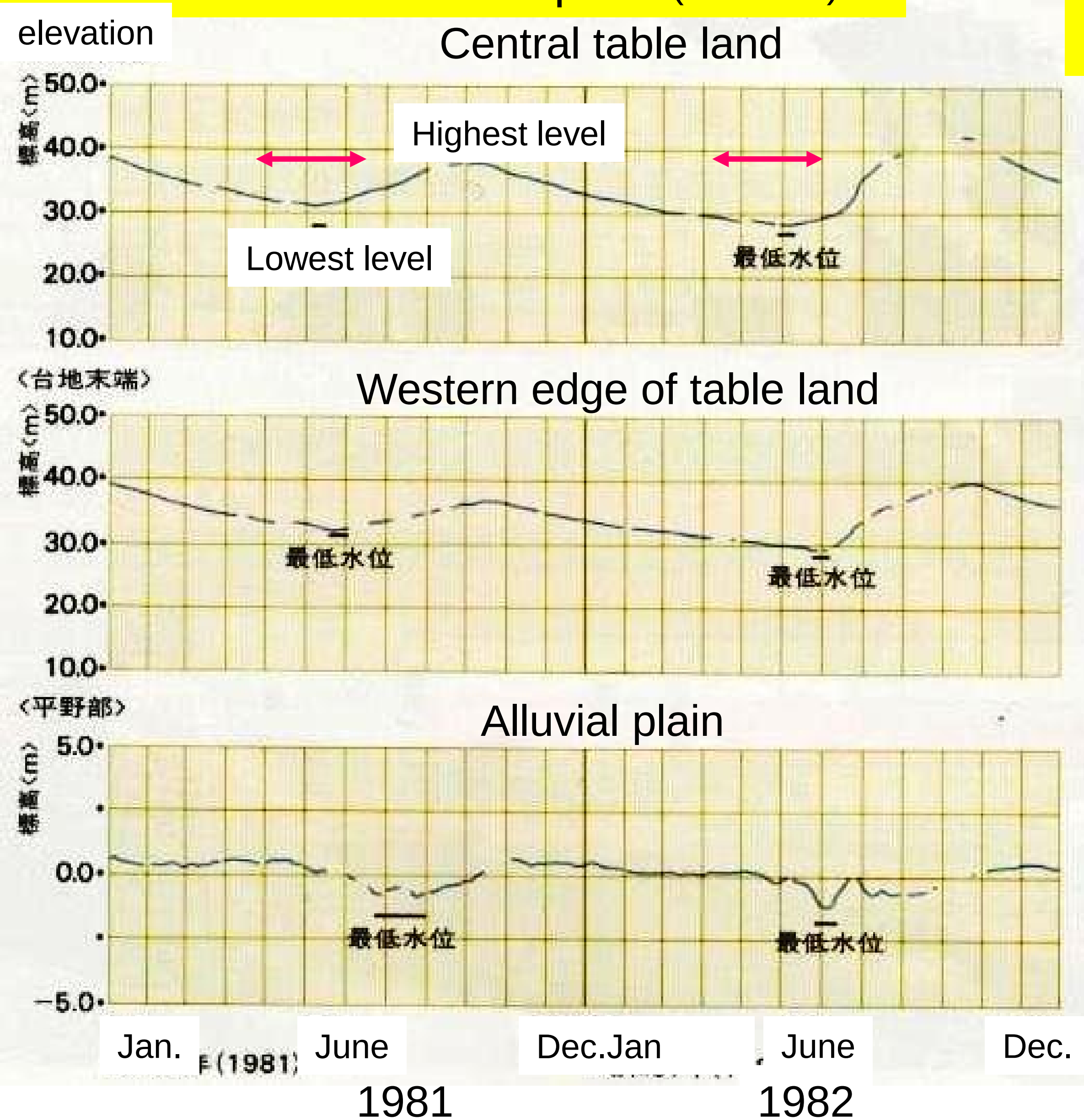
Geologic map



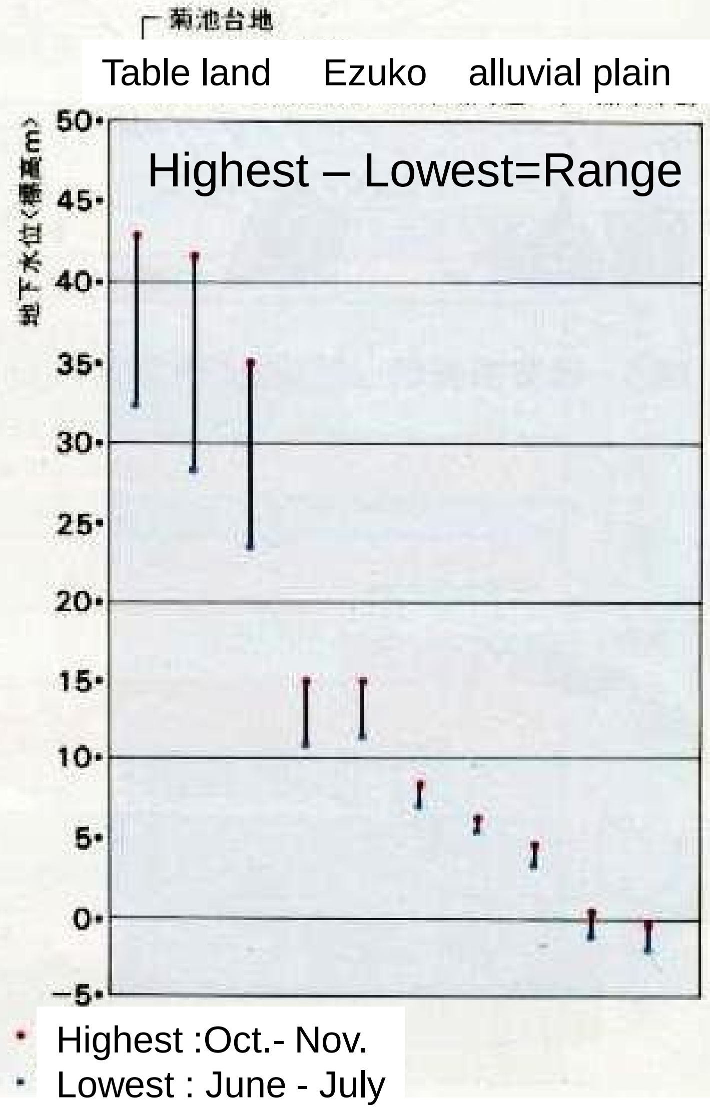
Sky view from the downstream to Mt. Aso



Seasonal fluctuation of water level in table land and alluvial plain (1981-82)



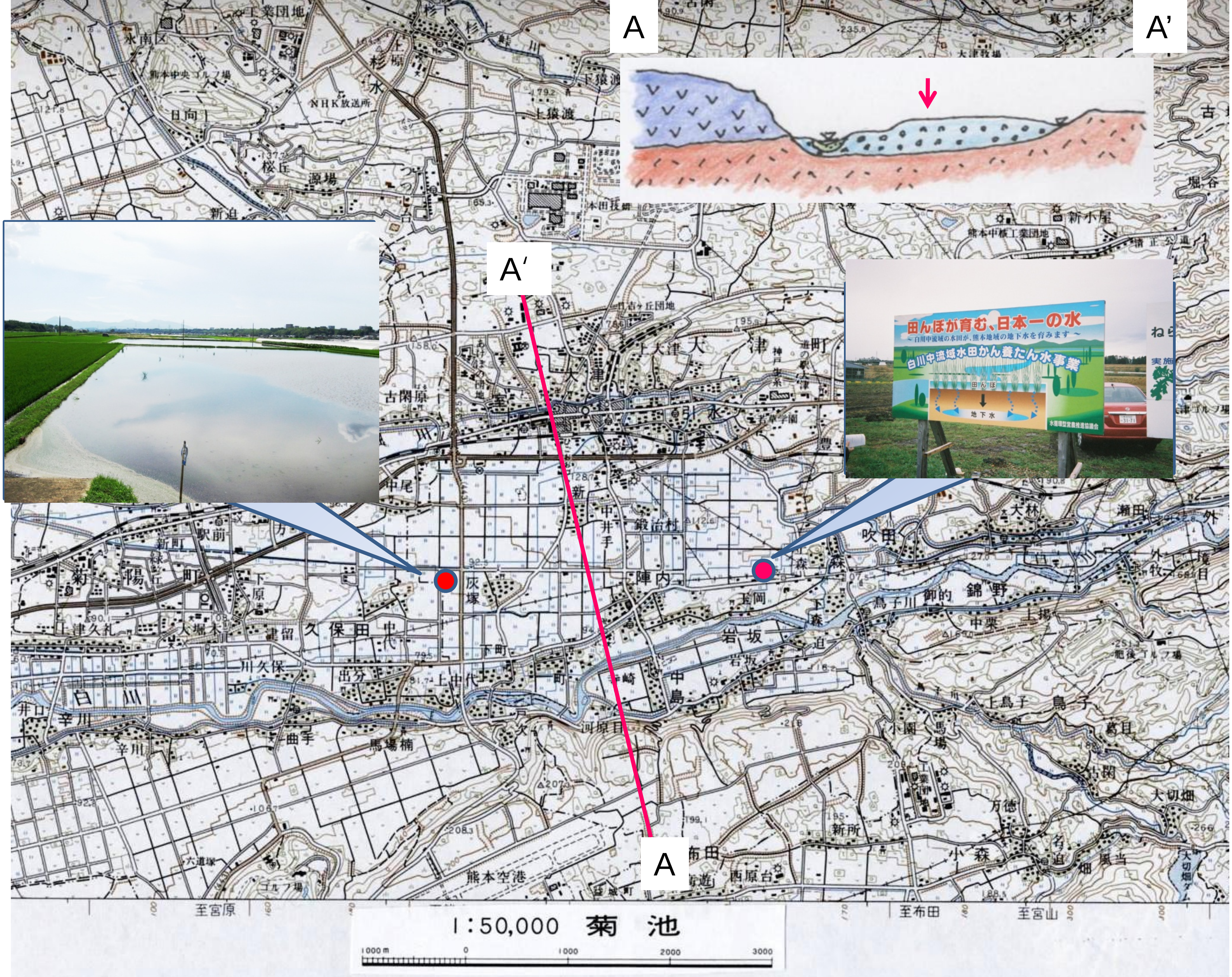
Fluctuation range of water level in table land and in alluvial plain (1982)



Impound artificial recharge in paddy field, Kumamoto, 2004

The project started in 2004. Artificial recharge planned : 7.65 mill. m^3/1 ~ 3 months(1 % of total recharge) : 255ha/60days=50 mm/day in average, at maximum 200 mm/day after plowing. Agreement between the Water Work and farmers : subsidiary paid 90,000 yen/ha(US $ 770), Surface water is impounded to fallow paddy during May to October.


