THE pebble PARTNERSHIP

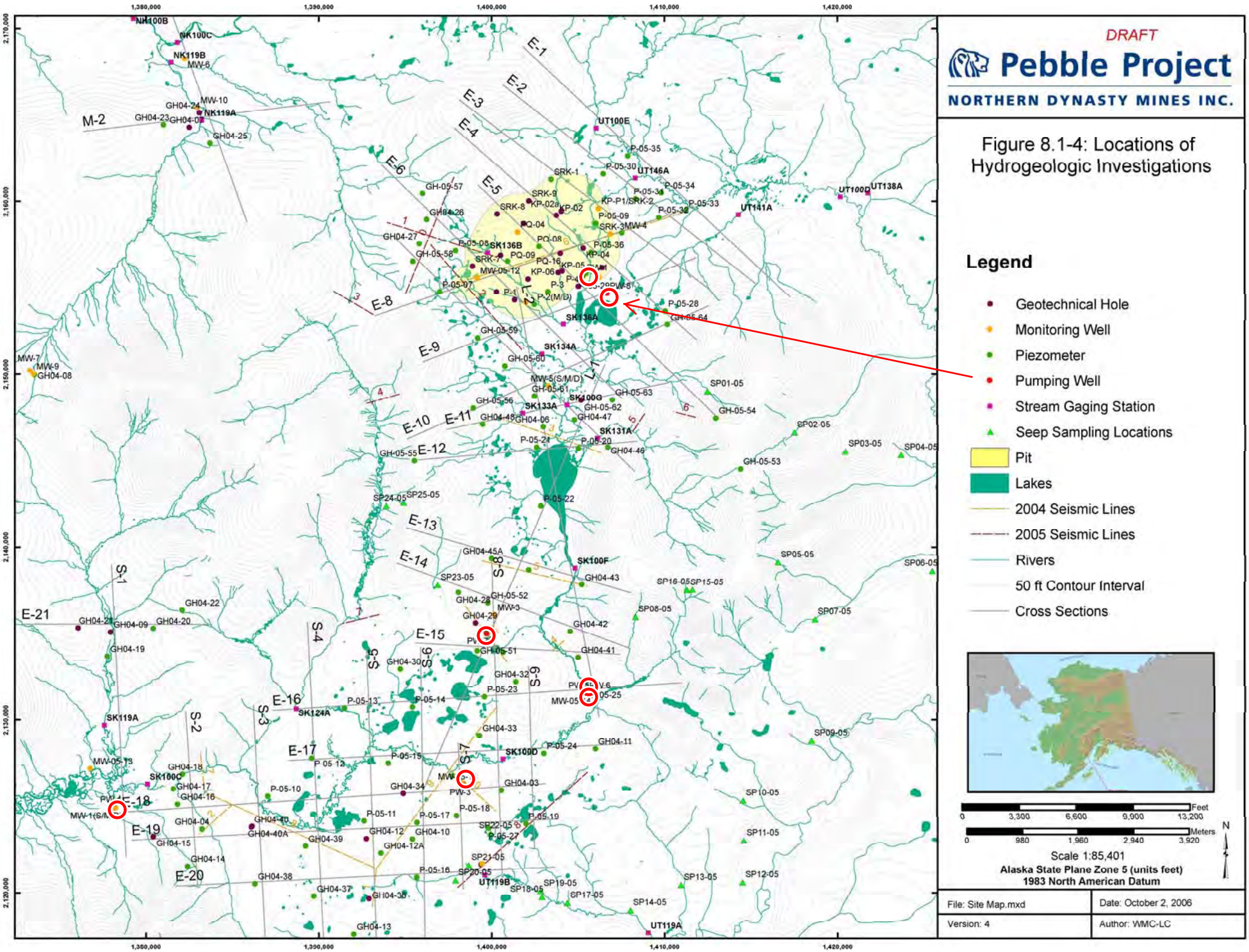
Groundwater Hydrology - Mine

November 28, 2007

Rod Smith, Hugh McCreadie
WMC

Hydrogeology Investigations

- Installation of piezometers and monitoring wells
- Well development and response testing of piezometers and monitoring wells.
- Installation of pumping wells and pumping tests
- Groundwater sampling quarterly
- Groundwater levels measured monthly


DRAFT
Pebble Project
NORTHERN DYNASTY MINES INC.
Figure 8.1-4: Locations of Hydrogeologic Investigations
Legend
Geotechnical Hole
Monitoring Well
Piezometer
Pumping Well
Stream Gaging Station
Seep Sampling Locations
Pit
Lakes
2004 Seismic Lines
2005 Seismic Lines
Rivers
50 ft Contour Interval
Cross Sections
Feet
0
3,300
6,600
9,900
13,200
Meters
0
980
1,960
2,940
3,920
N
Scale 1:85,401
Alaska State Plane Zone 5 (units feet)
1983 North American Datum
File: Site Map.mxd
Date: October 2, 2006
Version: 4
Author: WMC-LC
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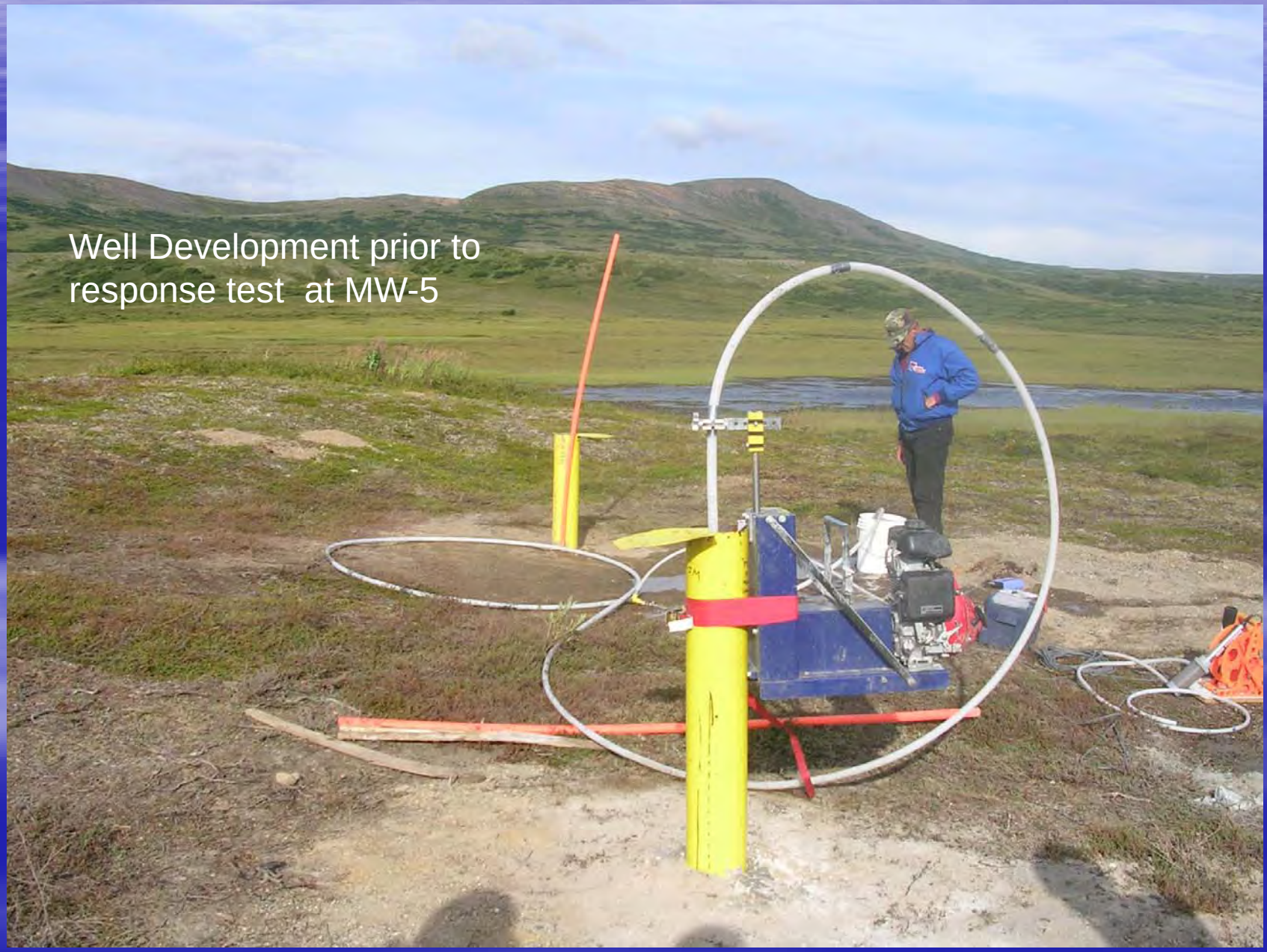
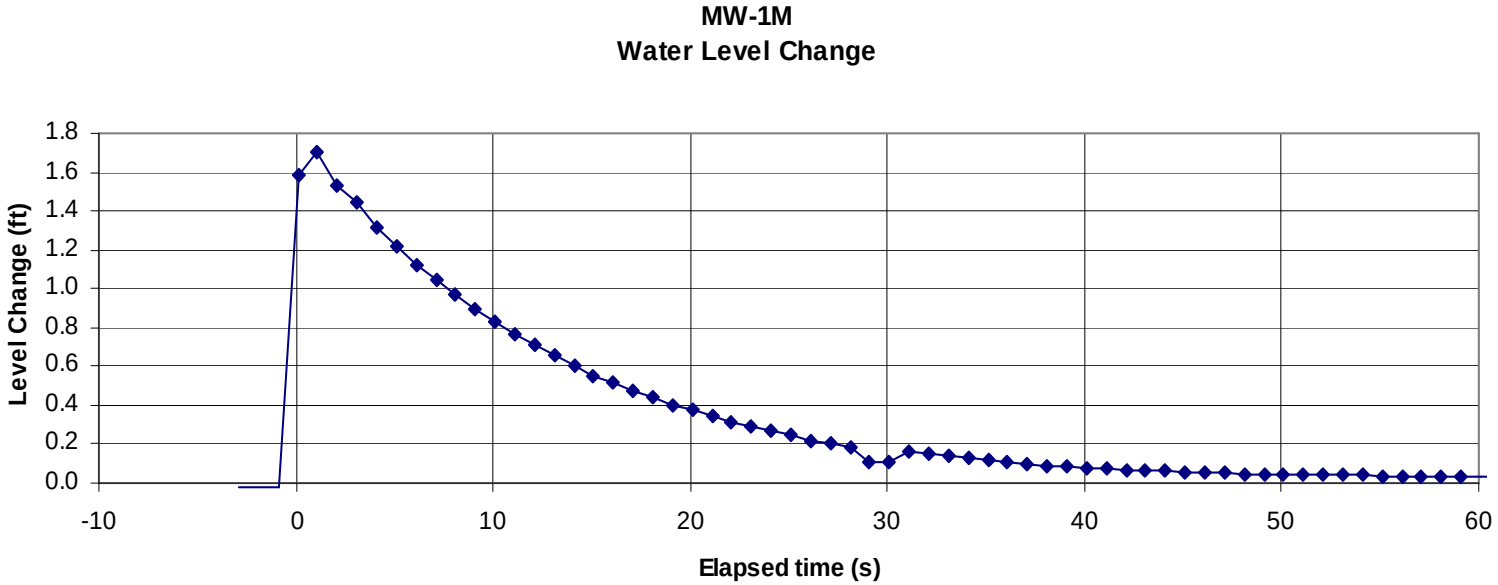
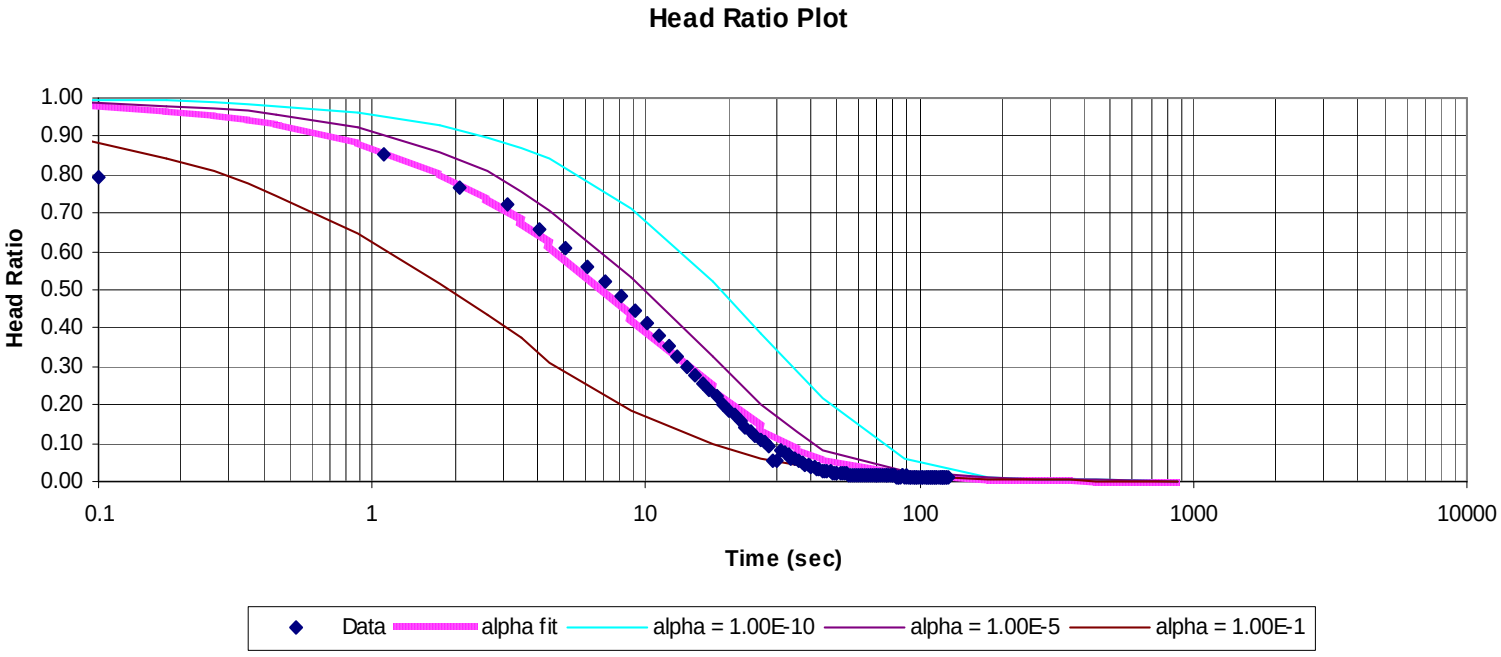
1,390,000
1,400,000
1,410,000
1,420,000
2,170,000
2,160,000
2,150,000
2,140,000
2,130,000
2,120,000

