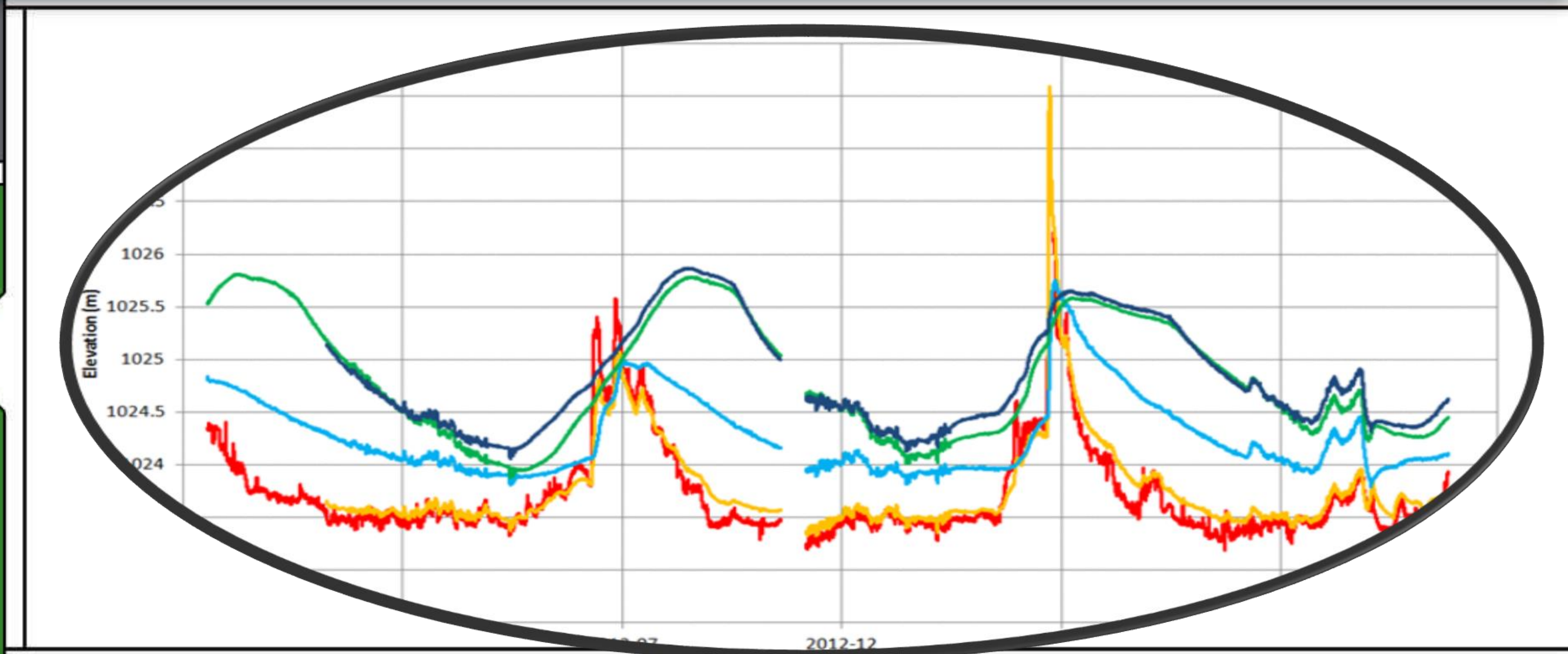
WaterTech 2015

Continuous Water Level Monitoring For Characterization of Contaminated Sites



April 2015

Authors and Presenter

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Outline

- Site Description
- Monitoring Program
- Data Interpretation
- Installation and Data Process
- Summary

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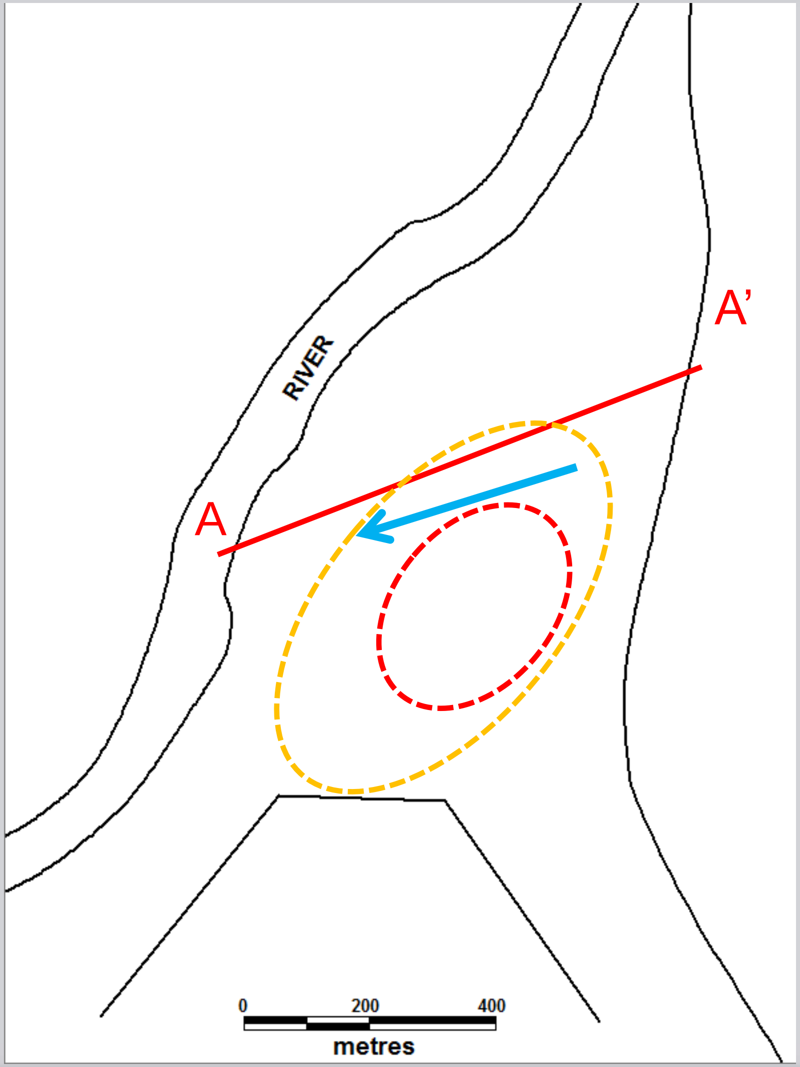
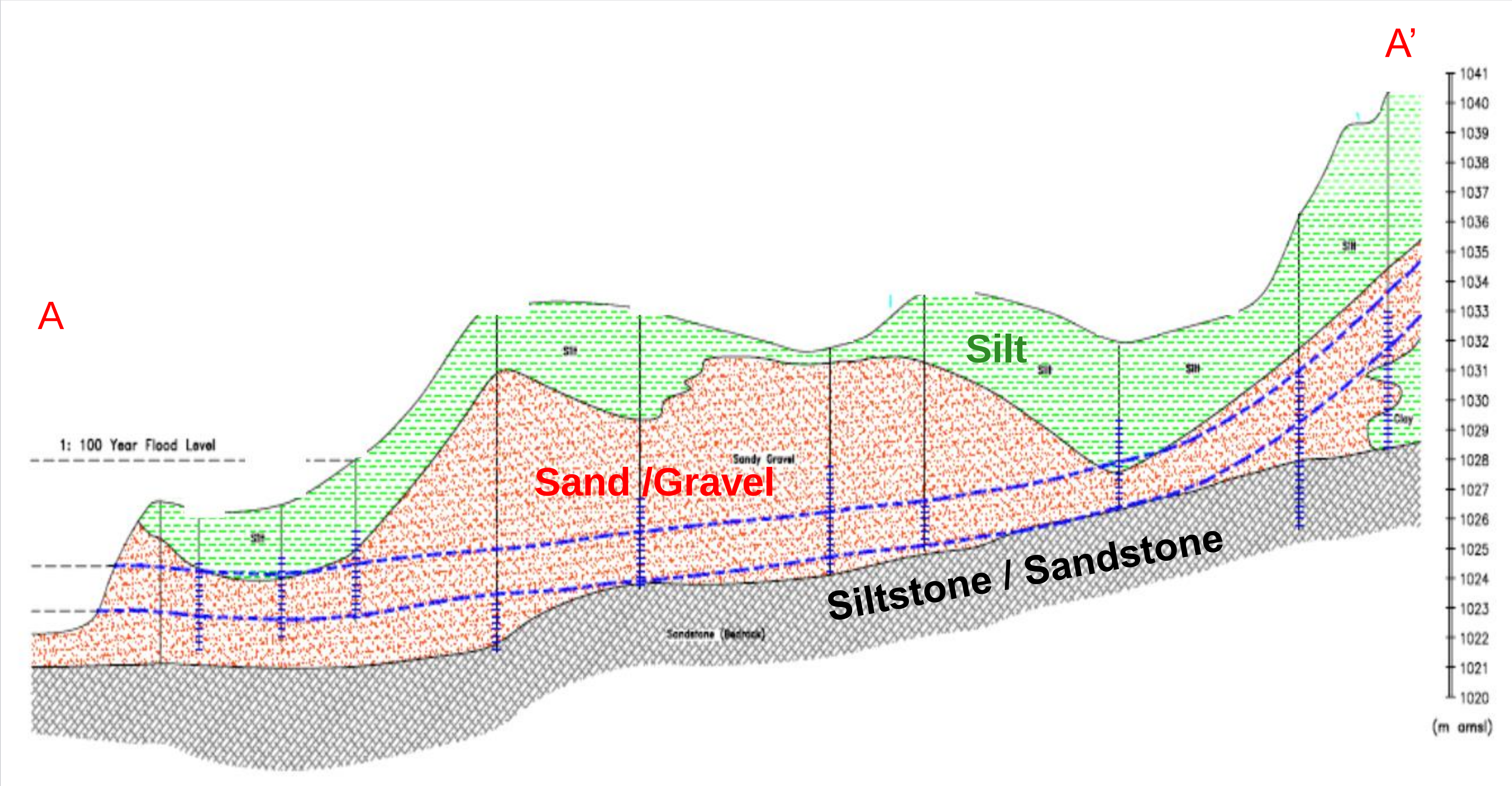
Site Description

- A site in southern Alberta
  - Adjacent to a major river
  - 1500 m by 500 m in size
- Groundwater and soil heavily impacted by petroleum hydrocarbons and other chemicals
  - Free product observed in a number monitoring wells
- One of the major concerns is migration of dissolved contaminants or even product to the river
- Remediation systems are in construction
  - Including a groundwater pump-treat-injection system and a 1.5-km barrier wall along the river

