

TECHNICAL MEMORANDUM

To: Bill Slater and Fred Green **Date:** 20 Sept 2016
Cc: Patricia Randell, Erik Pit, Emilie Hamm, Chris Dixon,
Jason Berkers, and Paul LePage **Project #:** A399-1
From: Alan Martin and Justin Stockwell (Lorax Environmental Services Ltd.)
Subject: Mount Nansen – 2016 Water Quality Update – **FINAL**

1.0 Introduction

The following memorandum provides a preliminary assessment of current water quality conditions at the Mt. Nansen Mine. Emphasis is placed on recent water quality trends (since 2010) in Dome Creek and Victoria Creek. Surface water sampling locations are shown in Figure 1. Groundwater sampling locations are shown in Figure 2.

The purpose of this memorandum is to provide a preliminary assessment of surface water and groundwater conditions at Mt. Nansen, as defined in Task 1 of the project scope of work (Slater Environmental, 2015). The results of this preliminary assessment will inform the scope and approach from which the remaining tasks of the Mount Nansen water quality review and aquatic risk assessment will be completed.

2.0 Water Quality Assessment

The water quality assessment has been divided spatially to assess the influence of the various contaminant source areas. In this regard, the assessment is presented for the following areas, from upstream to downstream:

- Mill Area and Upper Dome Creek;
- Tailings Facility (Tailings Pond, Tailings Area Groundwater, Seepage Pond);
- Lower Dome Creek; and
- Victoria Creek.

2.1 Mill Area and Upper Dome Creek

To assess the cumulative effect of contaminant sources associated with the mill site and waste rock, water quality for upper Dome Creek (up-gradient of the Tailings Pond) was assessed through inspection of data collected since 2010 for the following locations (listed from upstream to downstream):

- DC-DX: Dome Creek upstream of mine-related influences;

- DC-DX+105: Dome Creek adjacent to the mill area and downstream of the Huestis Workings;
- DC-D1: Downstream of mill area, upstream of D1B. May not capture all loadings from mill area and waste rock (data collected up to May, 2013);
- DC-D1b: Downstream of D1 (data for May 2012 to December 2015);
- DC-U1, DC-U2: South and north forks of Dome Creek, respectively, approximately 300 m upstream of tailings pond (data for May 2012 to November 2013); and
- DC-B: Tailings diversion channel downstream of all mill and waste rock loading areas (2014-2015 data).

At the upstream control location (DC-DX), time series profiles for major ions (Figure 3) and trace elements (Figure 5) show generally stable seasonal cycles, with pronounced minima observed during freshet. In contrast, the data for dissolved Mn and Fe at DC-DX show episodic spikes in concentration that are not observed for other parameters.

Long-term trends in Upper Dome Creek are not easily discerned given the relative lack of long-term time series data for a single location. Downstream of mine-related influences, DC-DX+105 shows the longest period of record for water quality monitoring (April 2012 to present). This site is the uppermost mine-impacted water quality sampling location on Dome Creek, and is located adjacent to the mill area and downstream of the historic Huestis Workings. Time series data for DC-DX+105 illustrate pronounced mine-related signatures with respect to major ions (SO₄, Ca and alkalinity; Figure 3) and several trace elements (Mn, As, Cd and Zn; Figure 4 and Figure 5). The magnitude of the elevated Zn concentrations at DC-DX+105 is not persistent across the drainage and could not be linked to Zn values in mill-area groundwater wells (SLR, 2015b). As described in Lorax, 2010, elevated Zn concentrations are likely associated with localized, point-source contamination associated with mine waste proximal to the historic settling ponds and potentially associated with adit-related seepage inputs to the surface water system.

In terms of temporal trends, values for SO₄, Ca and alkalinity at DC-DX+105 have remained relatively constant since 2012. In contrast, the time series profiles for As, Cd and Zn show evidence of decreasing values. Dissolved As, for example, shows a dramatic drop in concentration in 2013, while Cd and Zn show more gradual and congruent declines over the period of record (Figure 5).

Downstream of DC-DX+105 at DC-D1b, major ions (e.g., SO₄ and Ca) show generally higher concentrations, reflecting additional mine-related inputs upstream of this location (Figure 3). These major ion signatures show evidence of further increases at DC-B, possibly indicating the influence of waste rock drainages. In contrast to the major ion parameters, concentrations of As, Cd and Zn show progressive decreases in concentration from upstream (DC-DX+105) to downstream (DC-B). The data for dissolved Cd and Zn, for example, show strong parallels,

illustrating that similar processes govern their remobilization and attenuation within Upper Dome Creek (Figure 5). For both parameters, the highest values are observed at DC-DX+105, with progressively lower values occurring with distance downstream to minima at DC-B. Dilution may play a role in the observed decrease as flows increase by roughly a factor of 10 between the two sites, however other mine signatures (e.g., SO₄ and Ca) show increasing trends with distance downstream (Figure 3). Based on these combined observations, the decrease in Cd and Zn between DC-DX+105 and DC-B is interpreted to reflect the attenuation processes along the creek system flowpath and is consistent with the data and interpretations provided in Lorax (2010) and SLR (2015b). The exact nature of the attenuation processes has not been defined, but likely include to some degree, adsorption/co-precipitation with Fe/Mn oxides, and possibly adsorption to organic substrates.

