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MEMORANDUM

DATE: November 18, 2008
TO: Christopher Prucha (WM)
C.C:
FROM: François Richard and David Harding (WESA)
PROJECT #: K-B5691-6
SUBJECT: **MOE Review Comments on 2006 Annual Monitoring Report, Richmond Landfill: Apparent increasing trends in chloride concentrations at several on-site monitors**

MESSAGE:

Chris:

The following comment made by MOE hydrogeologist Kyle Stephenson in his review of the 2006 annual monitoring report for the WM Richmond Landfill site was raised during a meeting held in Kingston on November 5, 2008. The comment (shown below) relates to an "apparent trend of increasing chloride concentrations" at groundwater monitoring locations.

> As part of the trend analysis, the consultant should further assess the apparent trend of increasing chloride levels at several on-site monitoring wells (e.g. M43, M45, M9, 2054 and 2055). For example, chloride levels at monitoring wells 2054 and 2055 have significantly increased since they were first monitored in 1994. These wells were constructed as open-hole drilled wells and would be expected to obtain water from shallow fresh water zones and from deeper zones where poorer water quality is present. The trend of increasing chloride concentrations at these wells suggests that the quantity of water from the shallow fresh water zone has been reduced which has also reduced the dilution of deeper poor quality groundwater. This trend is also apparent at other site monitoring locations which monitor discrete intervals/zones. As part of their assessment, the consultant should determine how the landfill may be influencing the shallow fresh groundwater zone and area groundwater quality.

This memorandum has been prepared to address the reviewer's comments.

The increasing trend in chloride concentrations observed in some monitors results from upconing of naturally saline deep groundwater from well purging, and is not related to landfilling activities.

Dilution of saline groundwater from fresher shallow groundwater is apparent in open borehole 2054. Low volume purging procedures were implemented in 2003 following a significant spike in chloride concentrations (14,000 mg/L) caused by upcoming of saline groundwater. Concentrations have been decreasing steadily ever since the low flow purging techniques were implemented (130 mg/L in April 2008). Chemistry in well 2055 shows a similar mixing of deep saline groundwater with fresh groundwater from shallow water bearing zones. While the well was an open borehole, the concentrations of chloride were low (median 69 mg/L between 1994-99), but increased drastically following monitor installation in

1999, thus preventing seeping of shallow groundwater into the well bore (median 34,500 mg/L between 1999-2007).

The following prevents a summary of the evaluation of the trends recommended by the reviewer. All historical chloride concentrations available for the cited wells as well as for leachate (South Chamber and North Chamber) are shown on the attached graphs, along with historical water levels. Monitor construction and other relevant details are shown in Table 1, while historical chloride concentrations are summarized in Table 2.

The following are noted:

- Leachate chloride concentrations are much lower than most of the cited monitors:
  - Median chloride concentration (North & South Chambers combined): 876 mg/L
  - North Chamber: 278-1,950 mg/L (median 744 mg/L)
  - South Chamber: 563-2,780 mg/L (median 1,850 mg/L)

- 2054: Open borehole (36.6 mbgs), not a proper monitoring well. Chloride concentrations starting in 2003 are indicative of deep saline groundwater, well above leachate levels (median 876 mg/L). Huge increase between 2002-2003 from about 500 mg/L to over 14,000 mg/L but decreasing since. This suggests that well purging caused upconing of the deep seated saline groundwater interface; the smaller volume well purging procedures have been used since approximately 2003 explain the gradual decline.

- 2055: Open borehole (30.2 mbgs) until July 21, 1999 when the well was instrumented with a deep groundwater monitor (30.8-33.8 mbgs). Chloride concentrations are indicative of deep saline groundwater (median 21,700 mg/L), well above leachate levels (median 876 mg/L). Steadily increasing chloride and water level since 2000 indicate extremely low hydraulic conductivity for this monitor.

- M9: Deep monitor (M9-1, replaced in 1999 by M9R-1) with chloride concentrations indicative of deep saline groundwater (median 5,910 mg/L (M9-1) and 23,802 mg/L (M9R-1)), well above leachate levels (median 876 mg/L). Increasing water level in M9R-1 since installation indicates extremely low hydraulic conductivity. Chloride concentrations in intermediate and shallow monitors below 250 mg/L, with no increasing trend apparent. The integrity of this multilevel well is suspect: water levels in M9-2 and M9-3 fluctuate in unison, indicative of compromised seal between screens.