Site Description



Site Description



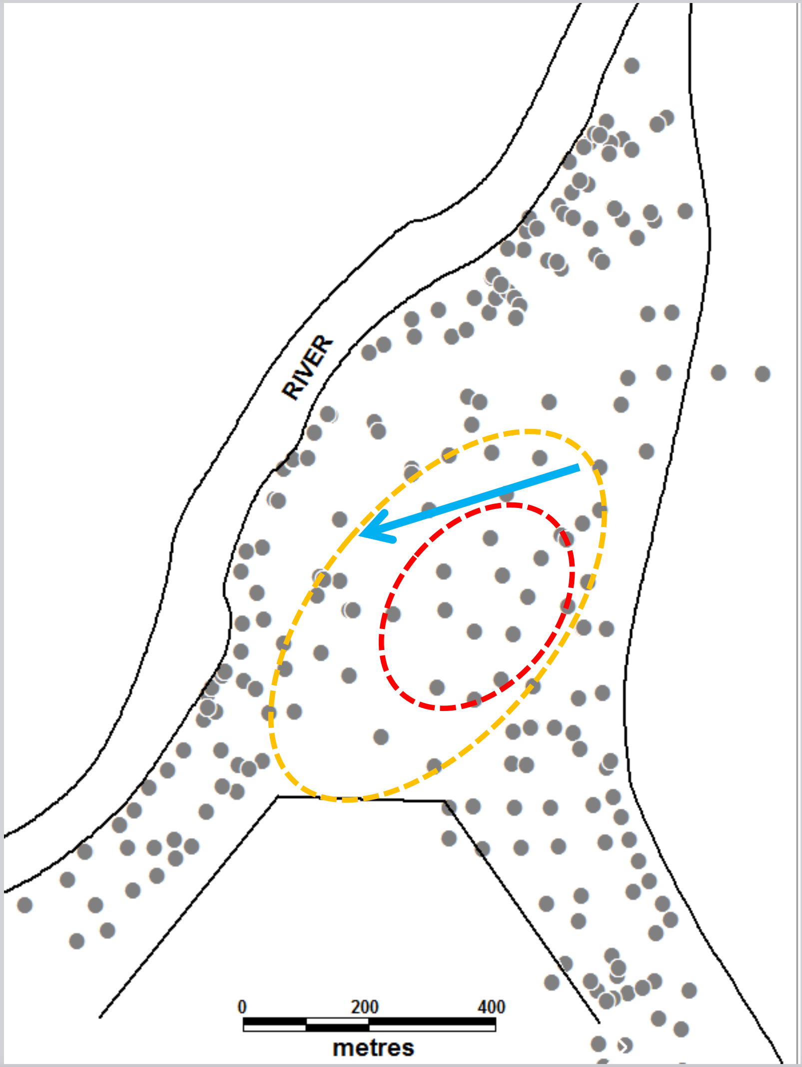
Site Description

- Geological cross-section
  - Very coarse sand and gravel above bedrock, with hydraulic conductivity in a range of 1×10^{-5} m/s to 1×10^{-3} m/s
  - Annual groundwater level fluctuation in a range of 0.5 to 2 m across the site
- Groundwater generally flows to the river
  - which causes migration of contaminants towards the river
  - River water levels can be higher the groundwater level, and flows inland during high level period (“inverse flow”). However, it is not shown based quarterly groundwater monitoring data.

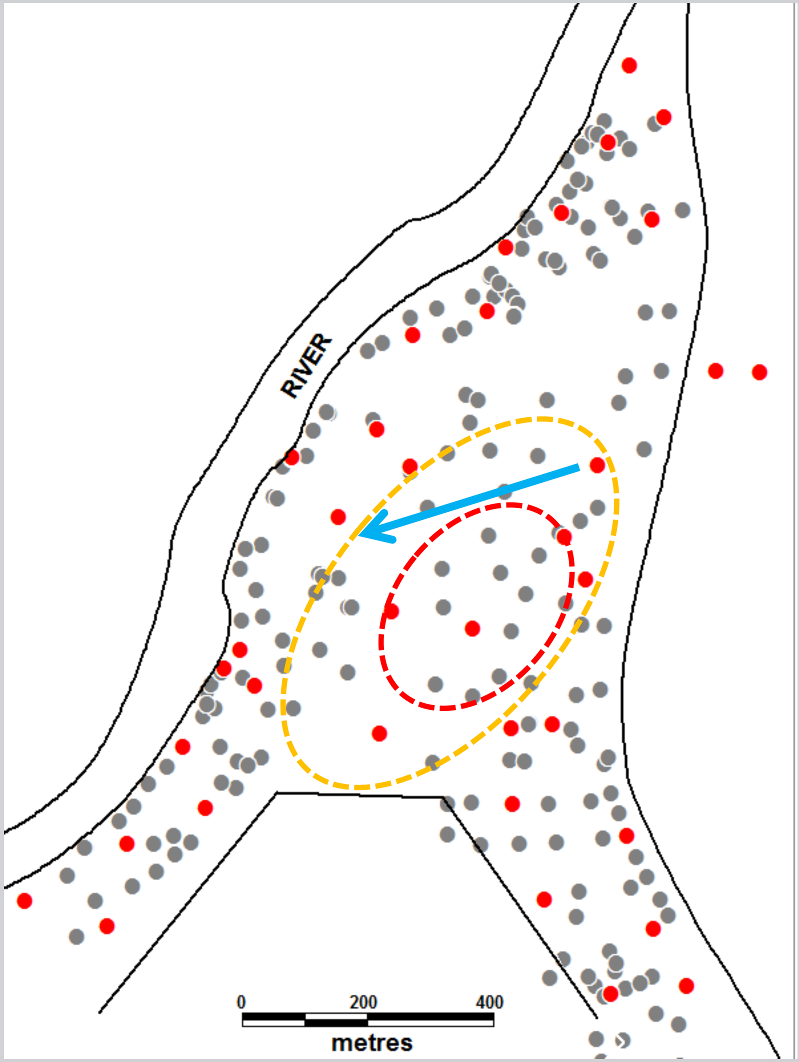
Monitoring Program

- More than 200 monitoring wells were installed during different phases of investigation
  - for groundwater level monitoring and sampling
  - Selected monitoring were monitored quarterly or semi-annually during different programs
- Pressure transducers with data loggers were installed in 40 monitoring wells since 2011 summer
  - 7 wells have data logger since 2008
  - Data loggers were set to record water levels every hour

Monitoring Program (Monitoring Wells)



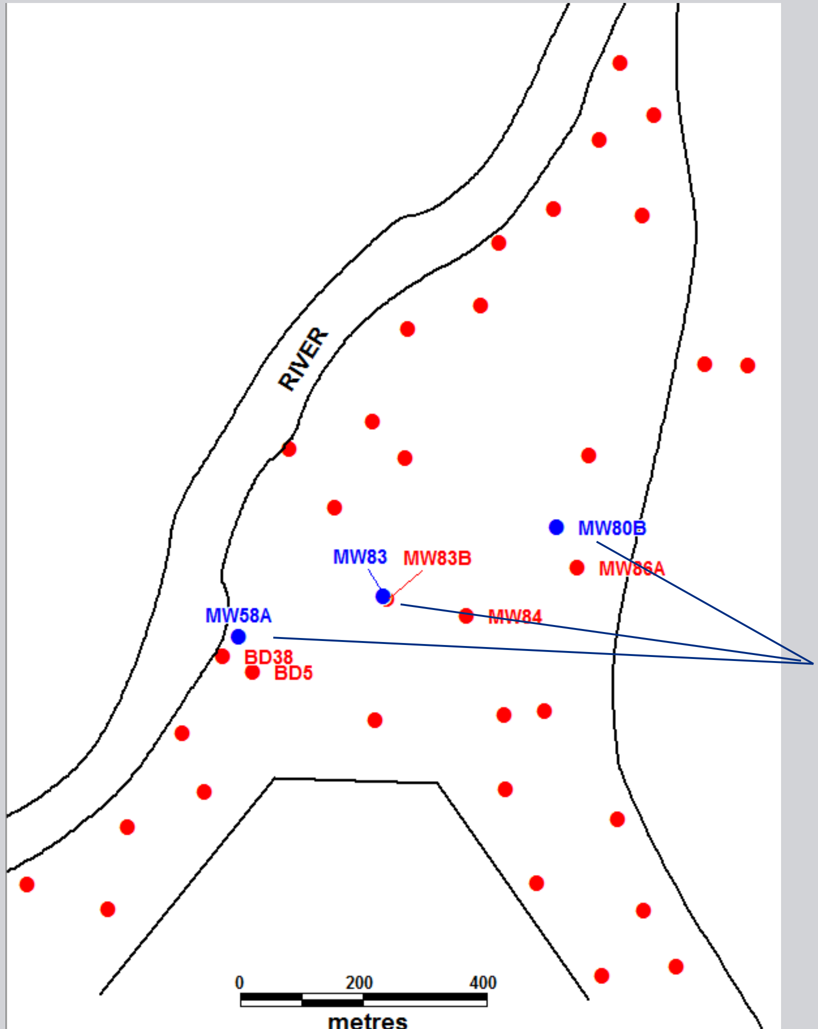
Monitoring Program (Data Logger Locations)