Hydrogeologic Properties

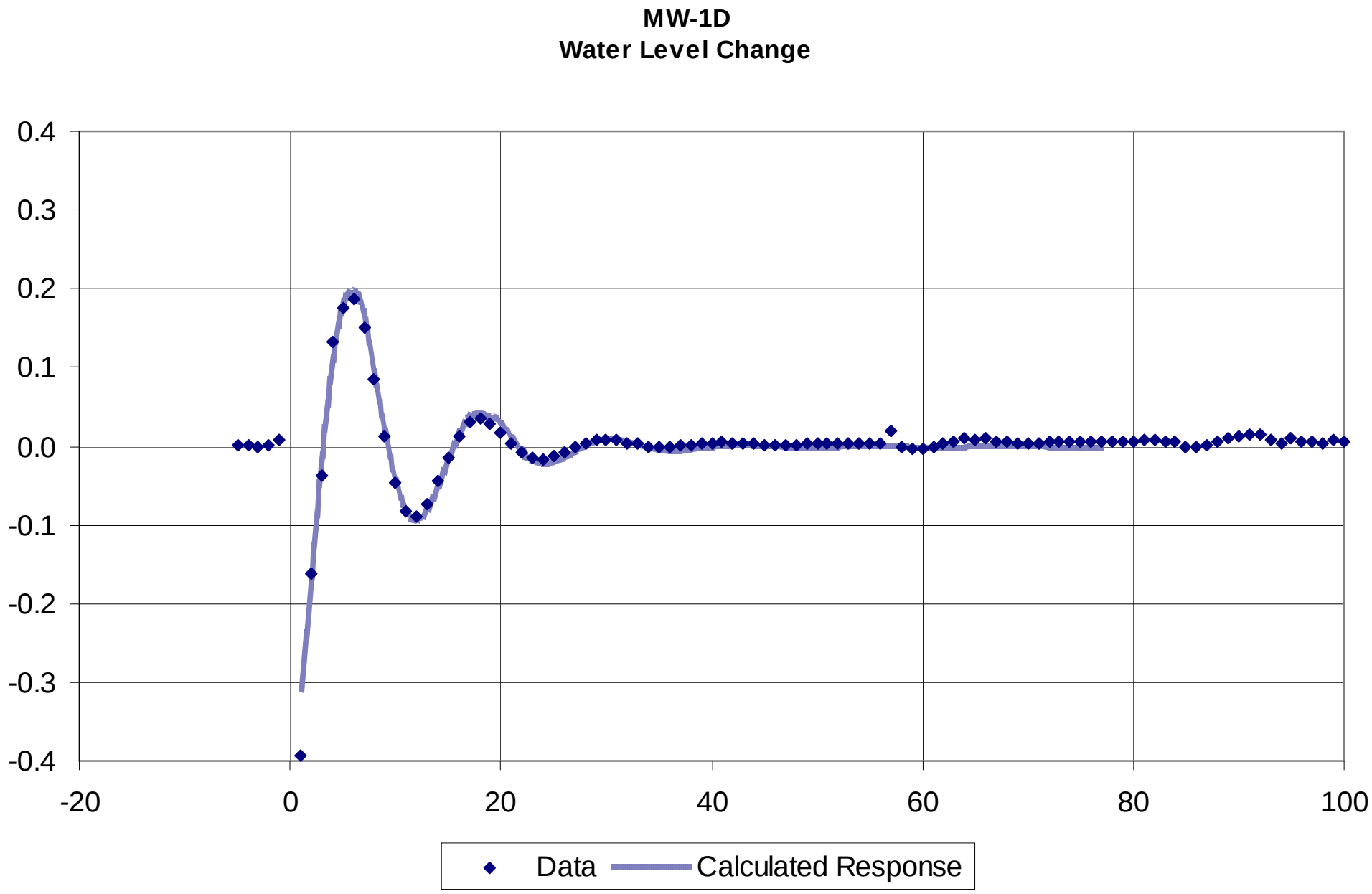


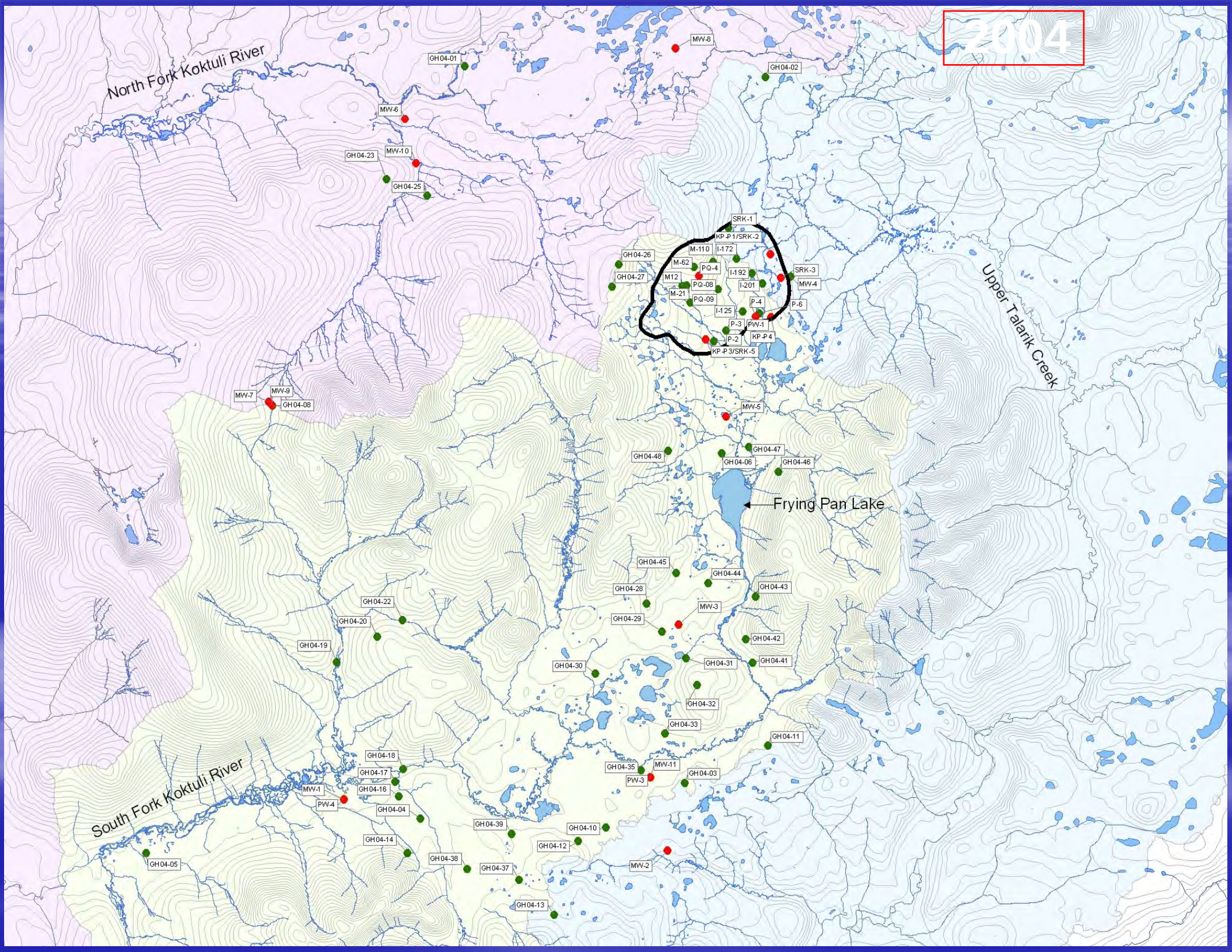
Hydrogeologic Properties





Hydrogeologic Properties

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North Fork Koktuli River
South Fork Koktuli River
Upper Talarik Creek
Frying Pan Lake
MW-8
GH04-01
GH04-02
MW-6
MW-10
GH04-23
GH04-25
SRK-1
KP-P1/SRK-2
M-110
I-172
GH04-26
M-62
PQ-4
I-192
SRK-3
GH04-27
M12
PQ-08
I-201
MW-4
M-21
PQ-09
P-4
P-6
I-125
P-3
PW-1
P-2
KP-P4
KP-P3/SRK-5
MW-7
MW-9
GH04-08
MW-5
GH04-48
GH04-47
GH04-06
GH04-46
GH04-45
GH04-44
GH04-28
GH04-43
GH04-22
MW-3
GH04-20
GH04-29
GH04-19
GH04-42
GH04-30
GH04-31
GH04-41
GH04-32
GH04-33
GH04-11
GH04-18
GH04-35
MW-11
GH04-17
PW-3
GH04-03
MW-1
GH04-16
PW-4
GH04-04
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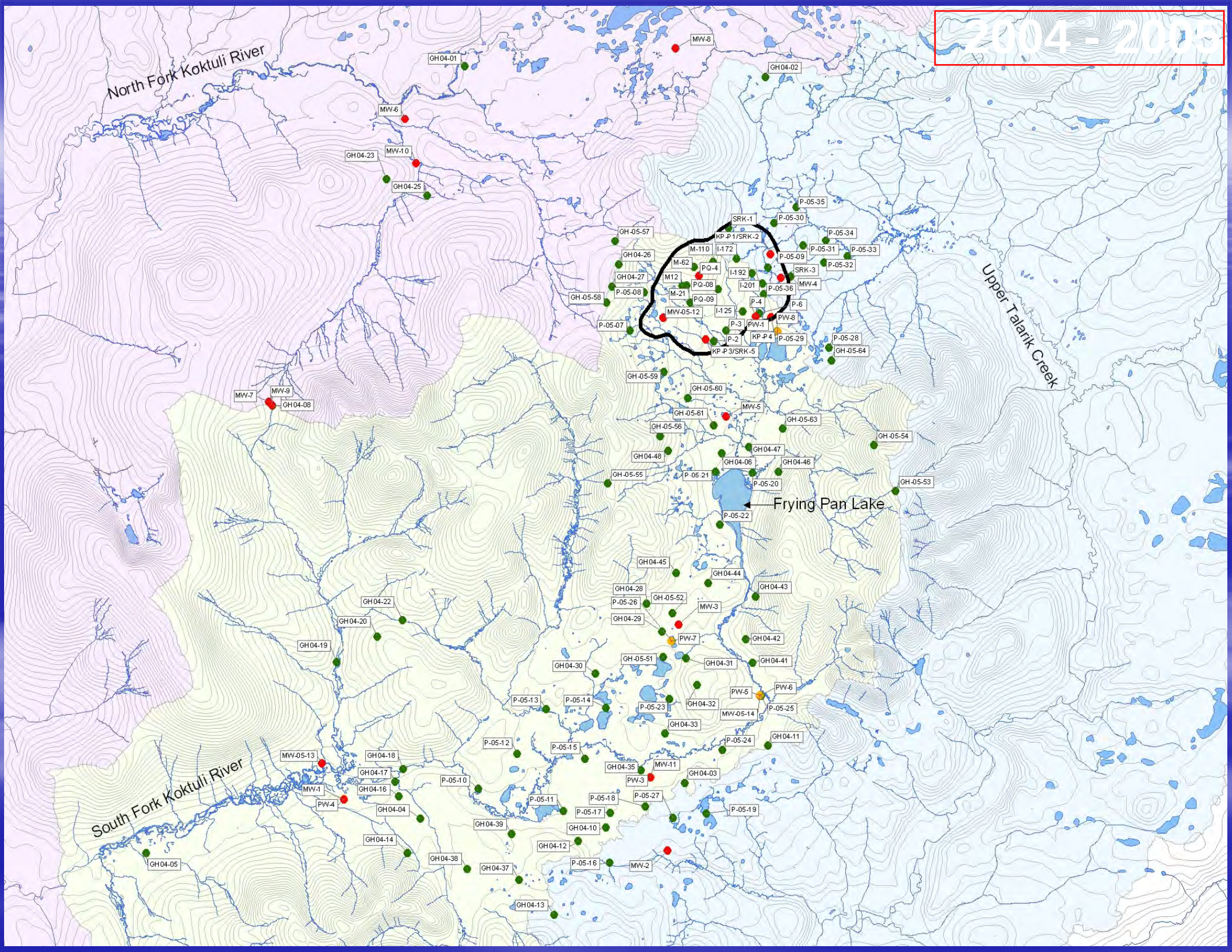
GH04-14
GH04-12
GH04-38
MW-2
GH04-05
GH04-37
GH04-13


2004 - 2005
North Fork Koktuli River
South Fork Koktuli River
Upper Talarik Creek
Frying Pan Lake
MW-8
GH 04-01
GH 04-02
MW-6
MW-10
GH 04-23
GH 04-25
P-05-35
P-05-30
SRK-1
GH-05-57
KP-P1/SRK-2
P-05-34
M-110
I-172
P-05-31
P-05-33
GH 04-26
P-05-09
M-62
PQ-4
P-05-32
I-192
SRK-3
GH 04-27
M12
PQ-08
I-201
P-05-36
MW-4
P-05-08
M-21
PQ-09
GH-05-58
P-4
P-6
MW-05-12
I-125
PW-8
P-05-07
P-3
PW-1
P-2
KP-P4
P-05-29
P-05-28
KP-P3/SRK-5
GH-05-64
GH-05-59
GH-05-60
MW-7
MW-9
GH 04-08
MW-5
GH-05-61
GH-05-63
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GH 04-47
GH 04-06
GH 04-46
GH-05-55
P-05-21
GH-05-53
P-05-20
P-05-22
GH 04-45
GH 04-44
GH 04-43
GH 04-28
GH-05-52
P-05-26
GH 04-22
MW-3
GH 04-29
GH 04-20
PW-7
GH 04-42
GH 04-19
GH-05-51
GH 04-31
GH 04-41
GH 04-30
PW-5
PW-6
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P-05-23
P-05-25
MW-05-14
GH 04-33
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GH 04-18
GH 04-35
MW-11
GH 04-17
PW-3
GH 04-03
P-05-10
MW-1
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P-05-11
PW-4
P-05-17
P-05-19
GH 04-04
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MW-2
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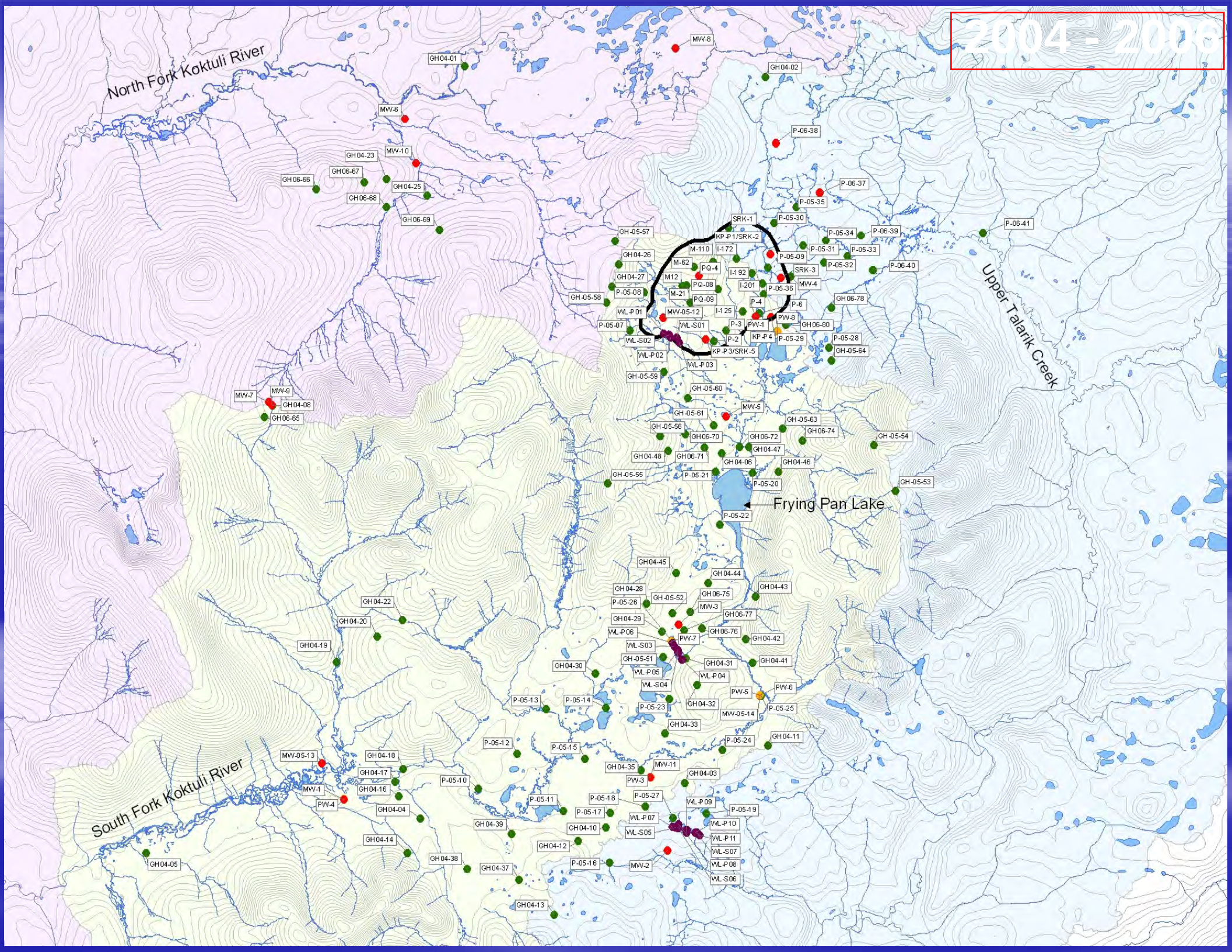
2004 - 2006
North Fork Koktuli River
South Fork Koktuli River
Upper Talarik Creek
Frying Pan Lake
MW-8
GH04-01
GH04-02
MW-6
P-06-38
GH04-23
MW-10
GH06-67
GH06-66
GH04-25
P-06-37
GH06-68
P-05-35
GH06-69
P-05-30
SRK-1
P-06-41
GH-05-57
KP-P1/SRK-2
P-05-34
P-06-39
M-110
I-172
P-05-31
P-05-33
GH04-26
P-05-09
M-62
PQ-4
P-05-32
P-06-40
I-192
SRK-3
GH04-27
M12
PQ-08
I-201
MW-4
P-05-36
P-05-08
M-21
PQ-09
GH-05-58
P-4
P-6
GH06-78
WL-P01
MW-05-12
I-125
PW-8
P-05-07
WL-S01
P-3
PW-1
GH06-80
WL-S02
P-2
KP-P4
P-05-29
P-05-28
KP-P3/SRK-5
GH-05-64
WL-P02
WL-P03
GH-05-59
GH-05-60
MW-7
MW-9
GH04-08
GH06-65
MW-5
GH-05-61
GH-05-63
GH-05-56
GH06-70
GH06-72
GH06-74
GH-05-54
GH04-48
GH06-71
GH04-47
GH04-06
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GH-05-53
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GH04-45
GH04-44
GH04-43
GH04-28
GH-05-52
GH06-75
GH04-22
P-05-26
MW-3
GH04-20
GH04-29
GH06-77
WL-P06
GH06-76
PW-7
GH04-42
GH04-19
WL-S03
GH-05-51
GH04-31
GH04-41
GH04-30
WL-P05
WL-P04
WL-S04
PW-5
PW-6
P-05-13
P-05-14
GH04-32
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MW-05-14
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GH04-33
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MW-05-13
GH04-18
GH04-35
MW-11
GH04-03
GH04-17
PW-3
P-05-10
MW-1
GH04-16
P-05-27
P-05-18
WL-P09
PW-4
P-05-11
P-05-17
P-05-19
GH04-04
WL-P07
WL-P10
GH04-39
GH04-10
WL-S05
WL-P11
GH04-14
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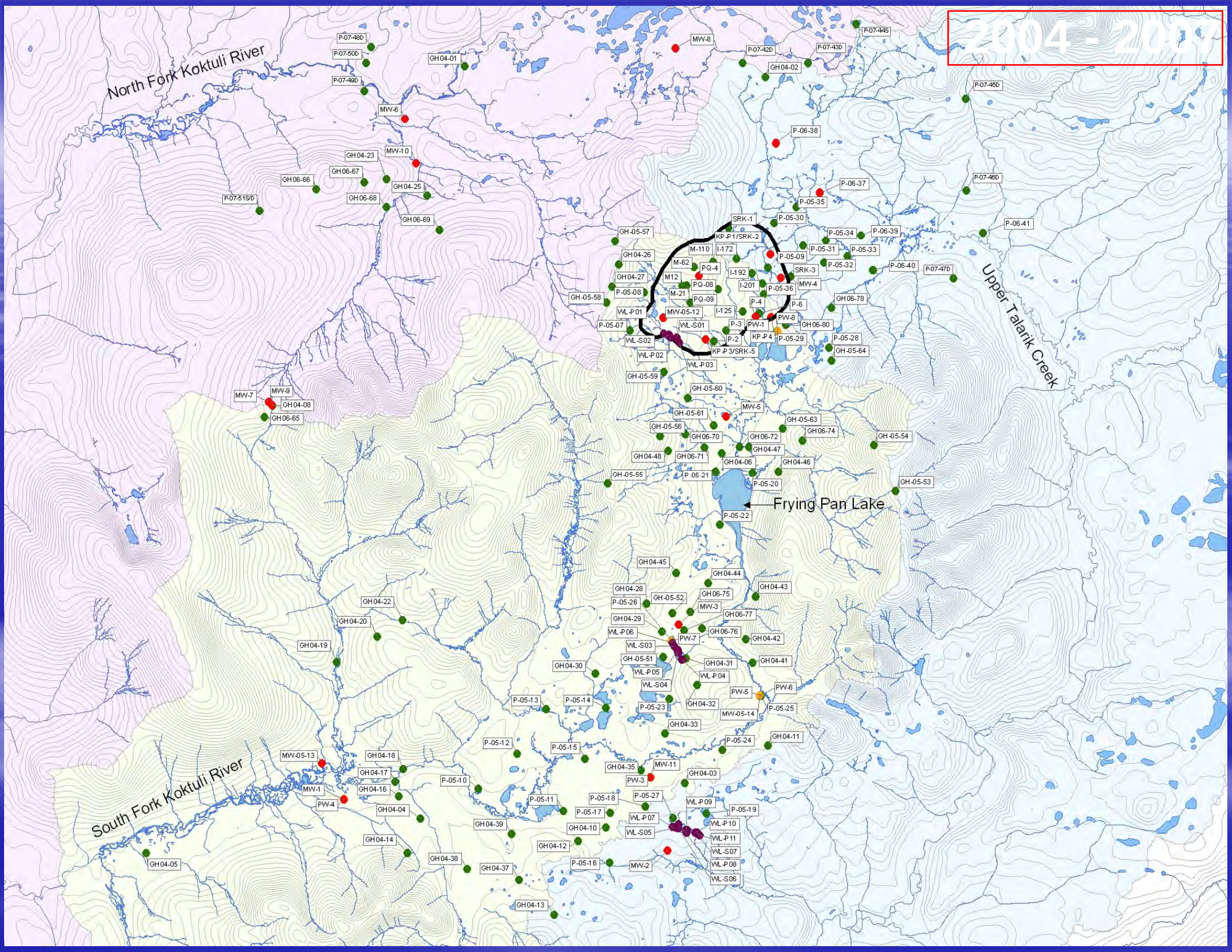
GH04-37
WL-S06
GH04-05
GH04-13