- M43: All three screens (multilevel well) are deep (> 30 m below bedrock) and saline (median concentrations 39,700 mg/L (M43-1), 10,095 mg/L (M43-2) and 2,075 mg/L (M43-3)), well above leachate levels (median 876 mg/L). Increasing trends in the deepest two (M43-1 and M43-2) are likely related to upconing of saline interface caused by purging. The integrity of this multilevel well is suspect: water levels in M43-2 and M43-3 fluctuate in unison, indicative of compromised seal between screens.

- M45: All three screens (multilevel well) are deep (> 10 m below bedrock) and saline (chloride up to greater than 100,000 mg/L), with increasing trends likely related to upconing of saline interface caused by purging; this well is located at the north extremity of the property, hydraulically upgradient from the landfill. The integrity of this multilevel well is suspect: water levels in M45-1 and M45-2 fluctuate in unison, indicative of compromised seal between screens.

The elevated – and in some cases extreme – chloride concentrations observed in some of the monitoring wells cited by the MOE reviewer are significantly higher than chloride concentrations in leachate (less than 2,000 mg/L, with a median of 876 mg/L), consistent with upconing of naturally saline connate water. The increasing trend in chloride concentrations observed at these (deep bedrock) locations results from upconing of the deep groundwater saline interface caused by well purging associated with sampling, and are not related to the landfill.

