Council for Development and Reconstruction (CDR)
Ministry of Energy and Water (MoEW)
Water Establishment Beirut and Mount Lebanon (WEBML)

Federal Institute for Geosciences
and Natural Resources (BGR),
Hannover, Germany

German-Lebanese Technical Cooperation Project

Protection of Jeita Spring

Monitoring of Groundwater Resources, Groundwater Balance and Water Resources Management Options

(project component 3)

Final Project Workshop
11 July 2014

Dr. Armin Margane & Philip Schuler

Outline

- Monitoring of Water Resources
- Groundwater Balance & WEAP Model
- Water Resources Management Options

Data Availability

- Insufficient and inadequate meteorological stations/data (not heated > no snow data)
- No groundwater monitoring > no water levels > no GW model
- Spring discharge monitoring stations not adequately designed, maintained and monitored
- Surface water gauging stations not adequately designed and maintained

► lack of funds and staff

Water resources assessment needs monitoring system for all water balance components

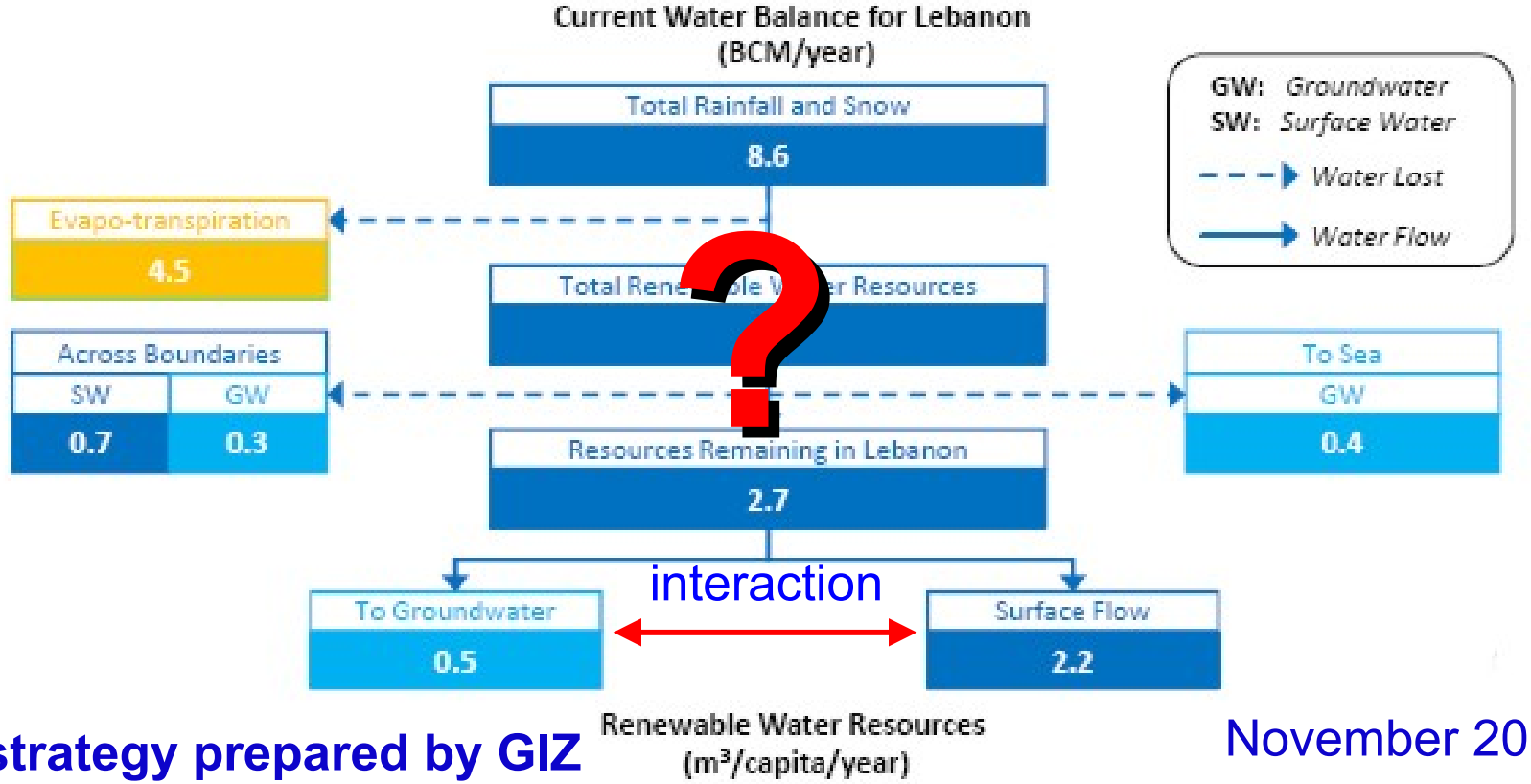
- rainfall / snow
- spring discharge
- runoff (surface water)
- groundwater abstraction
- irrigation water use (return flow)
- domestic water use / losses (return flow)

► no data > no correct water resources assessment
► wrong water resources assessment leads to wrong planning !
► failed investments in the water sector

Current Planning in the Water Sector

None of the Components of the Water Balance is monitored
Water Resources Availability was never assessed correctly
wrong Information leads to wrong Planning

Renewable water resources per capita are already slightly below scarcity threshold, with expected decrease in the coming years

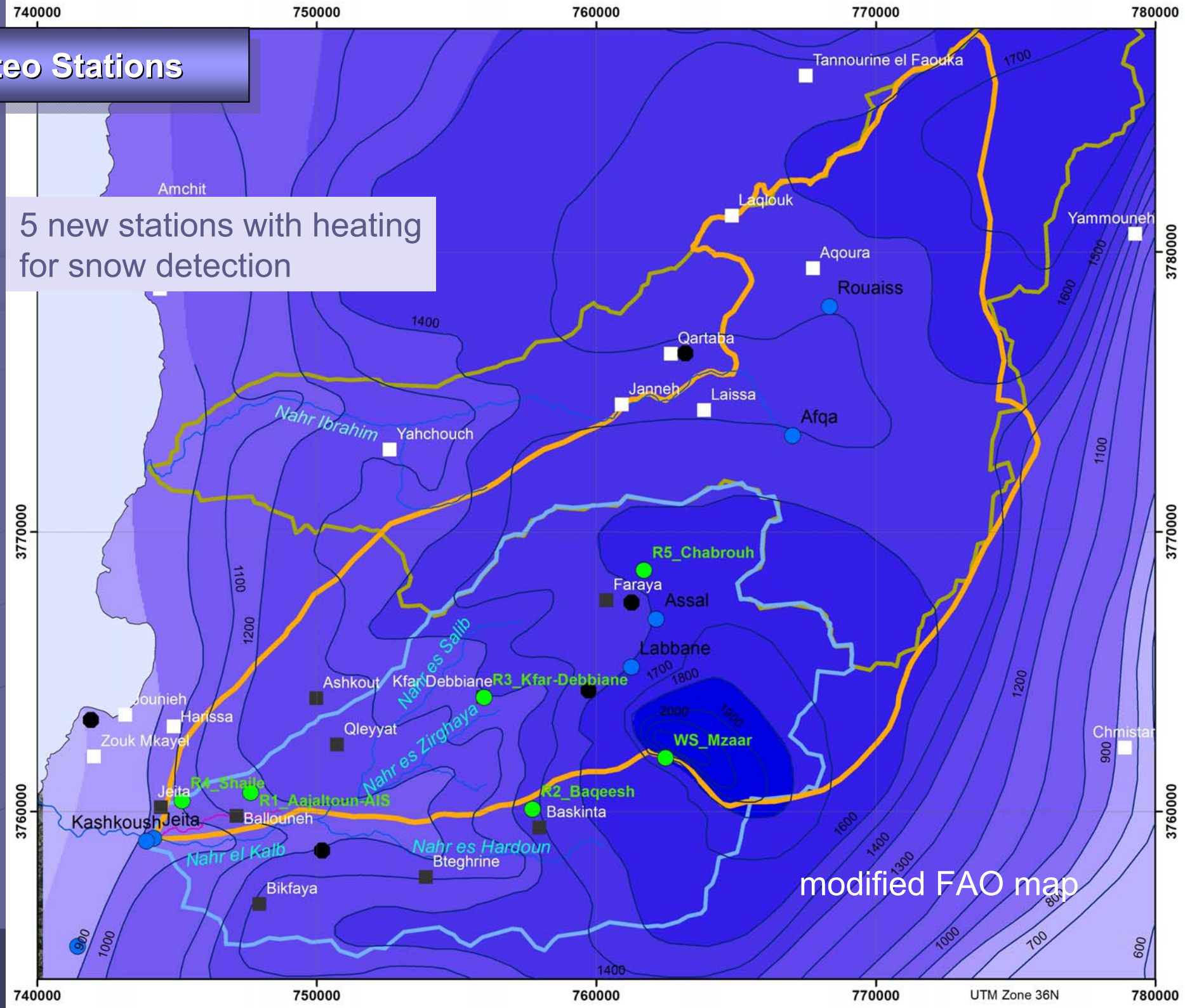


water strategy prepared by GIZ

November 2011

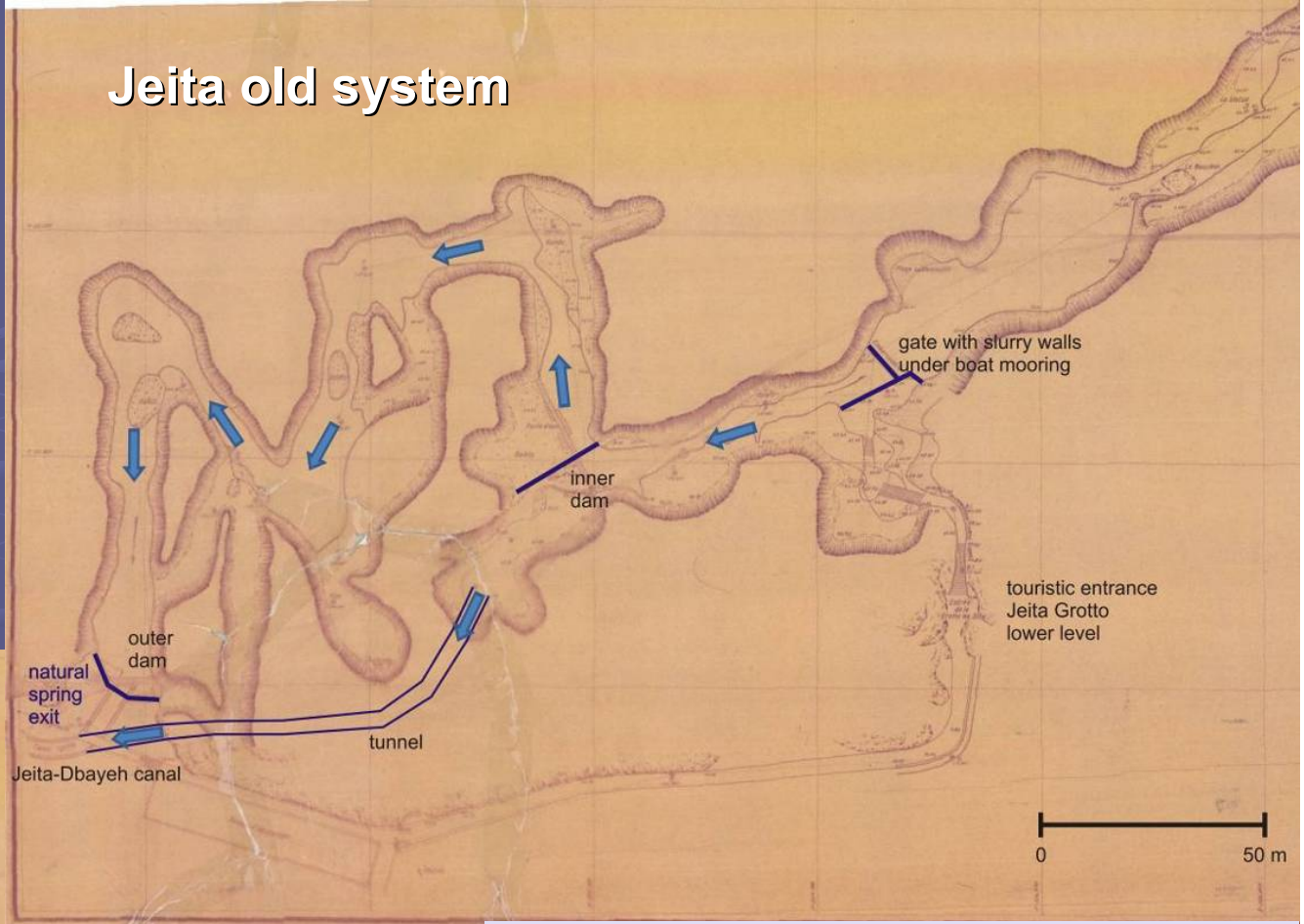
Meteo Stations

5 new stations with heating for snow detection

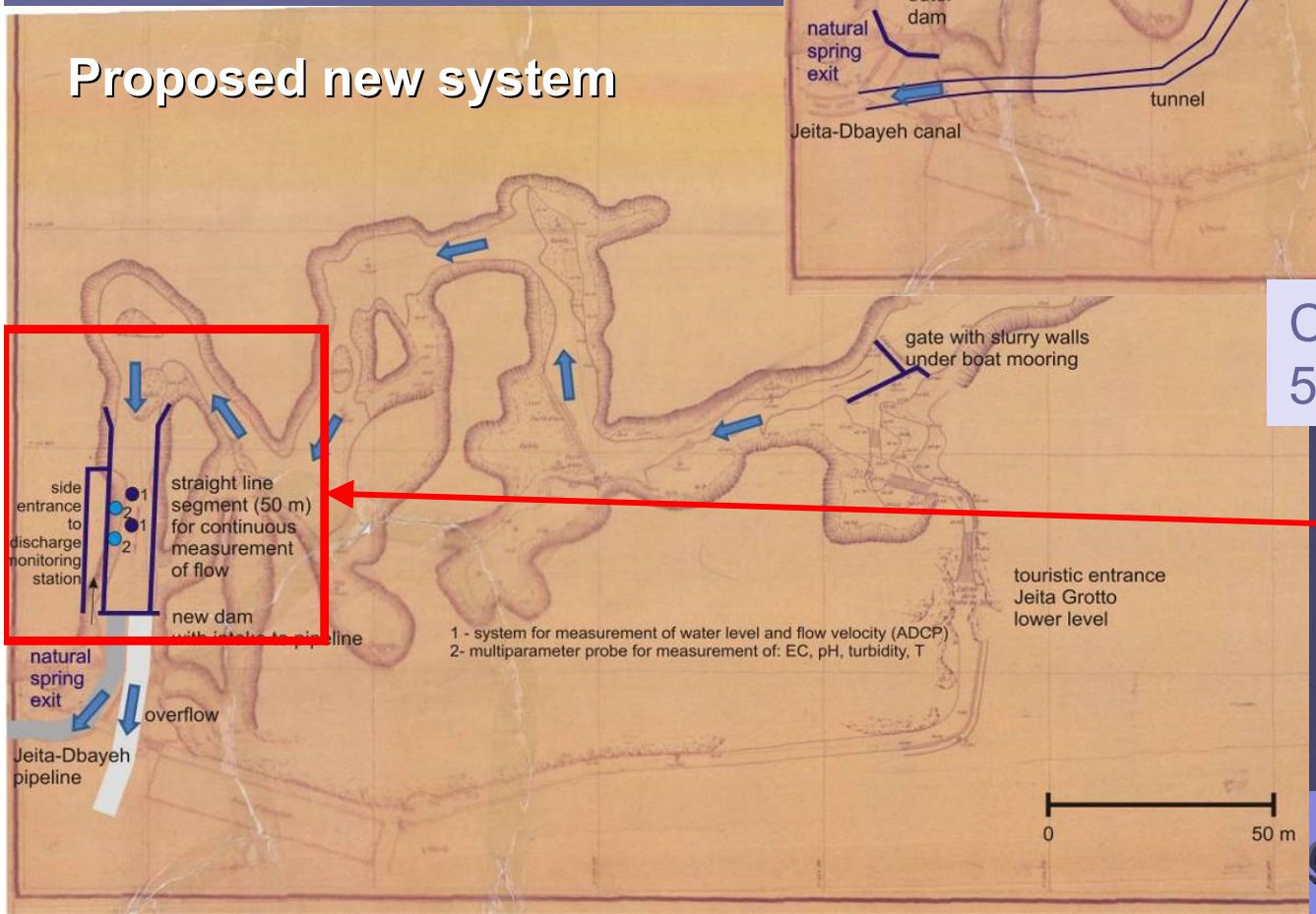


Spring Monitoring

Jeita old system



Proposed new system



Current BGR monitoring:
500 m upstream of boat moorings

monitoring

Spring Monitoring

- multiparameter probes
- gauging stations (weir, ADCPs)
- direct discharge measurement (> 300 dilution tests)