2004 - 2007
North Fork Koktuli River
South Fork Koktuli River
Upper Talarik Creek
Frying Pan Lake
P-07-48D
P-07-50D
P-07-49D
GH04-01
MW-8
P-07-42D
P-07-43D
P-07-44S
GH04-02
P-07-45D
MW-6
P-06-38
GH04-23
MW-10
GH06-67
GH06-66
GH04-25
GH06-68
P-07-51S/D
GH06-69
P-06-37
P-07-46D
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P-06-41
GH-05-57
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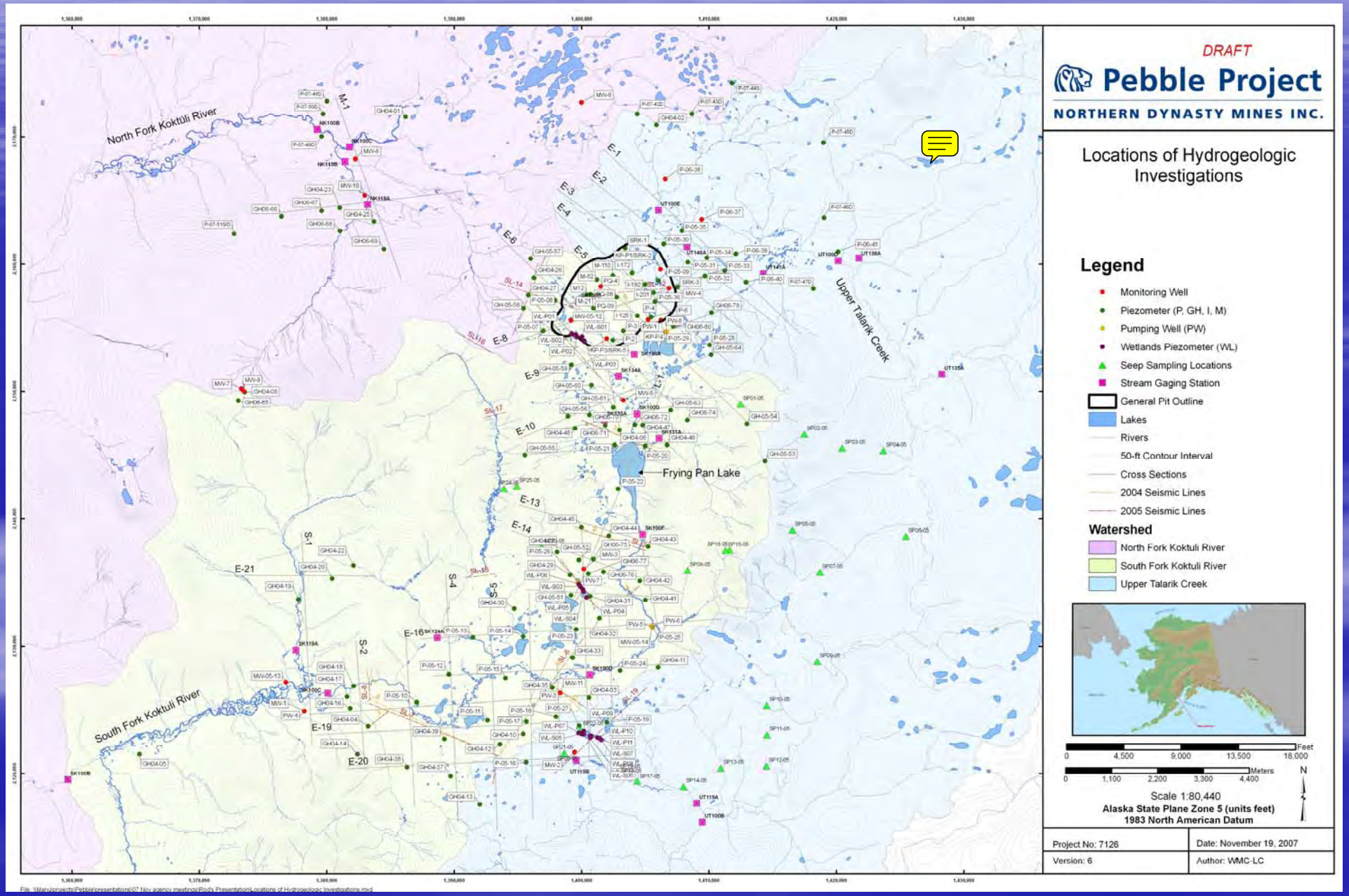
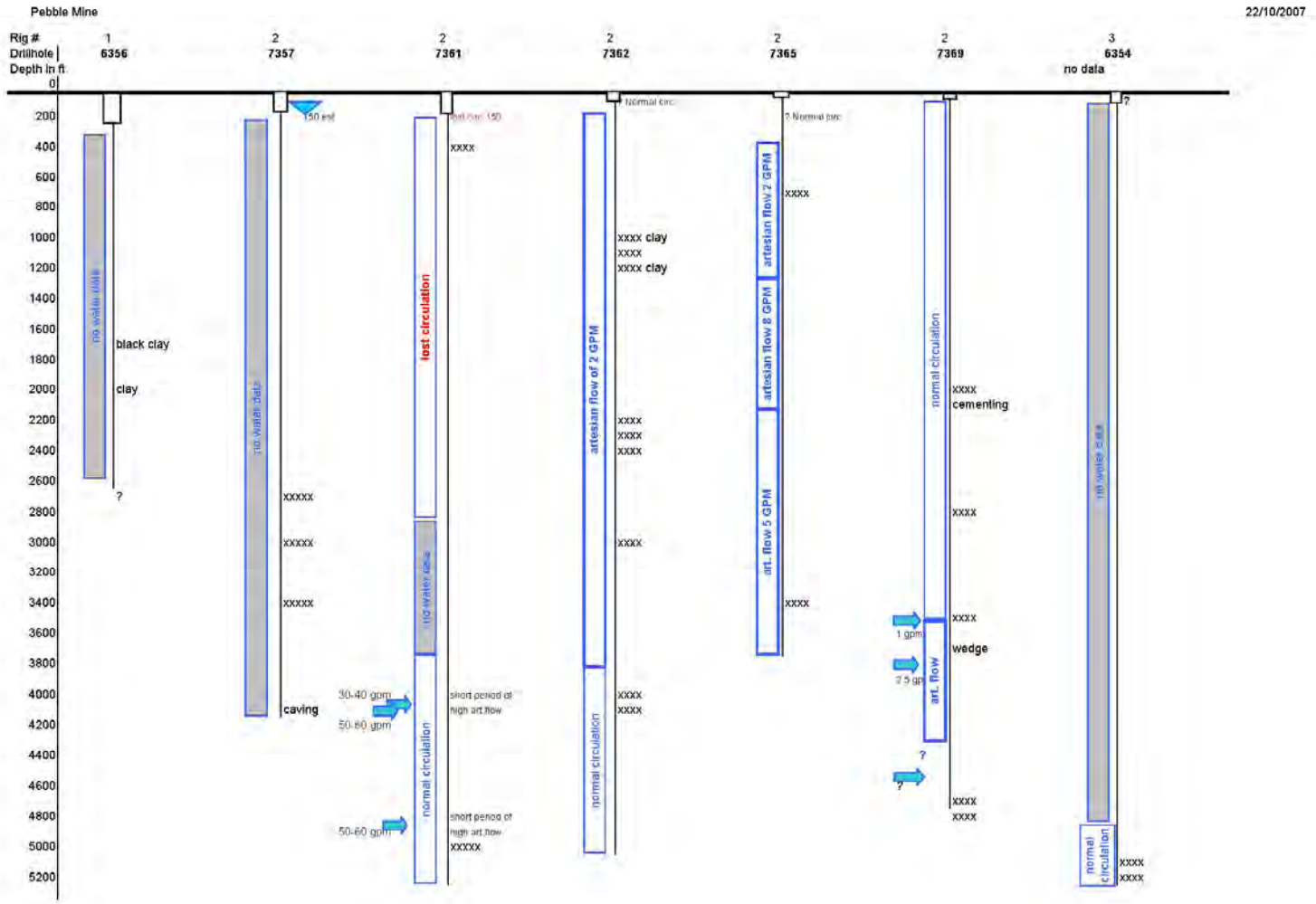


Summary of Hydrogeologic Investigations

ITEM	DESCRIPTION	2004	2005	2006	2007	TOTAL
1	Monitoring Wells	26	8	4	~4	42
2	Piezometers	14	58	10	10	92
3	Geotechnical Piezometers	55	13	17	~24	109
4	Pumping Wells	3	4	0	~1	8
5	Pump Tests	3	4	0	~1	8
6	Response Tests	31	63	10	~10	114
7	Geotechnical Response Tests	42	0	0	~24	66
8	Packer Tests	51	32	0	~70	153

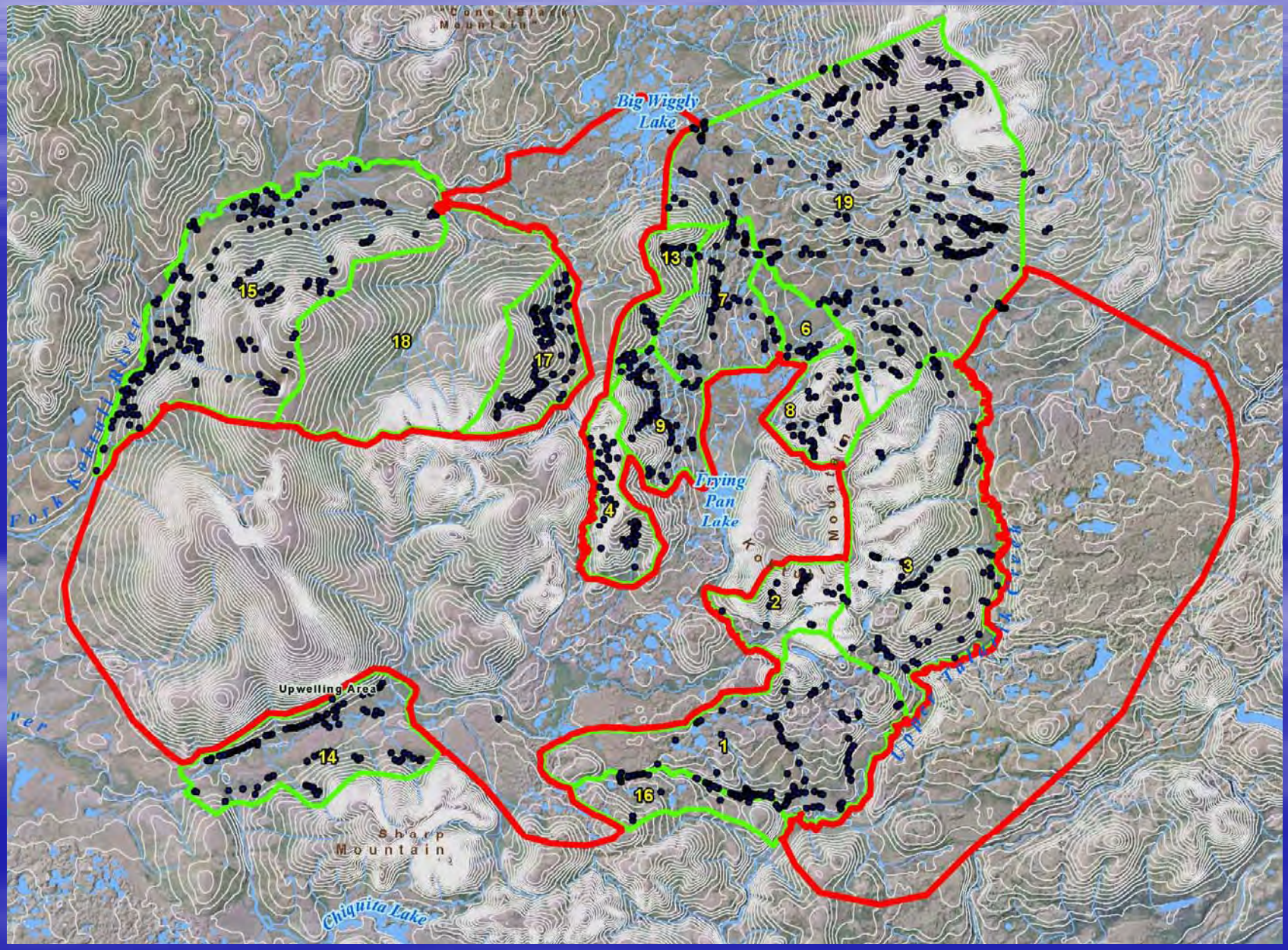
Supporting Investigations

- Surficial geology mapping program by Tom Hamilton
- Drilling and installation of piezometers by Knight Piesold (KP)
- Packer testing in geotechnical holes supervised by KP.
- Seismic refraction surveys by Frontier
- Resource drill circulation monitoring
- Springs and seeps sampled by HDR.

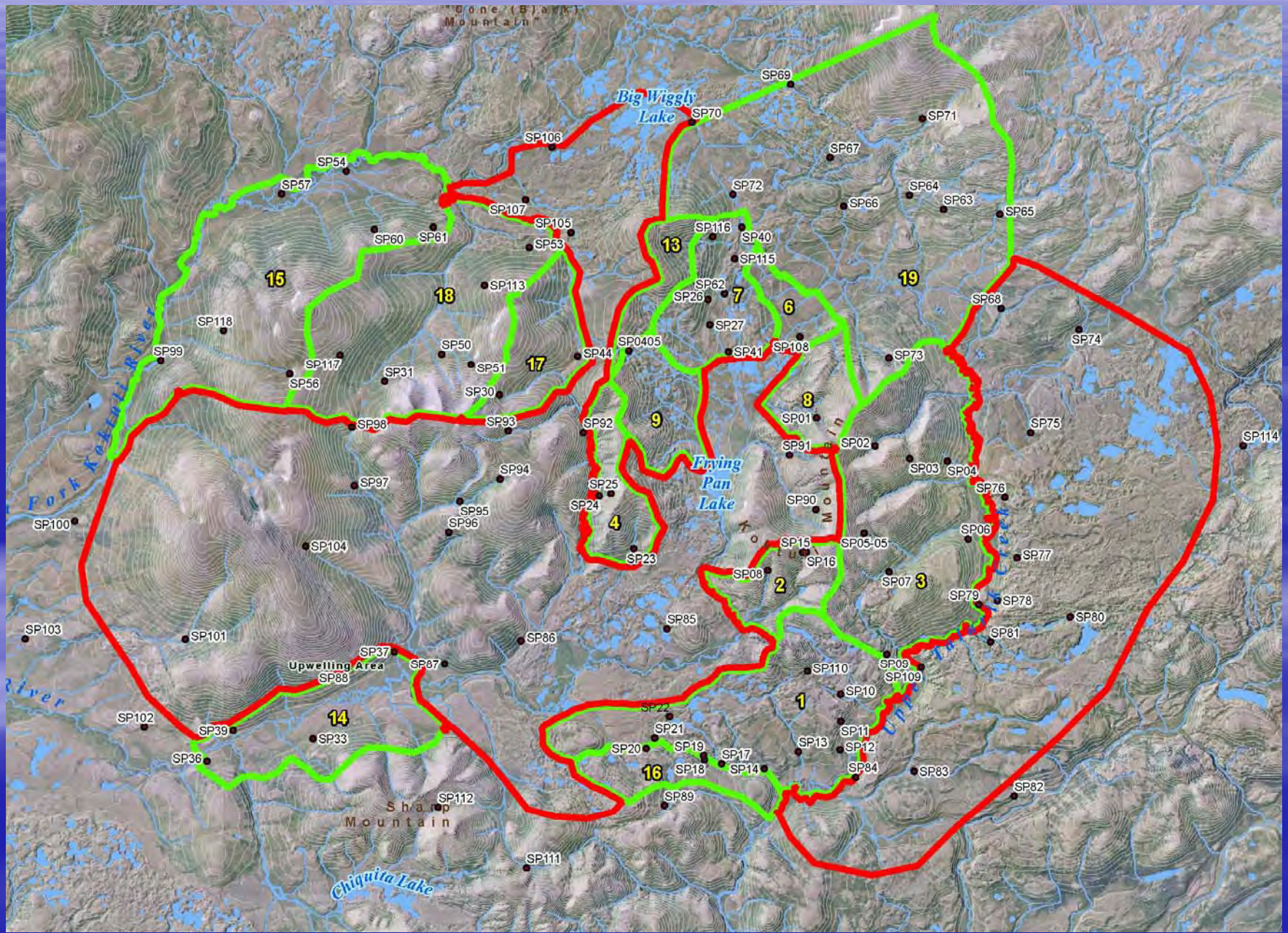


Drill circulation monitoring

Seep Inventory



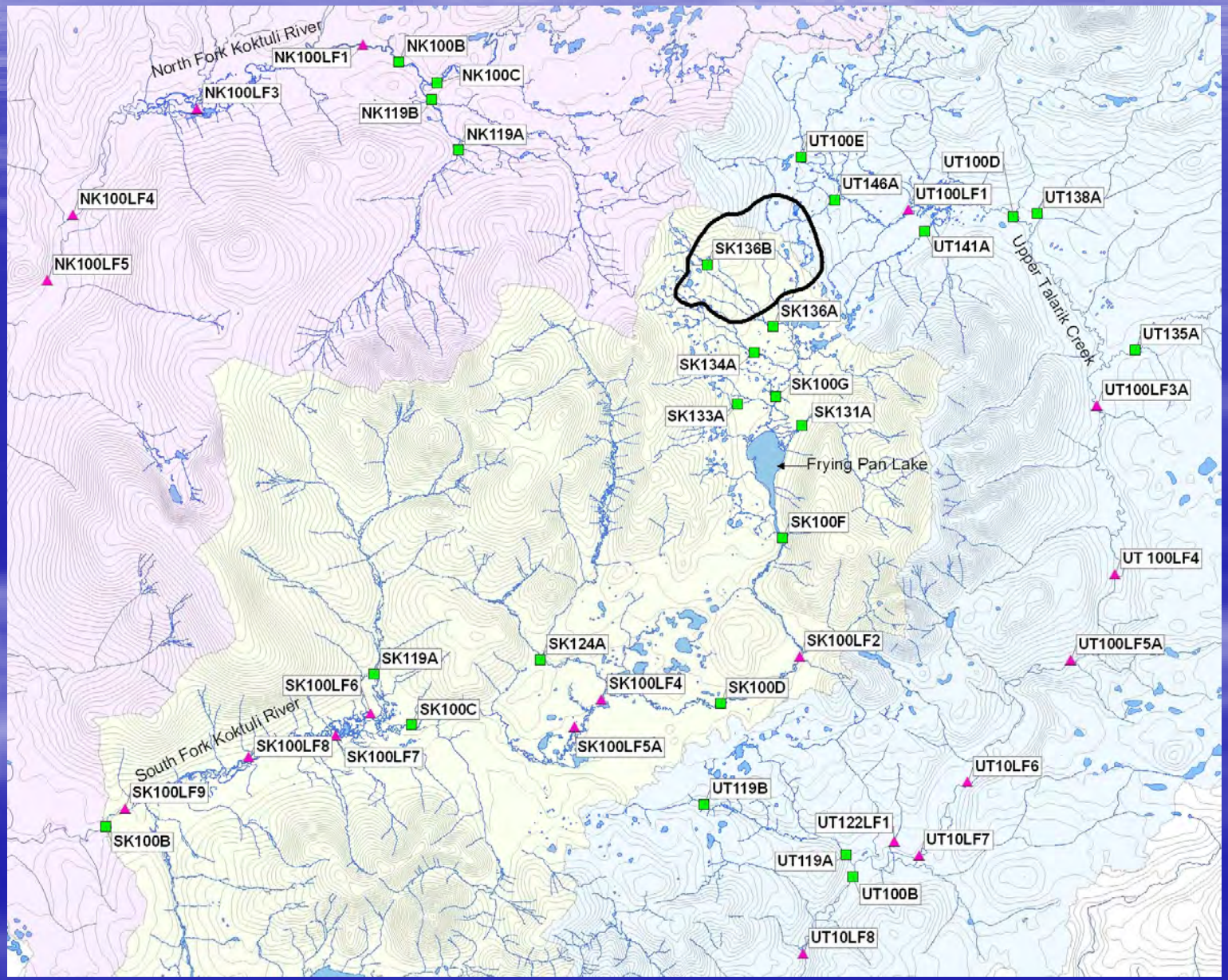
Seep Monitoring



Supporting Investigations

- Snow survey and climate data programs
- Stream gaging by HDR
- Low flow program and in stream program by HDR.
- Wetlands piezometer for Three Parameters by SLR.

Stream Gaging



Hydrogeology Studies

- WMC carried out data evaluation including:
  - analyzed pump tests and response tests.
  - prepared water level time histories.
  - correlated water level records with precipitation and stream flow records.
  - Prepared snapshots of groundwater levels.
  - Plotted and reviewed Westbay groundwater level data.

Hydrogeology Studies

- WMC carried out data evaluation including:
  - Prepared hydrogeologic cross sections with water level data and hydraulic conductivity values.
  - Evaluation of spring and seep surveys
  - Evaluation of exploration drilling circulation losses and gains
  - Prepared time histories, piper plots, stiff diagrams etc to track ongoing groundwater chemistry monitoring.

Hydrogeologic Setting

- Packer testing in bedrock and much of the drill circulation data implies moderate to low permeability in most of the bedrock.
- Some indication of high permeability zones, not yet linked to structures or lithology.
- Top of rock physically disintegrated as a result of frost activity (felsenmeer). This high permeability zone (up to 50 ft thick) is continuous over most of the site.