転作田
確認票
耕作者
氏名
住所
水田
字番地
実施
面積
水張り
前後の
作物名
水張り
期間
人参
不許複製



A
A'
A′
田んぼが育む、日本一の水
白川中流域水田かん養たん水事業
地下水
A
1:50,000 菊池

Paddy Field for Groundwater Recharge Project
“Paddy will give birth to the best tasted groundwater in Japan”

Groundwater recharge plan of 2nd stage scheme

area		target	2009	2010	2011	2012	2013
Kikuyou Town Ohtsu Town		recharge volume(*1000m3)	14,760	15,098	15,435	15,773	16,110
		total area (ha*month)	492	504	515	526	537
		new tactics (*1000m3)	—	—	—	—	6,334
Kumamoto City		recharge volume(*1000m3)	1,650	1,688	1,725	1,763	1,800
		total area (ha*month)	55	57	58	59	60
Table land (Nishihara,Mufune)		recharge volume(*1000m3)	—	—	1,476	2,951	4,227
Rain harvesting	huose,farmer	recharge volume(*1000m3)	222	444	666	888	1,110
	enterprise,factory	recharge volume(*1000m3)					419
total recharge volume (*1000m3)			16,632	17,320	19,302	21,375	30,000

- Kikuyou ,Ohotsu Towns and Kumamoto City :
  Recharge volume=infiltration rate 100 mm/day × total area ×30 days ×10000

- Table land : Nishihara 79 mm/day, Mifune : 43 mm/day
- Rain harvesting : household for infiltration by rain box , farmer for green house
- Groundwater users of enterprise and factory > 30,000 m3/ year : independent method

Monitoring of groundwater level in front of the City Hall of Kumamoto

Newspaper tells ″preserve groundwater by a new tax “
“Willingness to pay” extra burden 2287 yen/month acceptable


朝日新聞（夕刊） 2003年(平成15年)5月29日 木曜日 43691号 （日刊）

朝日新聞 夕刊

阿蘇の地下水 新税で守れ

熊本市が検討

阿蘇からの豊かな伏流水で知られる熊本市が、地下水保全のため、全国的にも珍しい「地下水保全税」の実施に動き始めた。同市は1月には市民を対象に「いくらなら支払うか」を尋ねるアンケートを実施し、地下水が生み出す価値を年間63億7千万円と推計した。今年度中にも研究会を立ち上げて、本格的な検討に着手する予定だ。（米谷陽一）

熊本市は50万人以上の人口を抱える全国の都市で唯一、上水道の100%を地下水で賄っている。豊富な地下水を求め、半導体や飲料メーカーも進出している。採取量は企業の節水対策や農業用水の減少で年々減っているが、01年度で年間約1億2千万立方㍍に上る。

一方で地下水量は減少傾向にある。市によると、7年後の2010年には、市中心部を流れる白川の中流域の地下水位が約5㍍低下するおそれがあり、一部で湧水が止まる可能性もあるという。

こうした状況に、同市は地下水を新税の財源とするとともに、節水対策を模索するため、アンケートを実施した。

報！

負担平均 市民「2287円なら…」

住民基本台帳から無作為で選んだ3千人が対象。阿蘇での植林など、地下水量を90年の水準に回復させるための財源として、「地下水保全税」の設置を提案。通常の水道料金に加えて、いくらの税負担ならば応じるか、などを調べた。

アンケートでは、まず「1世帯当たり毎月200円の税負担に応じるか」と質問。「支払う」と回答した人には「5…0円なら払えるか」、「支払わない」の人には「100円ならどうか」と尋ねる質問を繰り返して、許容額を絞り込んだ。

490人から得た回答では、毎月500円では66%が「応じる」と回答。5千円では13%に下がったが、平均金額は2287円だった。

荷、曲折も

これらの結果をもとに、自然の価値を算出する統計的手法である「仮想市場評価法」を用いて、地下水の価値をはじき出したところ、年額で63億7千万円と導き出された。

Additional payment of 2287 yen (UD $20)/month as a new tax is acceptable by the people of Kumamoto city.
Water charge: 3014 yen/m3.
Sewerage charge: 2400 yen/m3.
Total: 5414 yen/m3.

Water saving campaign
2003：254ℓ（Domestic）
2005：2.3%
2006：3.1%
2007： ?