Labbane spring


Daraya tunnel


old system,
not functioning

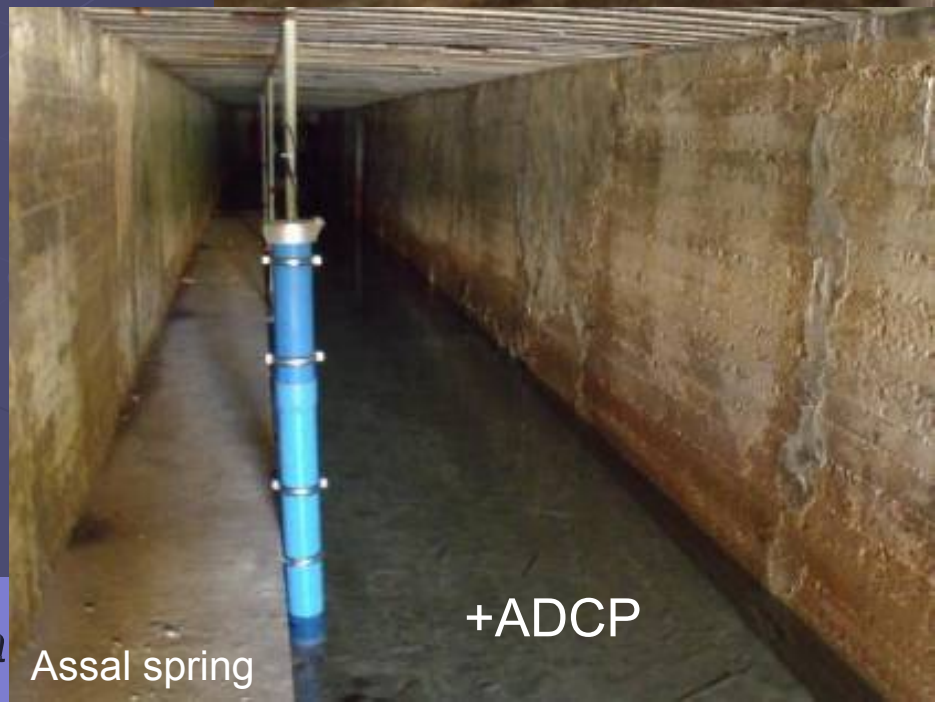
Kashkoush spring


Jeita spring

+ADCP

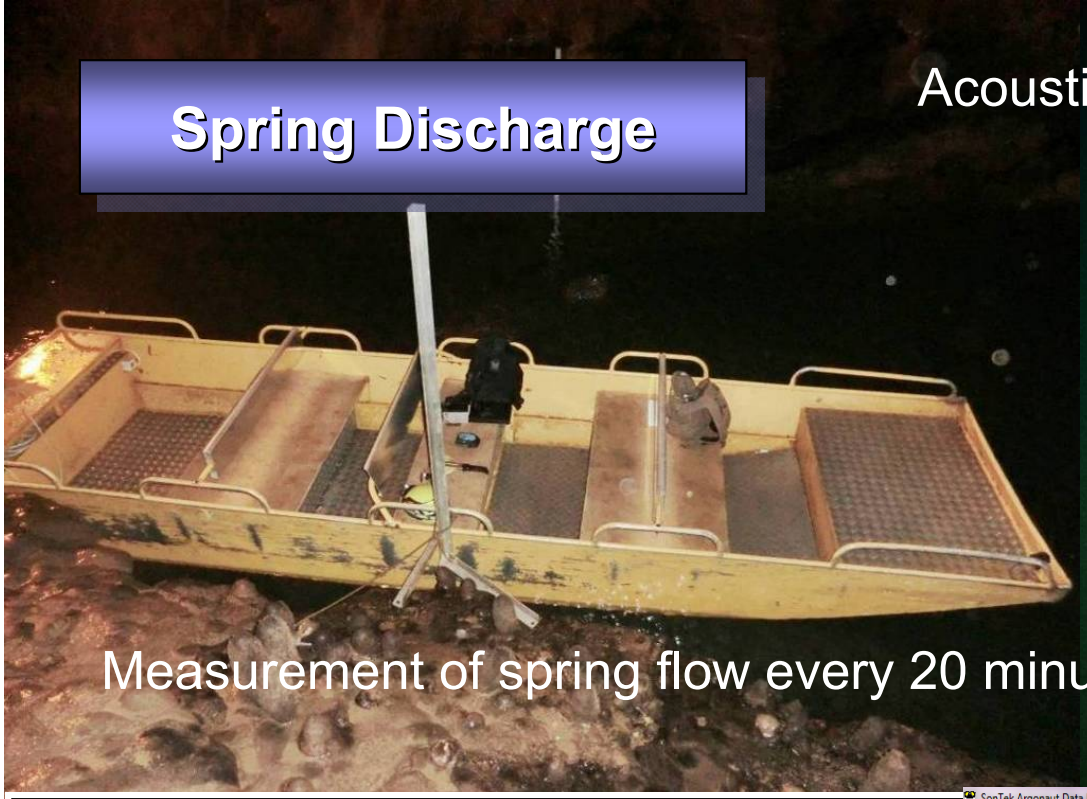
Multiparameter probes
parameters:
Water level
Temperature
EC
pH
ORP
DO
(ammonium)
(ISE)

Telemetric data transfer


+ADCP

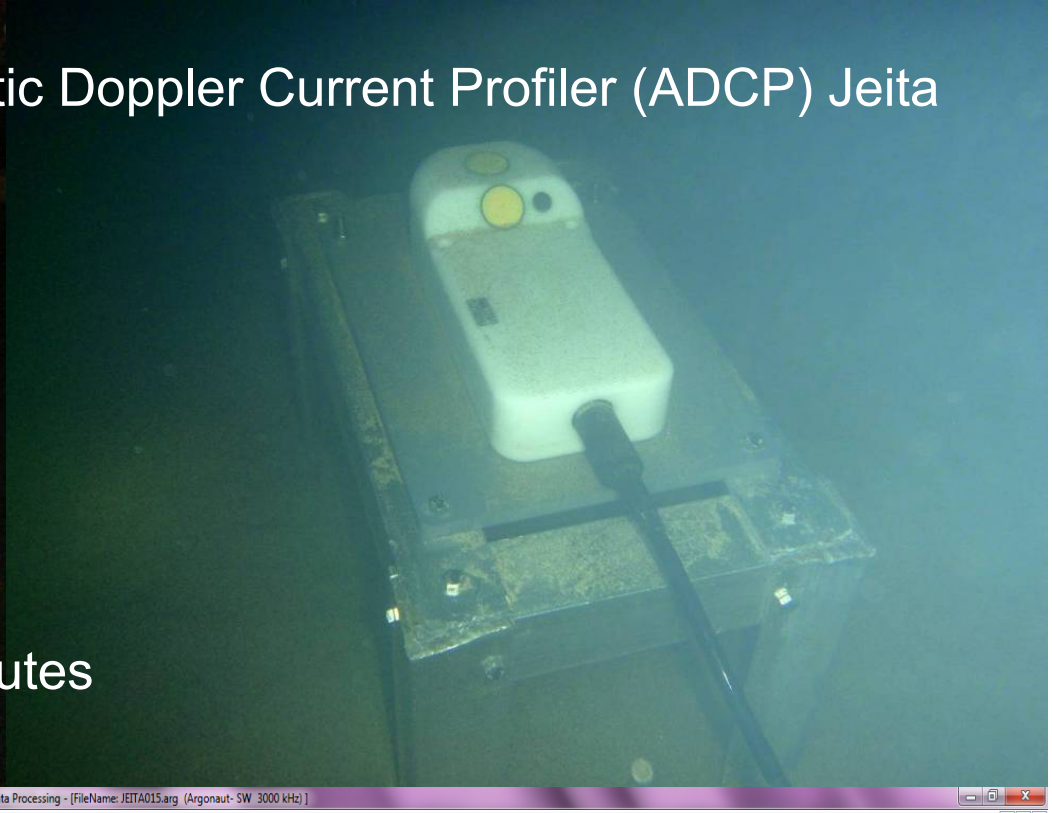
Assal spring

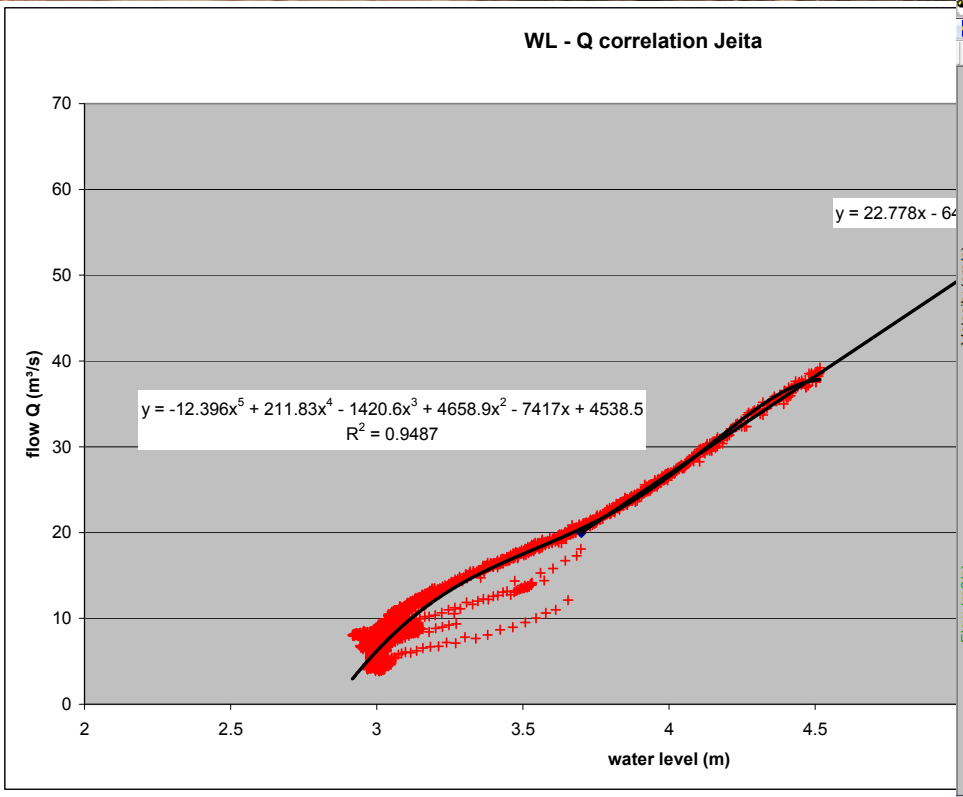
Spring Discharge

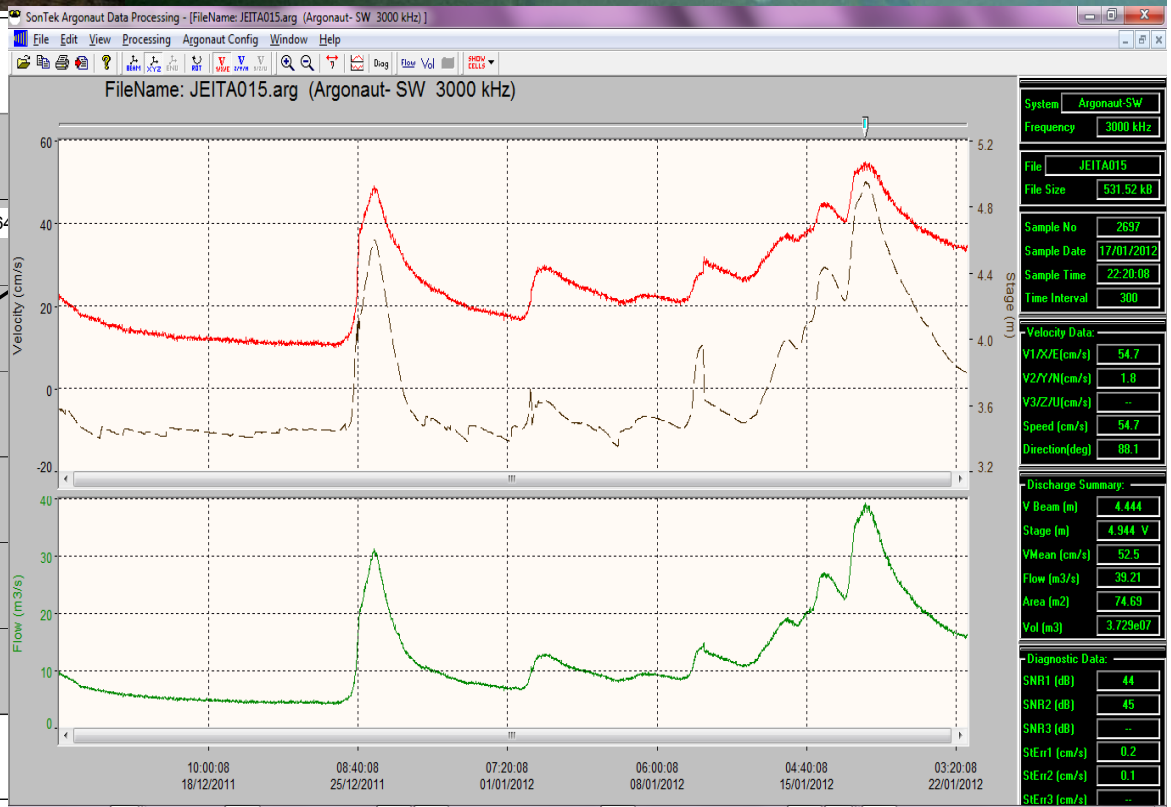


Measurement of spring flow every 20 minutes

Acoustic Doppler Current Profiler (ADCP) Jeita

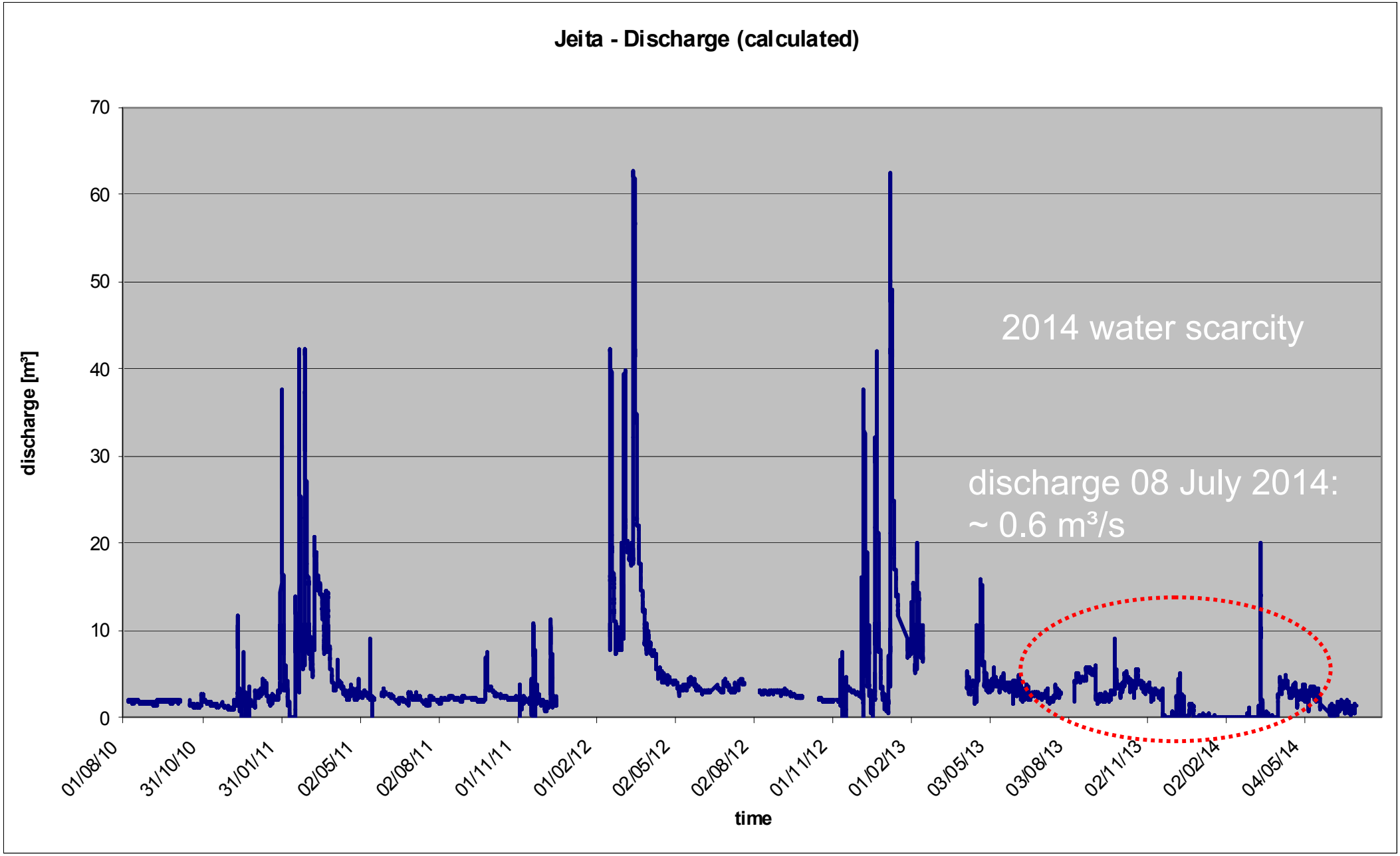




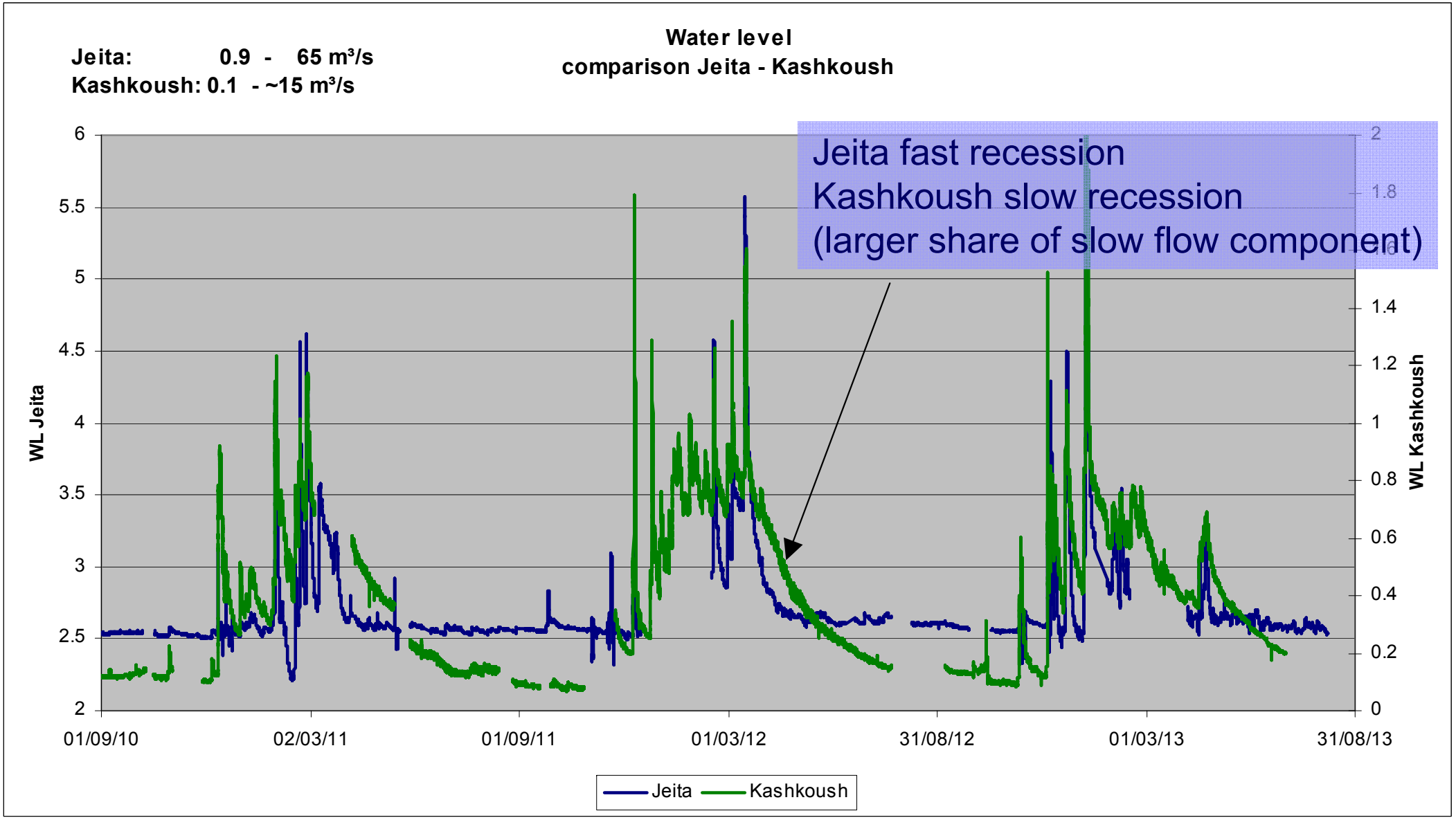


Spring Discharge

Why does discharge rarely fall below 1 m³/s ?