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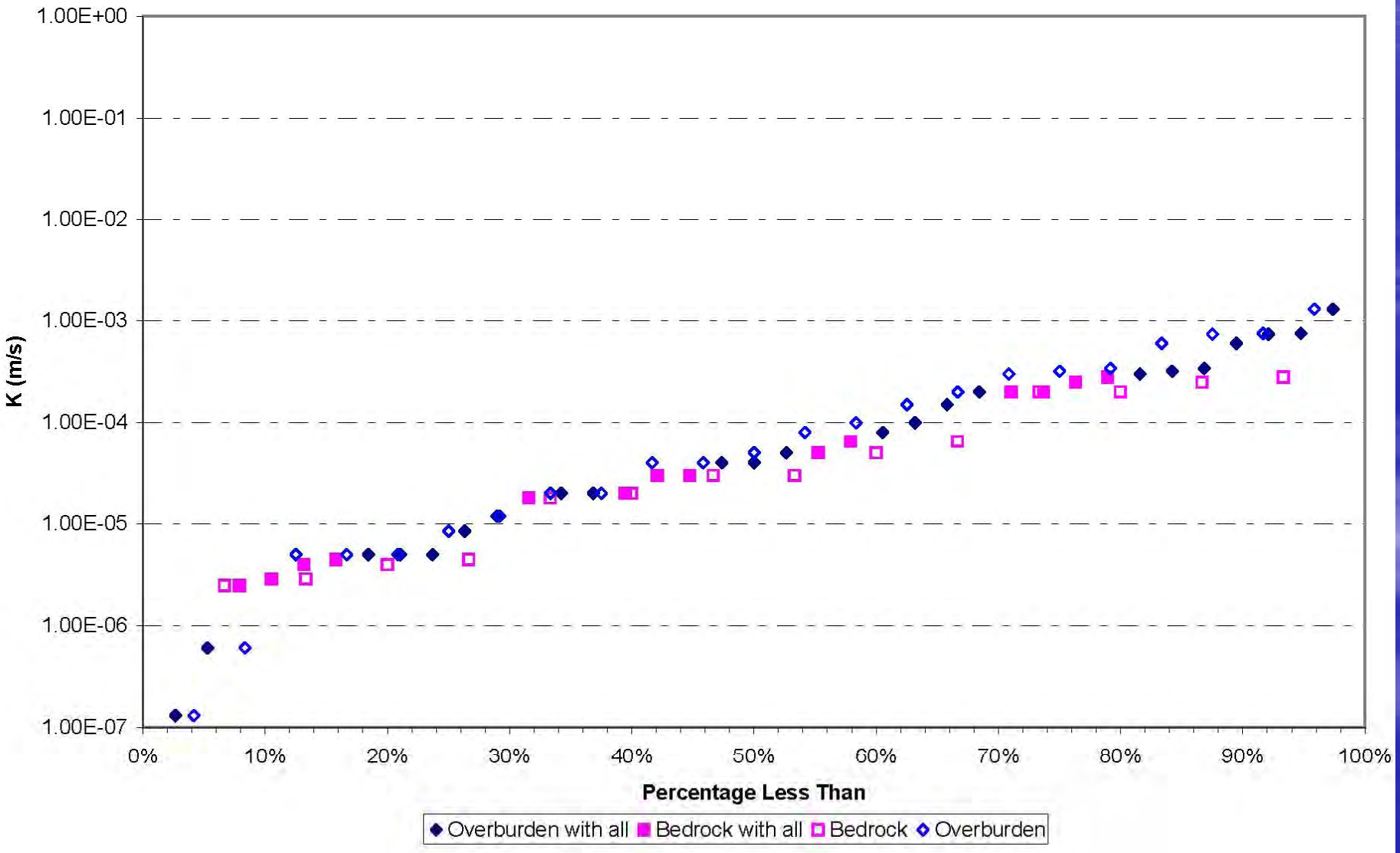
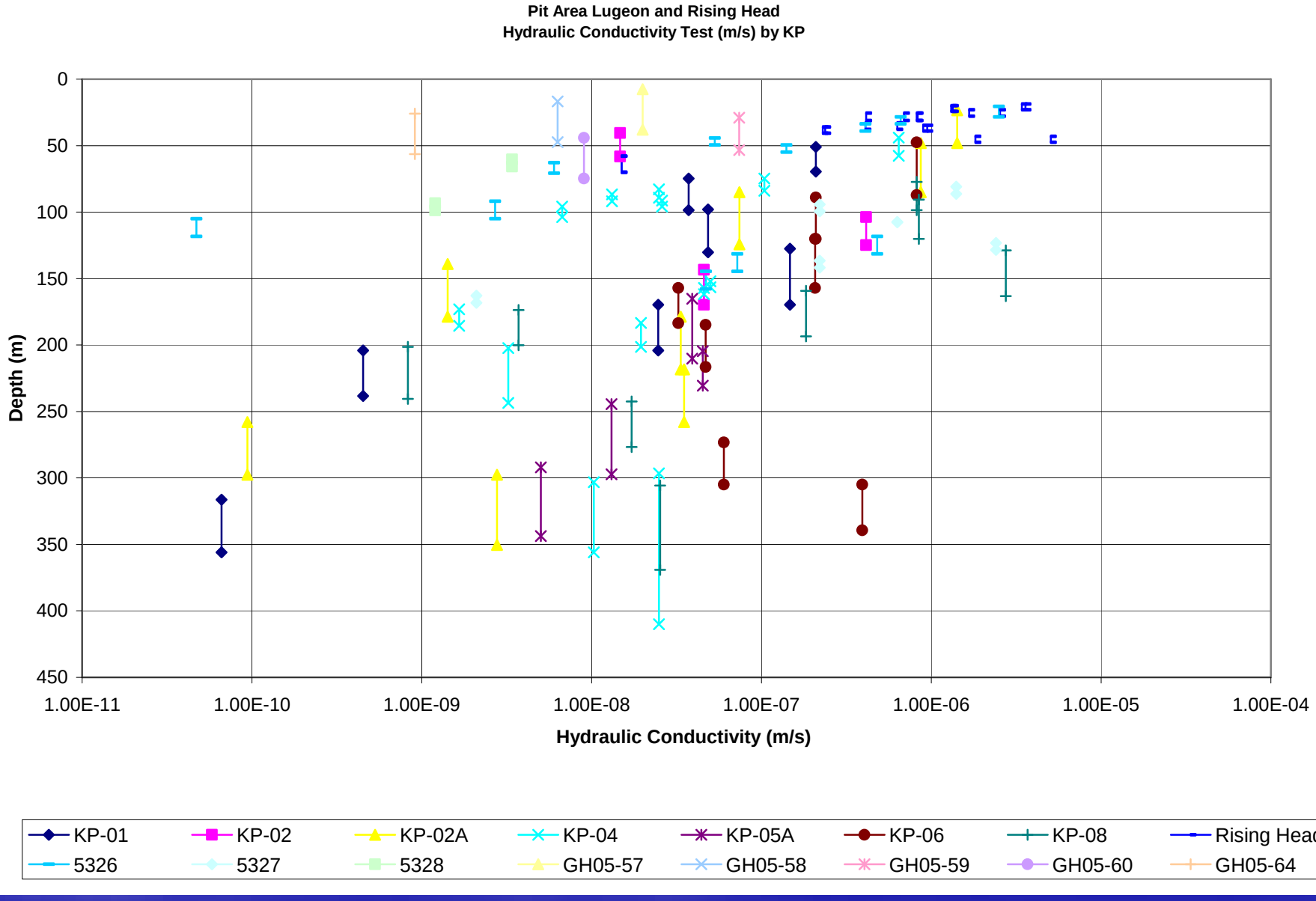
Cumulative Frequency of Hydraulic Conductivity in the Pit Area

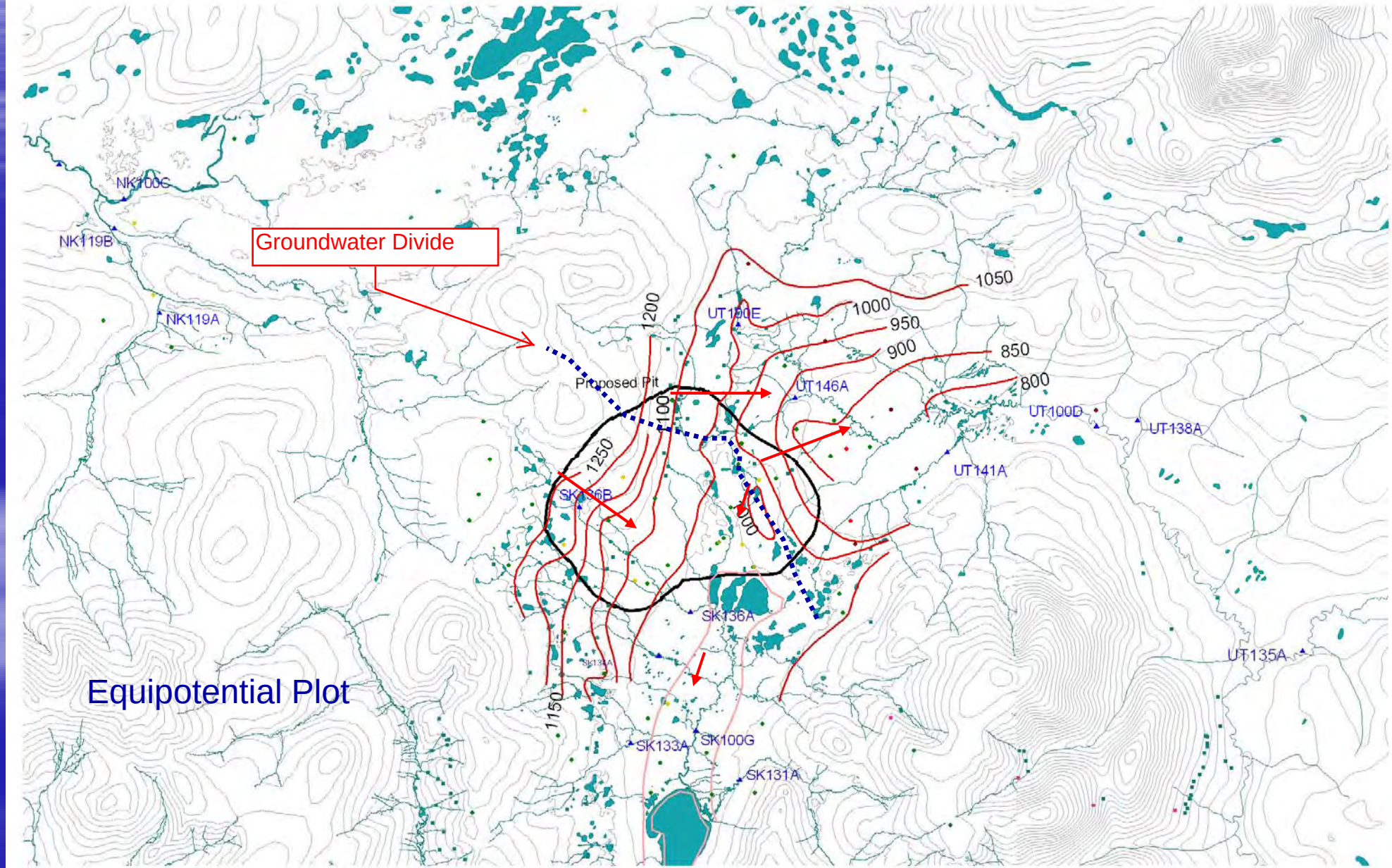
Pebble Gold-Copper Project Reponse Test Results 2004-2006



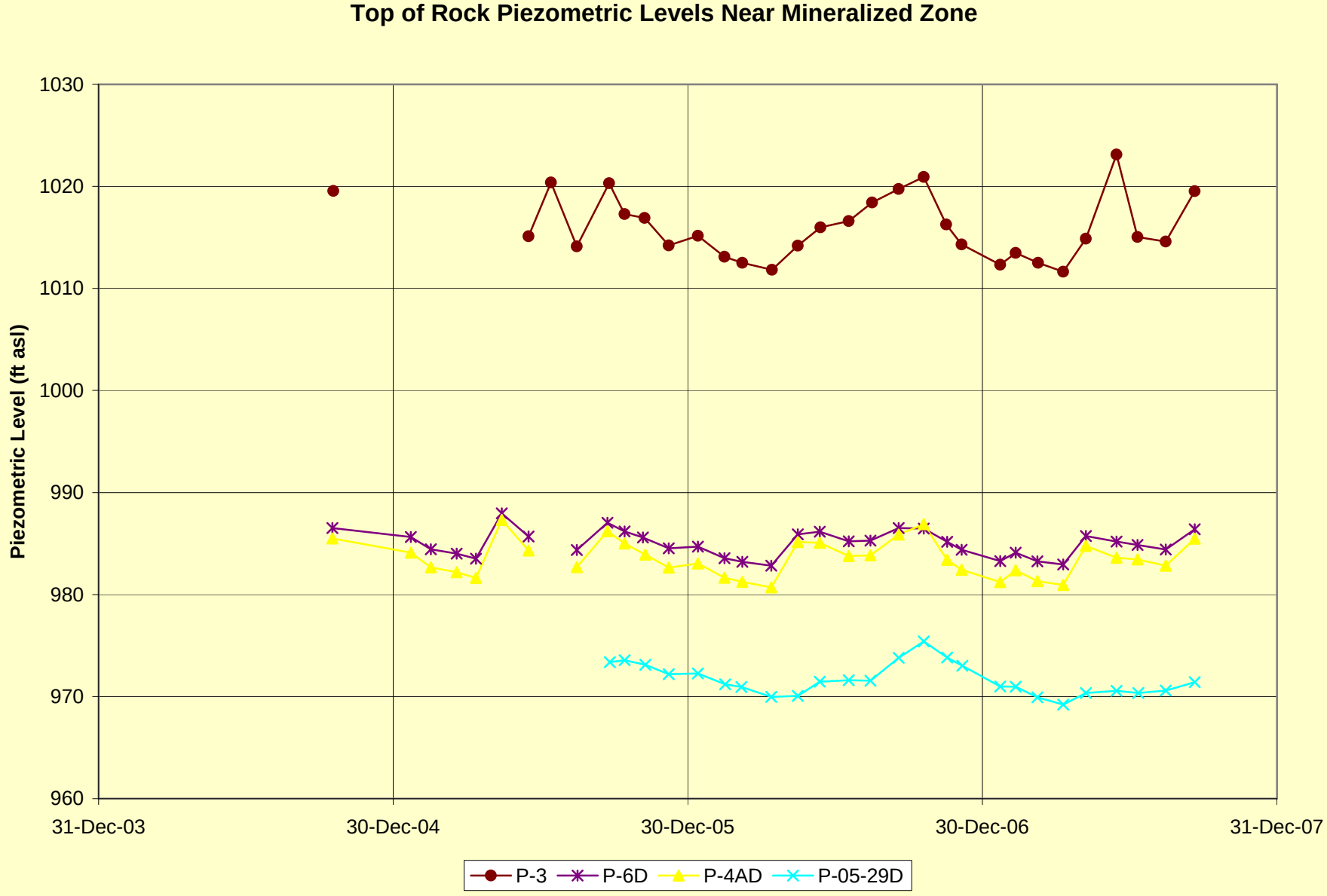
THE pebble PARTNERSHIP



Groundwater Levels



Groundwater Levels



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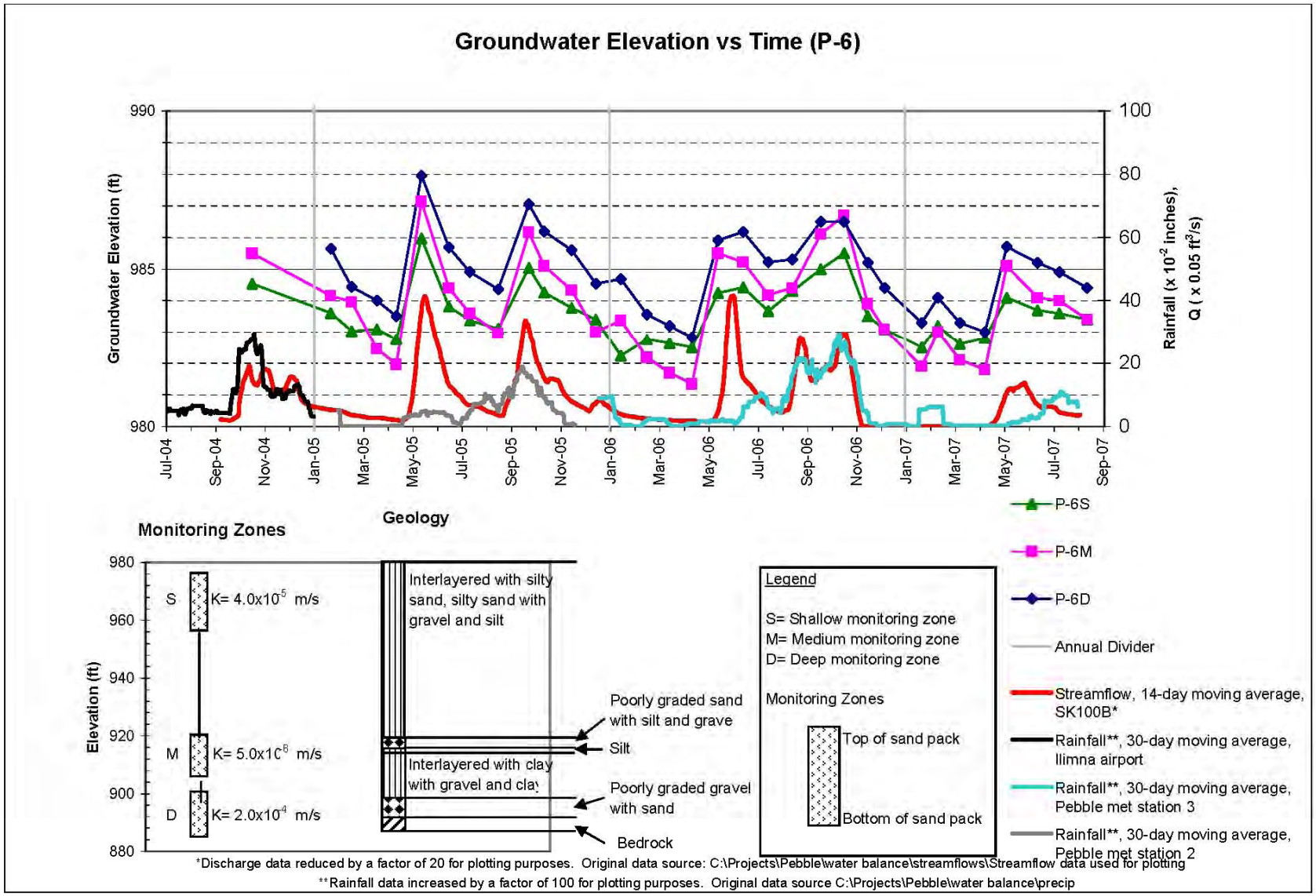
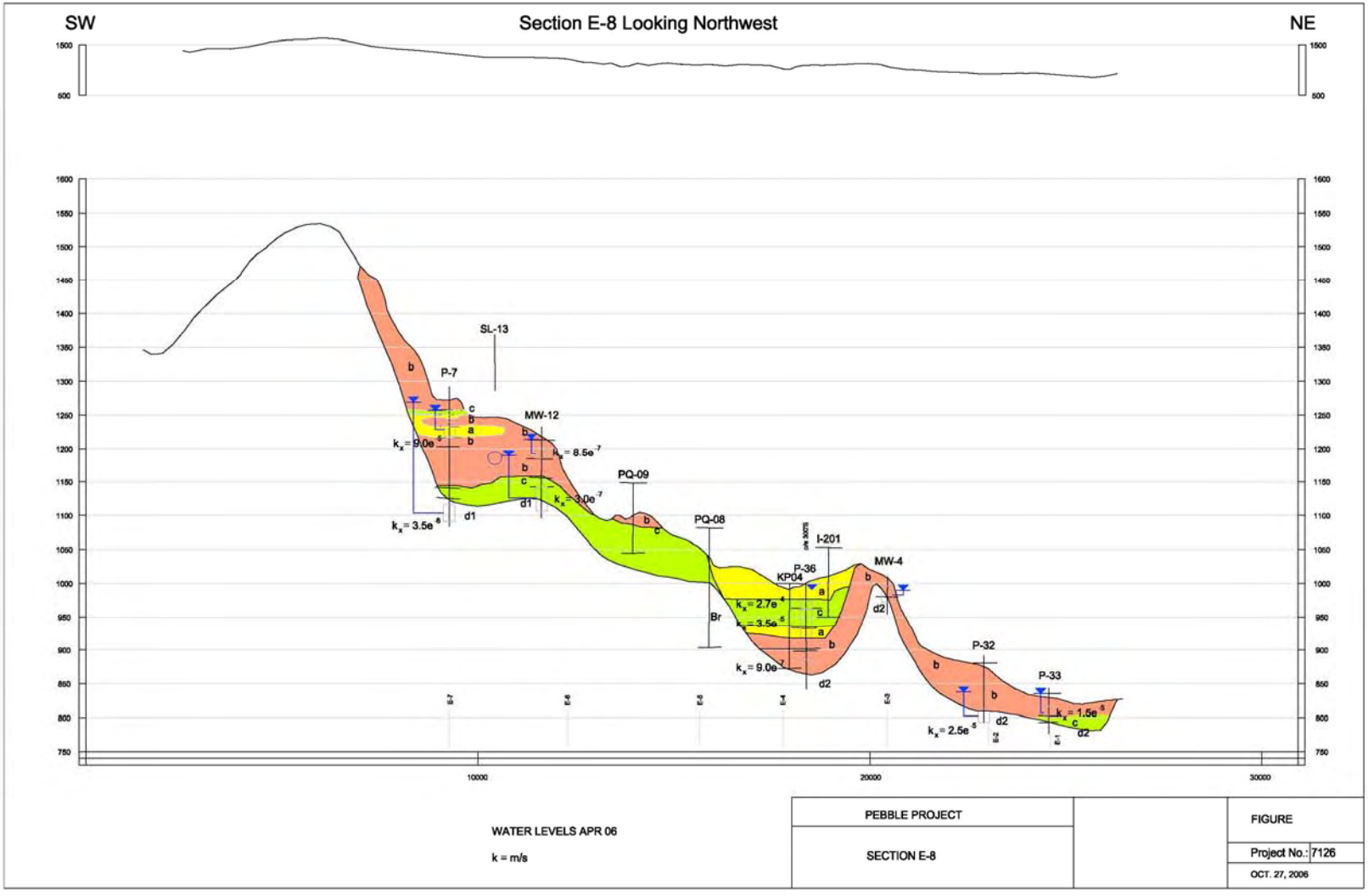