Challenge water saving

（2006.7）

Comparison of Domestic water supply unit cost & quantity (1US$=120Yen)

city	Item	Unit	2003	2002	2001
Kumamoto	Domestic	ℓ/day/capita	246	254	257
	Effective income rate	%	89.2	89.6	88.3
	Production unit cost	dollar/m³	1.24	1.24	1.31
	Supply unit cost	dollar/m³	1.42	1.42	1.42
Fukuoka	Domestic	ℓ/day/capita	202	203	205
	Effective income rate	%	95.5	96.6	96.0
	Production unit cost	dollar/m³	1.88	1.92	1.88
	Supply unit cost	dollar/m³	1.96	1.97	1.99

Establishment of Groundwater Conservation League of the Kumamoto Area in 2008

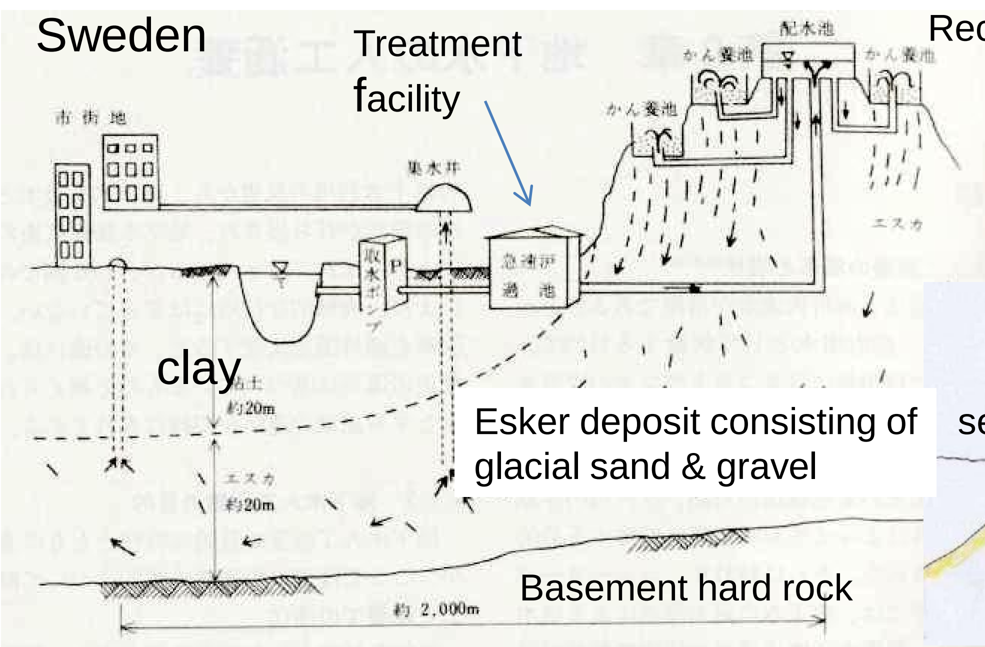
- 13 local autonomies signed to join the league.
- The league, which crosses administrative boundary, includes whole groundwater basin of ca.1041km^2.
- This means the administrations are workable in harmony with hydrological cycle of water.
- The agreement is worth taking concept of the one million people living in the basin into consideration.
- Because it is thought to be derived from mutual understanding that they live in the same “commons” and overcome opposition of stakeholder’s interest.

Discussion & summary

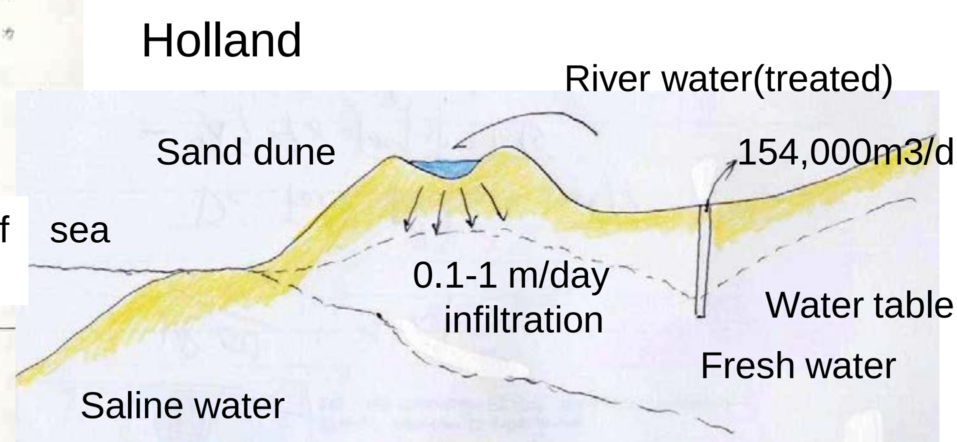
- Groundwater is regarded as viewpoint of water basin management
- Upstream: land use, artificial recharge
- Downstream: spring reservation, water saving campaign
- Local governments: institutional & financial frameworks constructed
- Informing, consultation and partnership are executed
- Citizens, experts and enterprises are involved
- To perform each part respectively based on global conception of environment preservation
- Essential parameters for evaluating local governance
- Basic Environment Law prescribes local municipal corporations play an important role to objectively execute environment preservation policy.
- Environment governance system is on the way to be established
- It is highly evaluated that Kumamoto city has contributed a great deal to international cooperation for long time.