Monitoring Program

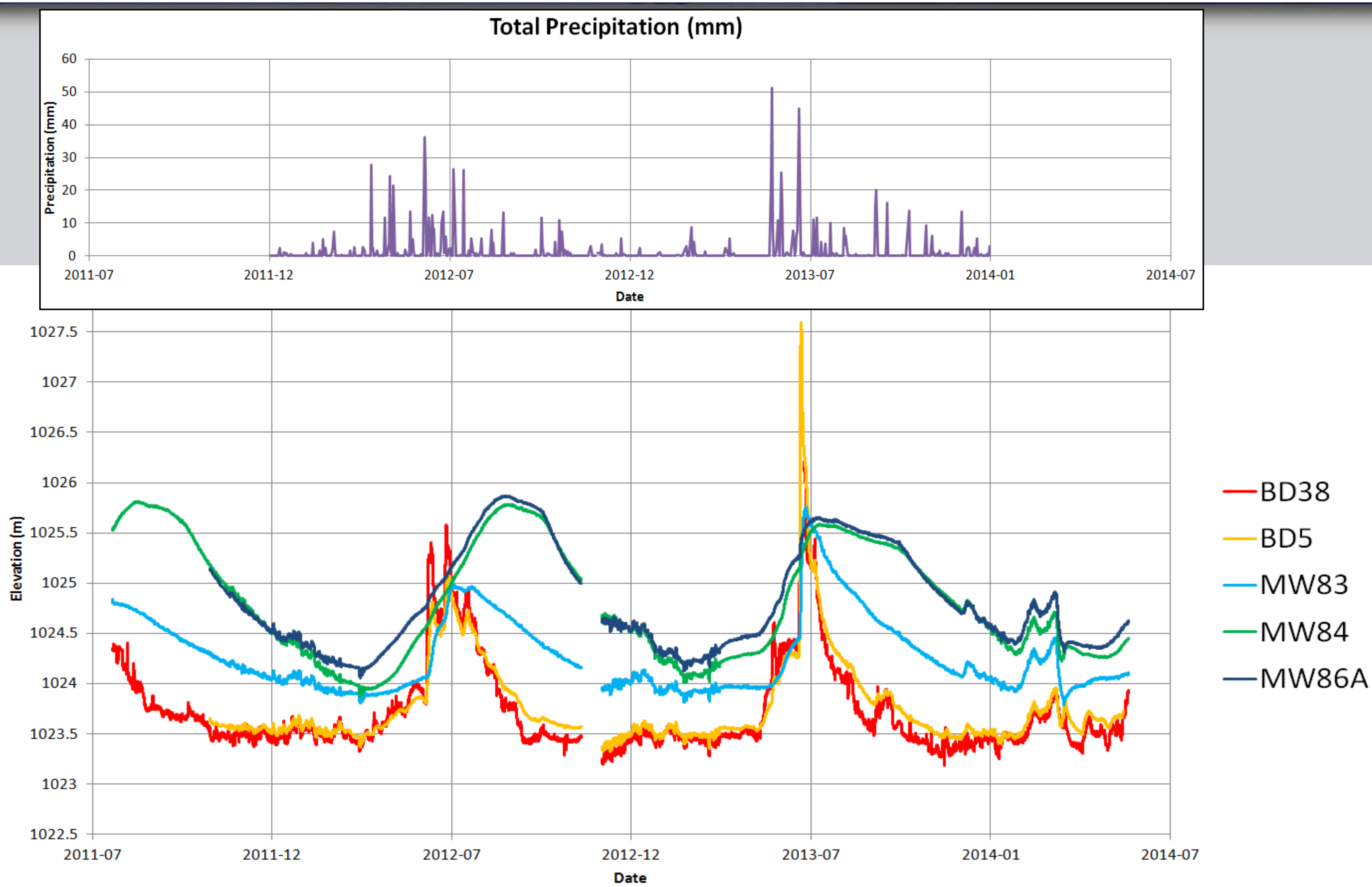
- Dada logger were installed for
  - Characterizing groundwater fluctuations caused by rainfall infiltration, lateral groundwater inflow from east boundaries and interactions before groundwater and the river
  - Data collection to provide design parameters for the groundwater pumping-treat-injection system and construction of a barrier wall
  - Providing data to update groundwater transport models

Water Level Fluctuation (selected locations)



Bedrock wells

Water Level Fluctuation



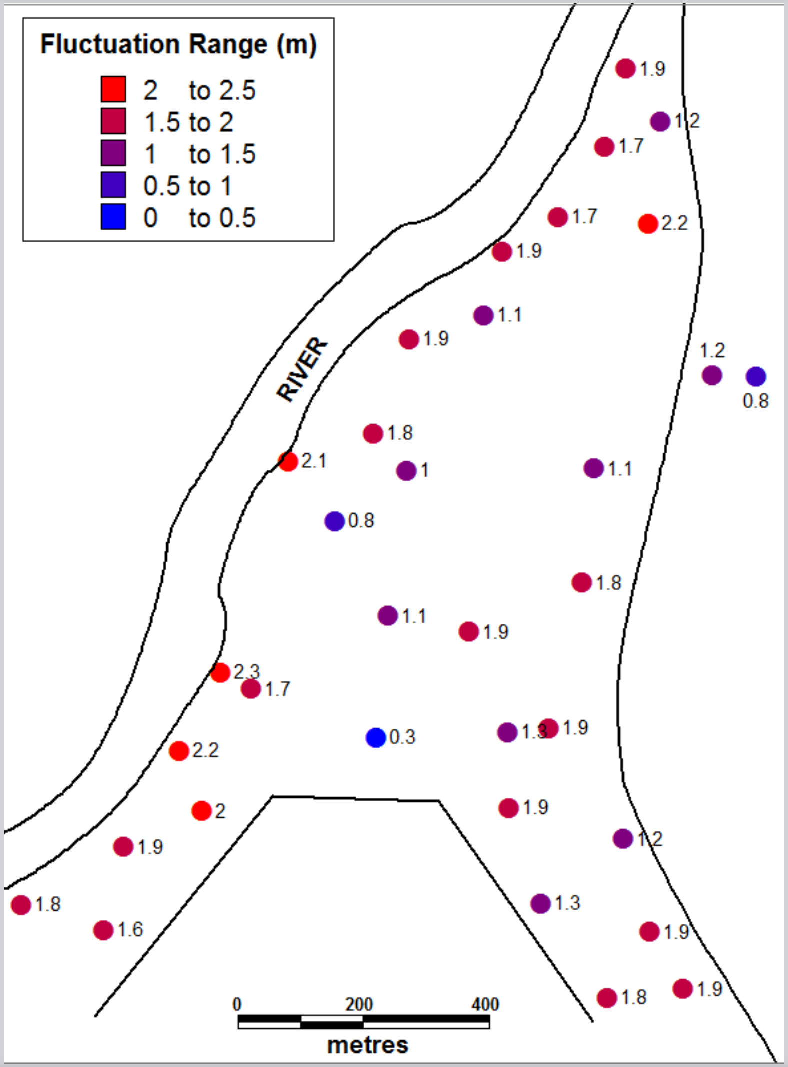
Water Level Fluctuation

- Monitoring well DB38 represents river level changes
  - Installed <10 m from the river
  - Perfect correlation observed with the river water levels
  - Installed more securely than the logger installed in the river directly
  - Approximately 2 m water level increase during 2012 high water level period (June and July). More than 4 m increase during 2013 flooding (at DB38 ground was under 2 m of water during flooding)

Water Level Fluctuation

- Monitoring wells near the river, i.e., BD5, show very similar fluctuations with river levels, but a closer look may reveal some interesting details (see later in the presentation)
- Wells away from the river show more influence by rainfall infiltration
  - More than 1.5 m yearly fluctuation
  - Look apparently as propagation of river level changes, but they are not
  - Similar fluctuations in 2012 and 2013, consistent with local total precipitation (502 mm and 478 mm), not showing much influence of 2013 historical flooding

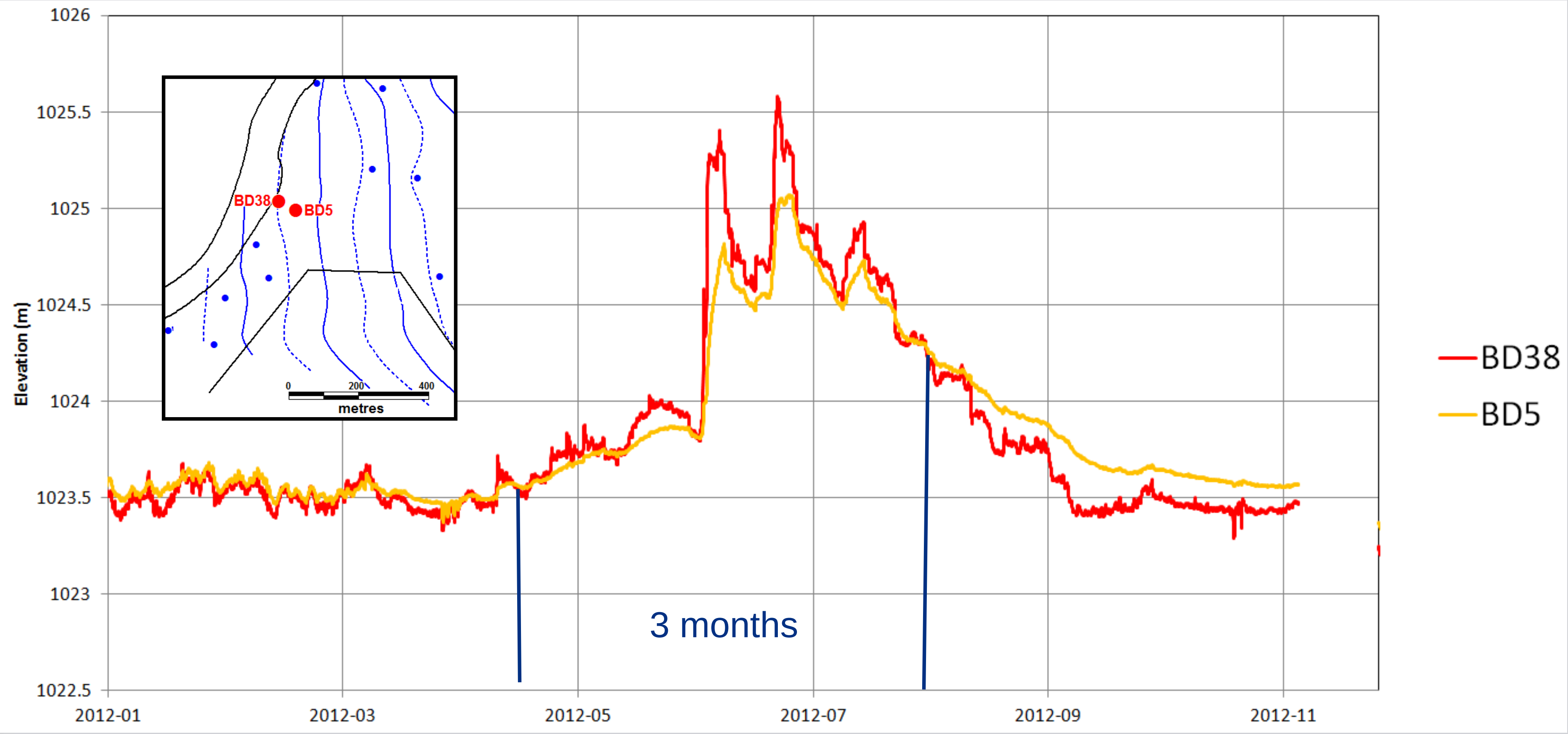
Water Level Fluctuation (2012)