Groundwater Levels



Groundwater Levels

Westbay Data

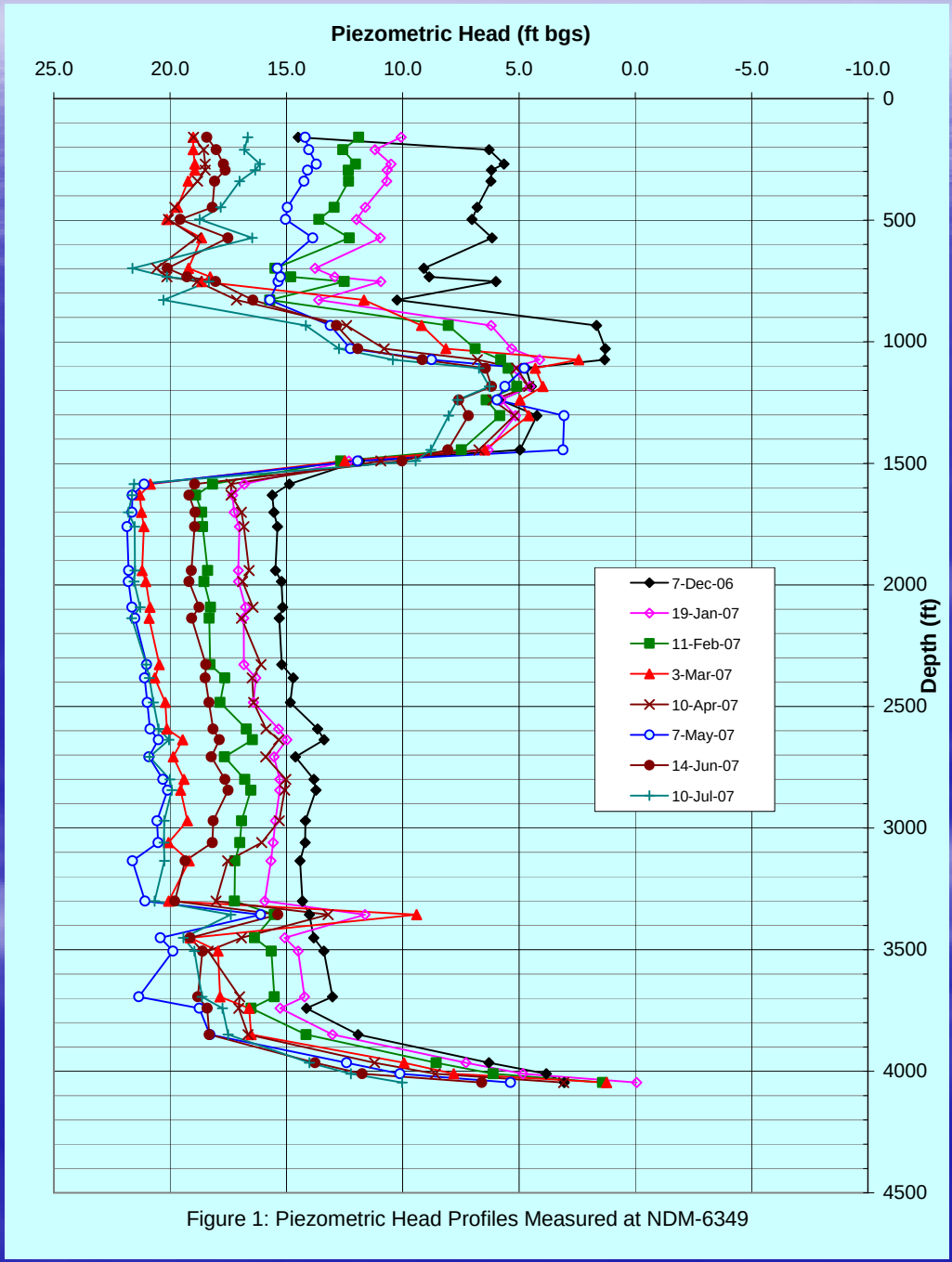
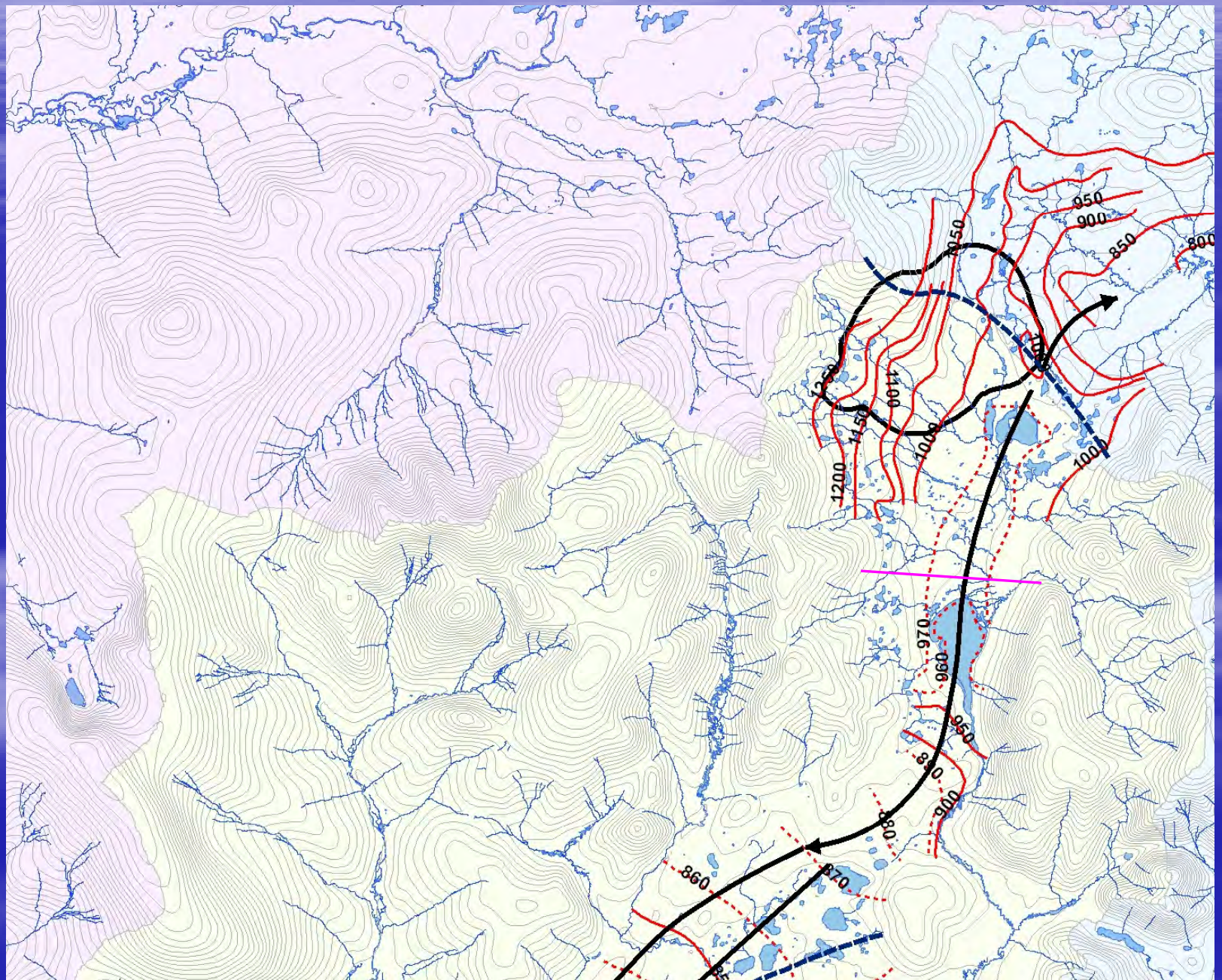


Figure 1: Piezometric Head Profiles Measured at NDM-6349

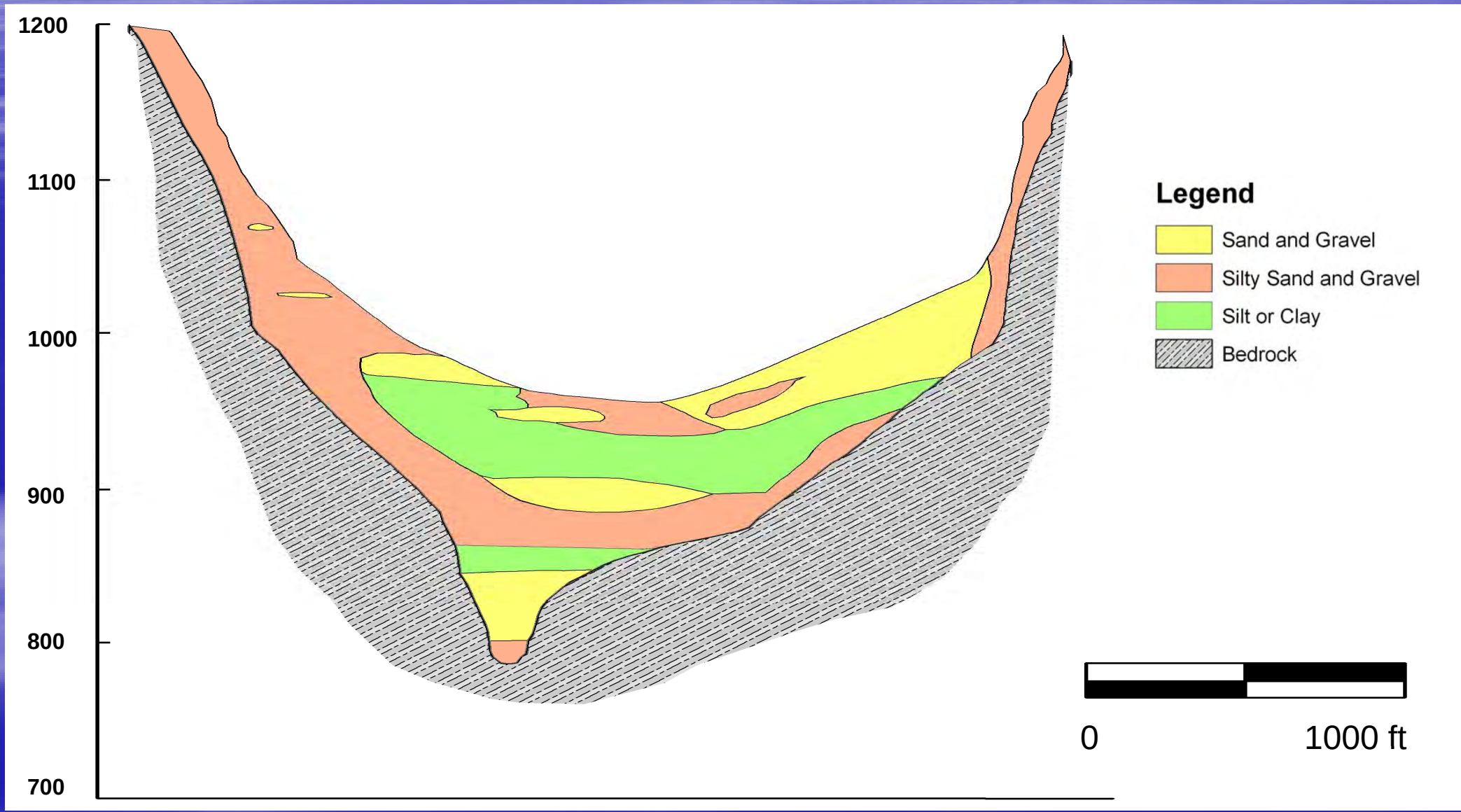
Hydrogeologic Setting

- Surficial geologic setting the result of frequent termination of glacial advances near the site.
- Glacial lakes, glacial moraines and outwash deposits mapped by Tom Hamilton.
- Extensive outwash deposits not present in the immediate mineralized area
- Upstream of Frying Pan Lake, glacial lake deposits including silts and silty sands are present

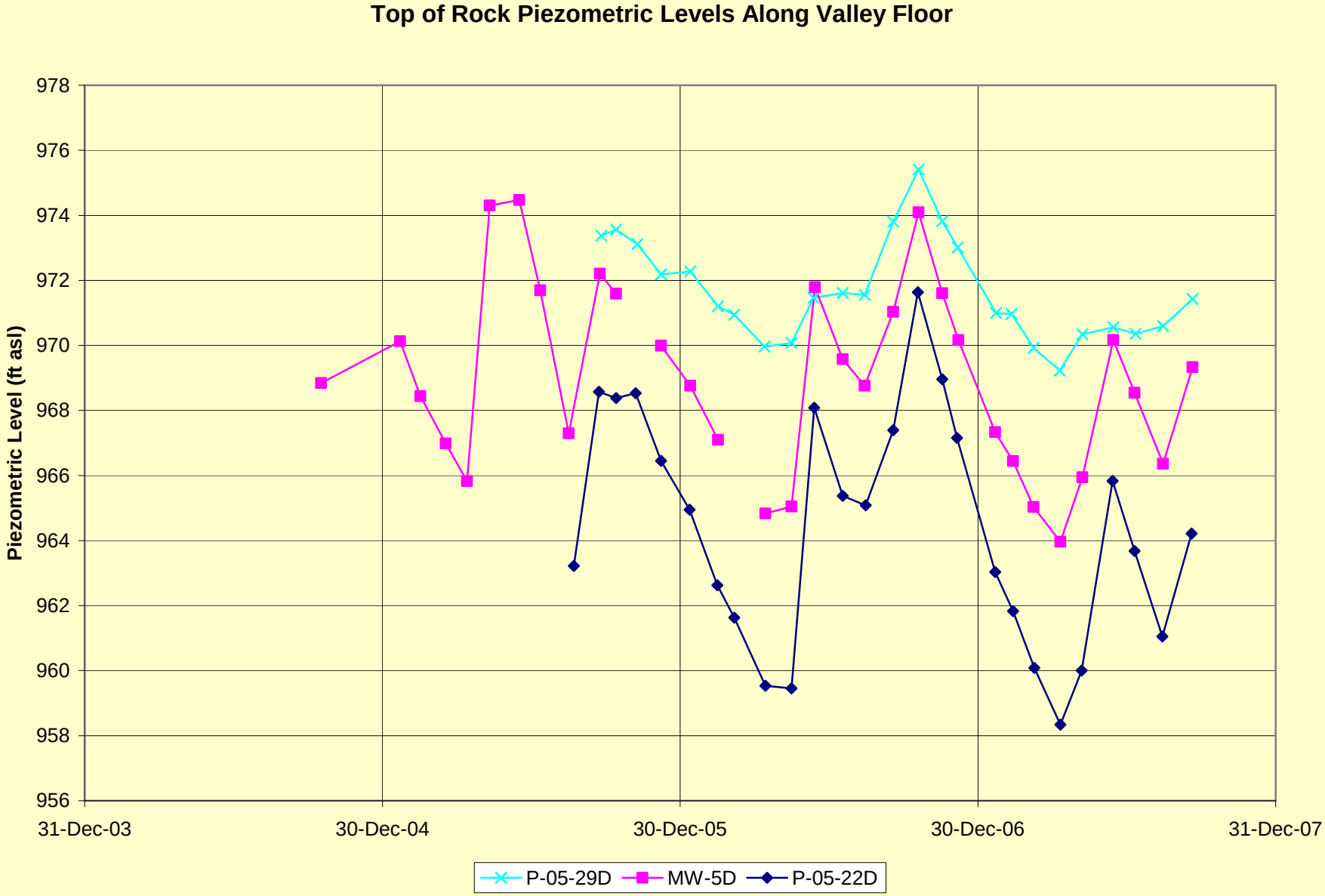
Groundwater Levels



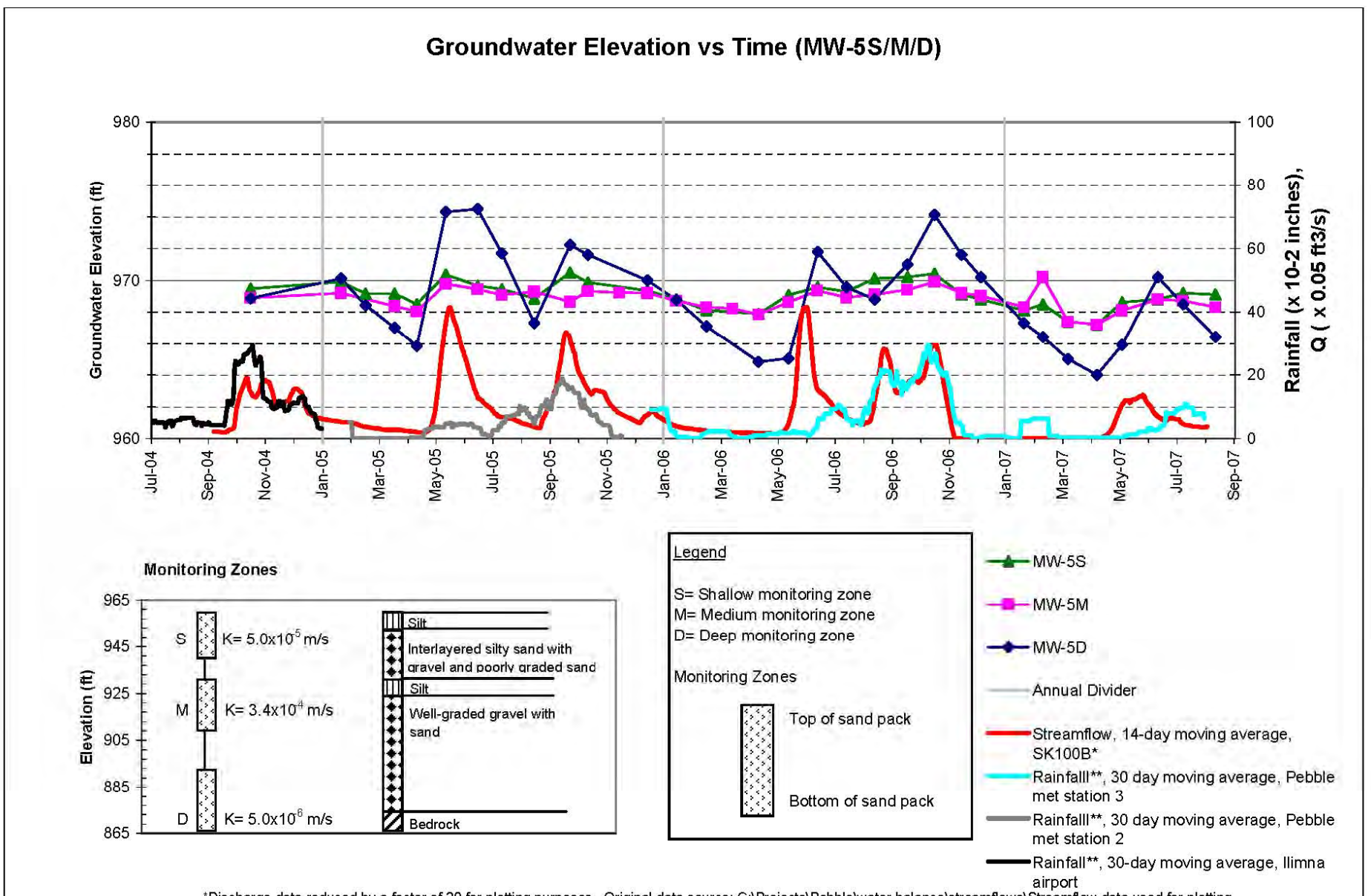
Hydrogeologic Setting



Hydrogeologic Setting



Groundwater Levels (MW-5)



*Discharge data reduced by a factor of 20 for plotting purposes. Original data source: C:\Projects\Pebble\water balance\streamflows\Streamflow data used for plotting

**Rainfall data increased by a factor of 100 for plotting purposes. Original data source C:\Projects\Pebble\water balance\precip

Hydrogeologic Setting

- Glacial outwash deposits result in large surficial aquifers of high permeability within all three catchments.
- High permeability aquifer present in South Fork Koktuli River downstream of Frying Pan Lake.
- Outwash gravels creating permeable aquifers also present in the North Fork Koktuli River valley and are also present east of Upper Talarik Creek.