Purpose of groundwater recharge

- ◆Purification of groundwater quality
- ◆Prevention of salt water intrusion
- ◆Strengthening of groundwater reservoir
- ◆Prevention of land subsidence
- ◆Groundwater heat reservoir



Recharge from a pond



Method of groundwater recharge

TABLE 13.1 Distribution of Artificial Recharge Projects in California by Method of Recharge (after Richter and Chun[62])

Method	Percent of Recharge Projects	Percent of Recharged Water
Basin	54	58.4
Stream channel	15	29.5
Ditch and furrow	8	9.4
Pit	7	1.3
Well	12	1.0
Flooding	4	0.4
	100	100.0

Todd, D.K. (1980)

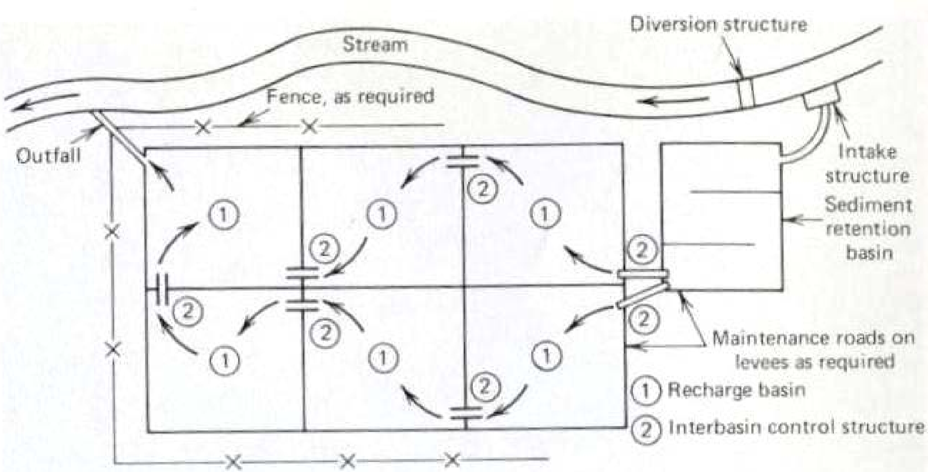


Fig. 13.1 Typical plan of a multiple-basin recharge project diverting water from a stream (after Amer. Soc. Civil Engrs., *Ground Water Management*, Man. and Repts. on Engrng. Practice 40, 1972).

Fig. 13.3 Channel spreading with rock-and-wire check dams in Cucamonga Creek near Upland, California (courtesy D. C. Muckel).

Fig. 13.2 Aerial view of spreading basins adjoining the San Gabriel River, Los Angeles, California, and temporary finger dikes within the river channel (courtesy Los Angeles County Flood Control District).

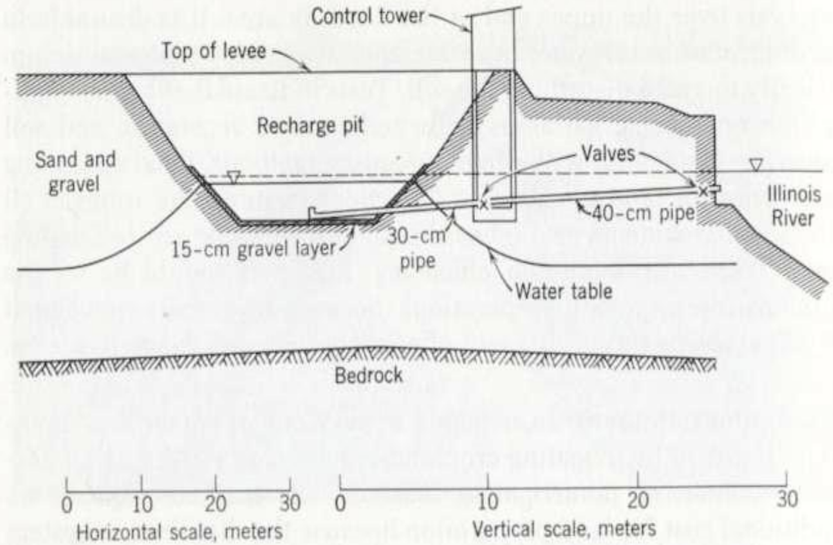


Fig. 13.5 Cross section of a recharge pit at Peoria, Illinois (after Suter and Harmeson[71]).

(Todd,D.K.,1980)