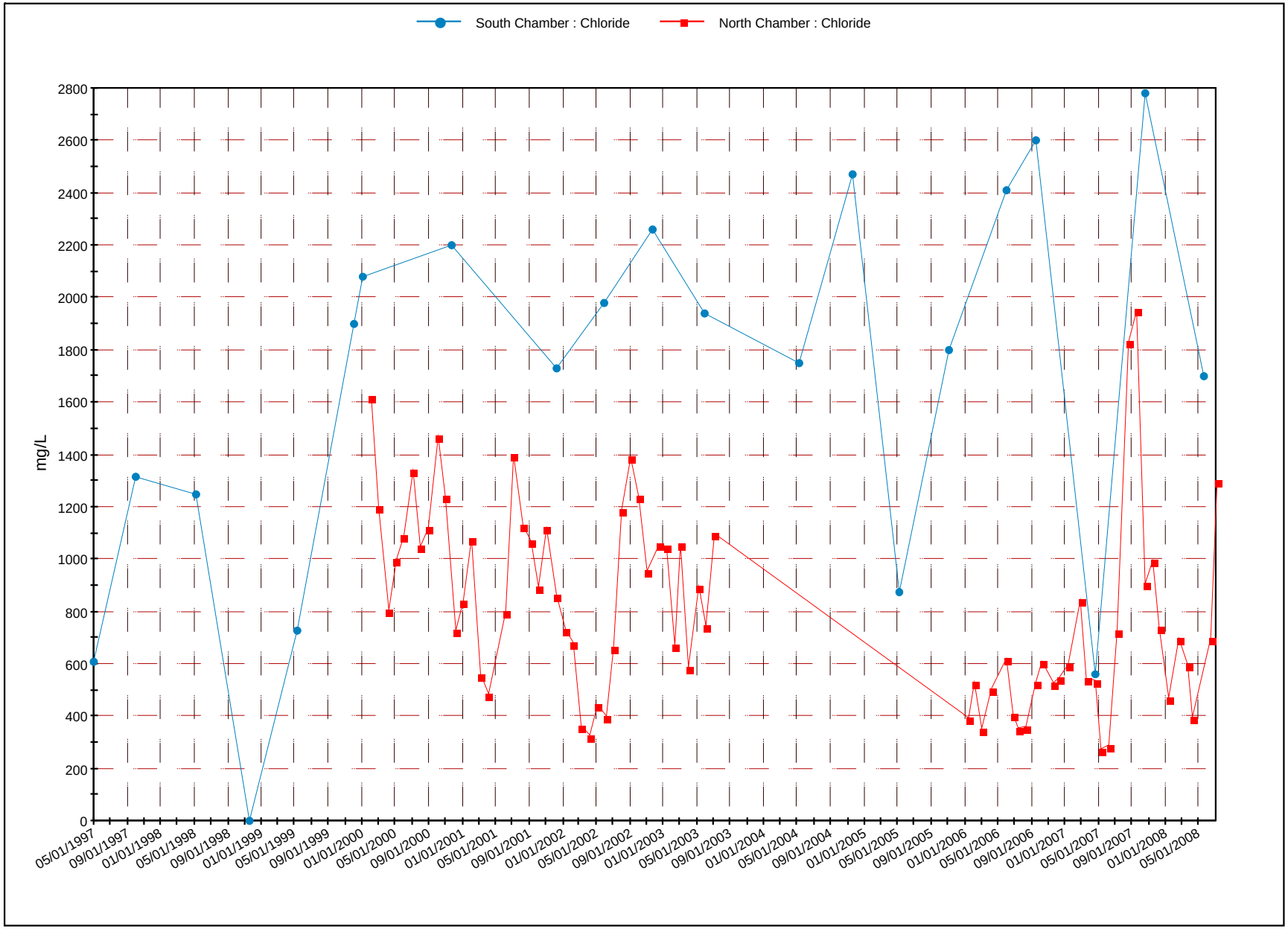
SUPPORTING INFORMATION

Table 1. Groundwater Monitor Details

Monitor	Drill Date	Install Type	Unit	Ground Elev. (masl)	Bedrock Elev. (masl)	Overburden Thickness (m)	Monitor Top Depth Below Bedrock Surface (mbBR)	Monitor Bottom Depth Below Bedrock Surface (mbBR)
2054	1949	open BH	n/a	128.0	121.90	6.10	1.22	30.50
2055	1966	multilevel	>10 mbBR	124.8	122.42	2.40	28.40	31.40
M9-1	1991	multilevel	>10 mbBR	124.8	121.90	2.90	25.10	27.30
M9-2	1991	multilevel	>10 mbBR	124.8	121.90	2.90	15.60	20.10
M9-3	1991	multilevel	3-10 mbBR	124.8	121.90	2.90	6.40	7.90
M9R-1	1999	single	>10 mbBR	125.5	122.02	3.51	25.12	28.17
M43-1	1991	multilevel	>10 mbBR	127.0	123.60	3.41	51.59	55.68
M43-2	1991	multilevel	>10 mbBR	127.0	123.60	3.41	44.09	47.09
M43-3	1991	multilevel	>10 mbBR	127.0	123.60	3.41	30.09	31.59
M45-1	1995	multilevel	>10 mbBR	126.8	125.64	1.20	54.80	59.76
M45-2	1995	multilevel	>10 mbBR	126.8	125.64	1.20	26.20	29.28
M45-3	1995	multilevel	>10 mbBR	126.8	125.64	1.20	12.20	14.00

Table 2. Historical Chloride Concentrations

Monitor	Chloride Concentrations (mg/L)				
	Data since	# samples	Minimum	Maximum	Median
North Chamber	2000	71	278	27000	865
South Chamber	1997	20	400	2260	1123.5
2054	1994	30	7	14400	283
2055	1994	29	47	44100	21700
M9-1	1991	7	811	28560	5910
M9-2		18	42	435	59
M9-3		18	31	420	114
M9R-1	1999	10	20400	27000	23802
M43-1	1992	15	15109	78300	39700
M43-2		10	4500	49200	10095
M43-3		16	1099	5318	2075
M45-1	1995	14	1300	122000	75850
M45-2		10	2010	80700	44650
M45-3		11	1790	74332	57900