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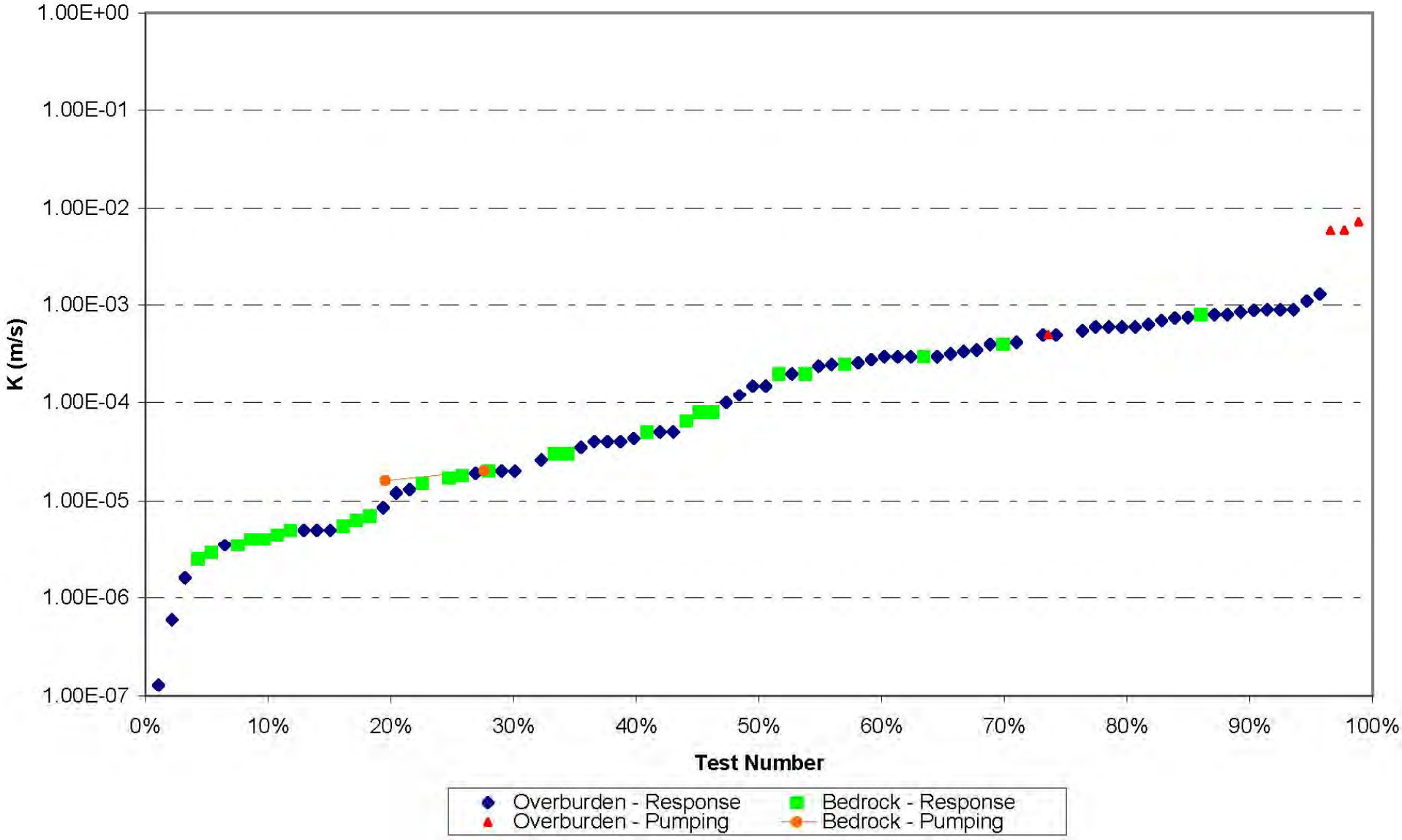
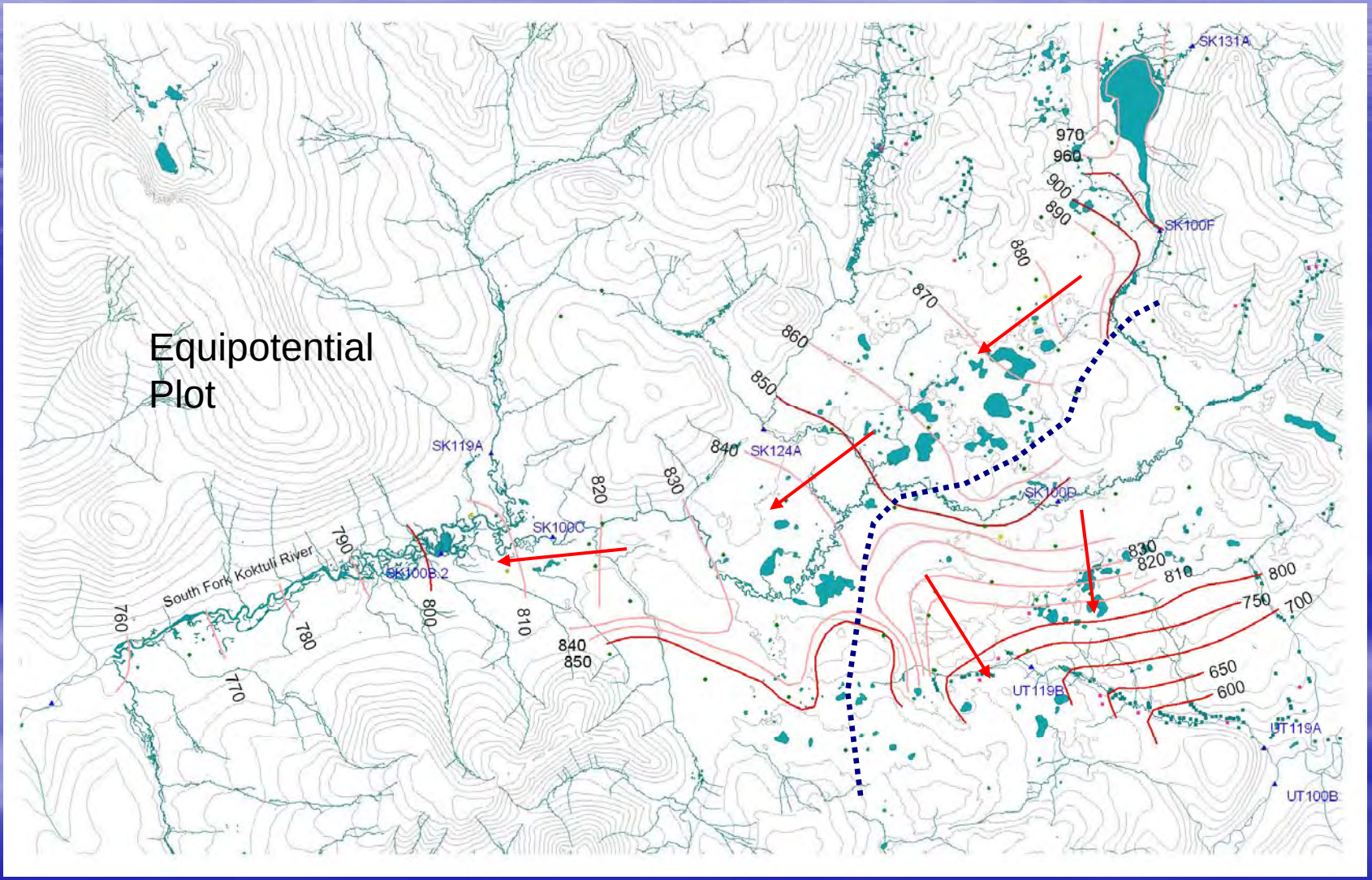
Cumulative Frequency of Hydraulic Conductivity

Pebble Gold-Copper Project Response Test Results 2004-2006



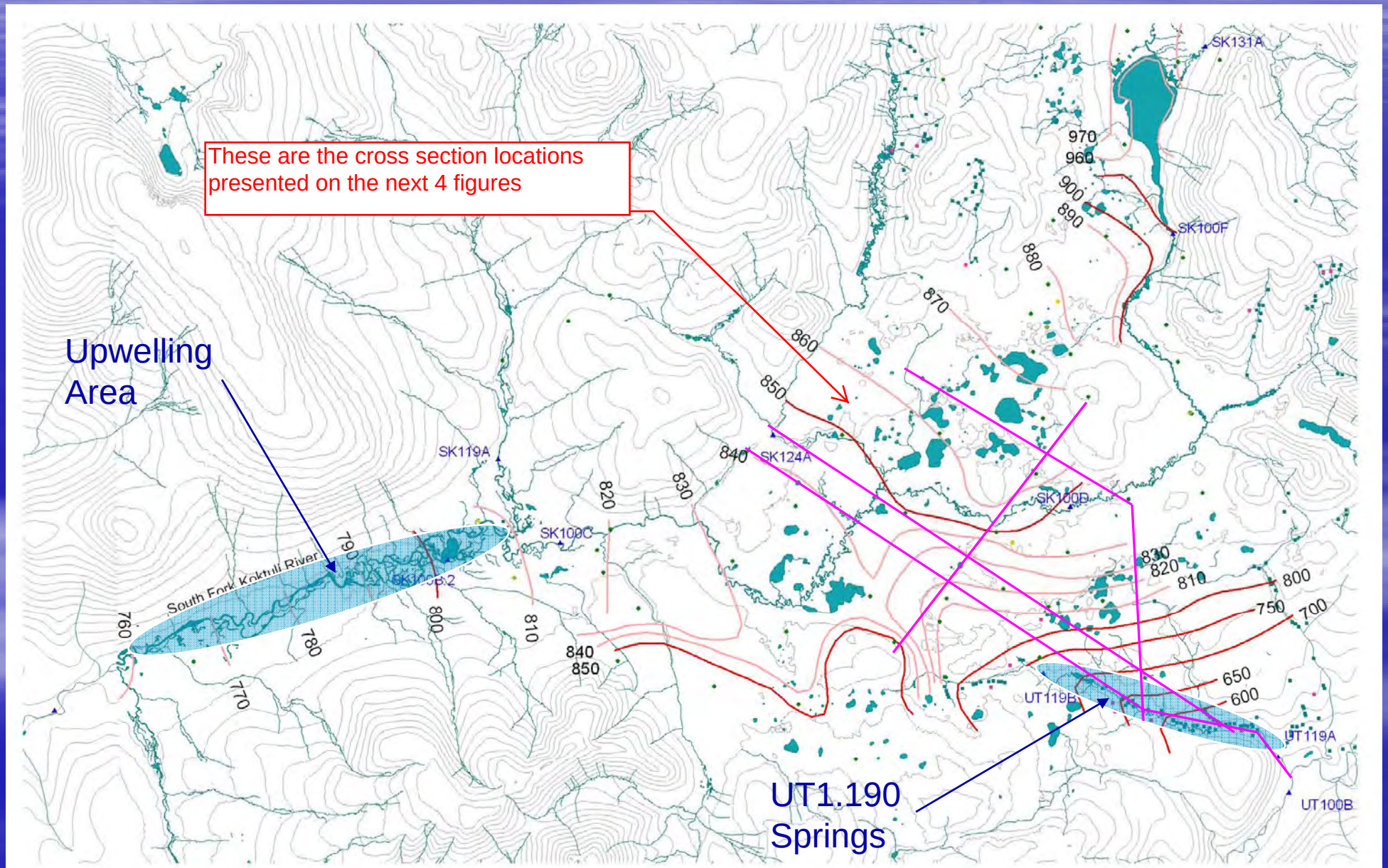
Groundwater Levels



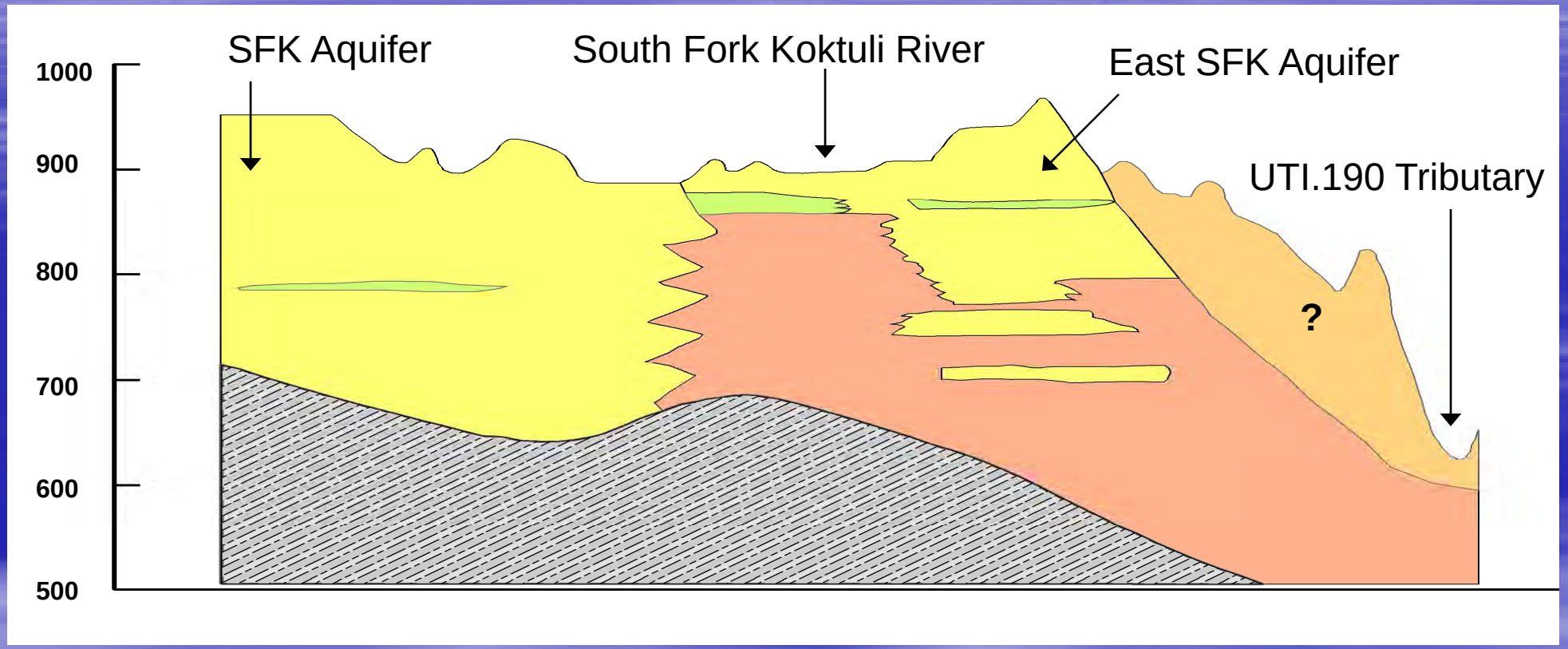
Hydrogeologic Setting

- Washing of near surface materials at the end of glaciation and the frost jacking of gravels and pebbles to the surface results in a ground surface with high infiltration capacity.
- Cross catchment groundwater flow occurs from South Fork Koktuli River to Upper Talarik Creek through interbedded silts and sands.
- Similar but less obvious cross boundary flow may be occurring from South Fork Koktuli River towards Kaskanak Creek and from North Fork Koktuli River headwaters into the Upper Talarik Creek headwaters.

Groundwater Levels



Hydrogeologic Setting



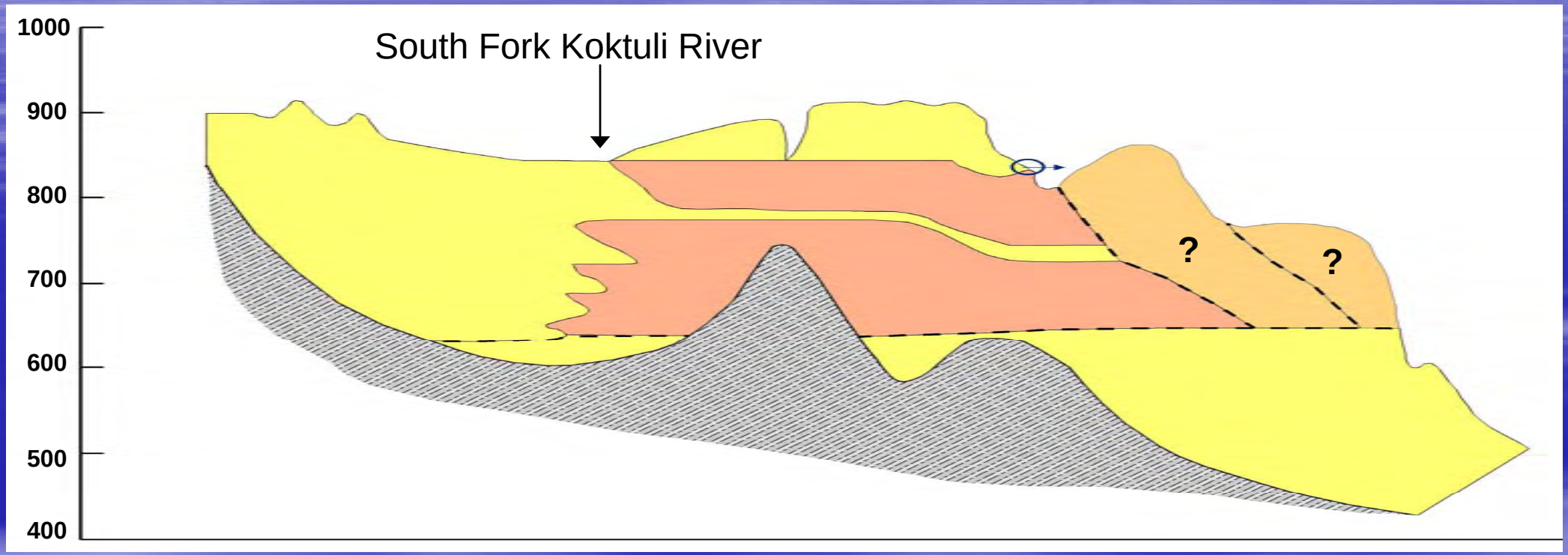
0 1000 ft

High permeability and rapid recharge

Legend

- Sand and Gravel
- Silty Sand and Gravel
- Silt or Clay
- Disturbed Ground
- Bedrock