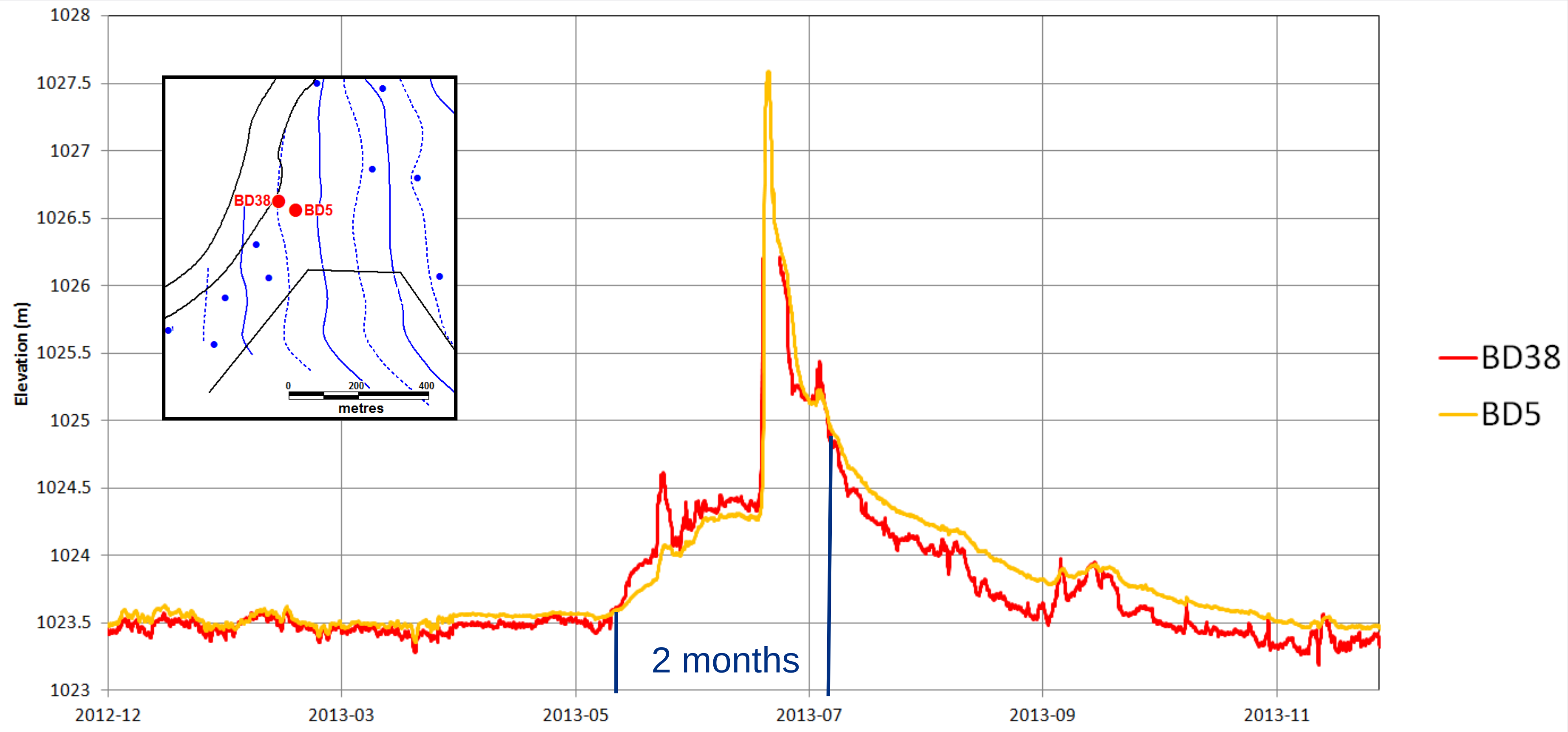
Detection of Inverse Flow

- Data logger data were used to detect inverse flow (river water flows inland to recharge groundwater)
  - Examine water level differences between a pair of wells near the river
  - Groundwater elevation contour maps during high water level periods
- Inverse flow may be significant to contaminant transport to the river
  - Change migration direction and flux
  - Mixing the impacted groundwater with “clean” river water

Inverse Flow (2012)

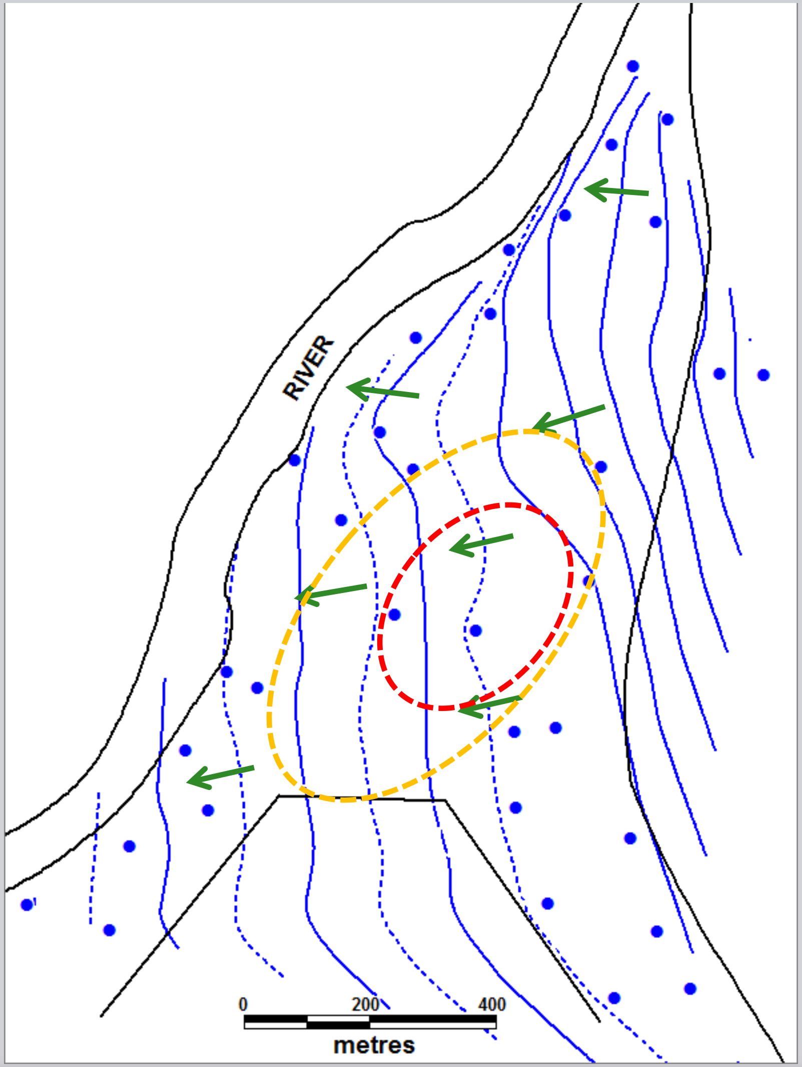


Inverse Flow (2013)



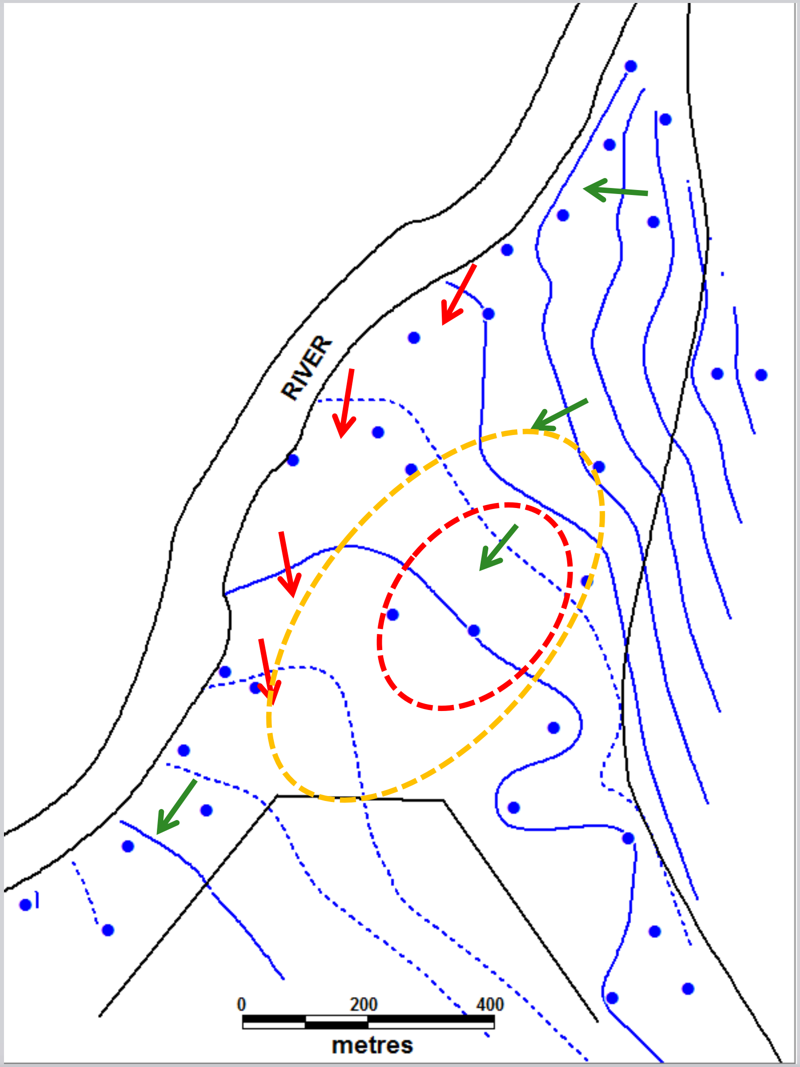
Groundwater Elevation (2012 November average level)

"Normal" flow directions for 10 months of a year



Groundwater Elevation (2012 June average level)