South Chamber : Chloride
North Chamber : Chloride
mg/L
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
05/01/1997
09/01/1997
01/01/1998
05/01/1998
09/01/1998
01/01/1999
05/01/1999
09/01/1999
01/01/2000
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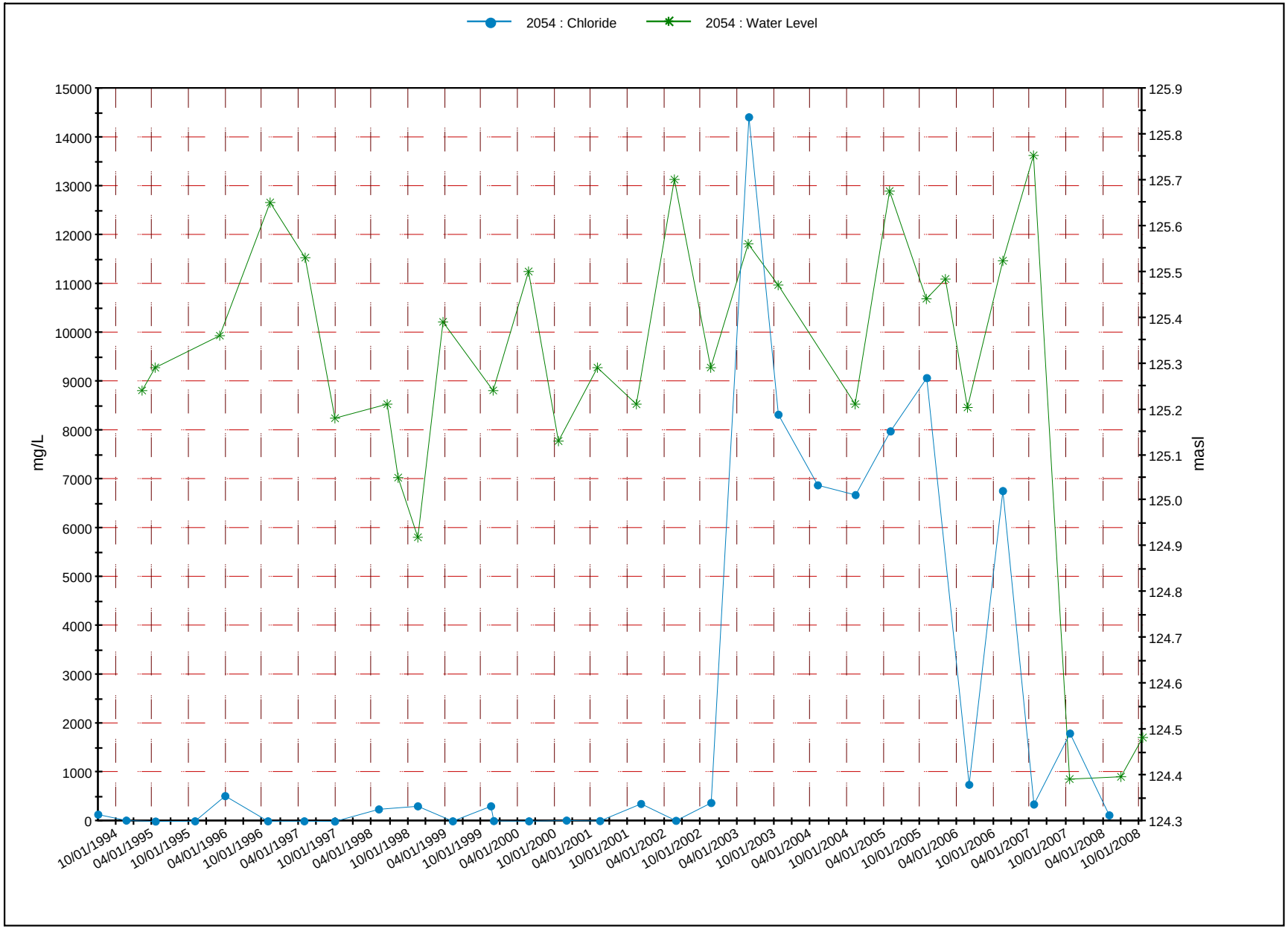
09/01/2007
01/01/2008
05/01/2008