Hydrogeologic Setting

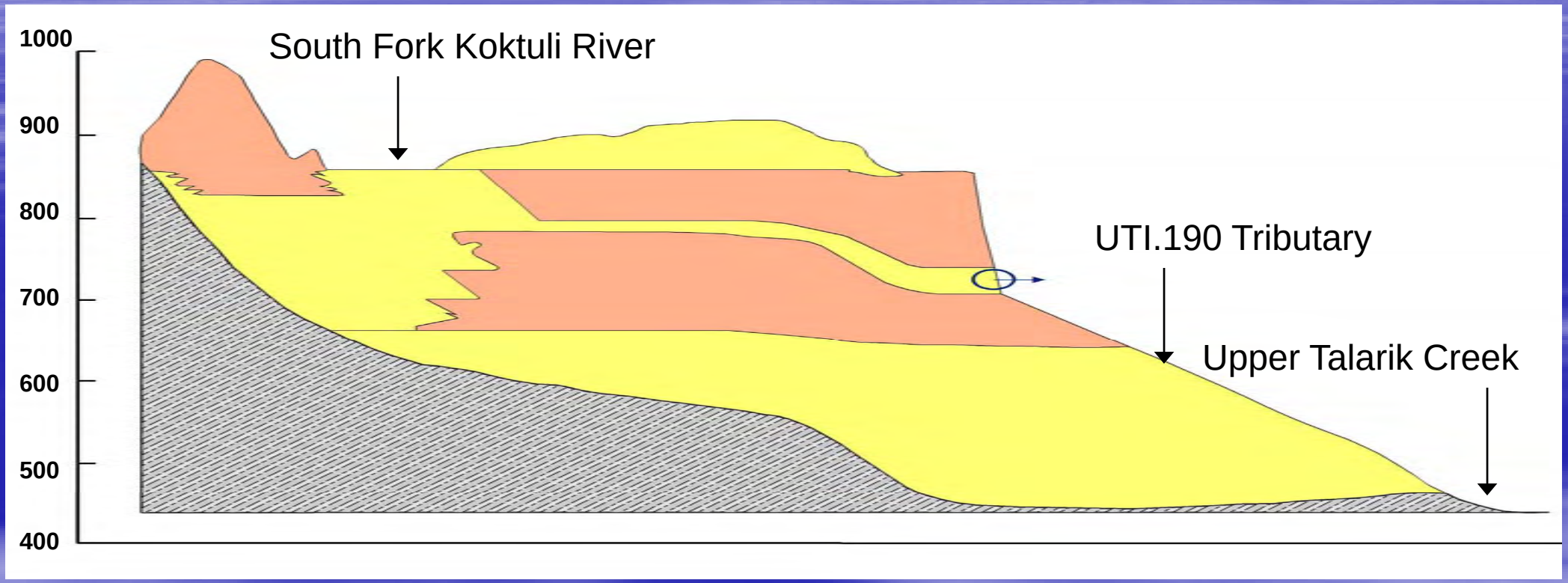


0 1000 ft

Legend

- Sand and Gravel
- Silty Sand and Gravel
- Disturbed Ground
- Bedrock
- Spring

Hydrogeologic Setting

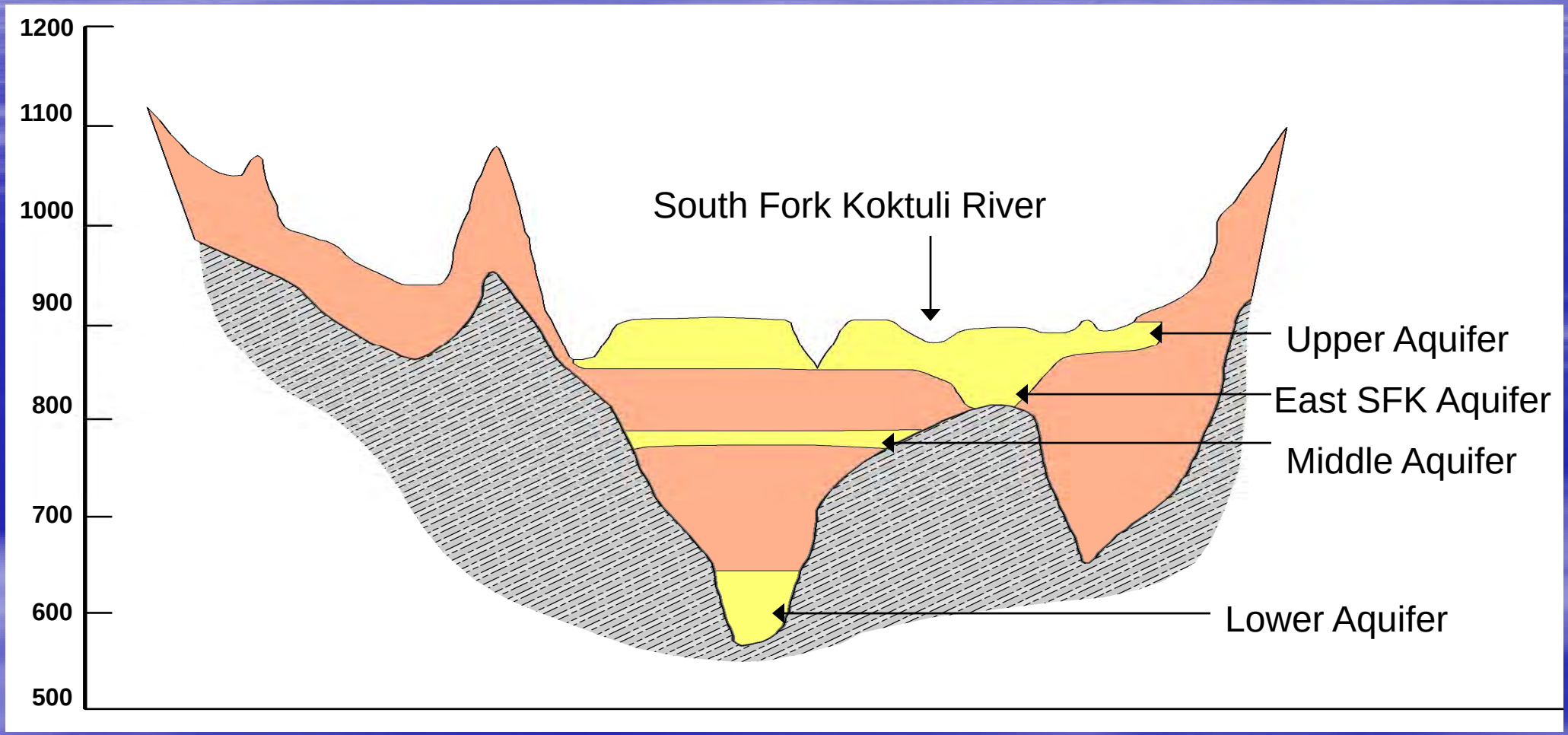


0 1000ft

Legend

- Sand and Gravel
- Silty Sand and Gravel
- Bedrock
- Spring

Hydrogeologic Setting

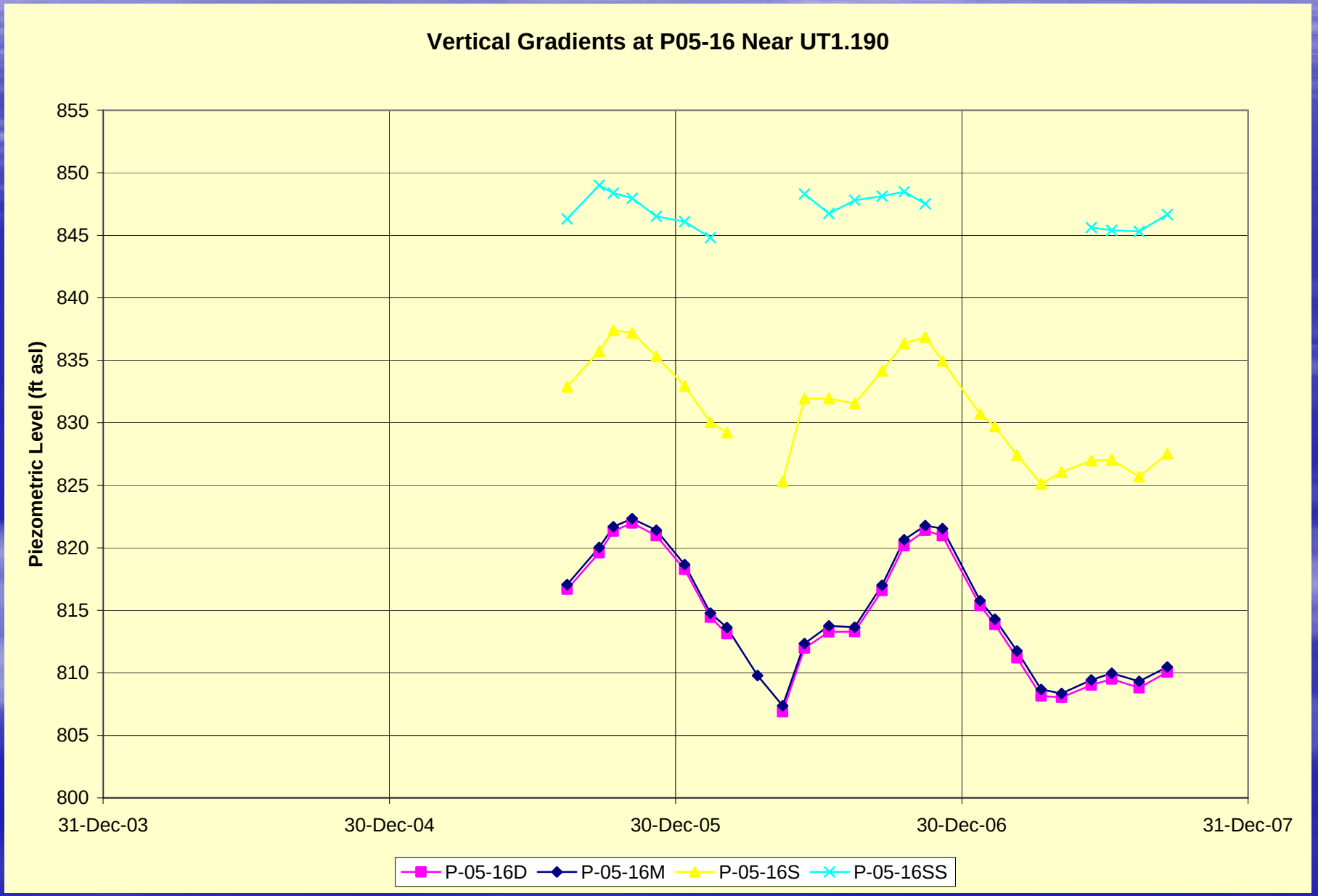


0 1000 ft

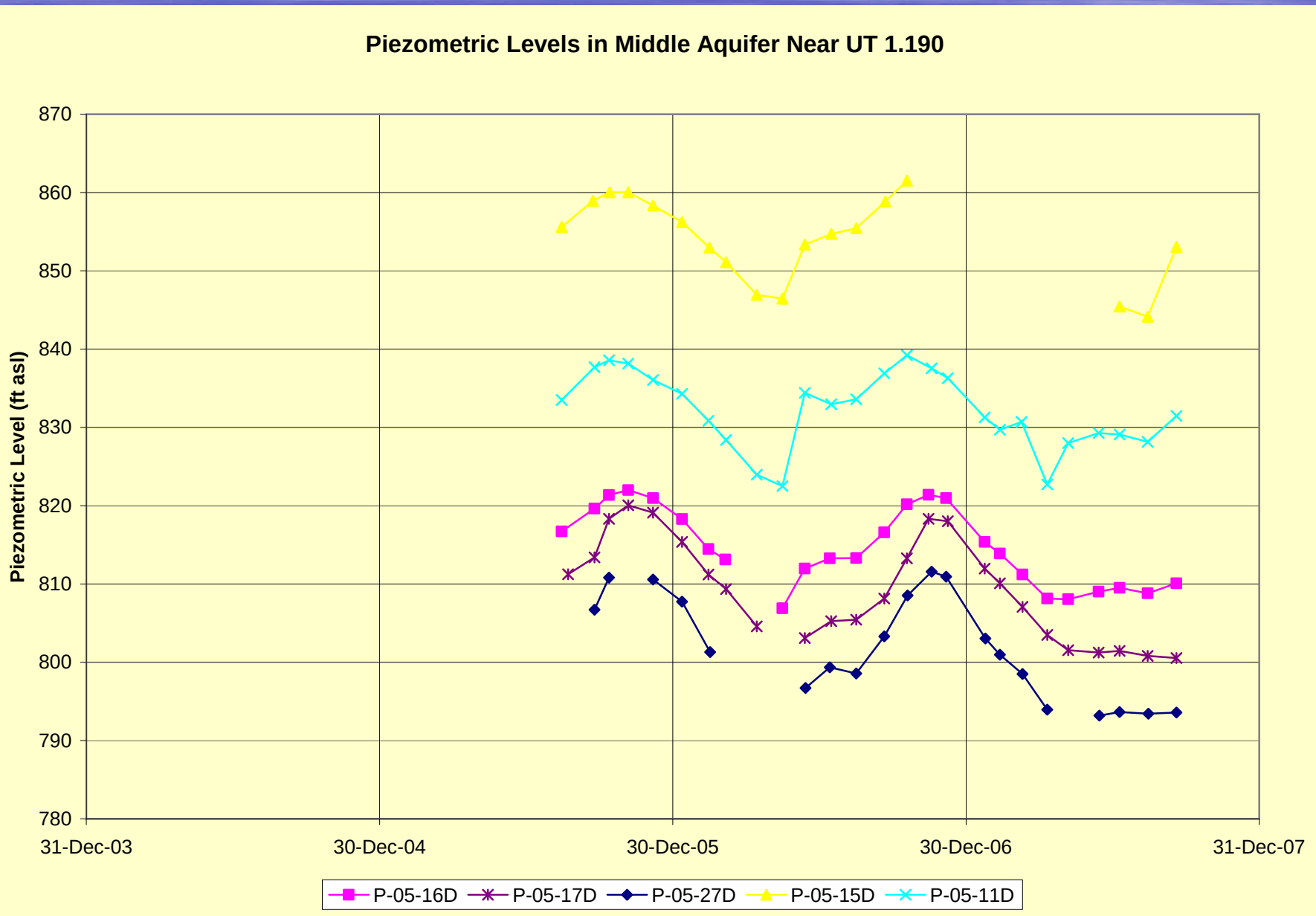
Legend

- Sand and Gravel
- Silty Sand and Gravel
- Bedrock

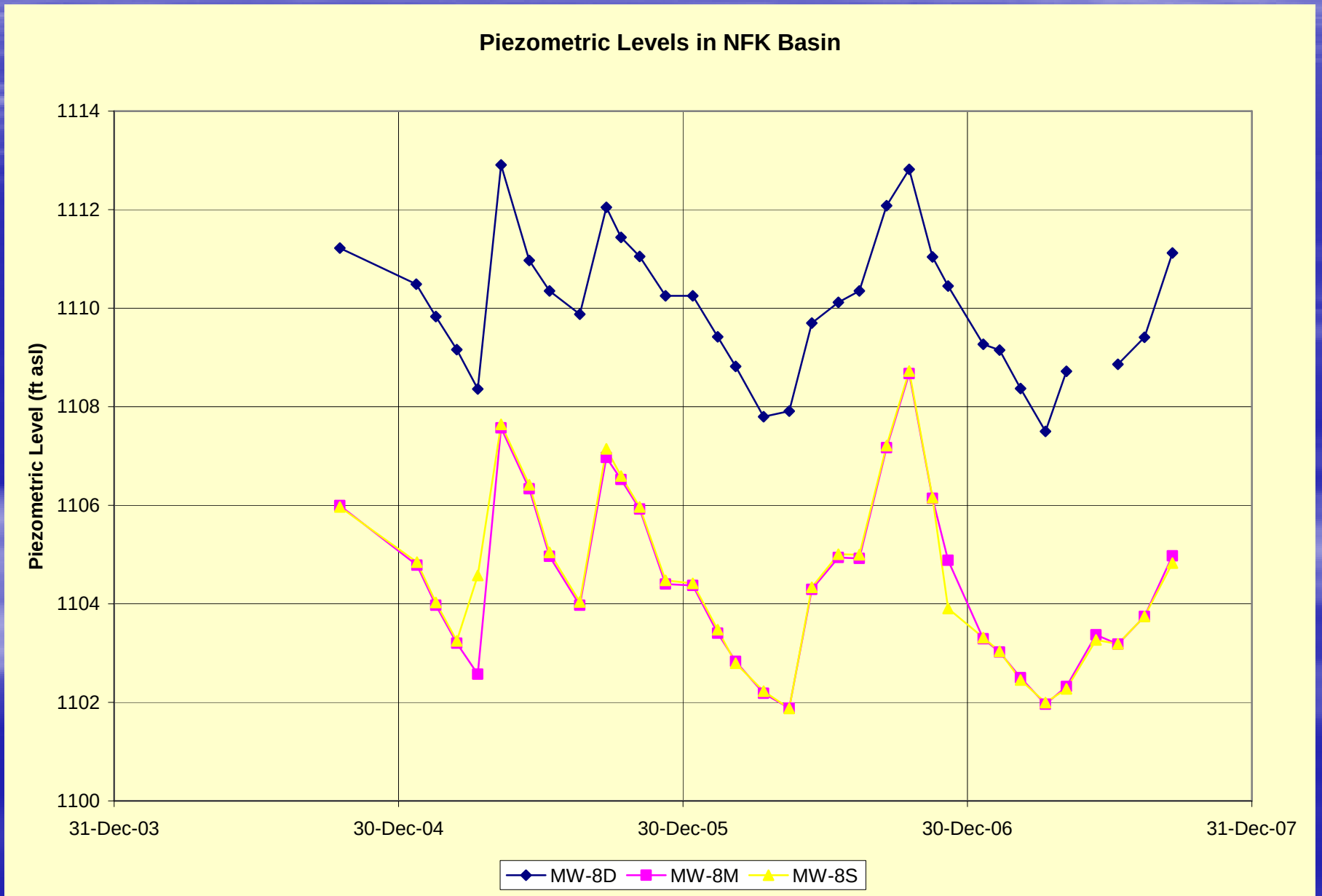
Groundwater Levels



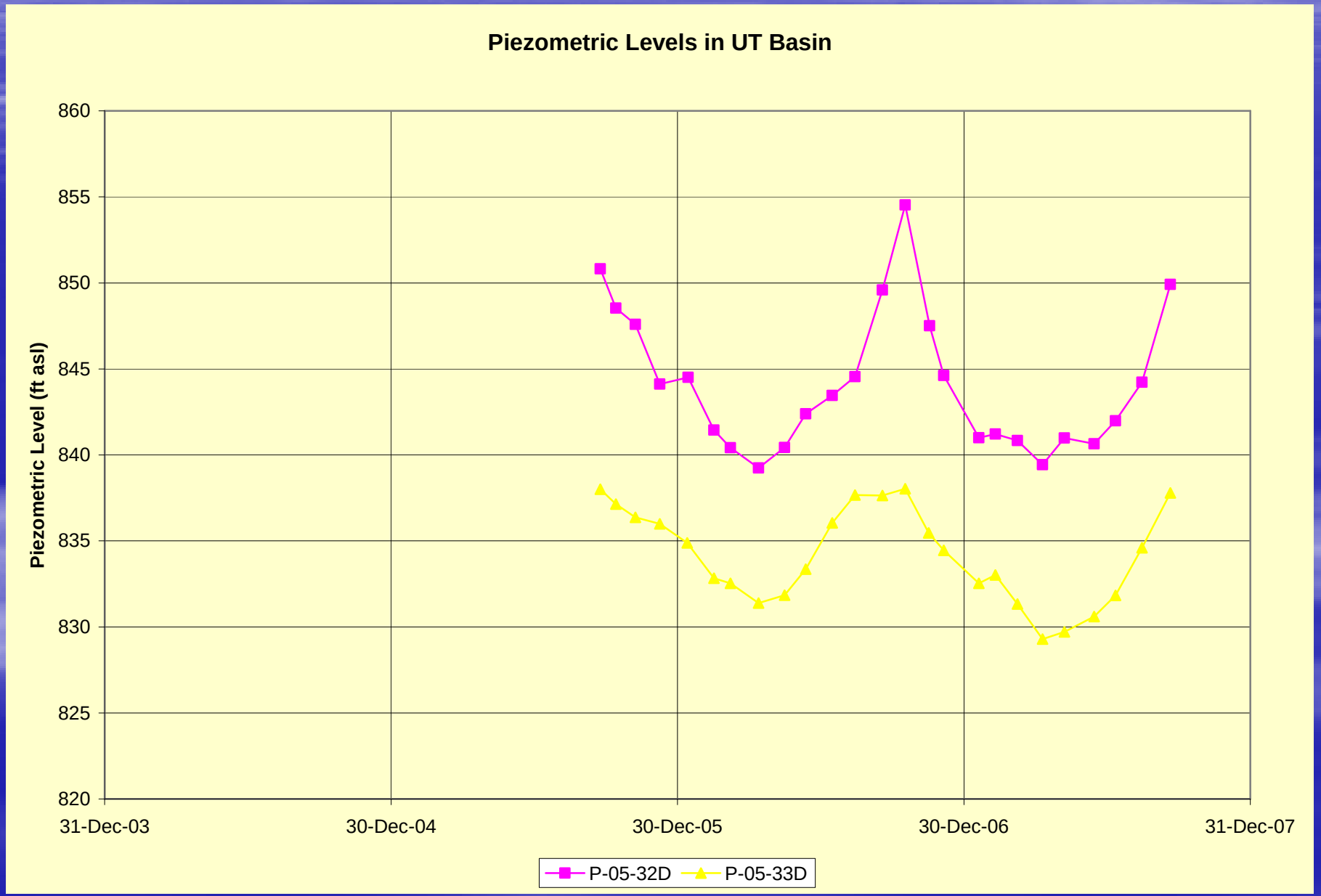
Groundwater Levels



Groundwater Levels



Groundwater Levels



Hydrogeology Calculations

- Two calculations methods
- Site wide water balance completed to constrain groundwater recharge and discharge rates
- Groundwater model to provide a more realistic assessment of groundwater flow physics

Reasons for integrated modelling

- Water Balance:
  - Groundwater flows consistent with overall water balance
  - Reduces non-uniqueness in groundwater model
- Numerical groundwater model
  - Checks groundwater component of water balance

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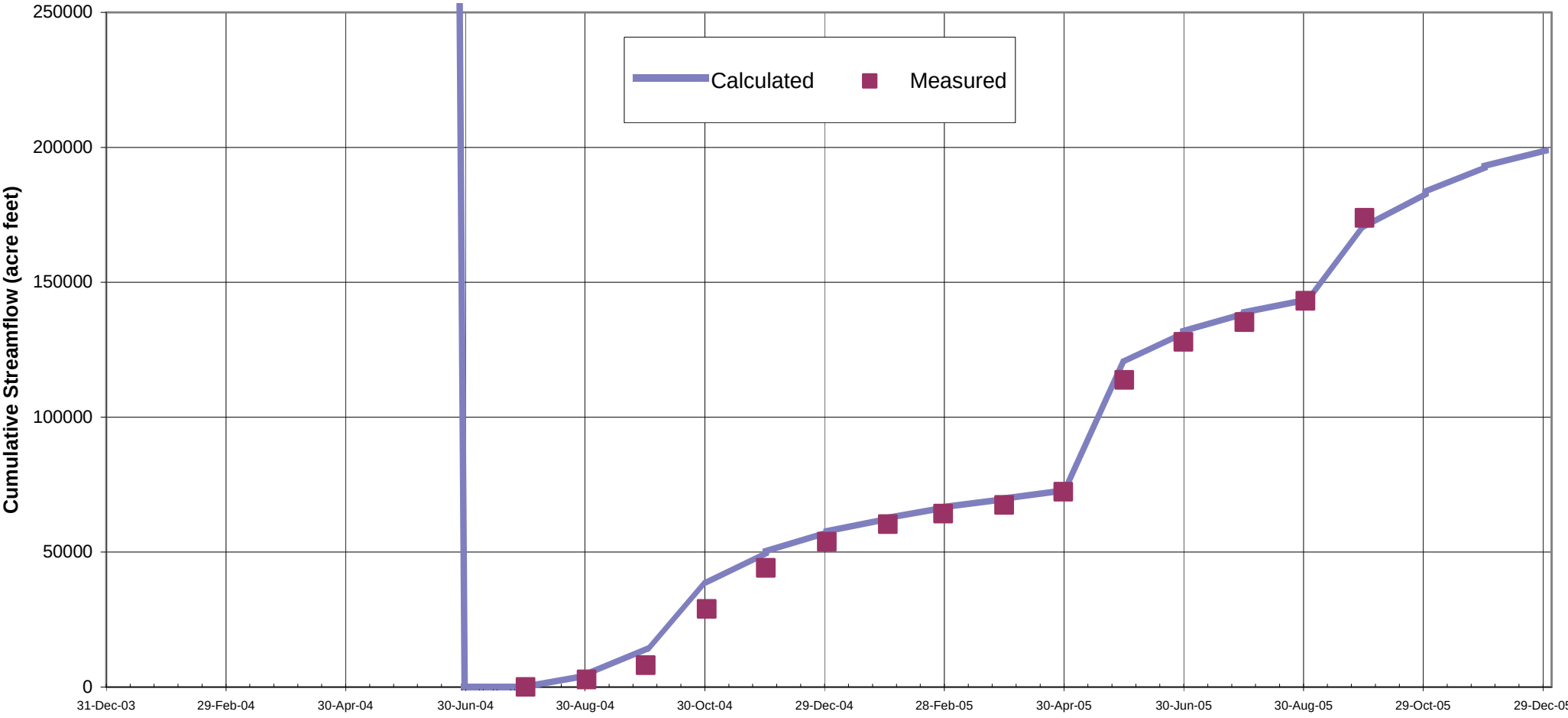
Calculated and Measured Cumulative Streamflow
SK100B