Analysis of flow characteristics (slow flow / fast flow component)

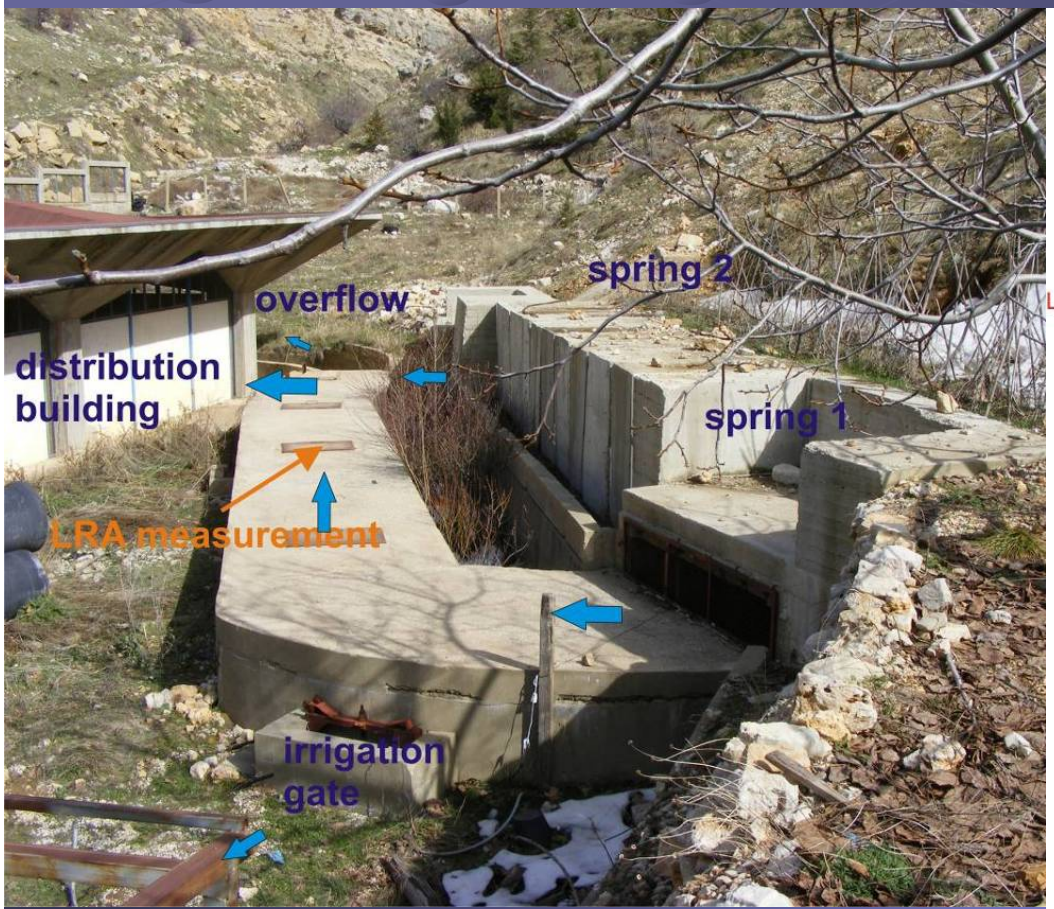


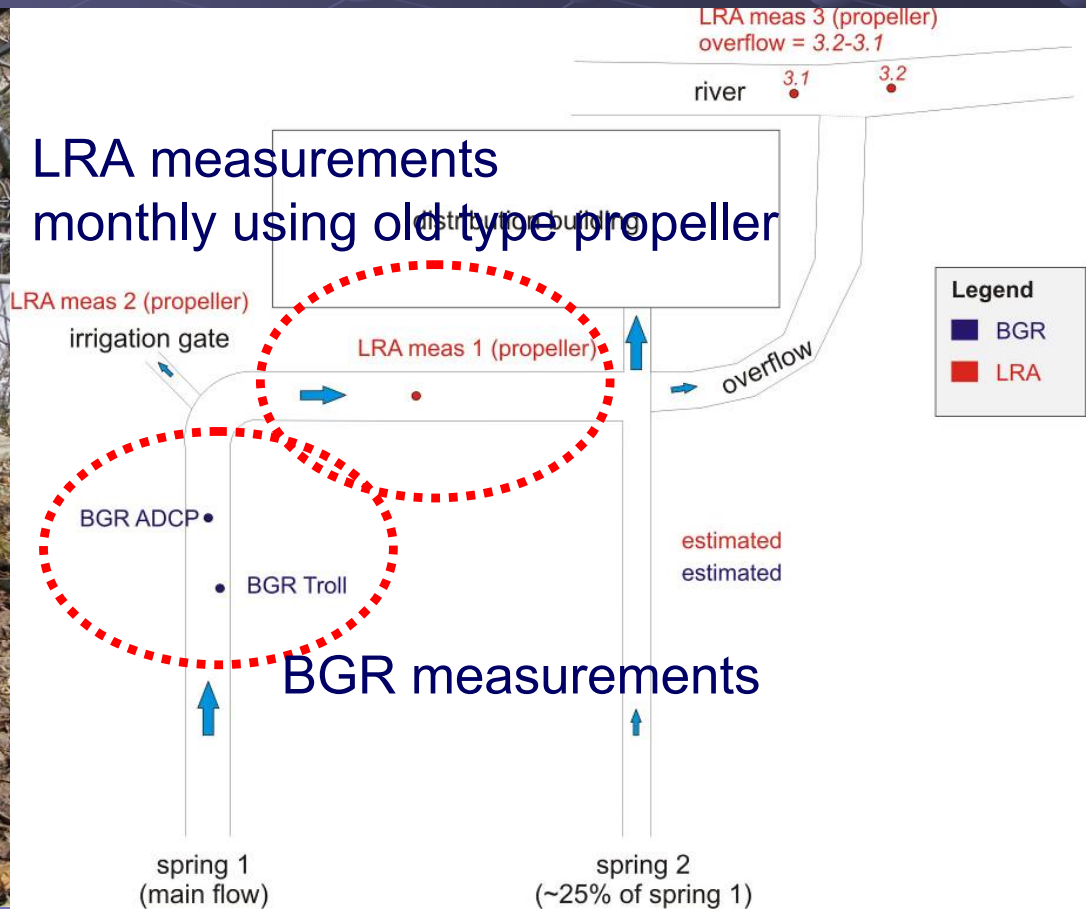
Spring Discharge

Assal spring

existing spring captures not suitable
for discharge measurements

- long straight line segments with no turbulent flow
- no variable impoundments (e.g. for irrigation)
- only one discharge point

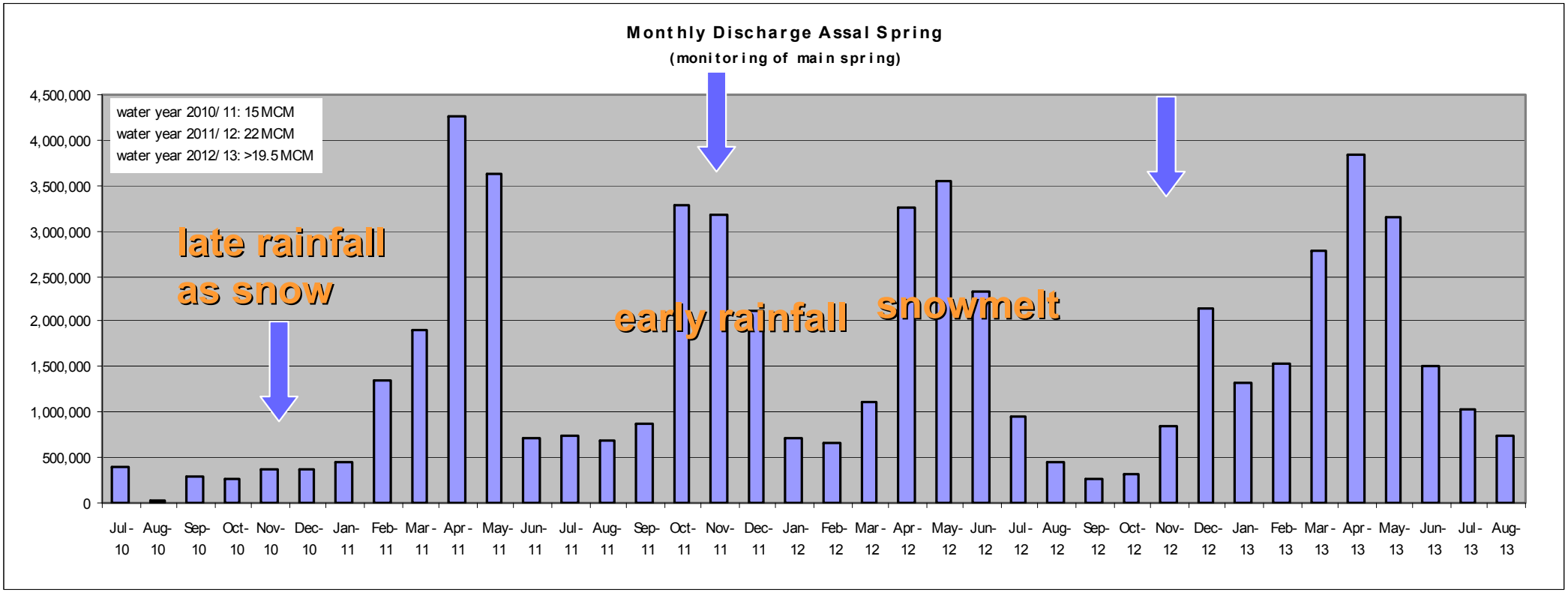




Spring Discharge

discharge behavior in C4

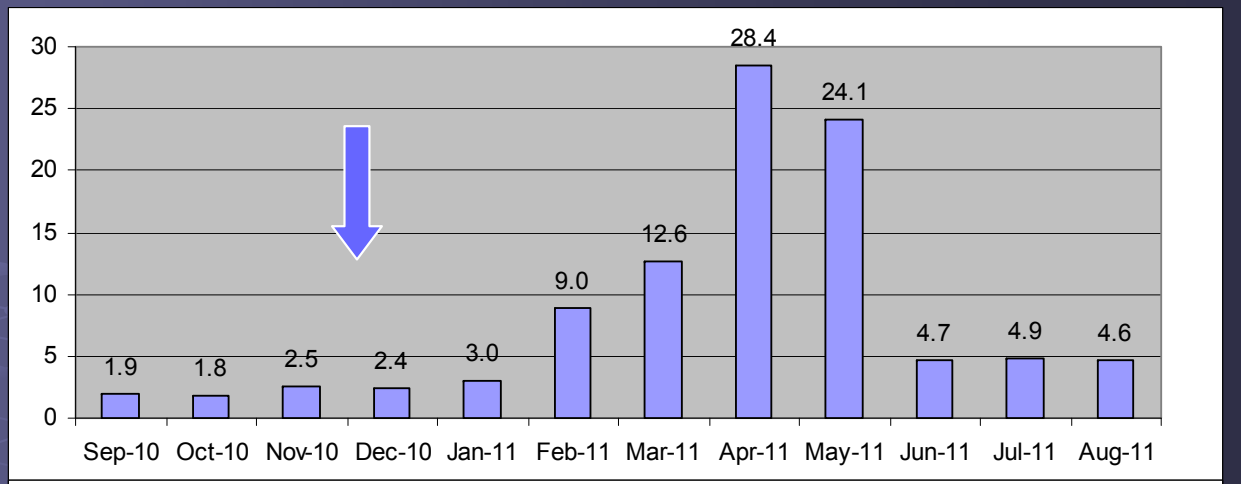
Spring discharge depends on how much, when, where and in which form precipitation falls



Spring Discharge

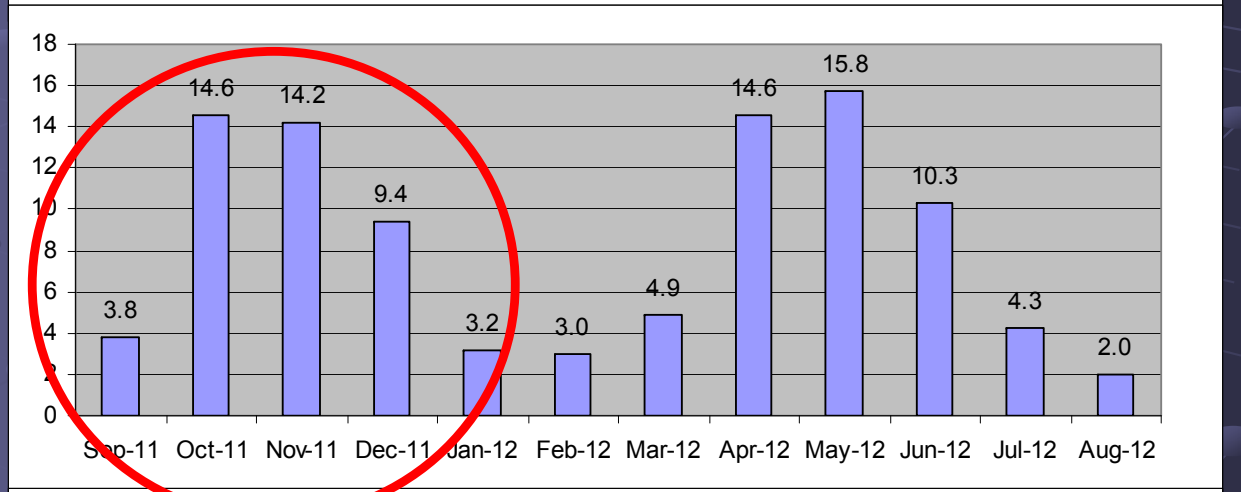
Assal (C4) percentage of annual discharge