2054 : Chloride
2054 : Water Level
mg/L
masl
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
125.9
125.8
125.7
125.6
125.5
125.4
125.3
125.2
125.1
125.0
124.9
124.8
124.7
124.6
124.5
124.4
124.3
10/01/1994
04/01/1995
10/01/1995
04/01/1996
10/01/1996
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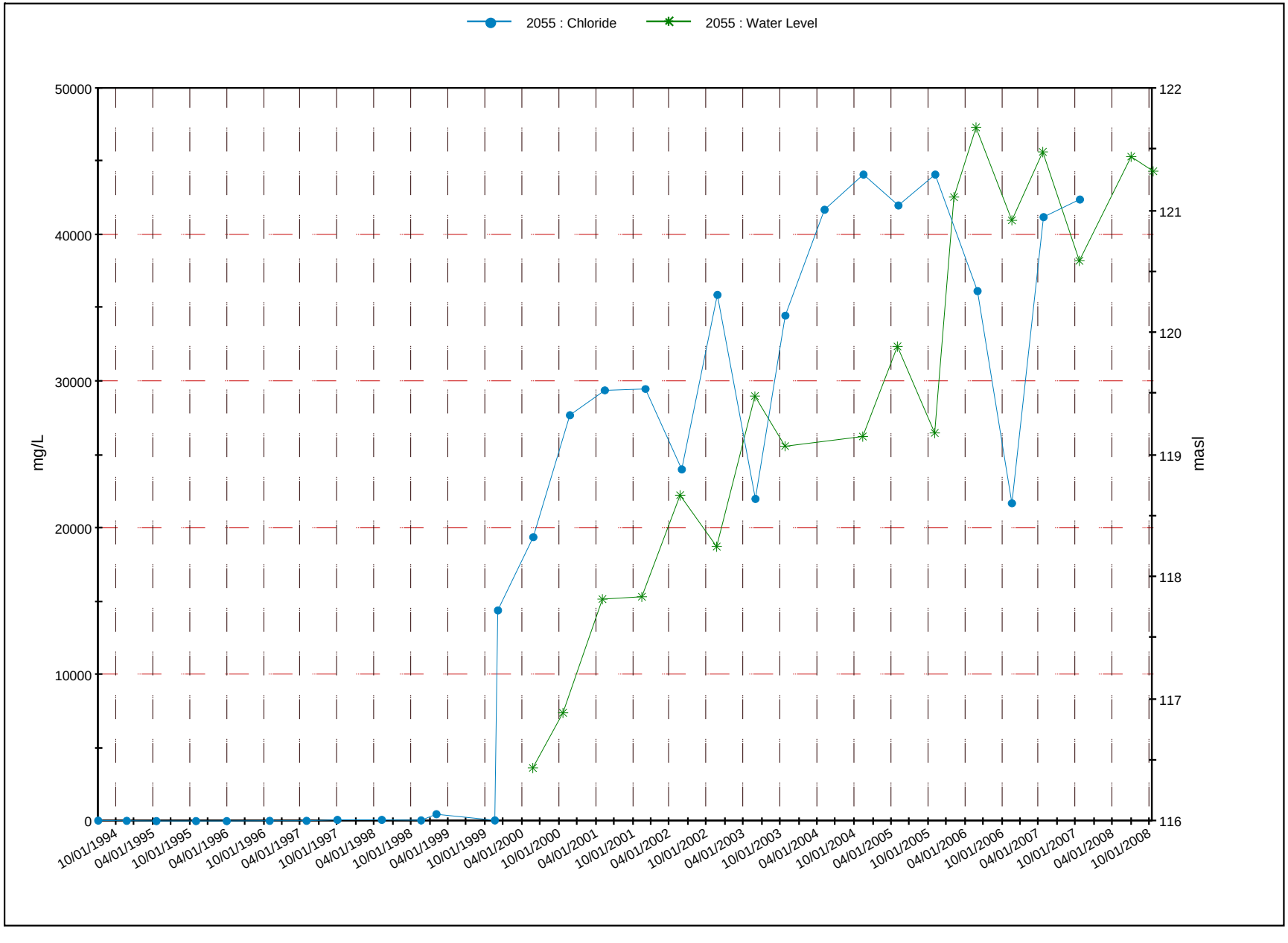
10/01/2008