One month average during high level period



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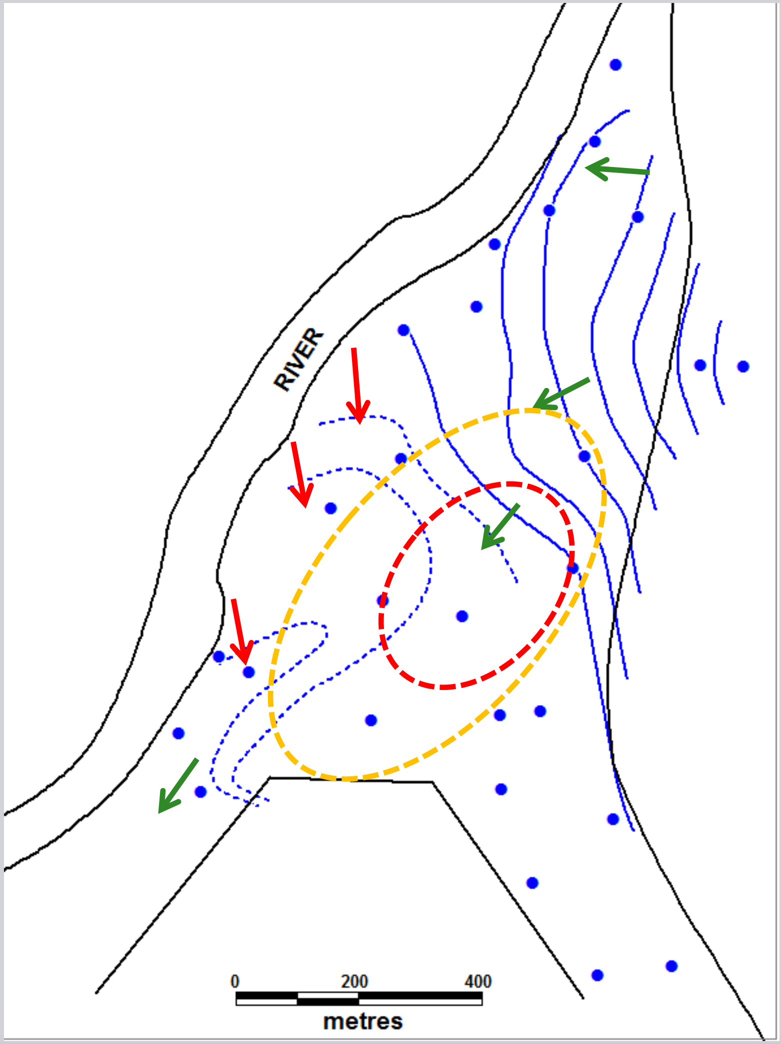
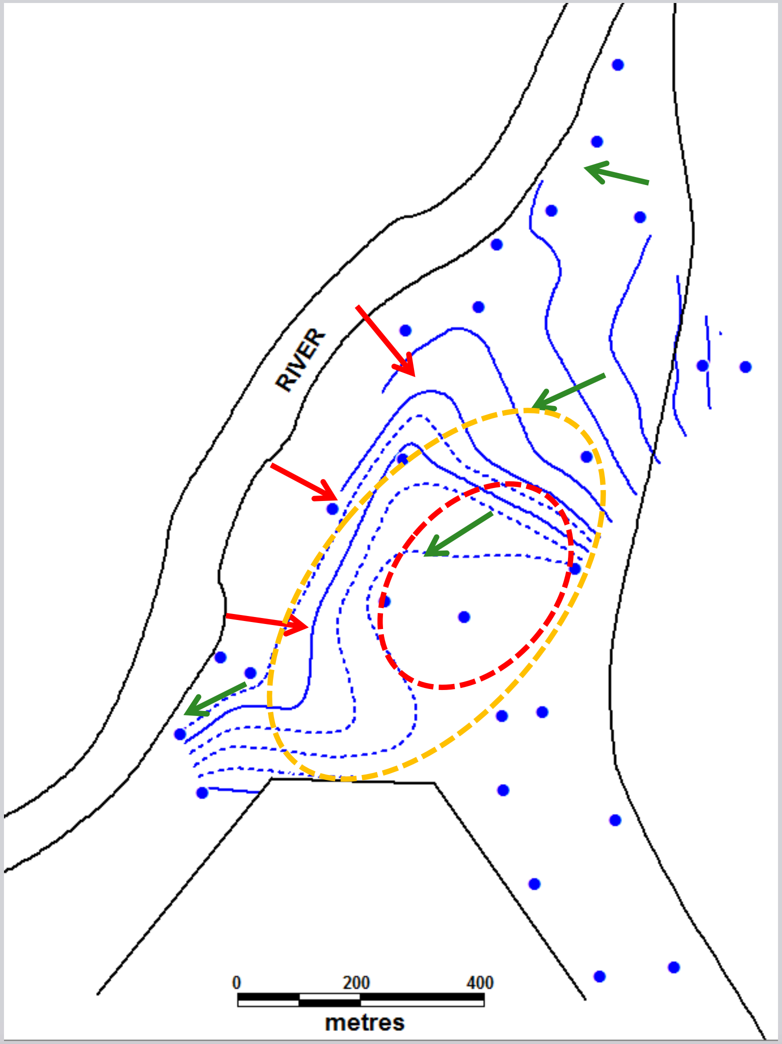
Groundwater Elevation (2013 May 20-Jun 19 Average)

One month average before June 20 flood



Groundwater Elevation (2013 June 21-27 average)

One week average during flooding

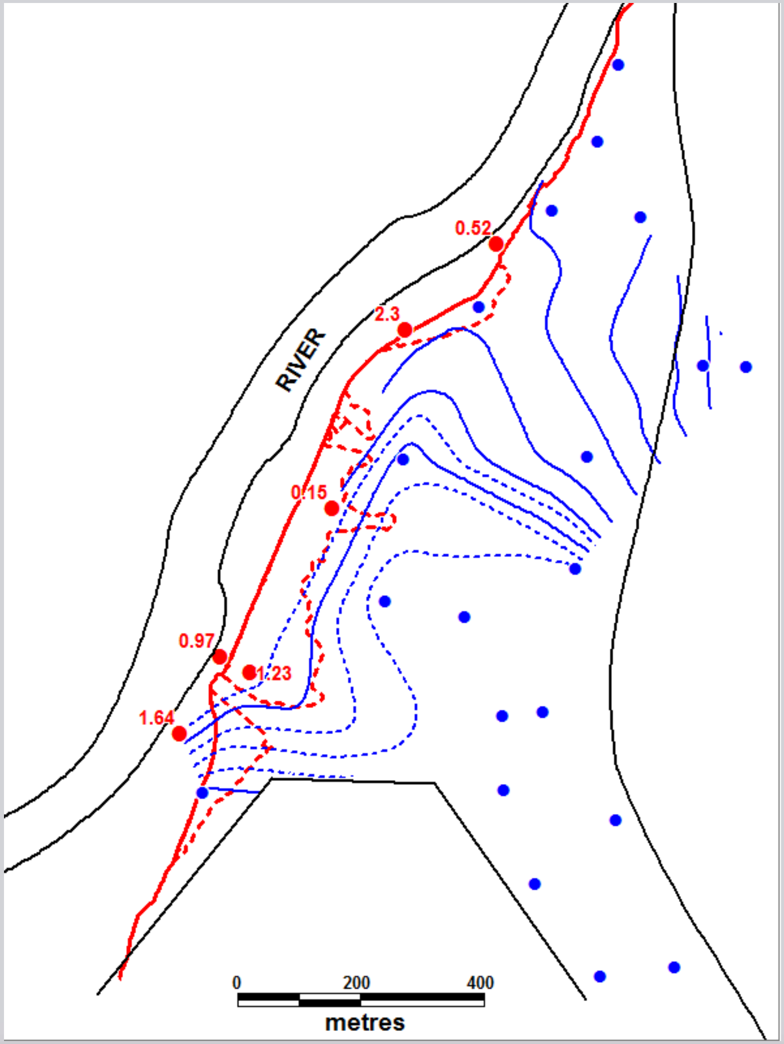


Flooded Locations during 2013 Flooding

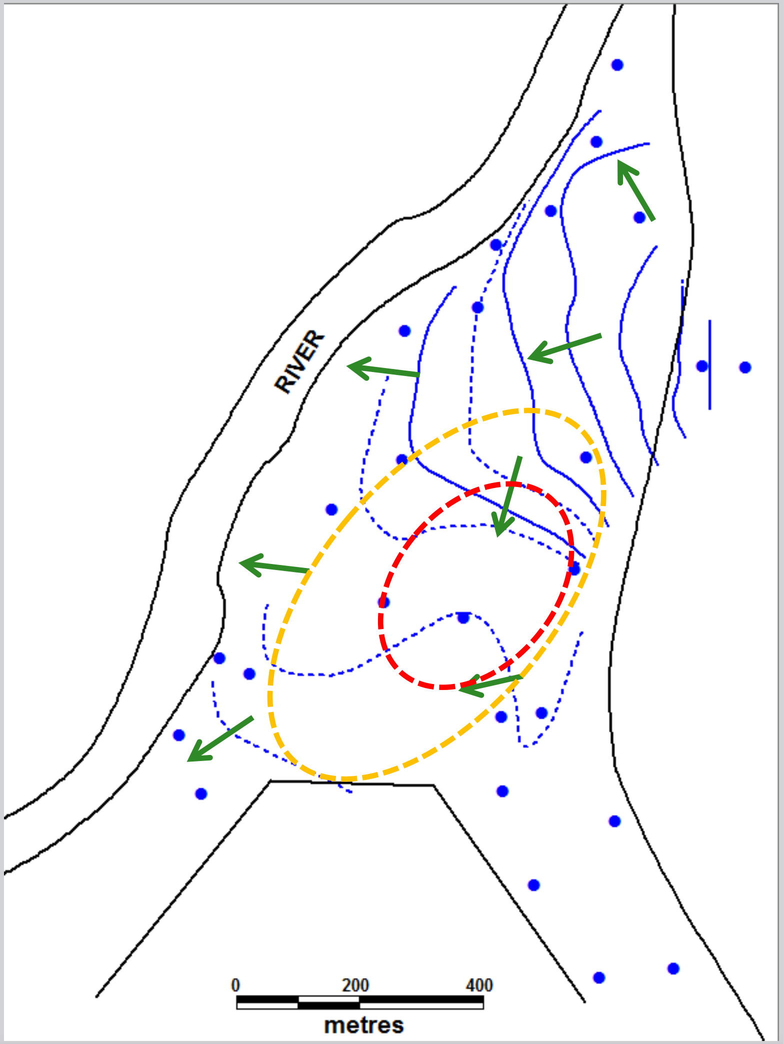
Numbers in red show recorded water level above ground

Red dashed line – 100 ear flood fringe

Red solid line – 100 year floodway



Groundwater Elevation (2013 June 28-14 average)