WY 2010/11



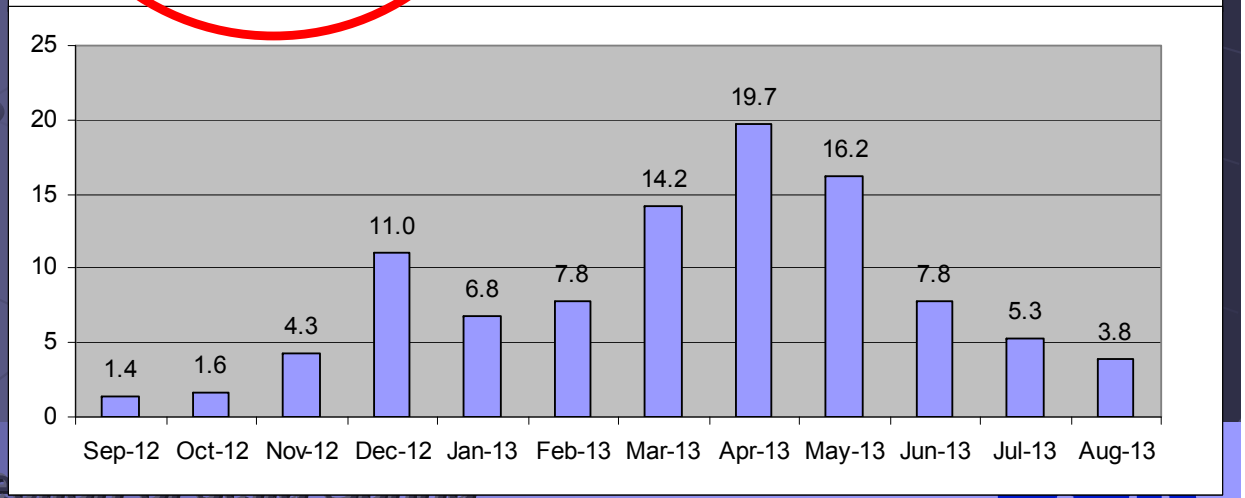
Precipitation as snow

WY 2011/12



Precipitation as rainfall

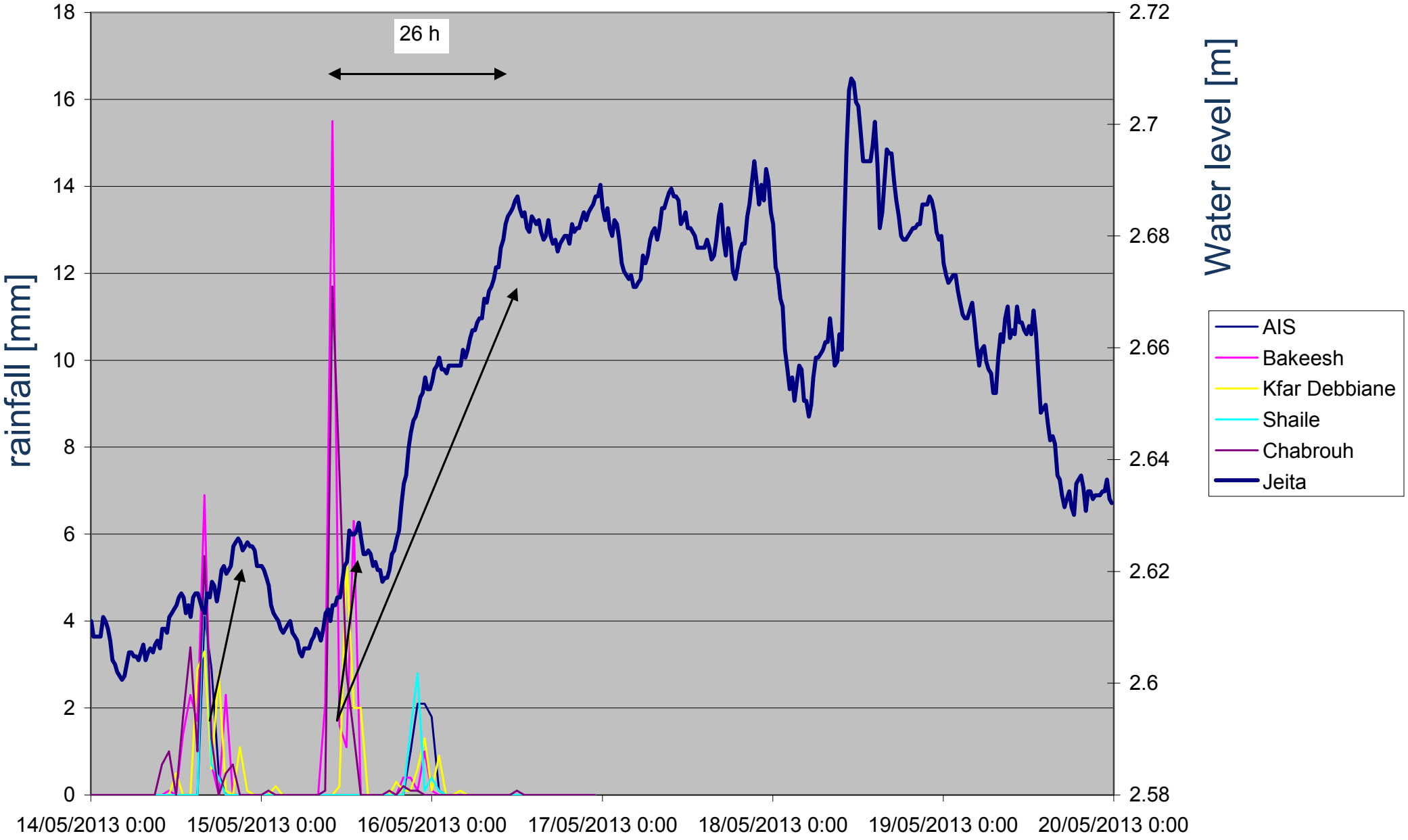
WY 2012/13

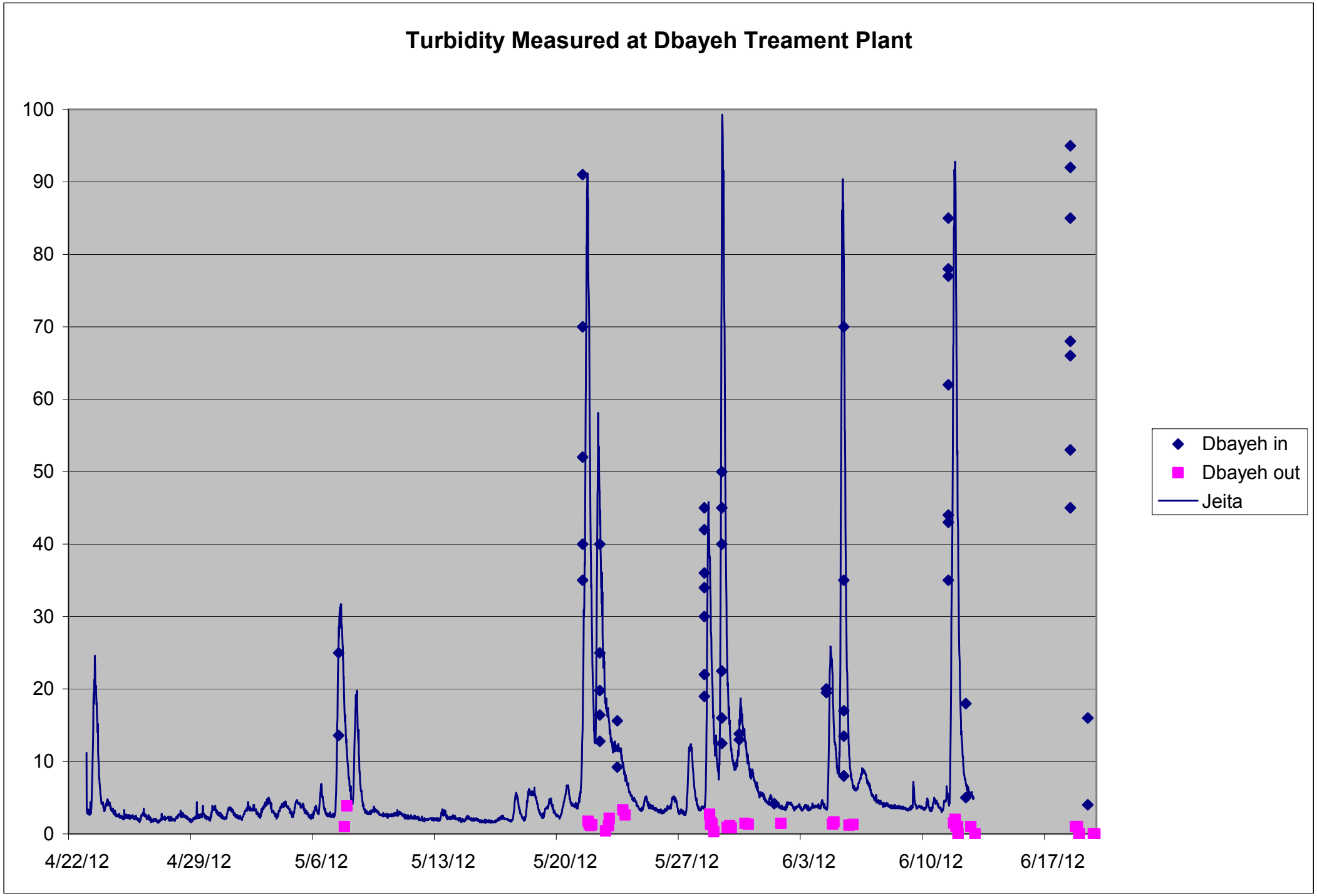



Labbane spring: flow between March/April and end July (snow melt)
Use for irrigation starts in mid May
2013: almost no rainfall in October and November
June 2014
Chabrouh dam almost empty in February 2014

Spring Discharge

Jeita spring: quick response to rainfall in J4 – rapid transfer of pollution




Turbidity Measured at Dbayeh Treament Plant
100
90
80
70
60
50
40
30
20
10
0
4/22/12
4/29/12
5/6/12
5/13/12
5/20/12
5/27/12
6/3/12
6/10/12
6/17/12
Dbayeh in
Dbayeh out
Jeita

Surface water data

Proposal for installation of streamflow gauging stations at
- Daraya (Nahr es Salib)
- Daraya (Nahr es Zirghaya)
- Jeita/Kashkoush (Nahr el Kalb)

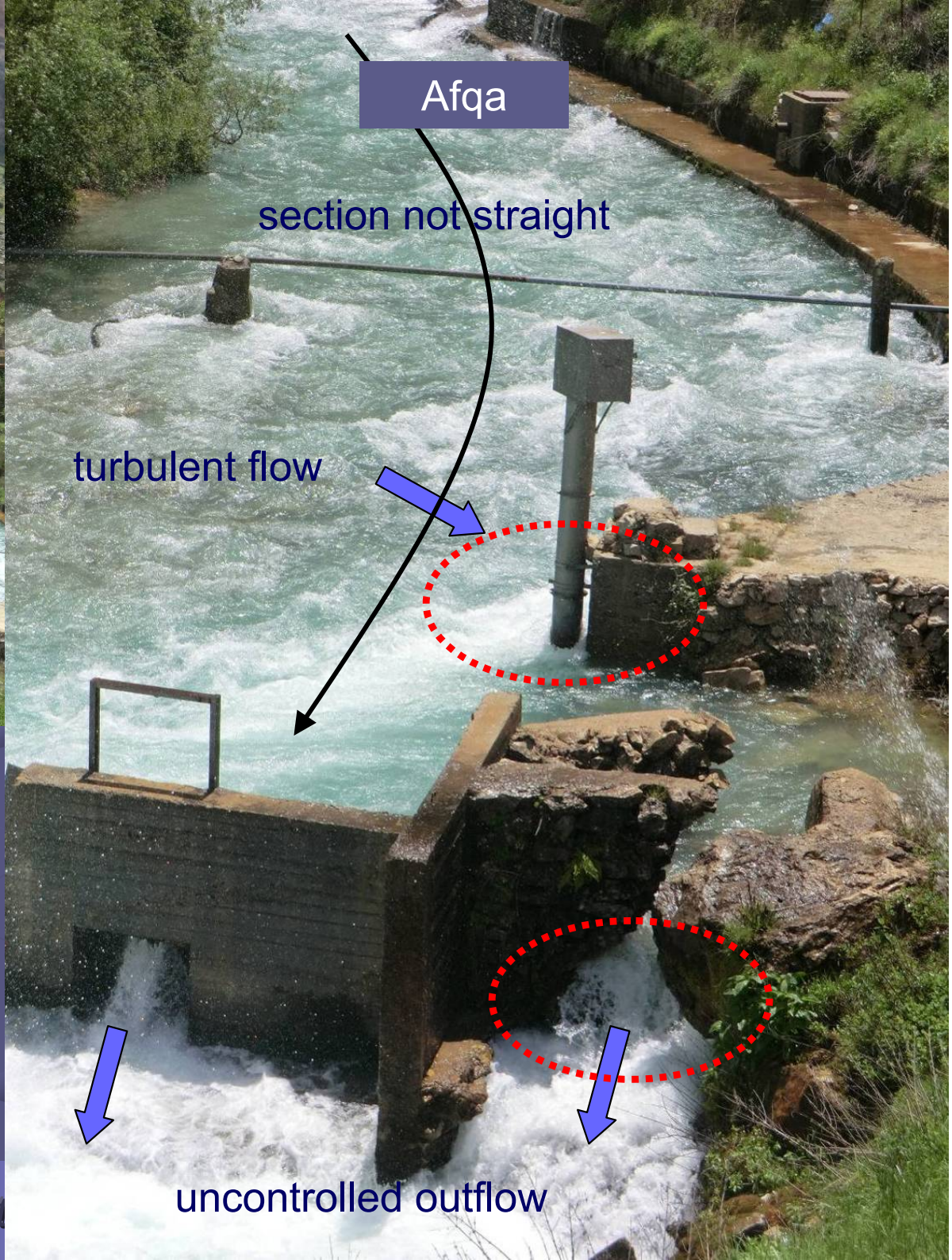
LRA station 226 Daraya
(Nahr es Salib + Nahr es Zirghaya)

Unsuitable location and profile
Highly turbid flow
Difficult calibration
No maintenance

Parshall flume weir Daraya (Nahr es Salib)

LRA measurements cannot give proper results

unsuitable location and profile
highly turbid flow
difficult calibration, outdated
no maintenance

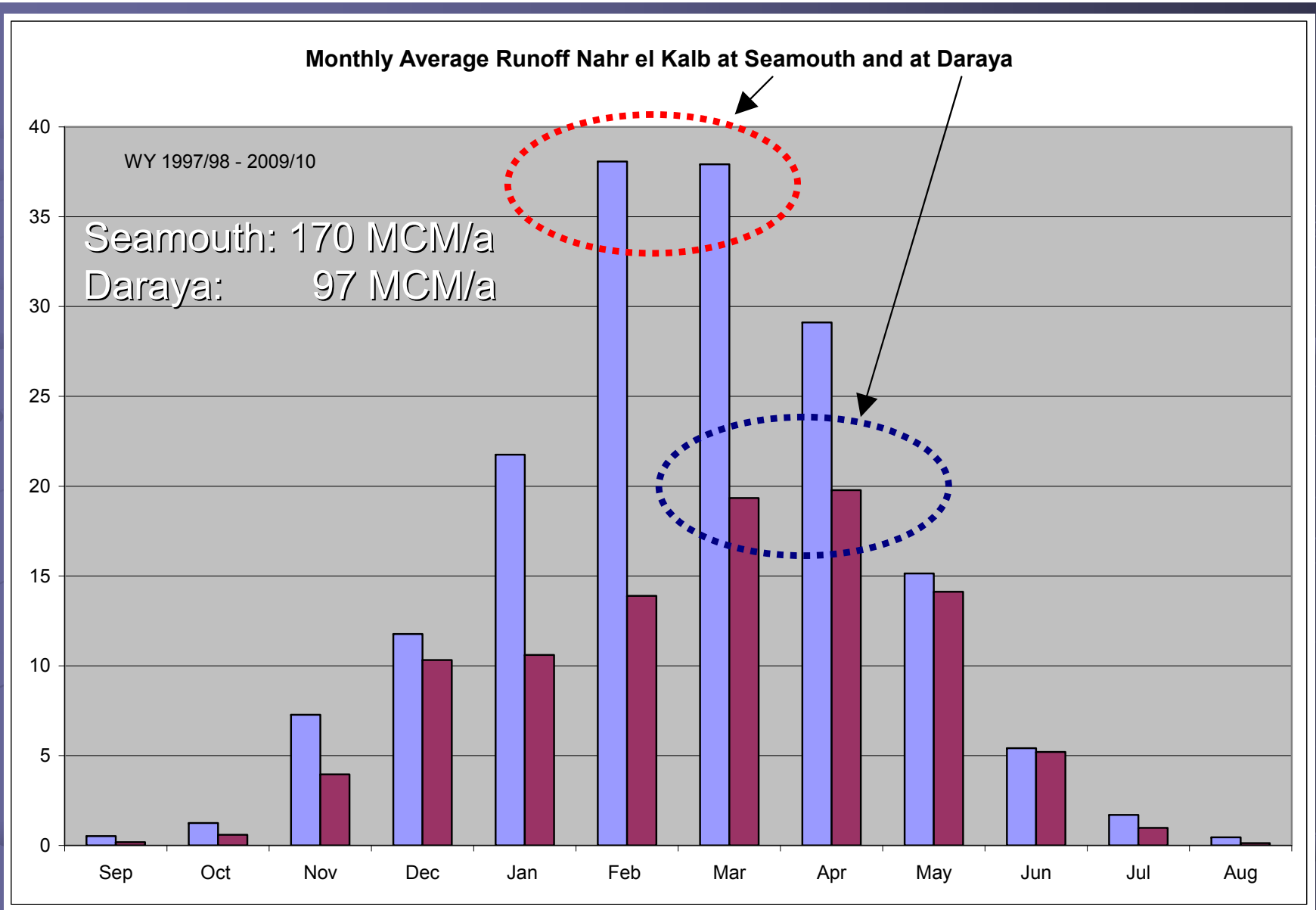


Surface Water Availability

Different Availability in Subcatchments

Daraya: flow pattern similar to Jeita spring

Seamouth: earlier peak (more rainfall-dependent)