2055 : Chloride
2055 : Water Level
mg/L
masl
50000
40000
30000
20000
10000
0
122
121
120
119
118
117
116
10/01/1994
04/01/1995
10/01/1995
04/01/1996
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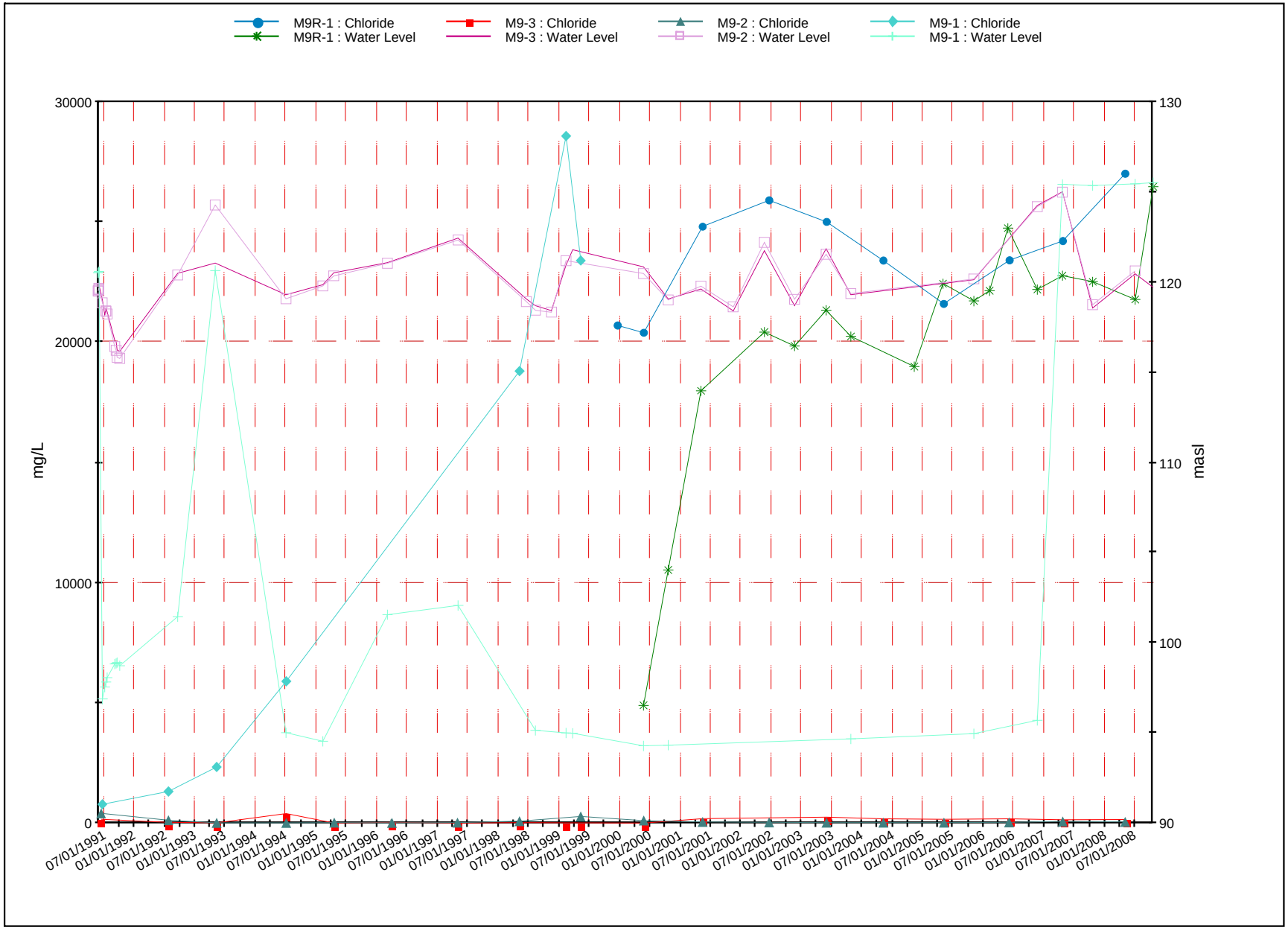
M9R-1 : Chloride
M9R-1 : Water Level
M9-3 : Chloride
M9-3 : Water Level
M9-2 : Chloride
M9-2 : Water Level