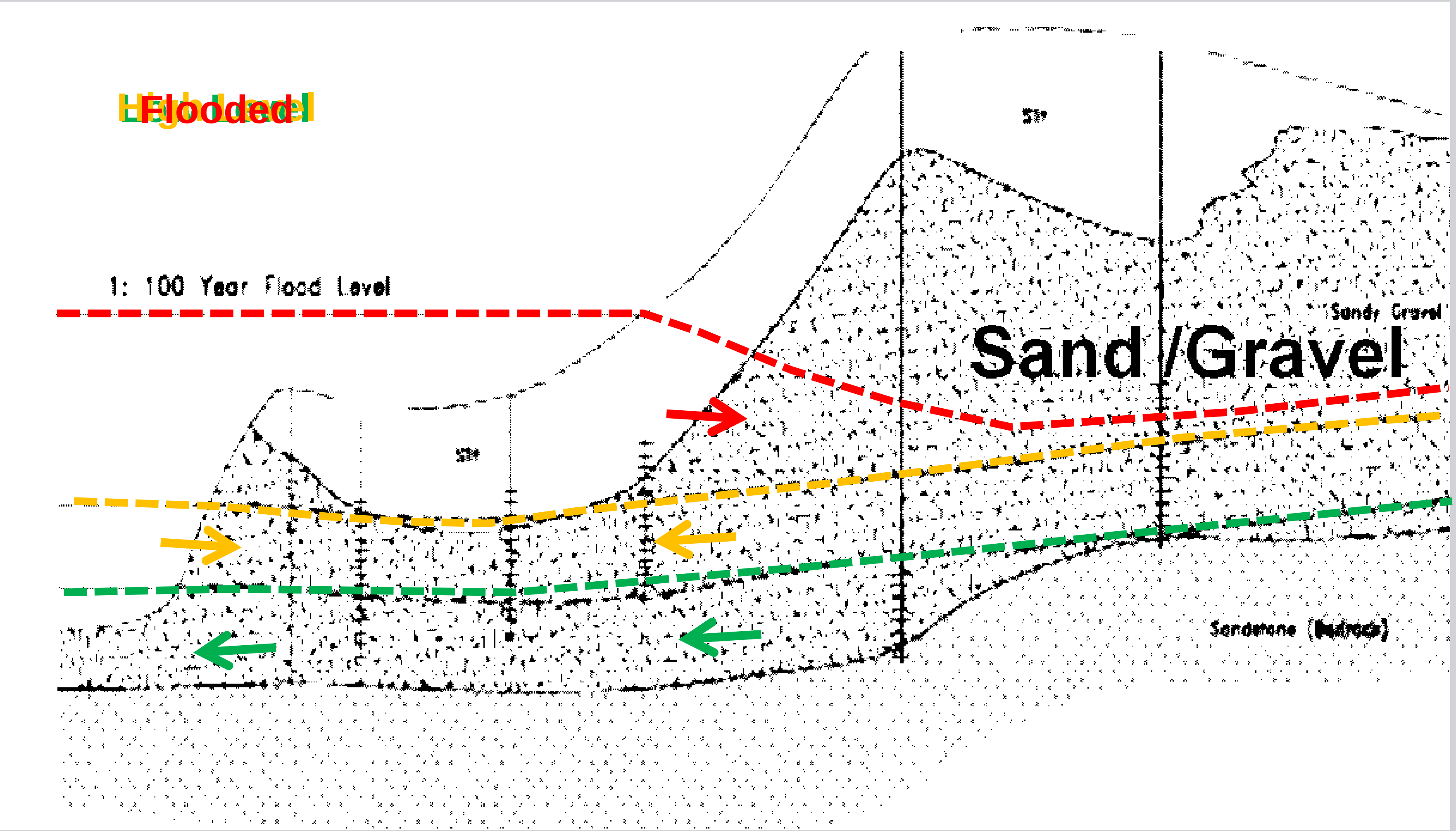


Questions on FAL Receptor

- When ground is flooded, impacted groundwater does not flow to the surface body (at this site), and therefore does pose any risk to the flooded areas
- Groundwater starts to flow to the river when the river water is back to normal course

The 300 m radius must be measured from the closest point of the zone of contamination exceeding the aquatic guidelines to closest point of the flood risk area (1 in 100 year flood area) of the water body. Where the flood risk area is not defined, it is up to the professional conducting the assessment to determine the distance to the flood risk area based on site information (e.g., geologic information, high water mark). In the absence of surface water bodies within the specified distance, this pathway may be excluded at Tier 2.

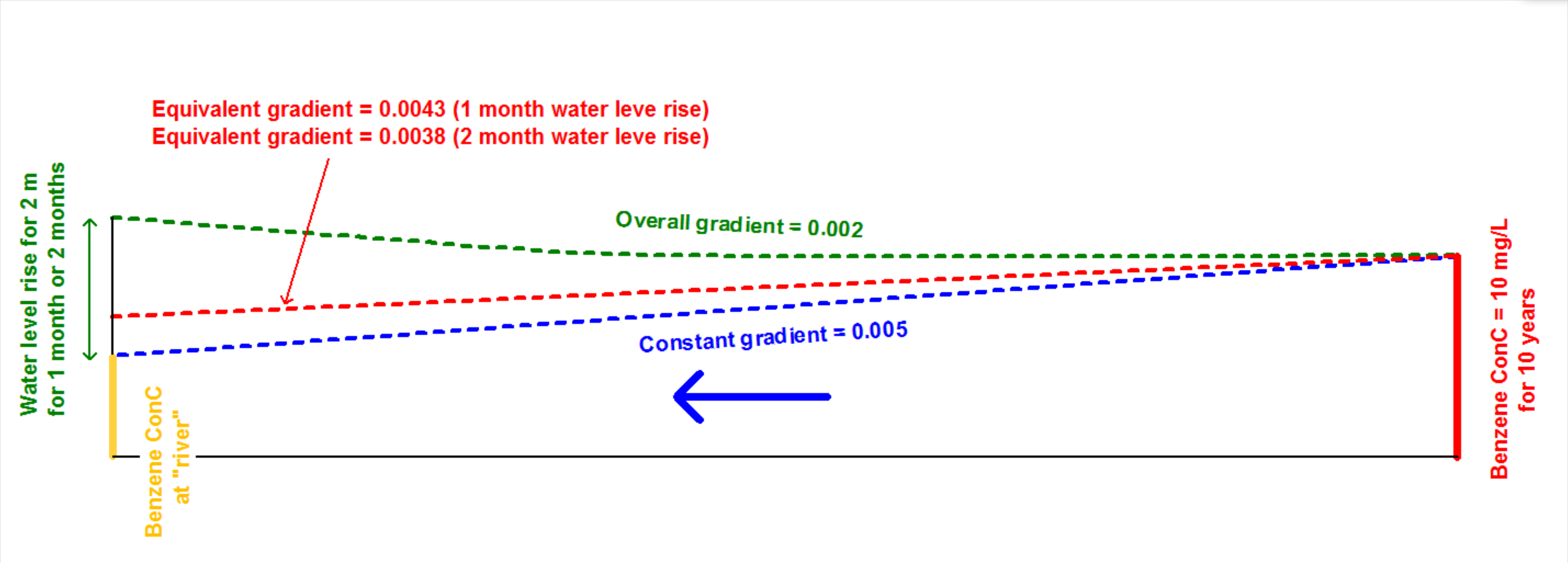
Groundwater Flow for Different Water Levels



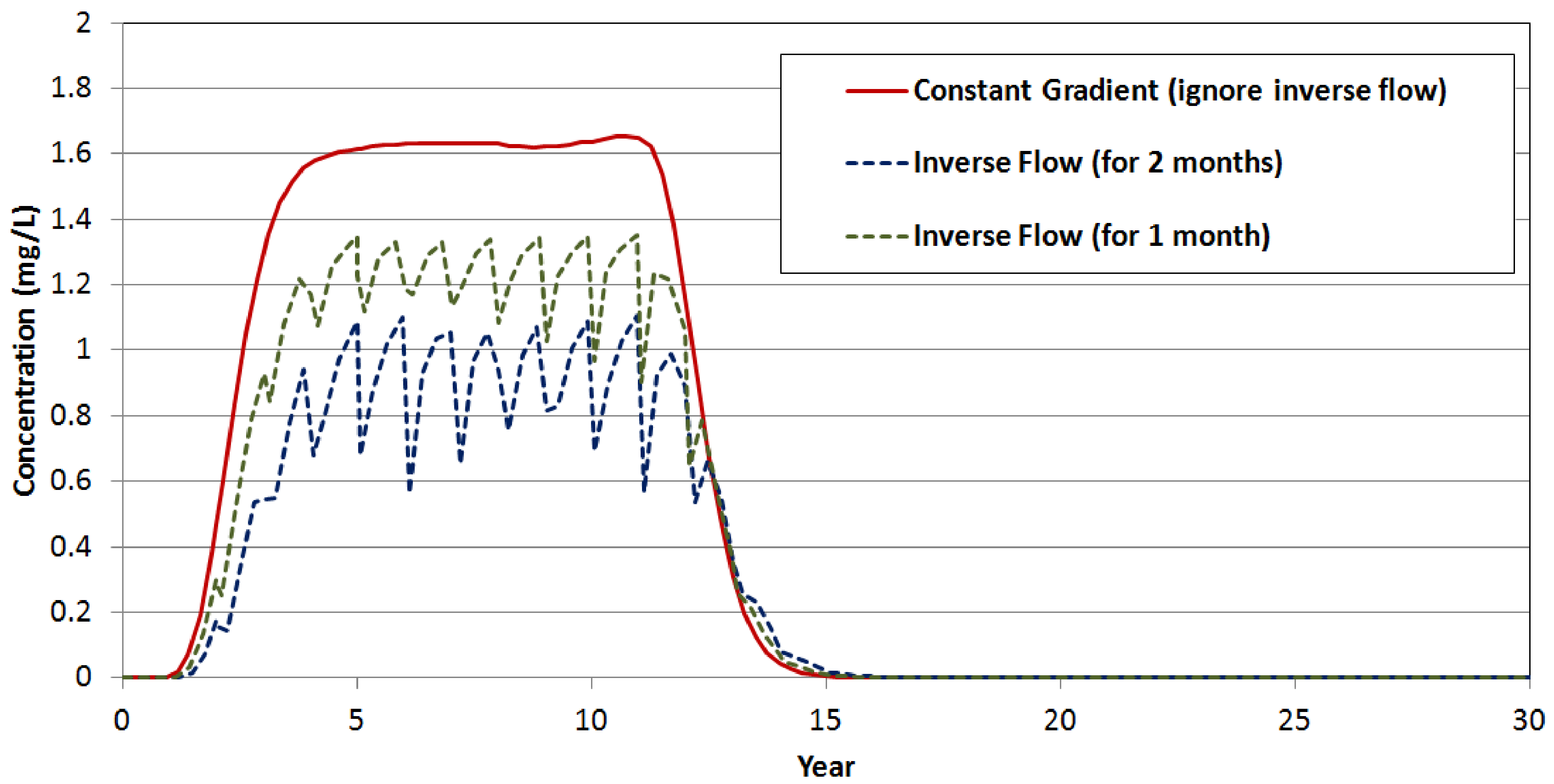
Significance of Inverse Flow

- Examined it based on a simple groundwater transport model
  - 1-D model with source concentration of benzene of 10 mg/L at 300 m away from a “river”.
  - Source release for 10 years
  - Predict concentration changes near the river
- Three scenarios:
  - A constant hydraulic gradient of 0.005
  - Gradient of 0.005 for 10 months of a year with inverse gradient of 0.002 (by raising river levels by 2 m) for 1 month or 2 months
  - Calculate “equivalent” gradients for scenarios 2