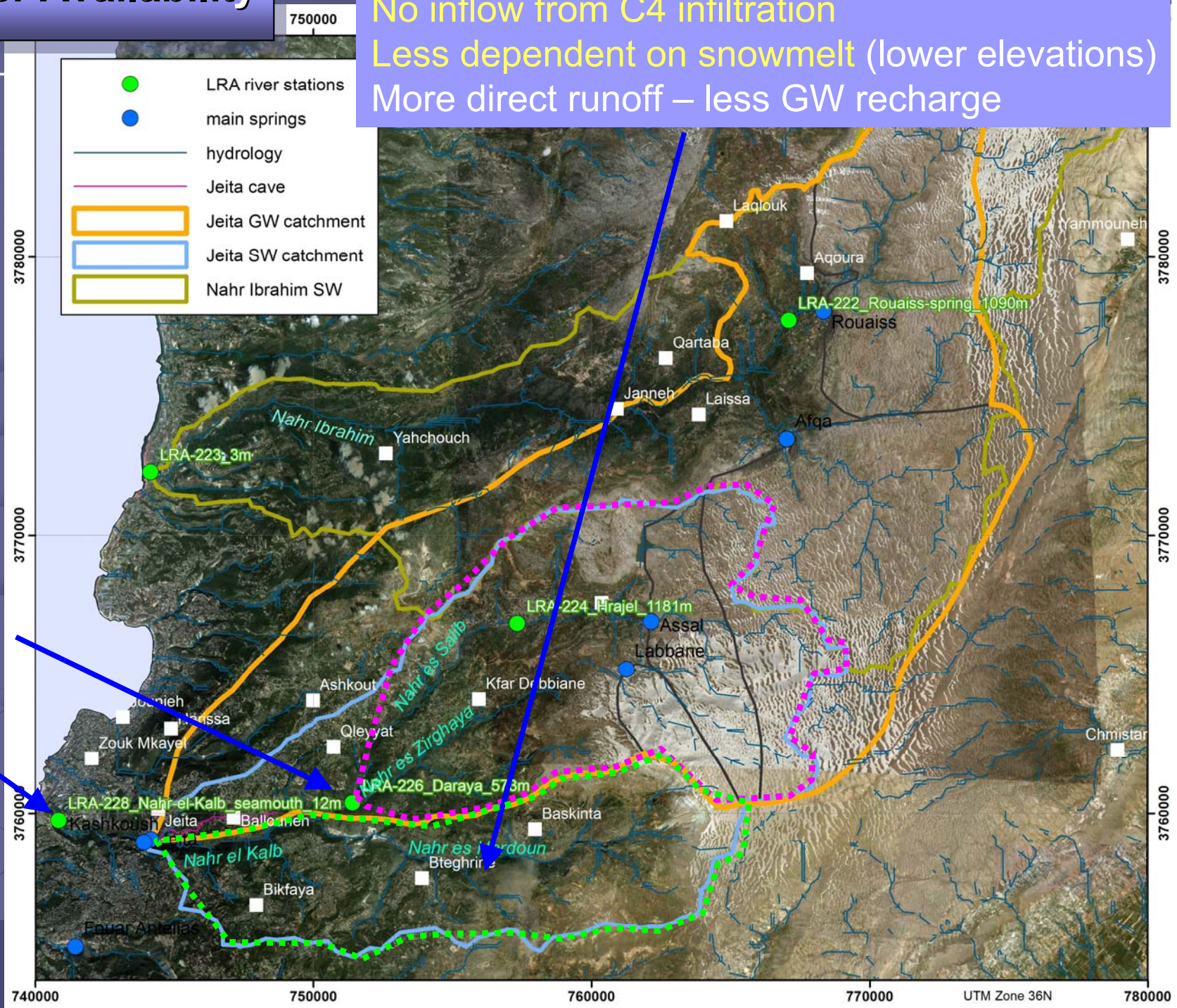


Surface Water Availability

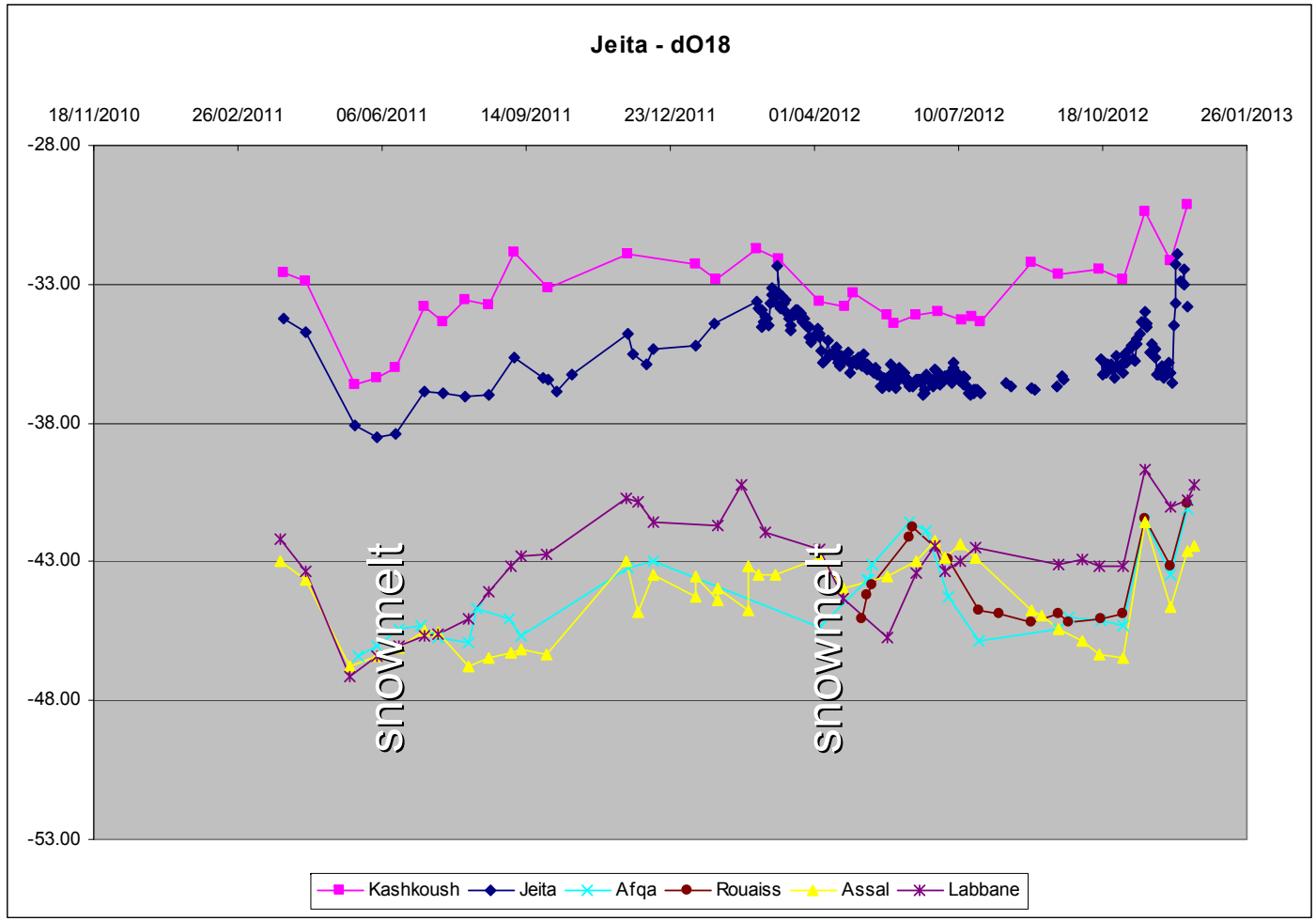
S Nahr el Kalb not part of Jeita GW catchment
No inflow from C4 infiltration
Less dependent on snowmelt (lower elevations)
More direct runoff – less GW recharge

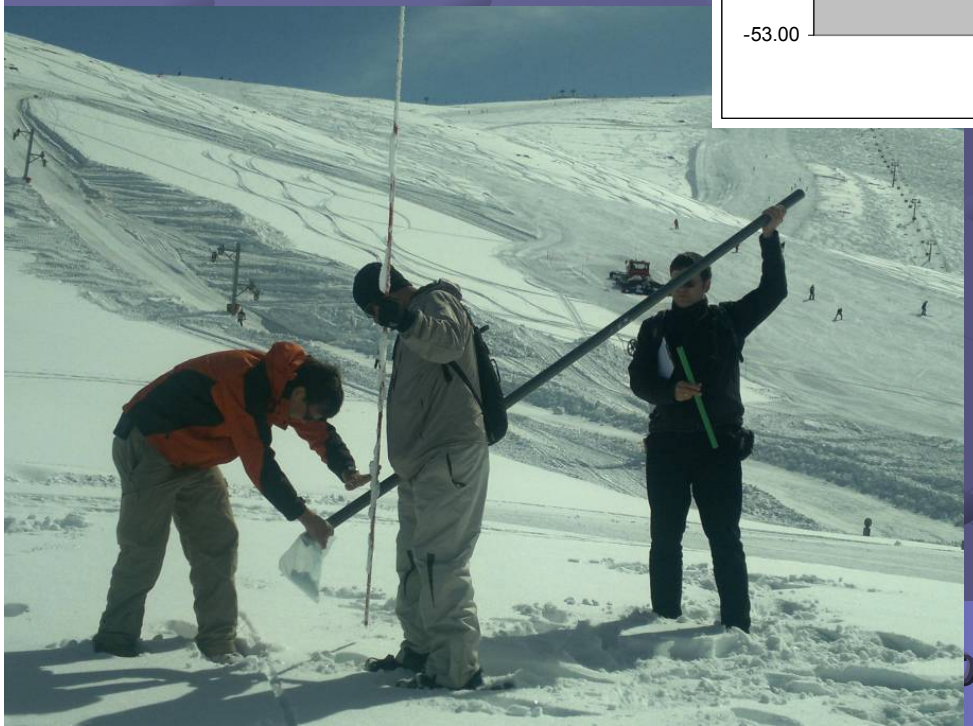
97 MCM/a

170 MCM/a



Isotope data





- deuterium/oxygen-18
- tritium/helium
- CFC (chlorofluorocarbon)

D/18O ~ 1,000 analyses

- 6 springs
- rainfall – 6 stations @ diff elev.
- snow sampling campaigns

Stable Isotope Sampling

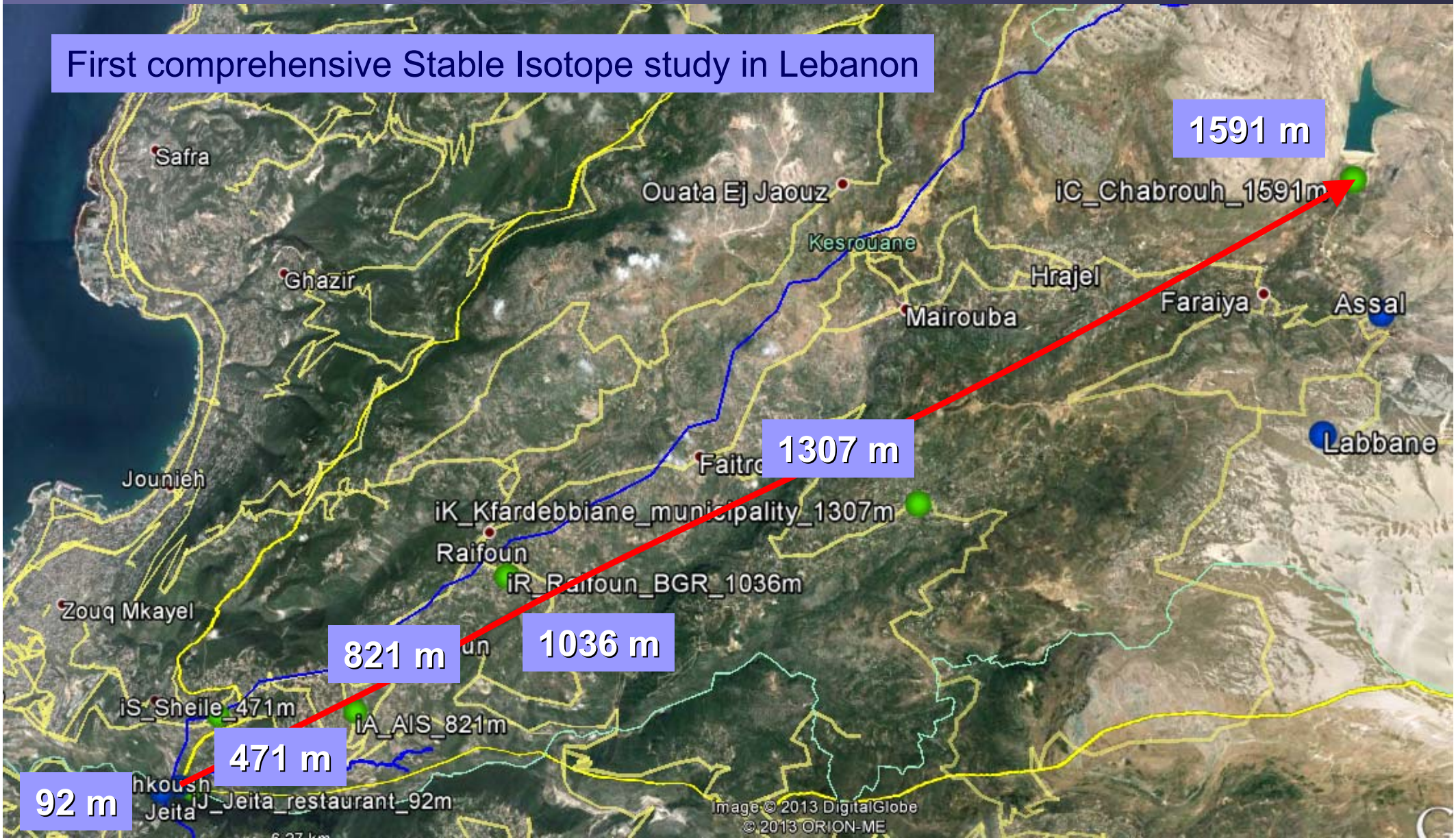
• **Springs** (every 2 weeks): Afqa, Rouaiss, Assal, Labbane, Jeita (daily), Kashkoush;

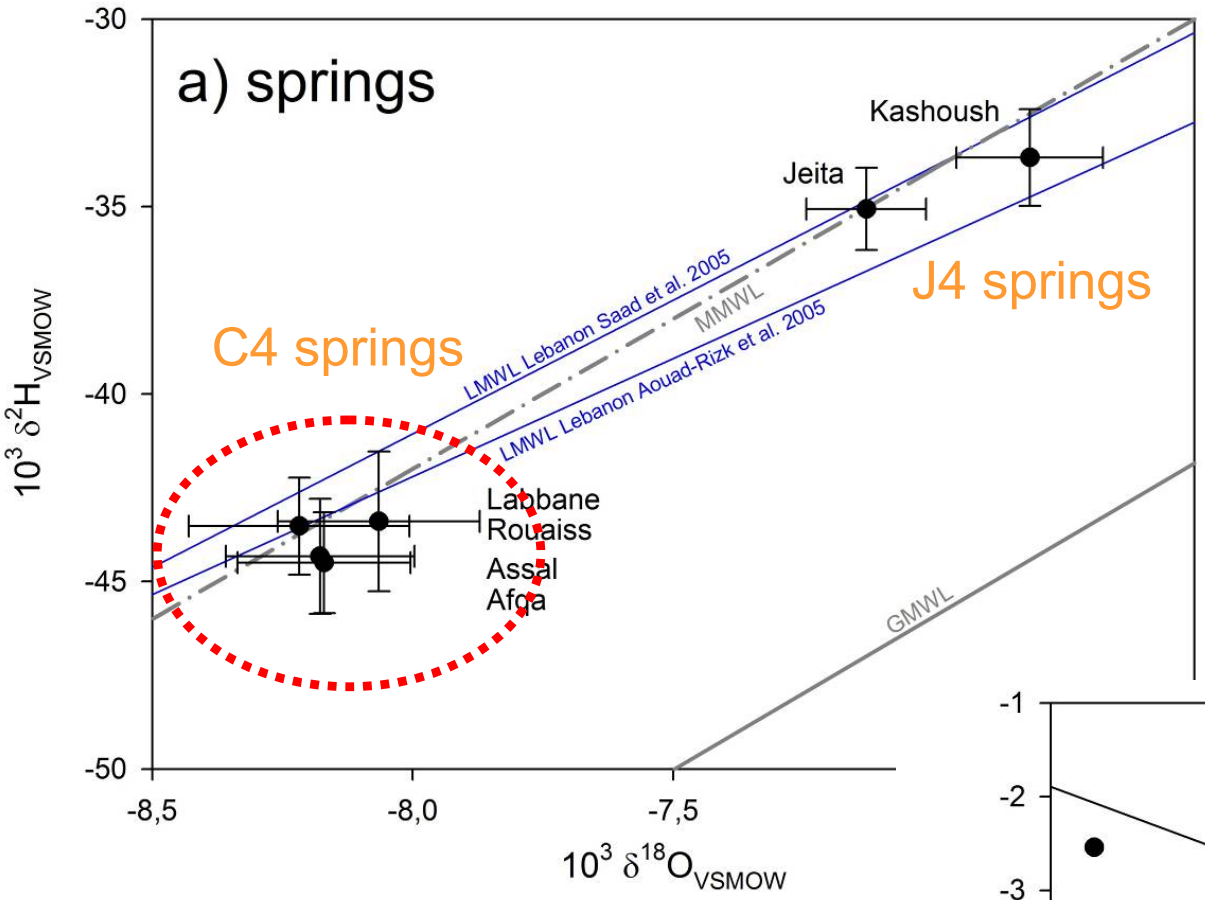
• **Rainfall** (every 10-15 days): 6 stable isotope rainfall sampling stations: Jeita Grotto restaurant (92 m), Sheile reservoir (471 m), Aajaltoun AIS (821 m), Raifoun BGR office (1036 m), Kfar Debbiane municipality (1307 m), Chabrouh dam treatment plant (1591 m);

• **Snow** (10 cm depth intervals and integral samples): approx. 20 sites during 2 sampling campaigns (February 2012, February 2013).