M9-1 : Chloride
M9-1 : Water Level
mg/L
masl
30000
20000
10000
0
130
120
110
100
90
07/01/1991
01/01/1992
07/01/1992
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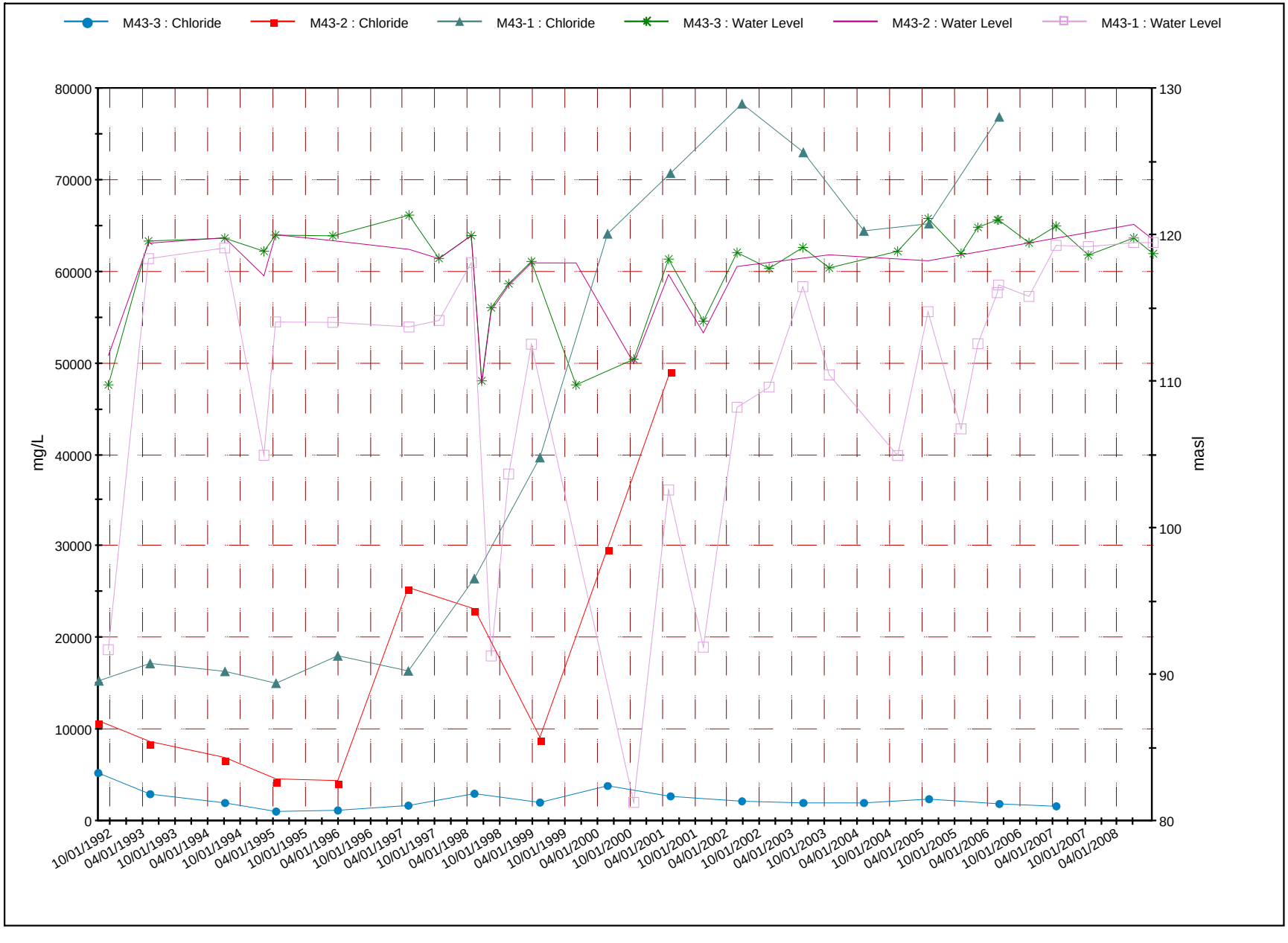
M43-3 : Chloride
M43-2 : Chloride
M43-1 : Chloride
M43-3 : Water Level
M43-2 : Water Level
M43-1 : Water Level
mg/L
masl