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Measured and Calculated Streamflow
SK100B (Area 4)

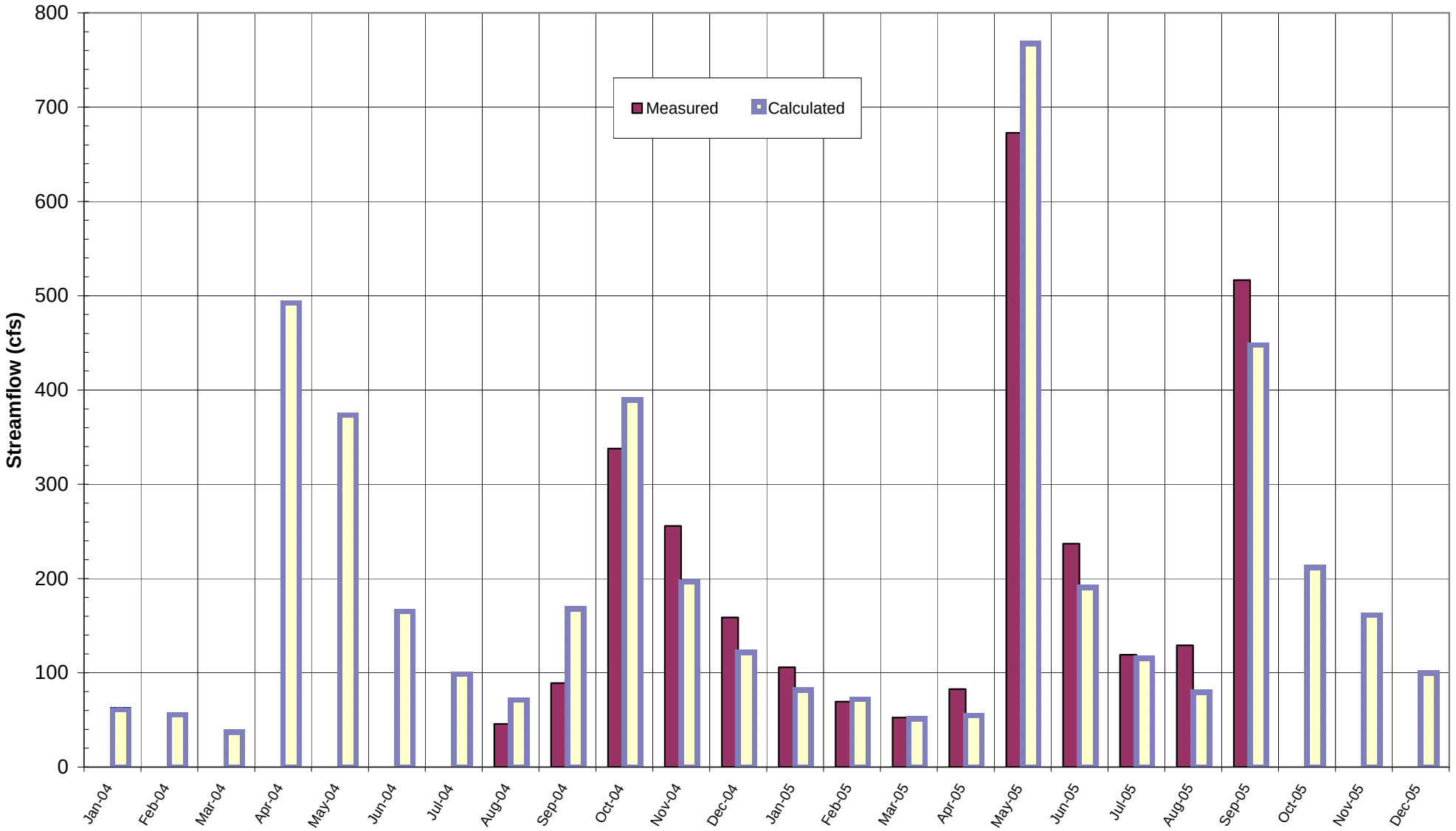

Figure 7 Calculated and Measured Cumulative Streamflow
SK100A

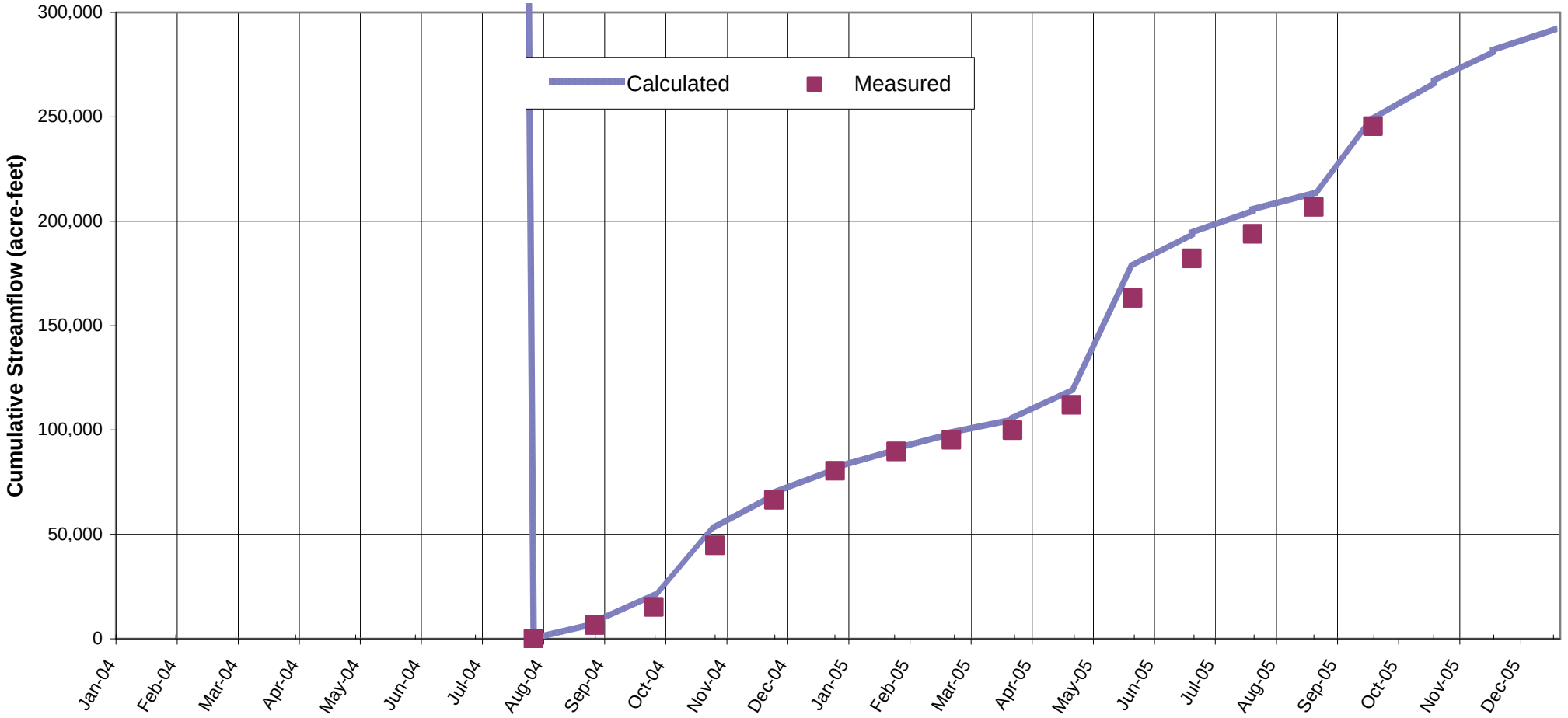

Figure 11 Measured and Calculated Streamflow
SK100C (Area 5)

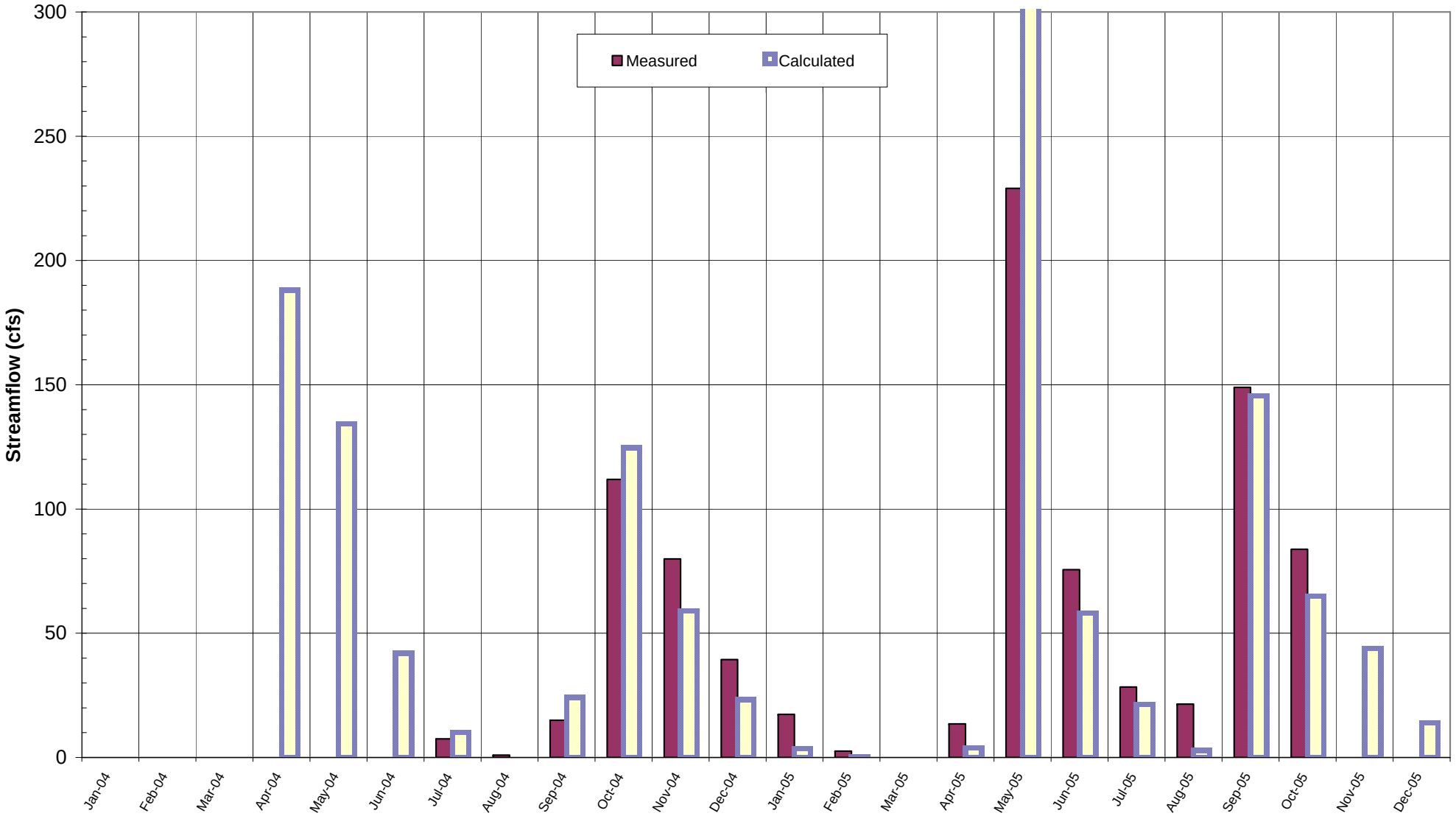

Figure 12 Calculated and Measured Cumulative Streamflow SK100C

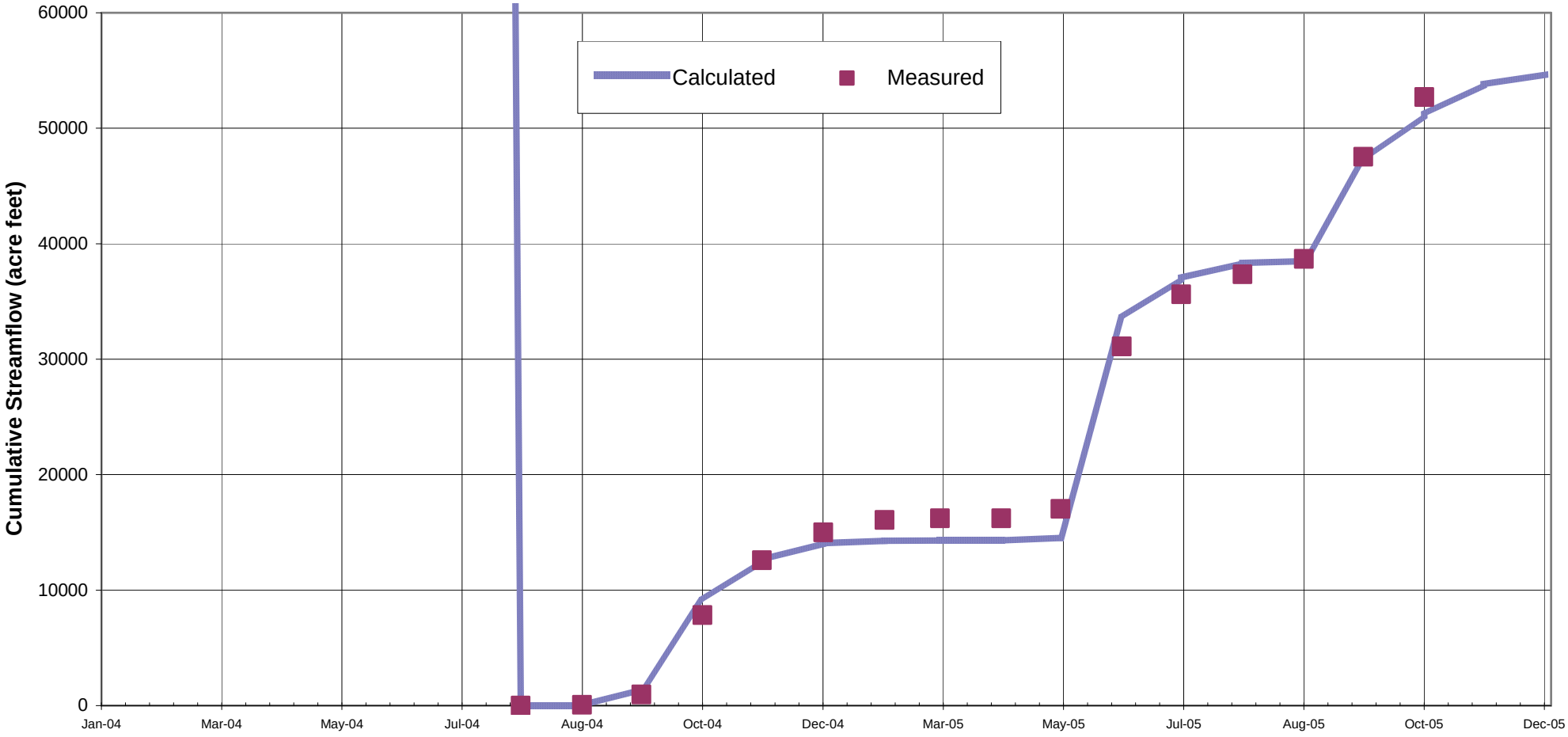

Figure 4 MW-1S comparison with Calculated volume

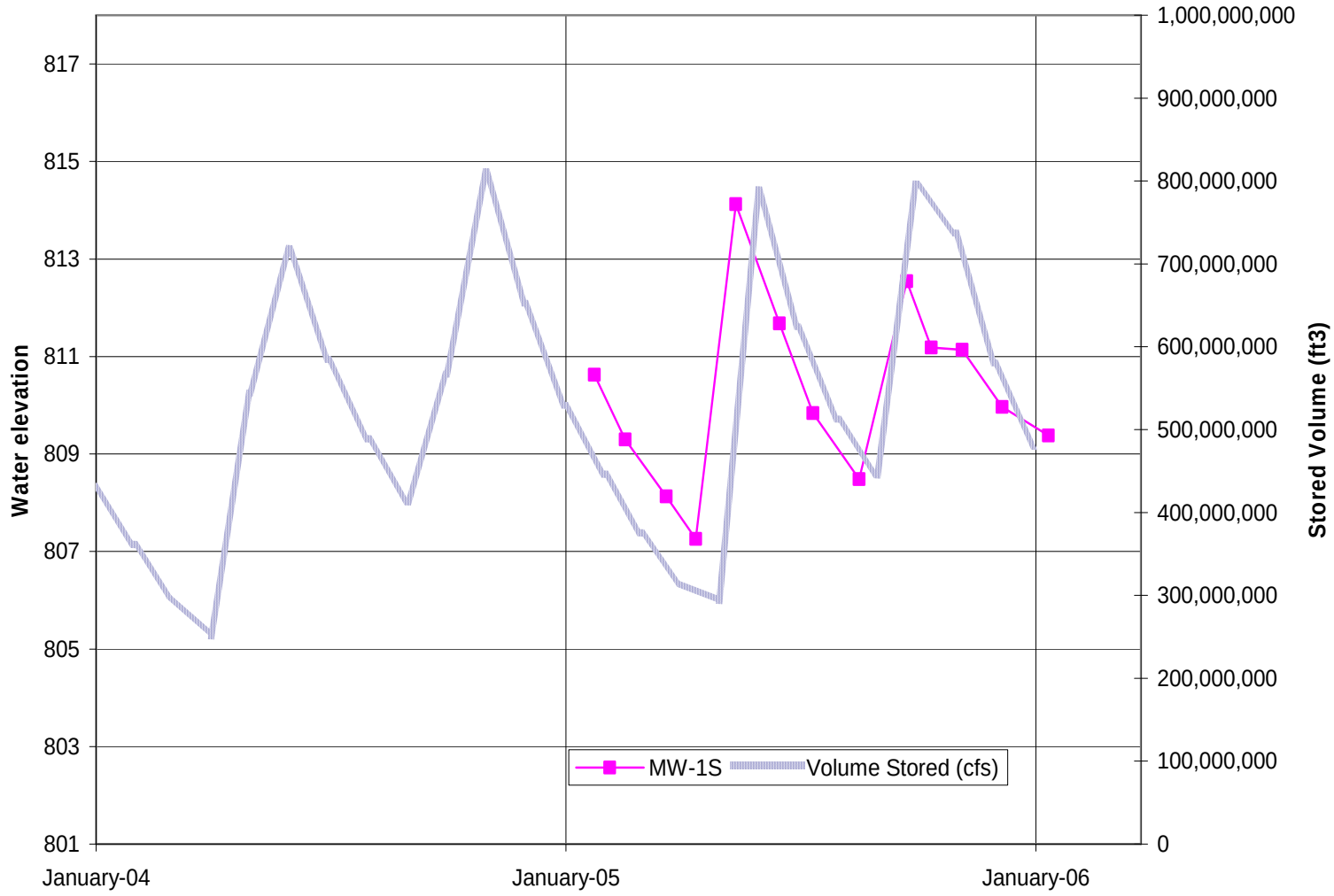

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Figure 1 - Calculated Flows for South Fork Koktuli
Pre-Mine Conditions (cfs)