Stable isotope rainfall samplers

decrease in heavy isotopes with increasing elevation

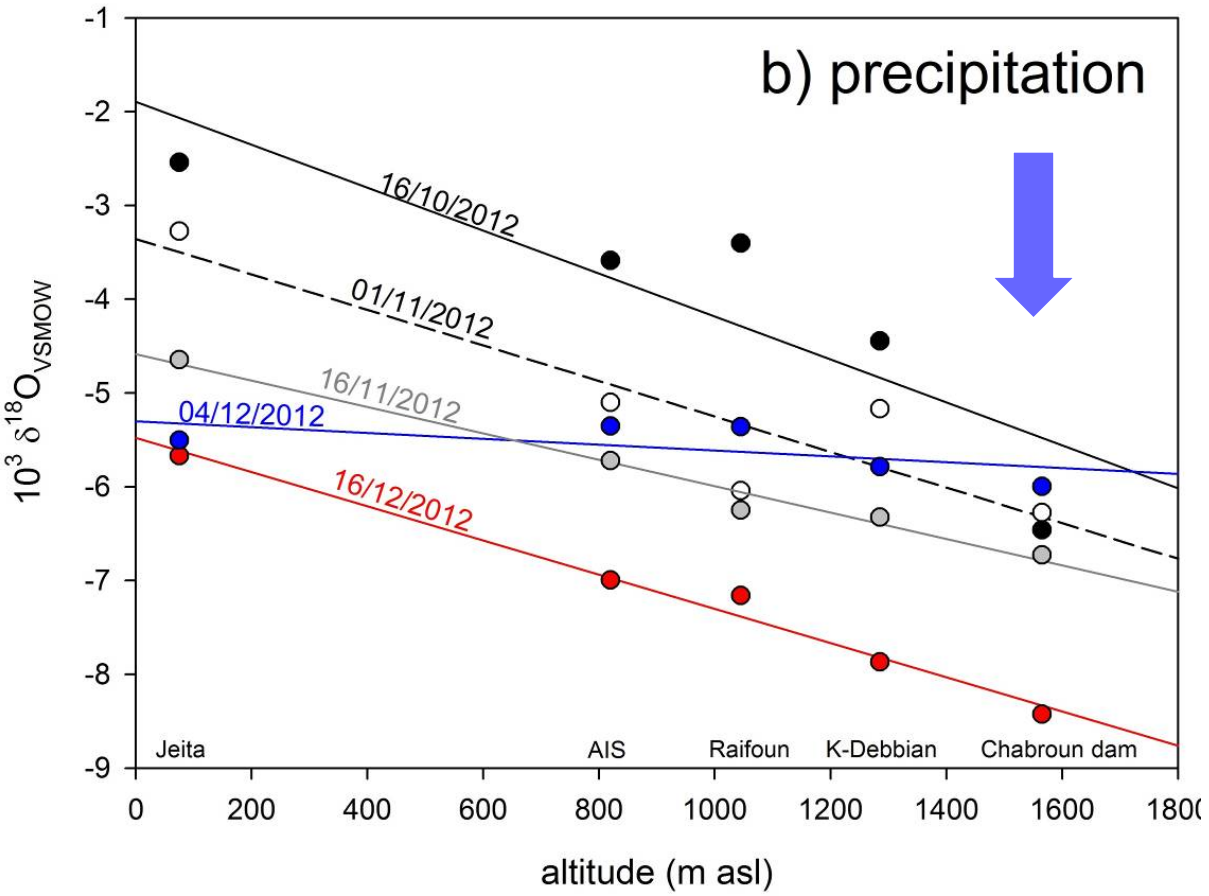




decrease in heavy isotopes with increasing elevation composition different for every storm event

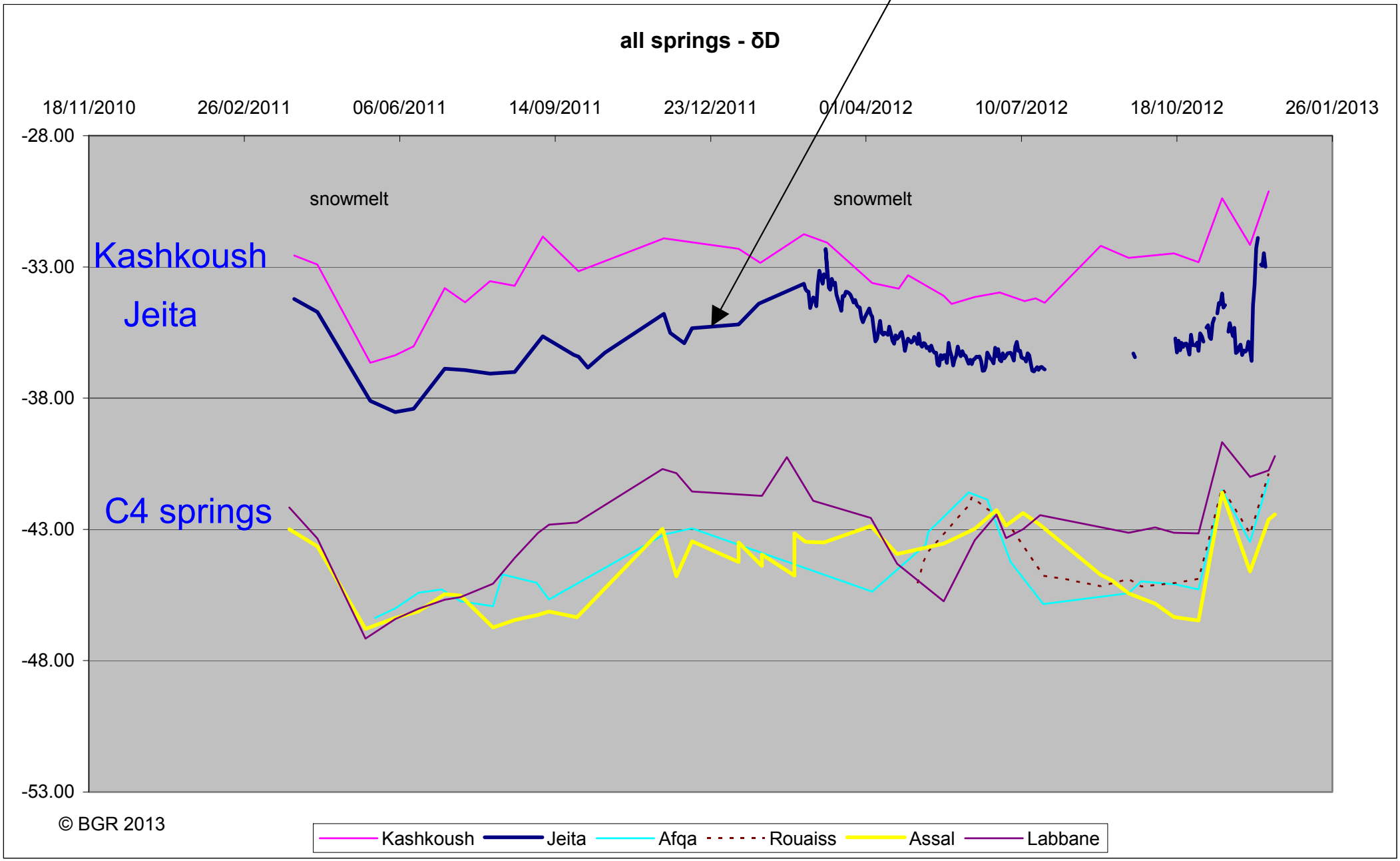
average composition of springs
Avg catchment elevation:

Afqa	2013 m
Rouaiss	1914 m
Assal	2067 m
Labbane	2171 m
Jeita (J4)	1021 m
Jeita (all)	1629 m



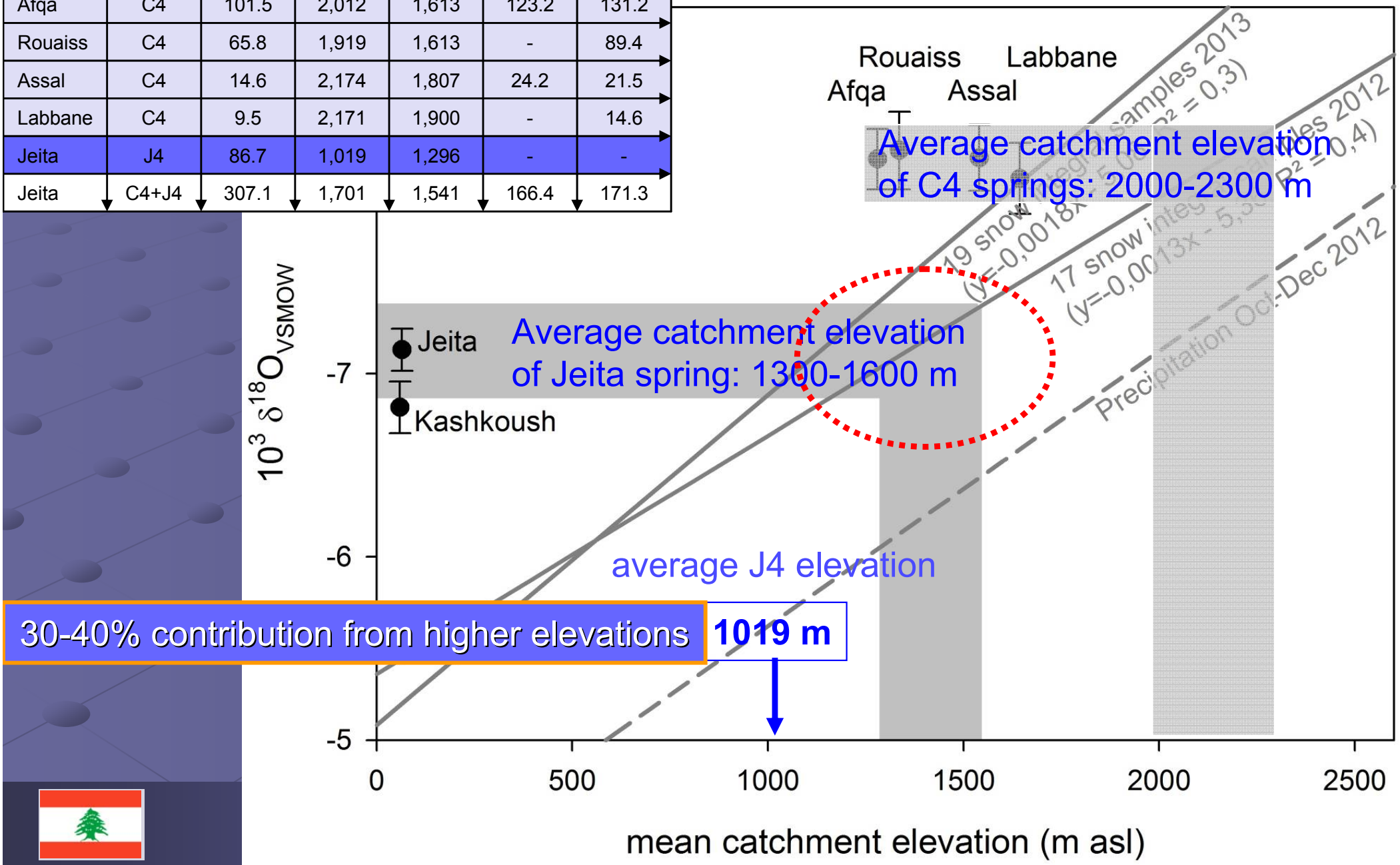
Spring Sampling

Average elevation of Jeita catchment is higher than Kashkoush



Stable isotope data

GW Catchment	Aquifer	Size [km²]	Mean Elevation [m]	Mean Rainfall [mm/a]	Mean Discharge Measured [MCM/a]	Mean Discharge WEAP model [MCM/a]
Afqa	C4	101.5	2,012	1,613	123.2	131.2
Rouaiss	C4	65.8	1,919	1,613	-	89.4
Assal	C4	14.6	2,174	1,807	24.2	21.5
Labbane	C4	9.5	2,171	1,900	-	14.6
Jeita	J4	86.7	1,019	1,296	-	-
Jeita	C4+J4	307.1	1,701	1,541	166.4	171.3



Spring Sampling

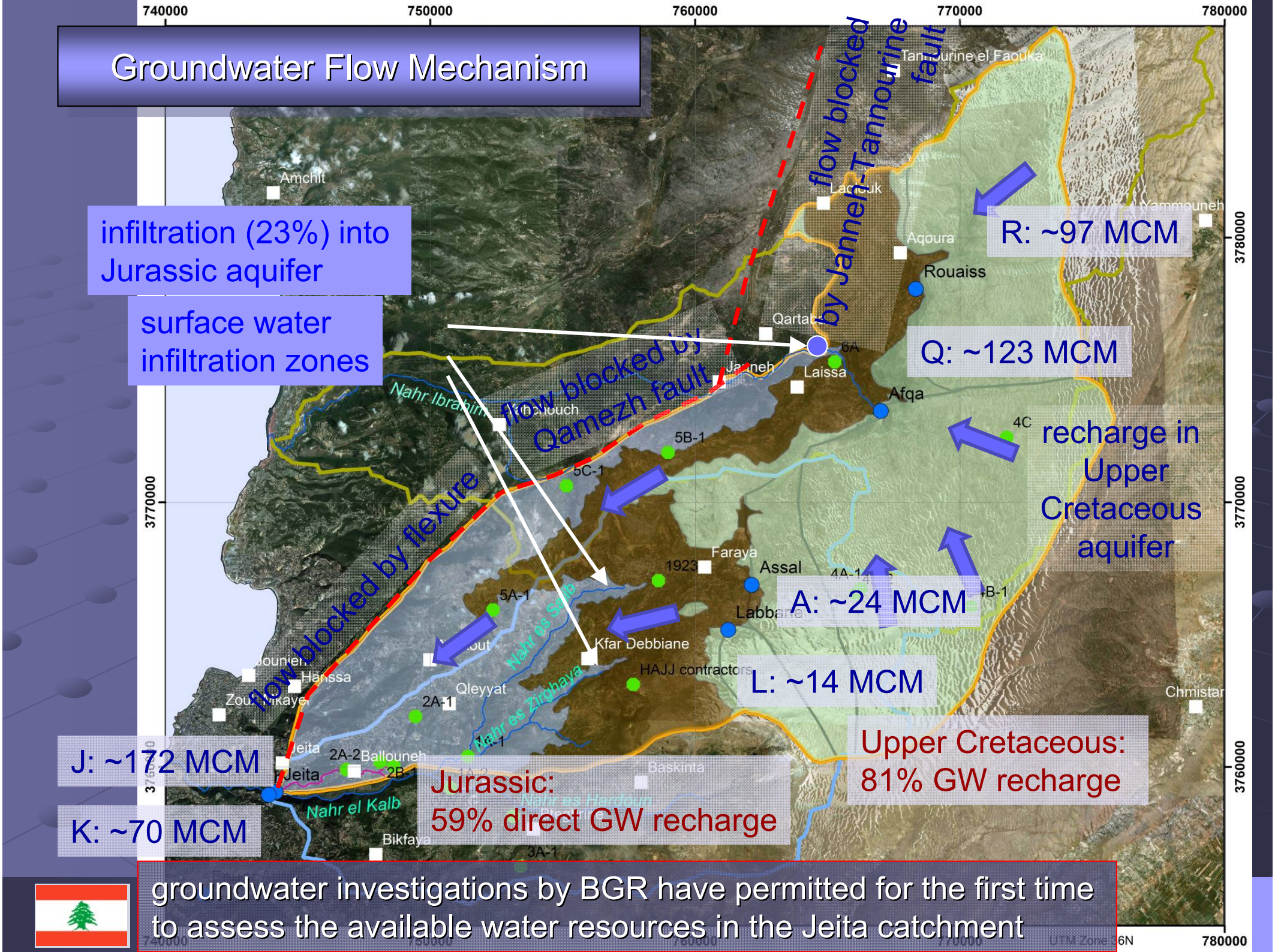
- Pronounced seasonal variation of $\delta^{18}O$ and $\delta^{2}H$ with fast response to snowmelt
- Significant difference between Jeita/Kashkoush and C4 springs
- Response of C4 springs fits with catchment elevation
- Difference in composition between Jeita and Kashkoush spring points to lower average catchment elevation of Kashkoush spring
- Jeita spring must be fed by significant contribution from higher elevations (30-40%)

Other Environmental Tracers

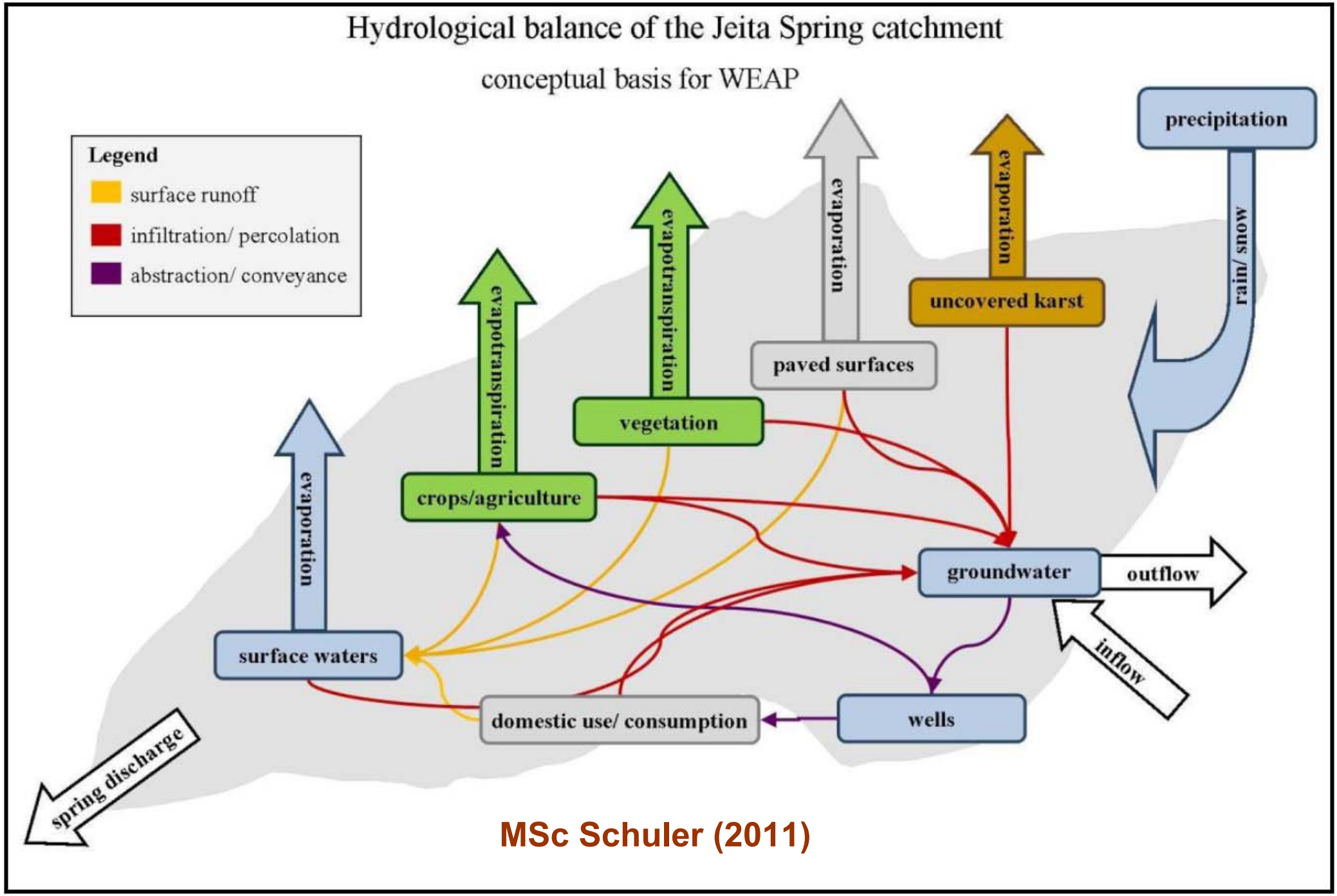
Special Report No. 15
(GEYER & DOUMMAR, 2013)