80000
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90
80
10/01/1992
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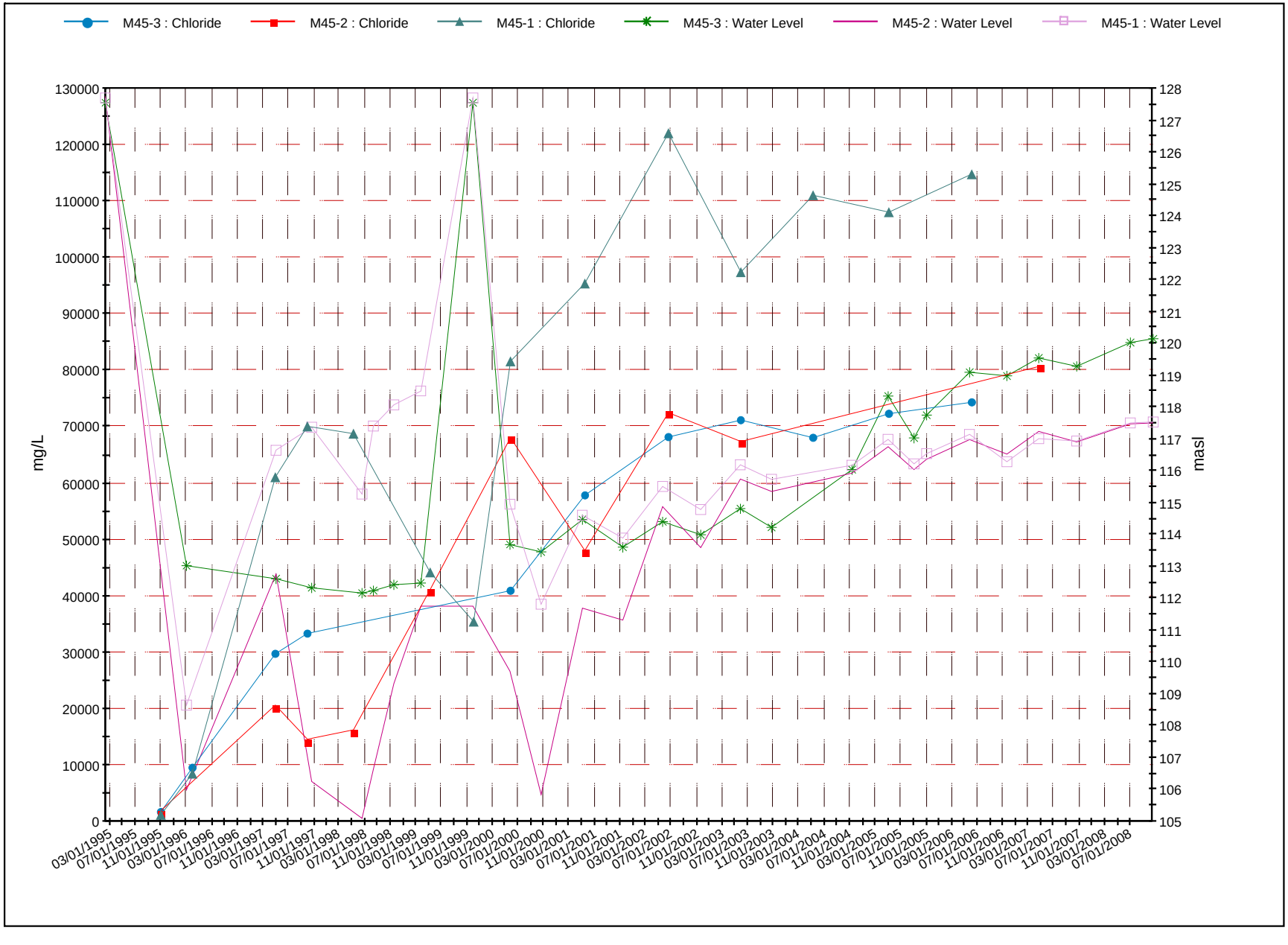
M45-3 : Chloride
M45-2 : Chloride
M45-1 : Chloride
M45-3 : Water Level
M45-2 : Water Level
M45-1 : Water Level
mg/L
masl
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