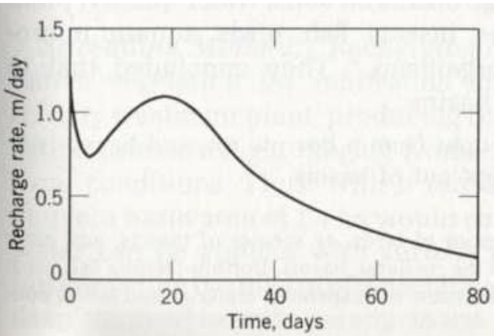
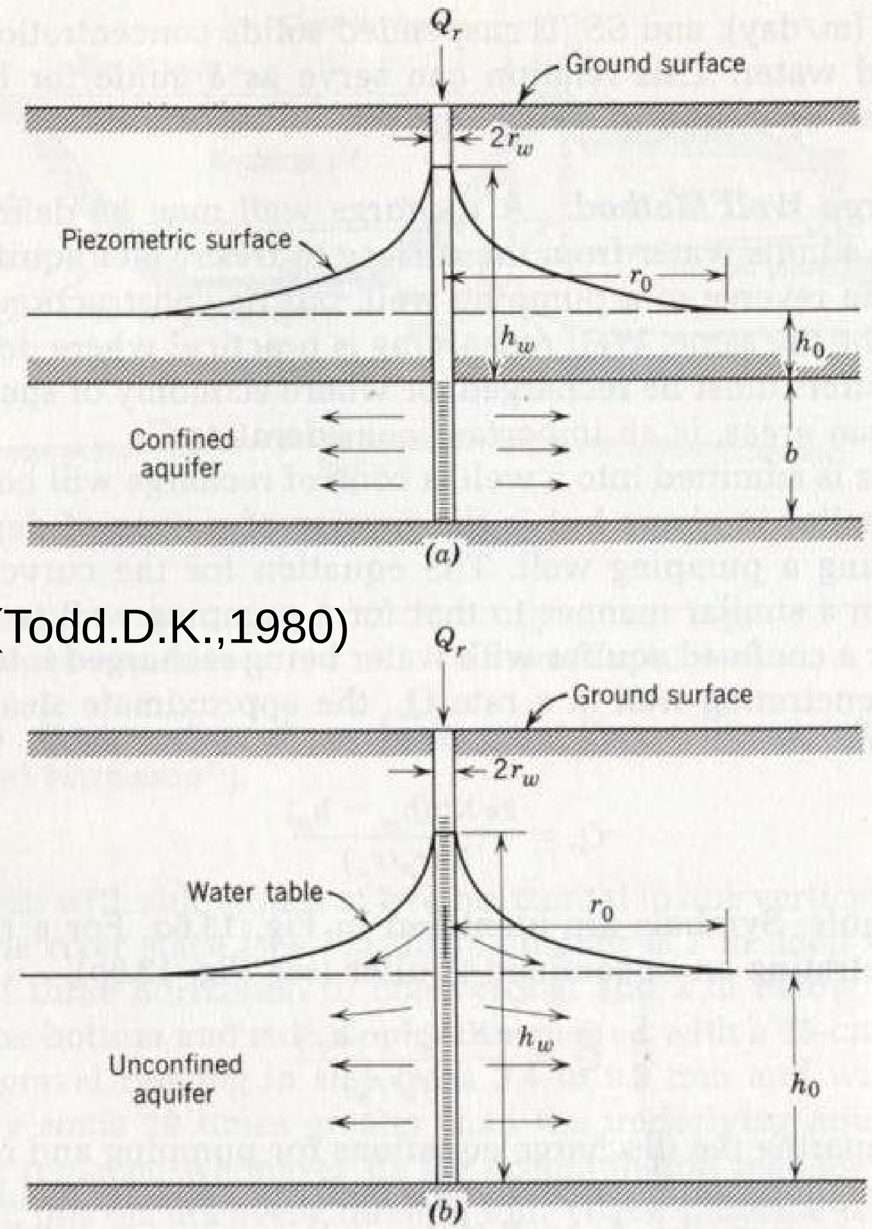


Fig. 13.9 Typical time variation of recharge rate for water spreading on undisturbed soil (after Muckel[51]).

Fig. 13.4 Spreading ditches in Tujunga Wash, Los Angeles, California (courtesy City of Los Angeles Department of Water and Power).

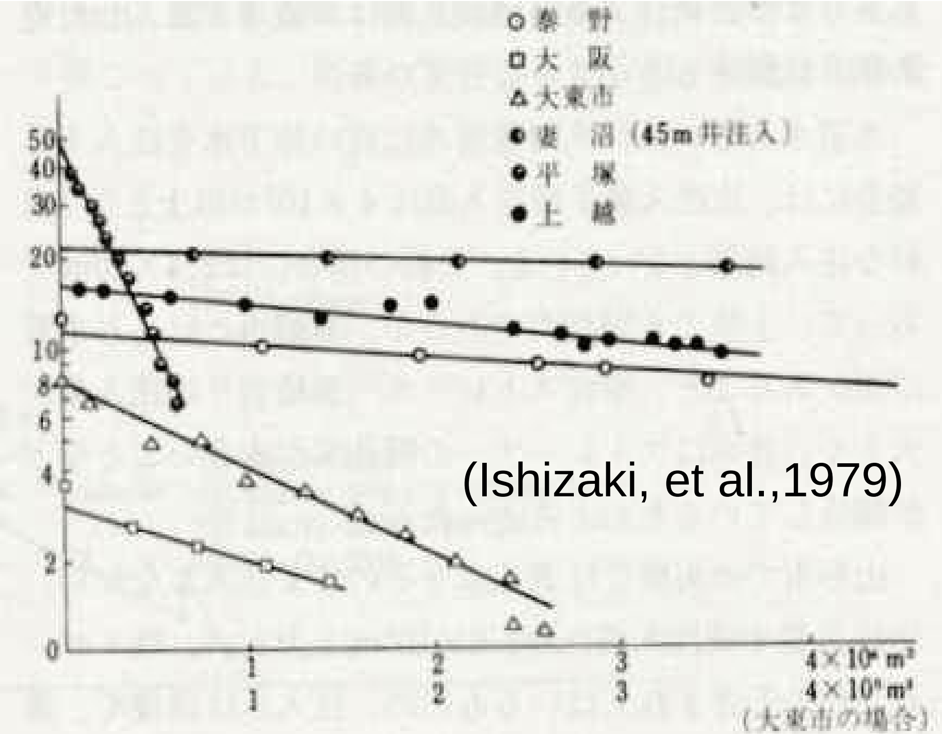
Decrease of specific injection rate

$$\text{Specific injection rate} = \frac{\text{injection rate}(m^3/sec)}{\text{water level rise in a well}(m)}$$



(Todd.D.K.,1980)

Fig. 13.6 Radial flow from recharge wells penetrating (a) confined and (b) unconfined aquifers.