Helium - Tritium
Chlorofluorocarbons (CFC) and SF6 samples from
Jeita, Daraya (Jeita siphon terminale), Assal, Labbane and Kashkoush springs

Location	Date	Tritium	Helium-3	Helium-4	Helium/ Tritium Age
		mean GW residence time 1-2 years			
		TU	ccSTP kg^{-1}	ccSTP kg^{-1}	Years
Jeita	17.09.2010	3,03 ±0,31	6.65E-11	4.85E-05	0,9
Daraya tunnel	17.09.2010	3,00 ±0,18	6.85E-11	4.97E-05	1,6
Labbane	18.09.2010	3,26 ±1,32	5.82E-11	4.20E-05	1,7
Assal	18.09.2010	3,27 ±0,23	5.81E-11	4.24E-05	1,5
Kashkoush	19.09.2010	2,99 ±0,24	6.91E-11	5.03E-05	0,9

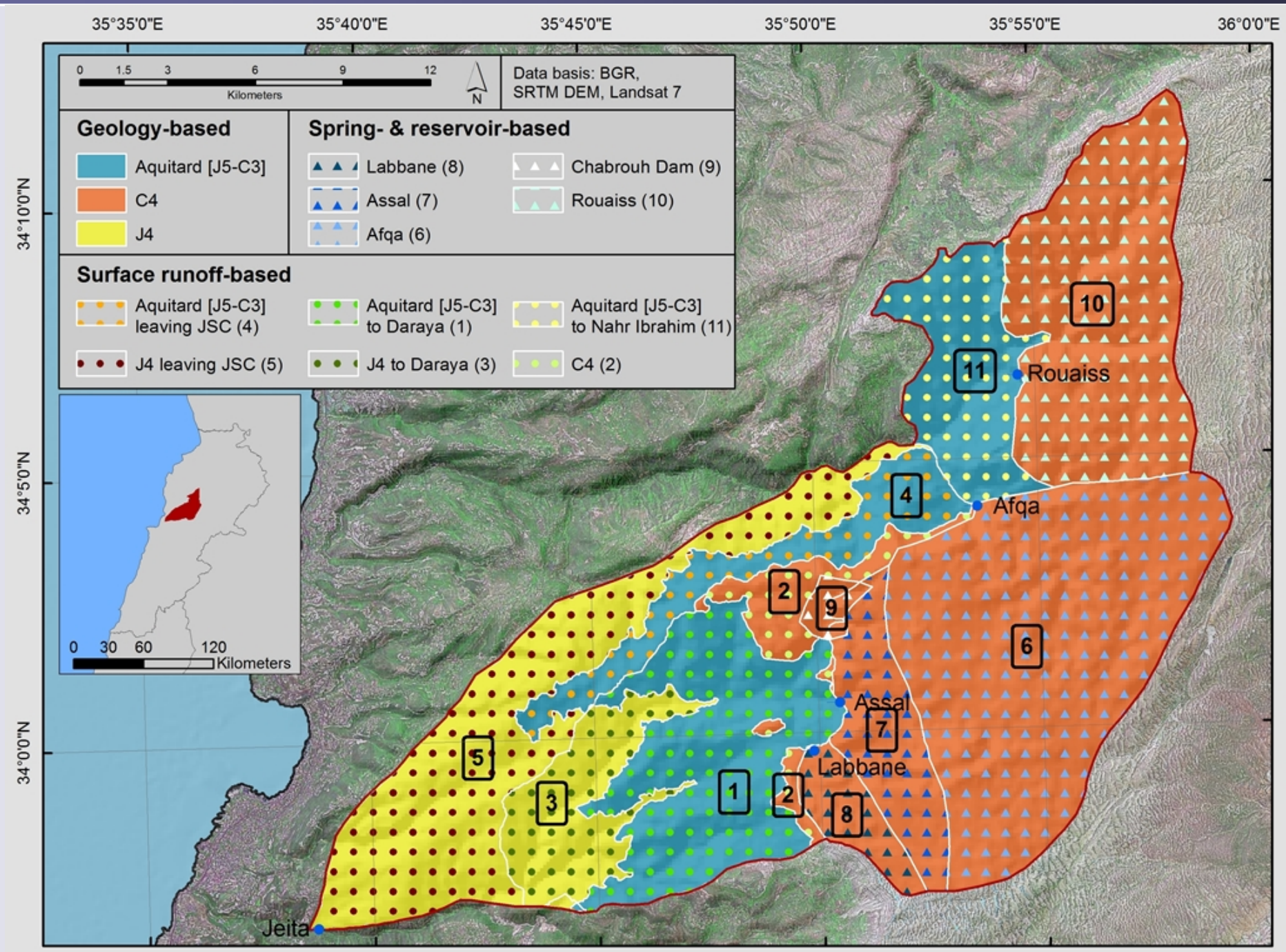

Groundwater Flow Mechanism
infiltration (23%) into Jurassic aquifer
surface water infiltration zones
flow blocked by Janneh-Tannourine fault
flow blocked by Qamezh fault
flow blocked by flexure
R: ~97 MCM
Q: ~123 MCM
recharge in Upper Cretaceous aquifer
A: ~24 MCM
L: ~14 MCM
J: ~172 MCM
K: ~70 MCM
Jurassic: 59% direct GW recharge
Upper Cretaceous: 81% GW recharge
groundwater investigations by BGR have permitted for the first time to assess the available water resources in the Jeita catchment
740000
750000
760000
770000
780000
3780000
3770000
3760000
Amchit
Aqoura
Rouaiss
Laissa
Afqa
Faraya
Assal
Kfar Debbiane
HAJJ contractors
Qleyyat
Hanssa
Jeita
Ballouneh
Bikfaya
Chmistar
Nahr Ibrahim
Nahr es Salib
Nahr es Zirghaya
Nahr el Kalb
5A-1
5B-1
5C-1
4C
2A-1
2A-2
2B-1
3A-1
1923
UTM Zone 36N

WEAP Model - Concept

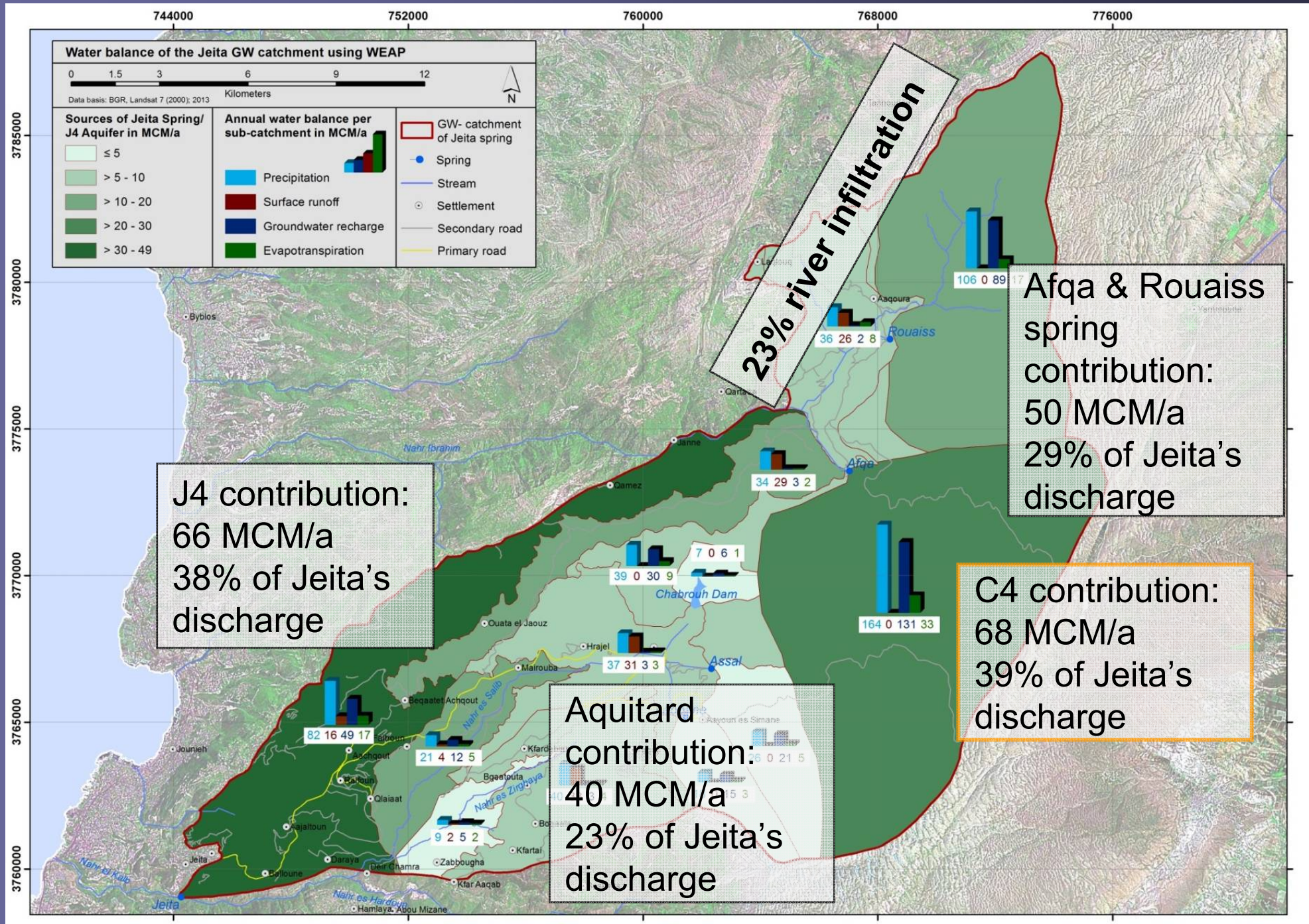


MSc Schuler (2011)

WEAP model


35°35'0"E
35°40'0"E
35°45'0"E
35°50'0"E
35°55'0"E
36°0'0"E
34°10'0"N
34°50'0"N
34°0'0"N
0 1.5 3 6 9 12
Kilometers
N
Data basis: BGR, SRTM DEM, Landsat 7
Geology-based
Aquitard [J5-C3]
C4
J4
Spring- & reservoir-based
Labbane (8)
Assal (7)
Afqa (6)
Chabrouh Dam (9)
Rouaiss (10)
Surface runoff-based
Aquitard [J5-C3] leaving JSC (4)
Aquitard [J5-C3] to Daraya (1)
Aquitard [J5-C3] to Nahr Ibrahim (11)
J4 leaving JSC (5)
J4 to Daraya (3)
C4 (2)
0 30 60 120
Kilometers
Rouaiss
Afqa
Assal
Labbane
Jeita
1
2
3
4
5
6
7
8
9
10
11

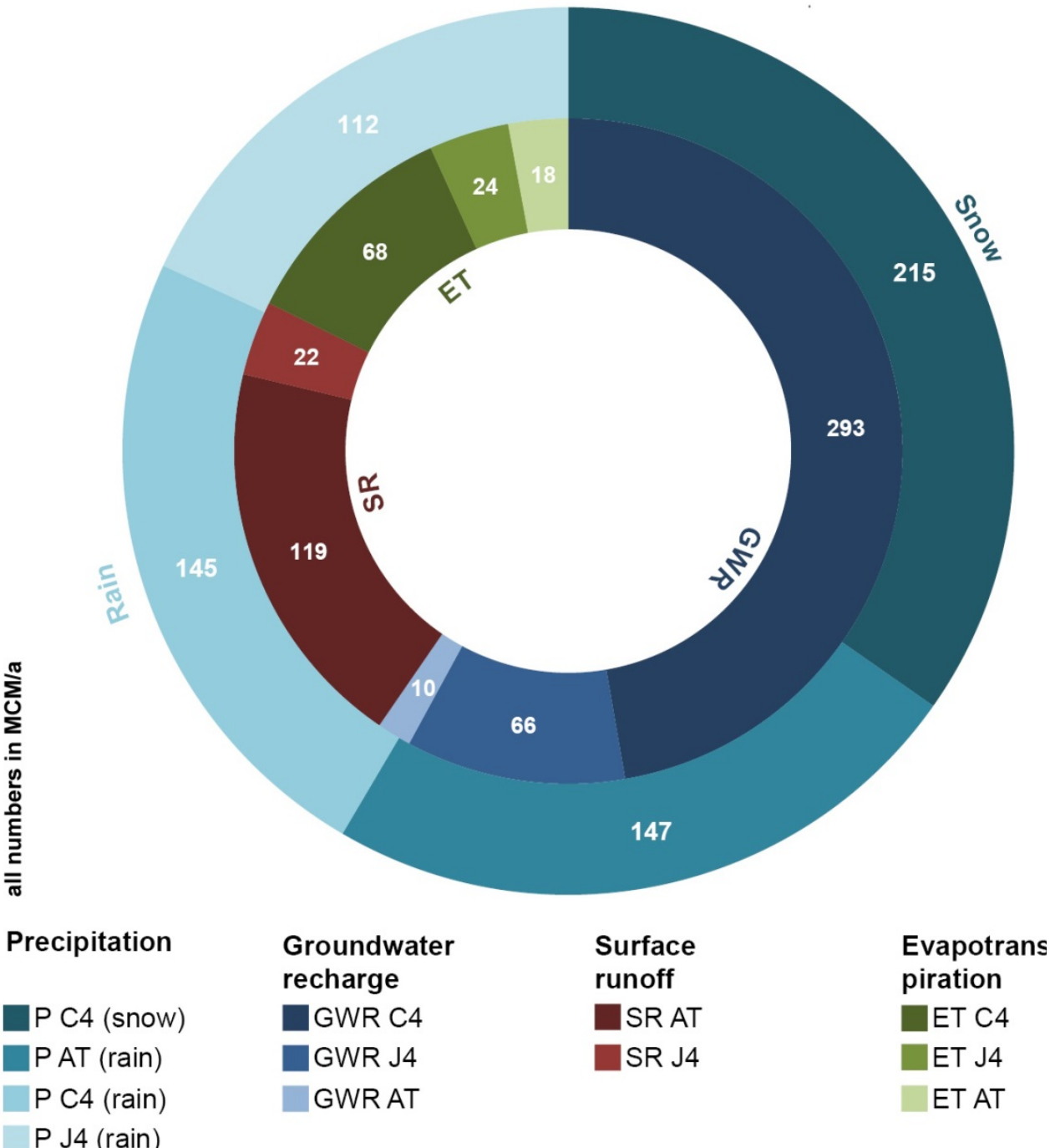
Water Balance



Water Balance

Annual natural flows in the Jeita GW catchment [MCM]

Hydrogeological Unit	GWR in %	SR in %	ET in %
Upper Aquifer (C4)	81.3	0.0	18.7
Aquitard Complex	7.0	80.8	12.2
Lower Aquifer (J4)	58.7	20.0	21.3