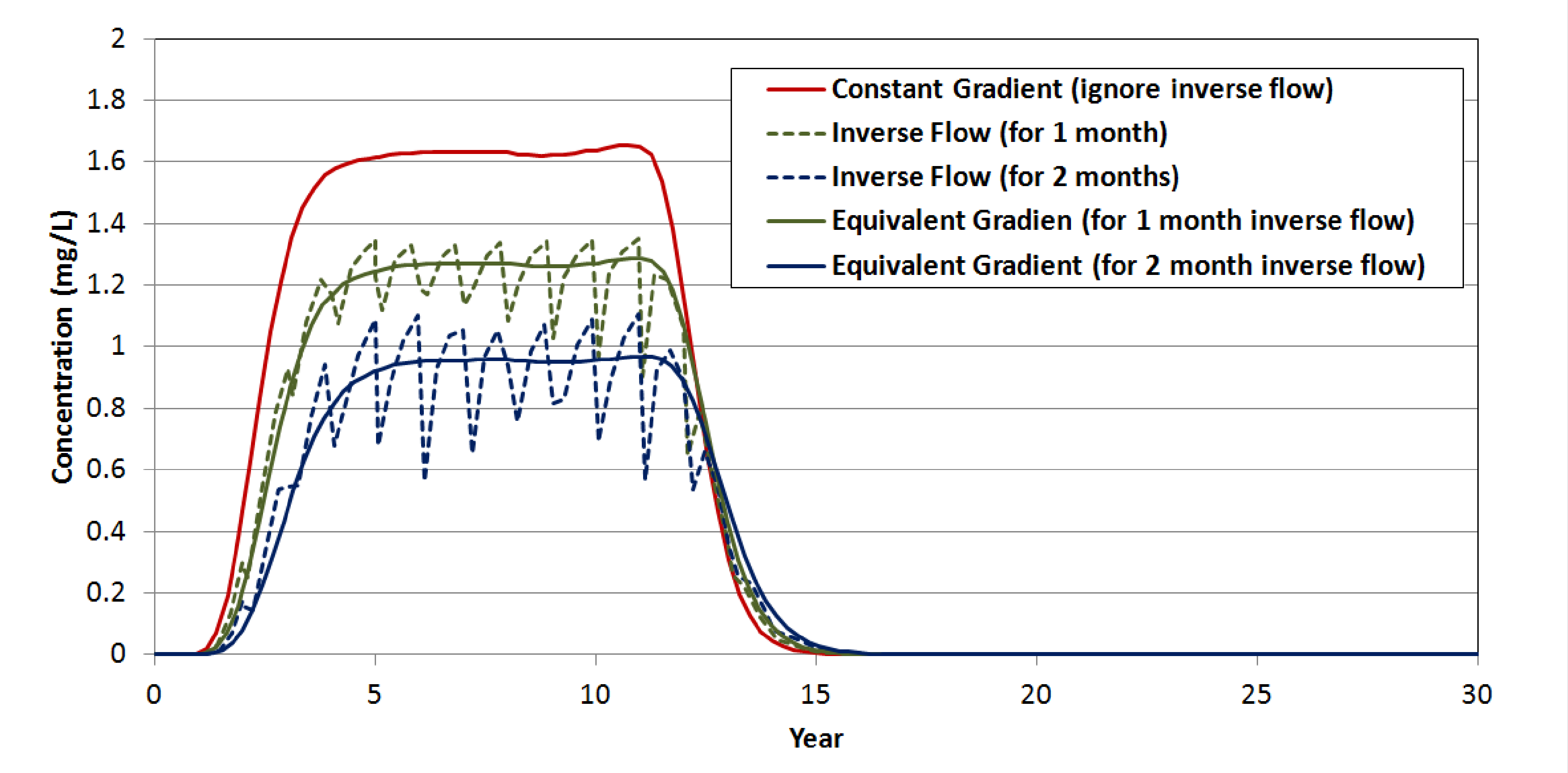
A Simplified Model



Predicted Concentration at “River” (Scenarios 1 and 2)



Predicted Concentration at “River” (Scenarios 1,2,3)



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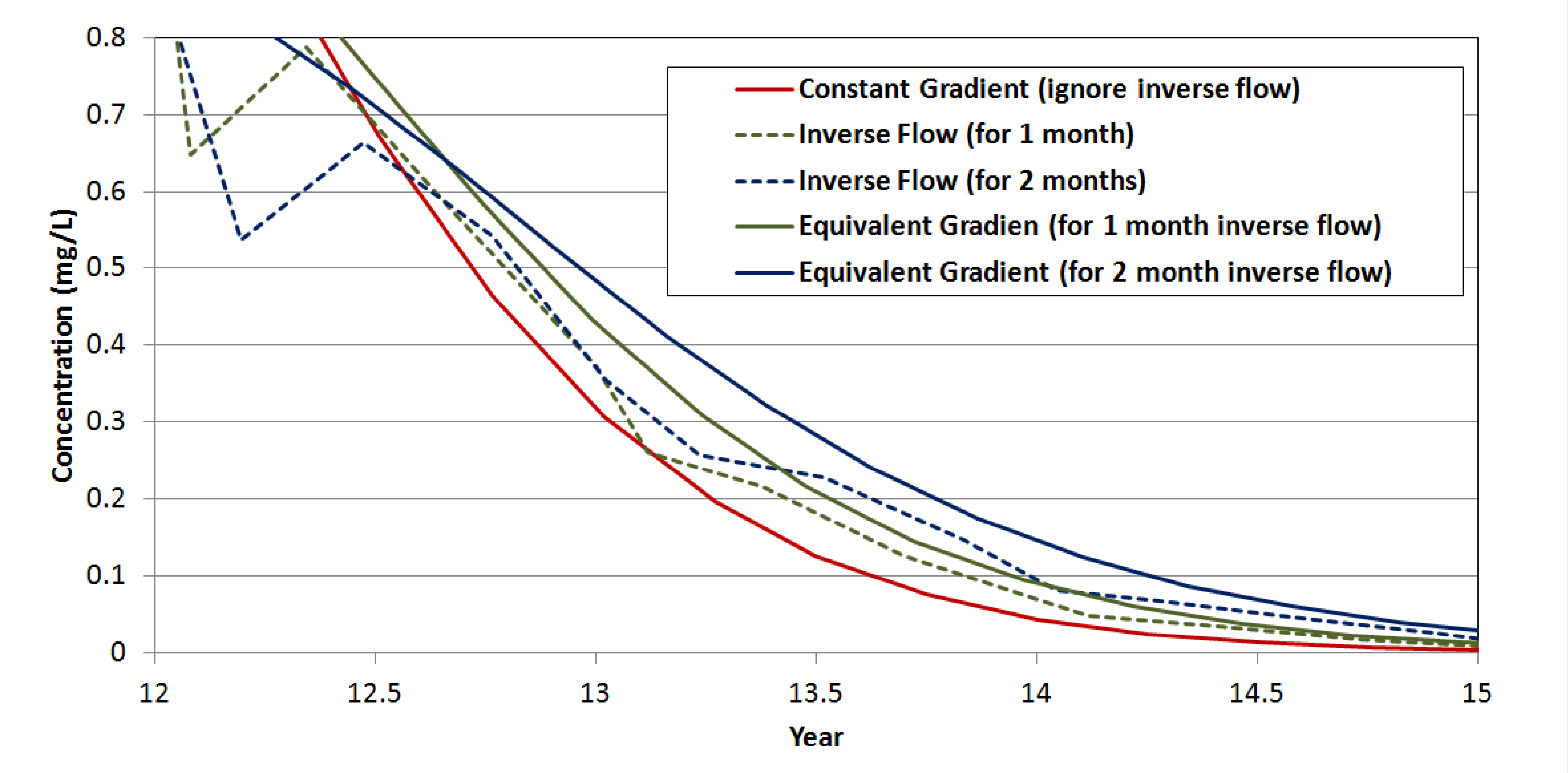
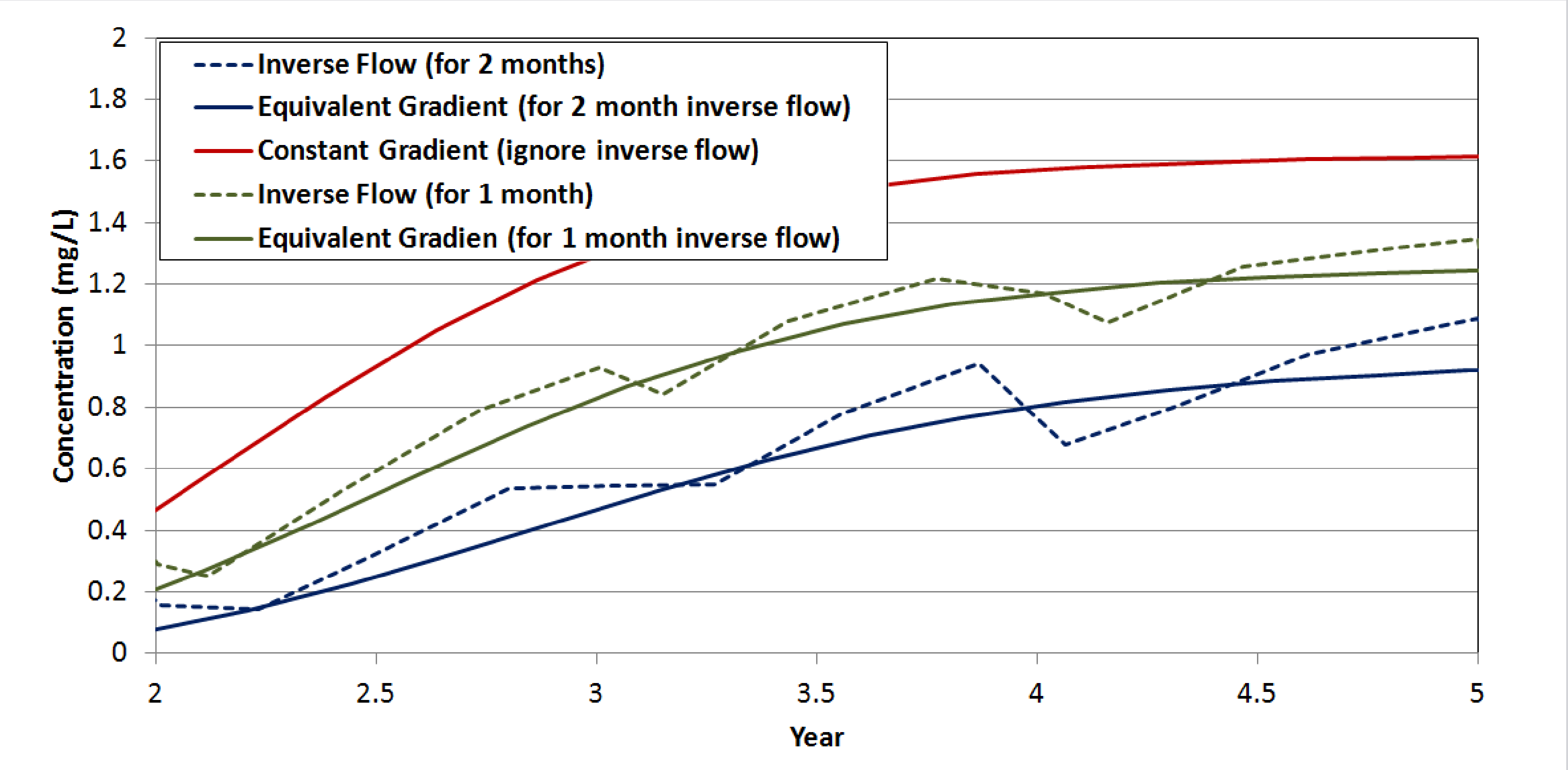
Predicted Concentration at "River" (tailing sections)