(Ishizaki, et al.,1979)

Accumulative volume of injection water m^3)

Three types of well strainer

Johnson type screen (Driscoll,1986)

Figure 15.3. Natural development removes most particles near the well screen that are smaller than the slot openings, thereby increasing porosity and hydraulic conductivity in a zone surrounding the screen.

Pipe-base screen (NST screen) (Driscoll,1986)

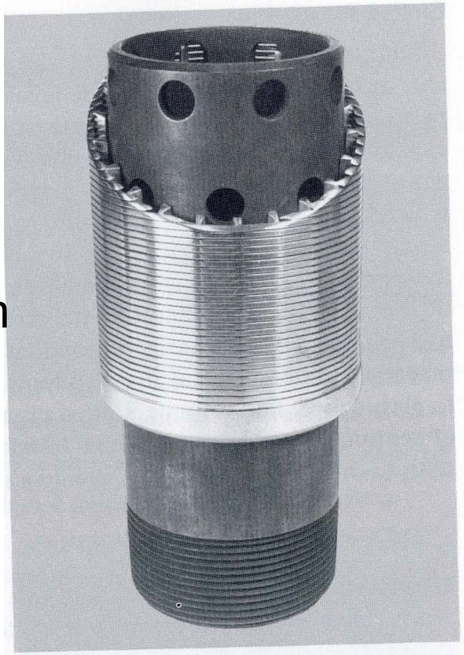
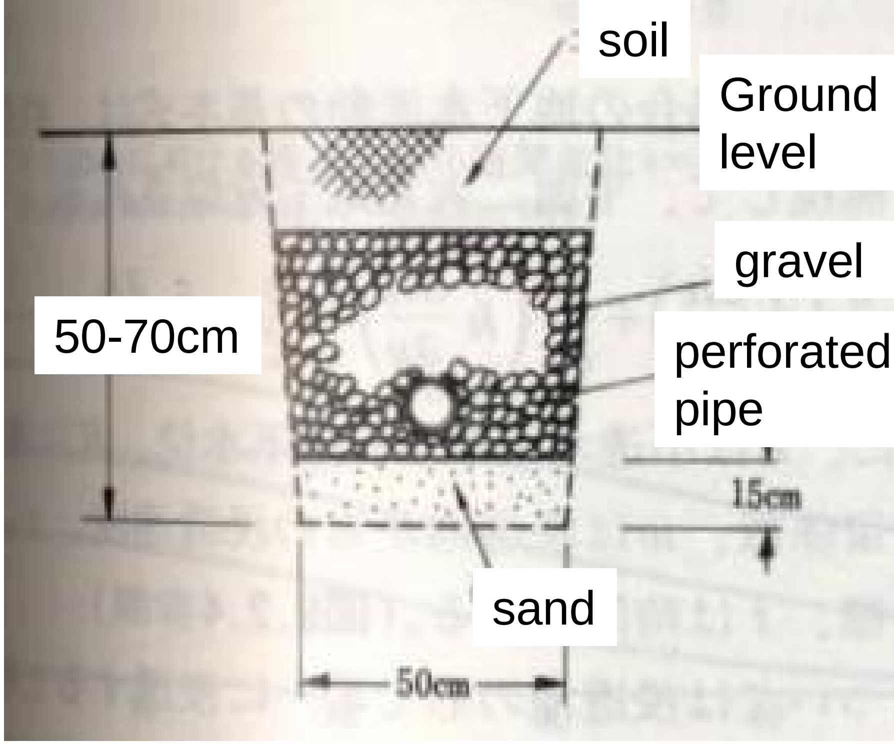


Figure 12.10. A pipe-base screen is constructed by wrapping wire around, or placing a continuous slot screen over, a perforated pipe base. This exceptionally strong construction is often specified for oil wells and occasionally for deep water wells. Both steel and plastic materials are used in this type of construction.