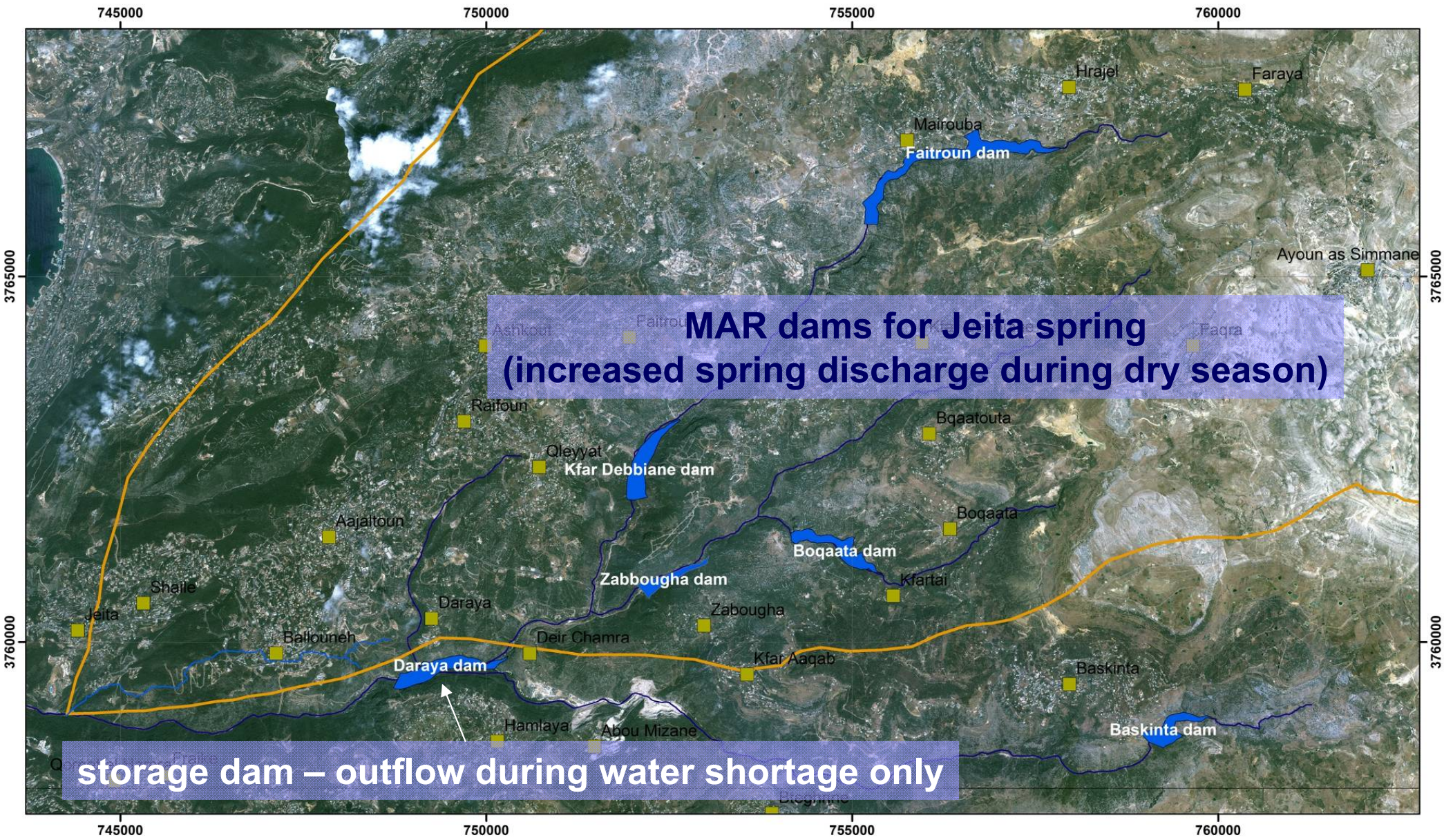


Water Balance for the Jeita Groundwater Catchment using WEAP (Schuler & Margane, 2013)

Water Balance component	Aquitard	Lower Aquifer (J4)	Upper Aquifer(C4)					**Total**
			Afqa	Assal	Labbane	Rouaiss	Total C4	
area in km^2	104.1	86.7	101.6	21.7	9.5	65.8	215.0	**405.8**
mean elevation asl	1424	1,019	2,013	2,067	2,171	1,914		
P in MCM/a	153.4	112.0	164.1	38.0	18.0	107.5	353.8	**619.3**
GWR in MCM/a	15.2	53.4	139.5	33.5	16.1	96.8	309.2	**377.9**
R in MCM/a	128.4	35.2	0.0	0.0	0.0	0.0	0.0	**163.6**
ET in MCM/a	9.9	23.4	24.4	4.5	2.0	10.7	44.6	**77.8**

P - precipitation, GWR - groundwater recharge, ET - evapotranspiration,
R - runoff, MCM - million cubic meters

Proposed Storage & MAR Dams



WEAP: MAR dam scenario

Proposed Dams	Elevation [m asl]	Dam crest [m]	Storage [MCM]	Surface area [m²]	Catchment [km²]	Rainfall [mm/a]	Rain volume [MCM/a]
Kfardebian	720	100	7.3	224.7	91.0	1,565	142.4
Faitroun	1,115	65	6.6	460.0	80.1	1,596	127.8
Boqaata	900	80	4.1	198.0	16.8	1,442	24.2
Baskinta	1,035	100	6.0	157.7	28.5	1,659	47.4
Zabbougha	635	100	3.0	105.0	46.9	1,454	68.2
Daraya	320	100	9.0	235.2	222.0	1,494	331.7

Proposed Storage & MAR Dams

Proposed Dam	Storage [m³] met by runoff	Function	Infiltration capacity
Kfar Debbiane	7.3	MAR > Jeita spring	High
Faitroun	6.6	MAR > Jeita spring	Very high
Zabbougha	3.0	MAR > Jeita spring	High
Boqaata	4.1	MAR > Jeita spring	Very high
Daraya	9.0	storage	Low
Baskinta	6.0	MAR > Faouar Antelias spring	Very high

MAR – managed aquifer recharge

Optimized Use of Water Resources

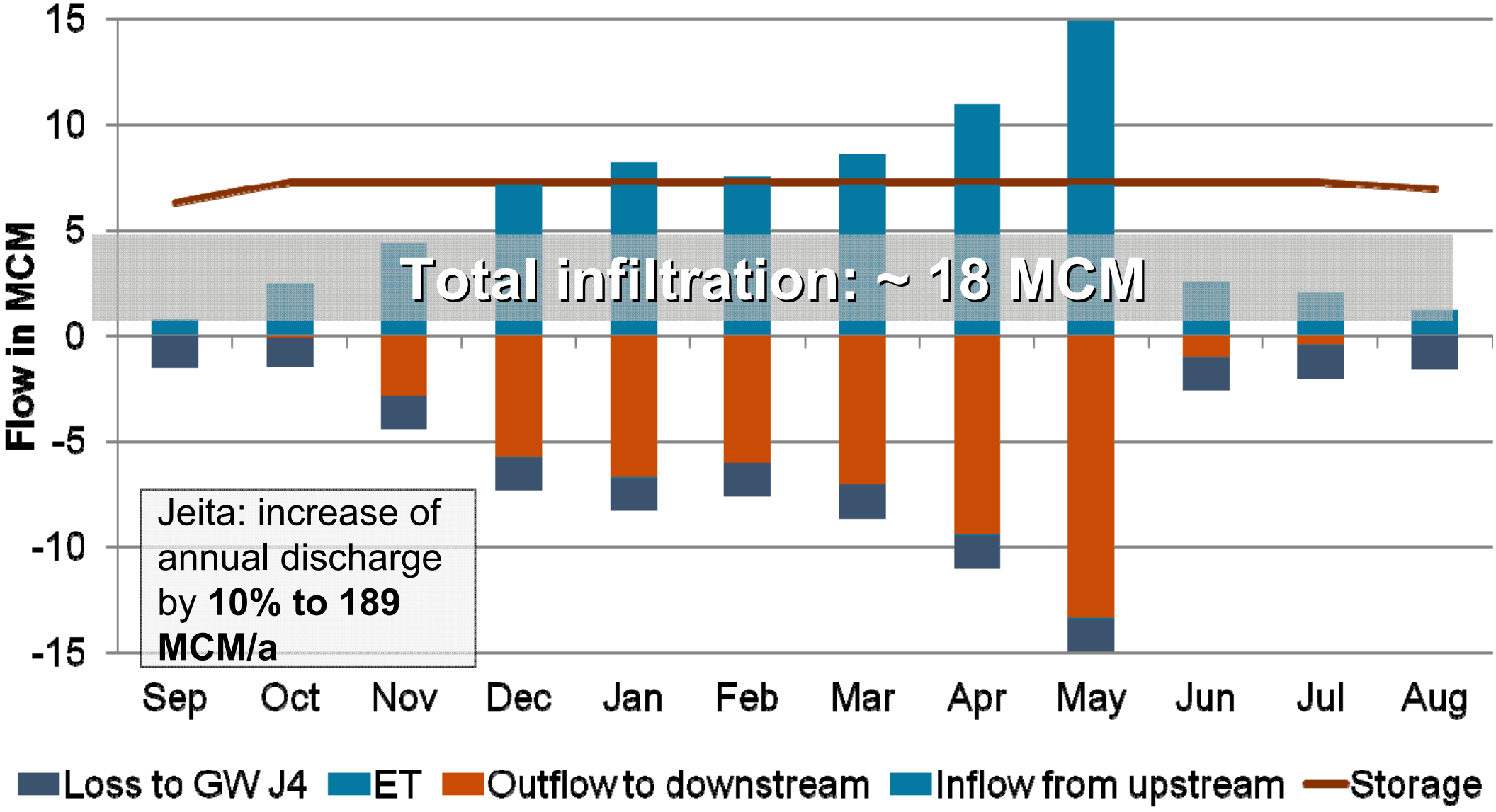
Surface water:

Capture of (rain)water and flow over aquitard (diversion): until March/April
Small-scale rainwater harvesting possible on aquitard
► storage in ponds at high elevations (1300 – 1600 m), agricultural use

Managed aquifer recharge (MAR) to reduce the water shortage periods in the domestic water supply of the Greater Beirut Area (October-December)
► storage in dams at medium – high elevations (March-July),
dam capacity (live storage) 3-7 MCM

Kfar Debbiane MAR dam

Storage volume and GW infiltration of Kfardebian Reservoir in MCM



WEAP Climate Change Scenario

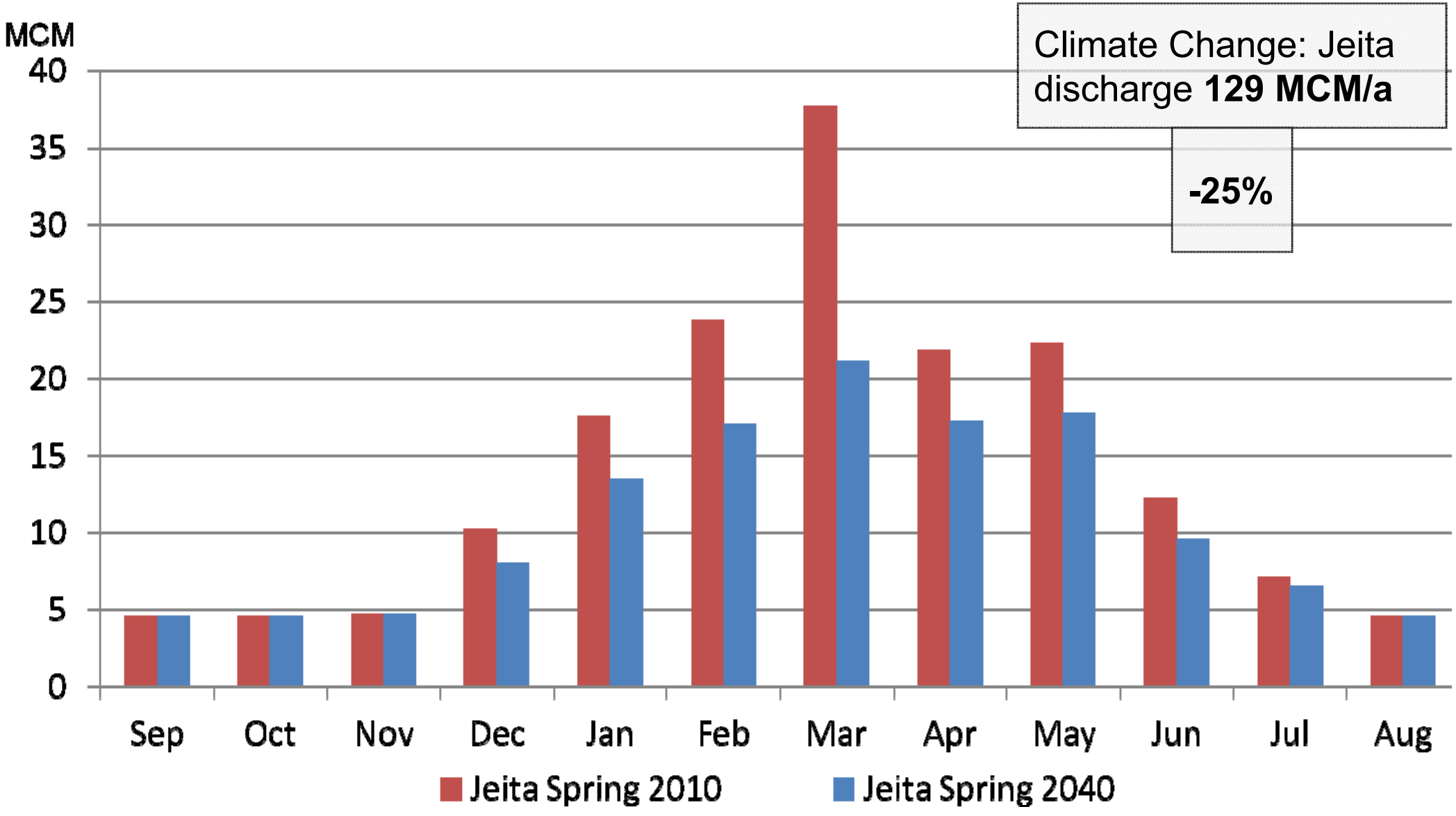
- Modeling period: 2010 to 2040
- Based on the A1B scenario (*)
  - *Most commonly used*
  - *Based on: Beirut, Cedars, Dahr el Baidar and Zahleh*
- Selected forecasts until 2040:

Precipitation (%)		Temperature(°C)		k_c	
Summer	Winter	Summer	Winter	Summer	Winter
-15	-20	+2	+1.75	+4.4	+3.1

(*) MINISTRY OF ENVIRONMENT (MoE) (2011): Lebanon's Second National Communication to the UNFCCC. Republic of Lebanon, Ministry of Environment, 191 p.; Beirut/Lebanon.

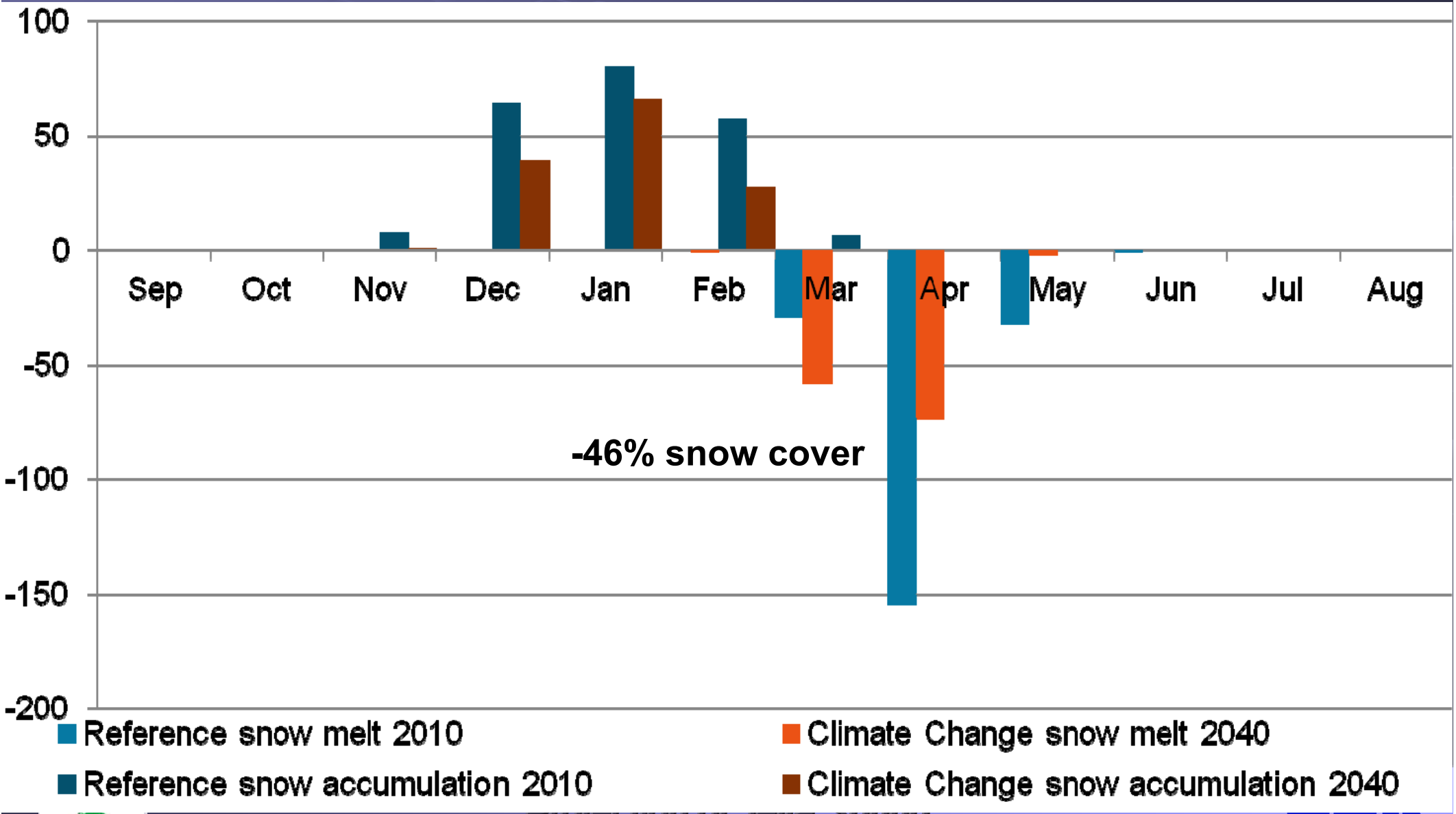
Results WEAP Climate Change Scenario

Discharge of Jeita Spring: Reference vs. Climate Change Scenario in MCM



Results WEAP Climate Change Scenario

Snow cover on the C4: Reference vs. Climate Change Scenario in m



WEAP Conclusions

- Approx. **40%** of Jeita's annual discharge comes from the C4
- Approx. **28%** of Jeita's annual discharge comes from Afqa and Rouaiss Spring
- Large quantities of water resources are unused: **141 MCM** direct runoff per year
- Potential for MAR: Increasing discharge at Jeita Spring

  → however, uncertainty about fast flow/ slow flow component
- Climate Change could severely impact water resources availability:

  - snow cover will be reduced by 46%

  - discharge of Jeita will decrease by 25% in 2040

Thank you for your kind attention

www.bgr.bund.de/jeita

Dr. Armin Margane – Project Team Leader
Raifoun, Saint Roche Street
armin.margane@bgr.de +961 70 398027