Predicted Concentration at “River” (uprising sections)



Significance of Inverse Flow

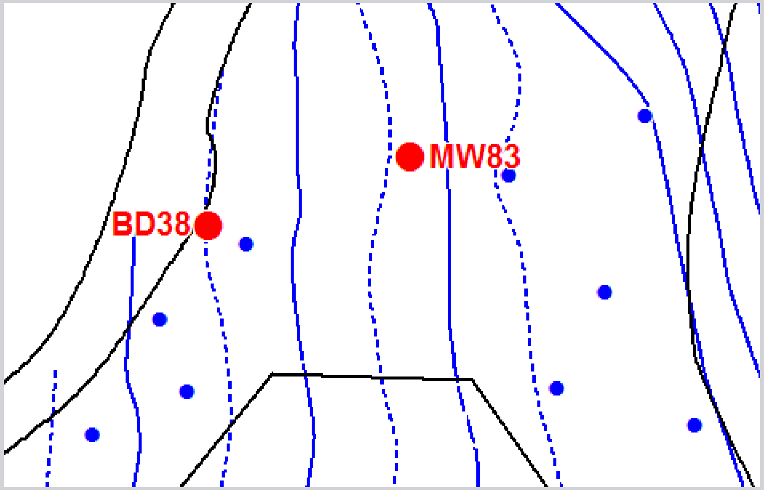
- Inverse flow for 1 or 2 months may reduce contaminant migration significantly
- Calculation of equivalent gradient may help to predict contaminant migration when the gradients change significantly in different seasons
  - Some uncertainties still exist, but much better than ignoring inverse flow completely
- Advanced modeling can be conducted to simulate migration with seasonably variable gradients
- Continuous water level measurements are required !

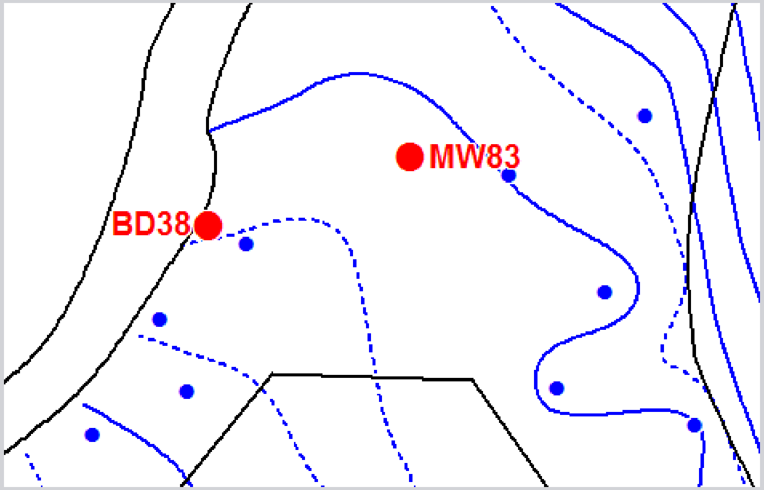
Continuous and Quarterly Measurements

- A comparison was made by calculating groundwater flow using two sets of data
  - Data 1: use 2012 hourly data from two wells and averaged for each day (to minimize data noise)
  - Data 2: Randomly pick up 4 daily data points from four seasons to represent typical quarterly monitoring events. Four different schedules were tested
- Groundwater flow rates calculated using two data sets
  - Use the data to calculate the average the early gradient using 266 data point for set 1 or 4 points for set 2 series
  - Calculate flow rates through 100 m wide section

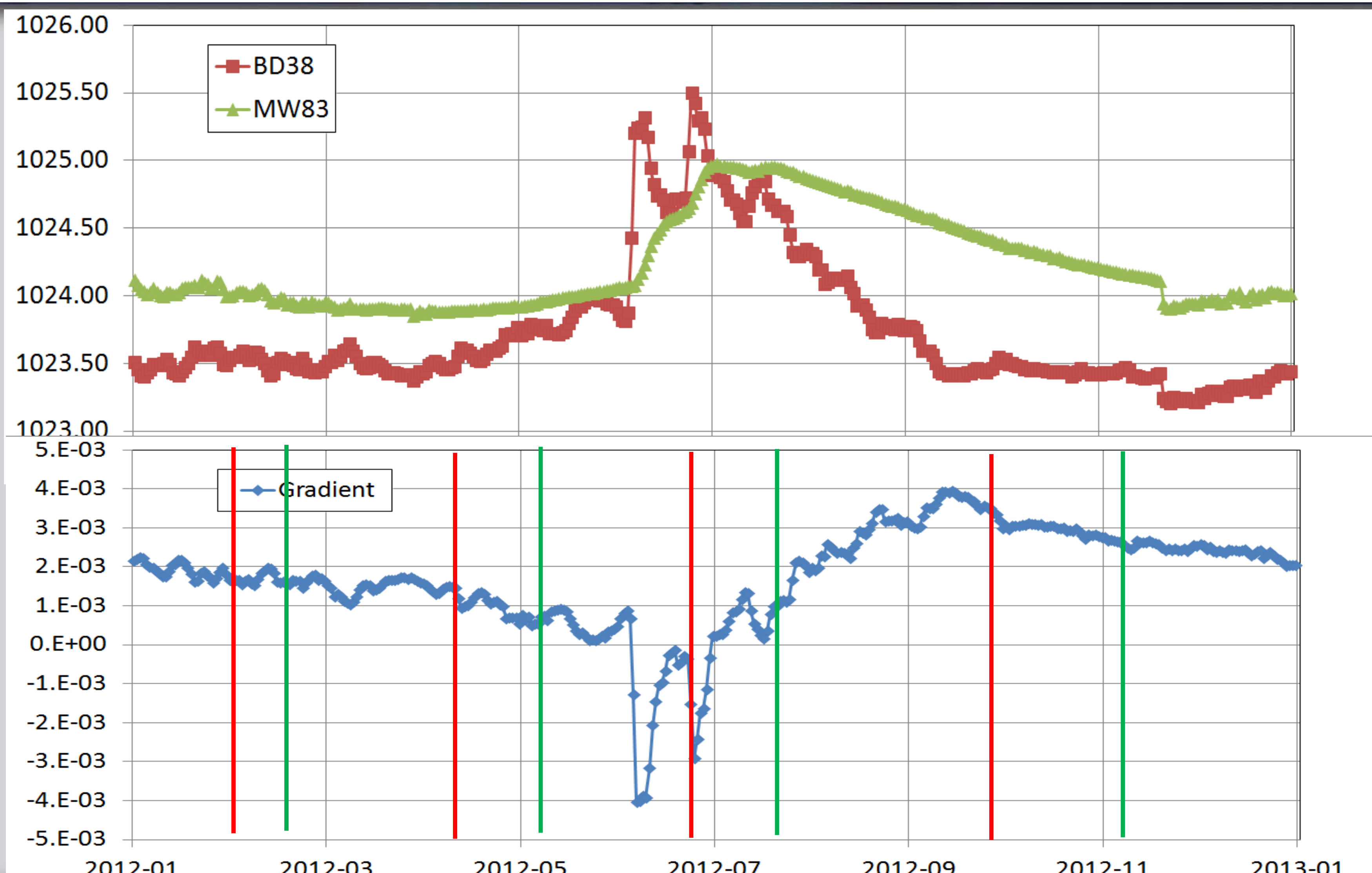
Continuous and Quarterly Measurements

- Flow rates calculated based on "quarterly" data sets show significant variations depending on which day is picked for monitoring





Water Level and Gradient



Comparison of Calculated Flow Rates

					Calculated Flow (m3/year)
Based on daily average groundwater level data					164
Based quaterly minitrong data					
Schedule 1	5-Jan	27-Mar	10-Jul	10-Sep	207
Schedule 2	10-Feb	7-May	27-Jul	24-Oct	176
Schedule 3	12-Mar	11-Jun	9-Aug	22-Nov	72
Schedule 4	25-Mar	22-Jun	11-Sep	9-Dec	184

Data Logger Installation and Data Process

- Specific procedures developed for data logger installation
  - Metal chains used to secure the depths of loggers
  - Onsite loggers for barometric pressure record
  - Manual water level measurements, particularly immediately before and after reinstallation, are required
- Data need to processed before used for analysis
  - Barometric pressure compensation
  - Calibrated (or compared with) manual water level measurements
  - Converting the hourly data to daily average or monthly average may help to reduce data noise

Summary

- Continuous water level measurements (using pressure transducers and data loggers) offer an efficient way to monitor groundwater fluctuations, which is critical to characterization of contaminated sites
- Changes in river and groundwater interactions were captured by the data logger data, which would have been missed if only quarterly monitoring data were available
- Quarterly water level measurements are not sufficient to estimate groundwater flux if groundwater fluctuations are significant

Summary

- 2013 flooding provided an opportunity to examine groundwater flow during flooding periods. During flooding, impacted groundwater did not flow towards the river and did not pose any risks to the flood fringe
- To maximize the value of data collected by data loggers, further groundwater flow and transport modeling may be required

Thank You!

- Questions…