Slit type



Infiltration by underground perforated pipe

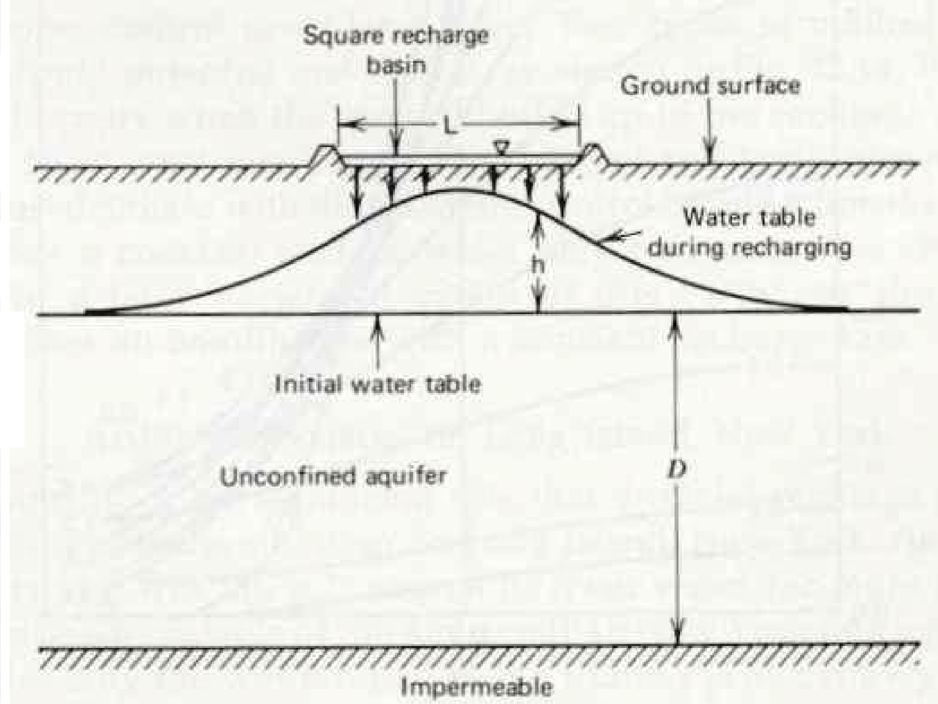


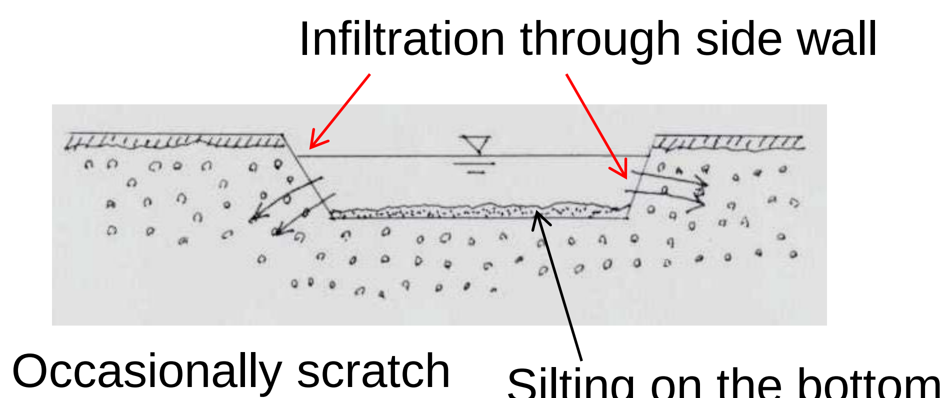
Fig. 13.12 Diagram of a recharge mound in a water table beneath a square spreading basin.

(Todd,D.K.,1980)

Negative factors for recharge

What causes clogging of injection rate ?

1) Suspended solid in injection water
2) Chemical reaction in aquifers
 (ex. deflocculation caused by reaction of high sodium water with fine soil particles)
3) Multiplication of bacteria (microbe)
4) Air bubble
5) Change of soil particles distribution



Recharge in the arid zone

- Locally made Check dam in Matmata, South Tunisia, fossil blackish groundwater => pumping =>pipeline =>desalinization plant => domestic use in the cities in the downstream
- Micro-catchment water irrigation & harvesting in Siraz, South Iran

shallow ditch and mound around the Fog tree

Tunisia
Iran
Shiraz
SPAIN
Barcelona
Zagreb
Belgrade
Sarajevo
ROMANIA
Chişinău
UKRAINE
Danube
Bucharest
Rome
Naples
Sofia
Skopje
Tiranë
BULGARIA
BLACK SEA
CASPIAN DEPRESSION
Elbrus
Caspian Sea
GEORGIA
T'bilisi
Baku
Yerevan
AZERBAIJAN
UZBEKISTAN
Dushanbe
Amu Darya
TURKMENISTAN
Ashgabat
Mashhad
AFGHANIS
Algiers
Palermo
Tunis
Etna
İstanbul
Bursa
Ankara
İzmir
TURKEY
Konya
Euphrates
Lake Urmia
GREECE
TUNISIA
MALTA
Adana
Tehrān
MEDITERRANEAN SEA
ALGERIA
SYRIA
LEBANON
Beirut
Damascus
Baghdād
Golan Heights
IRAQ
West Bank
Gaza Strip
Amman
Alexandria
Nile
ISRAEL
JORDAN
Cairo
KUWAIT
SAHARA
LIBYA
LIBYAN DESERT
Manama
Doha
UNITED ARAB EMIRATES
Masqat
EGYPT
Riyadh
Aswān
SAUDI ARABIA
NIGER
Jiddah
Mecca
OMAN
RED SEA
CHAD
SUDAN
YEMEN
ARABIAN
Lake Chad
c 1988-1996 Microsoft and/or its suppliers. All rights reserved.

Matmata district, Tunisia


23. 12. 2007


Image © 2010 DigitalGlobe
©2010 Goo
© 2010 Google
画像取得日: 2006 年 9 月 22 日
33° 32'13.67" N
10° 04'36.13" E
標高 954 フィート
高度 4906 フィ

Micro Catchment Water Harvesting for Fig Tree Farm in Iran (2009)

Micro Catchment Water Harvesting for Fig Tree Farm in Iran (2009)


Thank you for kind attention !


Thank you for kind attention.