The magnitude of attenuation in Lower Dome Creek is significant, with values for As, Cd, and Zn at DC-B being very similar to background ranges observed at DC-DX (Figure 5). The concentrations measured at DC-B are also lower than values measured in the Tailings Seepage Pond and downstream at DC-U and DC-R, indicating that Upper Dome Creek contributes negligibly to the Cd and Zn signatures in Lower Dome Creek.

With respect to redox-related parameters, dissolved Fe and Mn show the highest values at DC-B. Dissolved Fe and Mn are not stable in neutral, aerated waters. Given the circum-neutral pH conditions, the elevated levels of Fe and Mn are predicted to reflect the input of suboxic (reduced) waters to the creek system (Figure 4).

2.2 Tailings Facility

Current water quality conditions for the tailings facility were examined with respect to the Tailings Pond, tailings area groundwater, and Tailings Seepage Pond.

Tailings Pond

Major ion concentrations in the Tailings Pond show a consistent seasonal pattern of minima during freshet (typically May), and increasing over the summer/fall/winter to maxima in the late winter period (April) (Figure 6). Superimposed on this seasonal cycle is a trend of decreasing major ion values since 2010, with both the annual minima and maxima generally showing lower values over time. Tailings pond pH values have remained stable (most values 7.2<pH<8.2). With respect to redox-related parameters, data for dissolved Fe, Mn, nitrite (NO₂-N) and ammonia (NH₃-N) show variable values, with no discernible inter-annual trends (Figure 7). In contrast, nitrate (NO₃-N) has shown a trend of declining concentrations since 2010, with all values in 2015 being <0.2 mg/L.

Trace element data for the Tailings Pond show mixed trends (Figure 8). Dissolved Co, Cu and Ni, for example, show generally decreasing concentrations since 2010. In contrast, As, Cd, and Zn do

not show any definitive inter-annual trends, with the exception of decreasing annual minima since 2010 (Figure 8). Chromium shows a pronounced decline in concentration beginning on April 17, 2013. This date coincides with decreases for other trace elements (Pb and Se) and NO₂-N, as well as a transition to higher detection limits for chloride, thiocyanate and cyanate. These observed changes may reflect a systemic analytical change (e.g., laboratory, instrument or methodology change) and are assumed to not be related to changes in the natural environment.

Tailings Area Groundwater

Water quality data for groundwater wells in the tailings facility are shown for major ions and pH (Figure 9), trace elements (Figure 10) and redox-related parameters (Figure 11). In general, major ions show seasonal and spatial variability. Data from piezometer MP09-12 are generally interpreted to be representative of background conditions and are shown in bold for comparison to other locations. With respect to major ions, SO₄ shows significant temporal variability with some evidence of increasing concentrations at MW09-1, MW09-2, and MW09-22. Data from MW09-1 should be viewed with caution, however, as the well head is reportedly cracked at surface (Hemmera, 2016) and likely has been contaminated by near-surface tailings and/or pond water. Possible SO₄ increases are evident at MW09-22, which shows a trend towards higher values in 2014 and 2015 (809 to 1990 mg/L) in comparison to values in 2009 and 2011 (70 to 156 mg/L).

Increases in SO₄ concentration as a result of sulfide mineral oxidation may be expected to also show increases in the levels of calcite neutralization products (e.g., Ca), and decreases in porewater, alkalinity, and pH. Indeed, the increases in SO₄ in MW09-22 are accompanied by commensurate increases in dissolved Ca and decreases in total alkalinity (Figure 9), suggesting the SO₄ additions may reflect the early stages of enhanced sulfide oxidation within the tailings facility, however the evidence for this is limited. Possible pH depression may also be evident at MW09-22, which shows a trend towards lower values in 2014 and 2015 (6.3 to 6.7) in comparison to values in 2009 and 2011 (6.9 to 7.4). Similar increases in dissolved Ca are observed at MW09-21, although alkalinity and pH values remain relatively stable. MW09-1 also shows pronounced increases in the concentrations of both dissolved Cd and Zn in 2013-2015, with 2015 maxima of 0.03 mg/L and 3.0 mg/L, respectively (Figure 10). Repair of MW09-1 and continued monitoring will be required to confirm if these measurements represent a change in porewater chemistry or an artifact of well disrepair and tailings pond contamination.

Overall, the data trends described above may indicate the transition towards acid generating conditions within the tailings mass. However, the data do not allow for definitive conclusions given the subtle changes in groundwater values. A transition towards acid generating conditions could result from: 1) depletion of neutralization potential (e.g., dissolution of carbonate minerals) in the tailings; and/or 2) enhanced sulfide mineral oxidation. With regards to the latter, pond water elevations in 2015 were 0.5 to 1 m lower than those in 2012-2013. Lower water elevations in the

tailings area would result in a greater degree of tailings de-saturation, which in turn could promote higher rates of sulfide mineral oxidation. In this regard, water management in the Tailings Pond may serve as an effective measure to minimize the extent of tailings de-saturation and acid generating processes; however, any geotechnical risks associated with such activity would need to be assessed and managed accordingly.

Inspection of redox-related parameters shows evidence for increasing Mn values in most wells since 2013, including MW09-1, MW09-2, MW09-3, MW09-21, MW09-22 and MW09-23 (Figure 11). Of these wells, MW09-2, MW09-21 and MW09-22 also show increases in dissolved Fe concentration in recent years. These observations may indicate a trend towards more reducing conditions in tailings porewaters, as supported by data for the Seepage Pond (discussed below).

Tailings Seepage Pond

Water quality data for the Tailings Seepage Pond represent a robust indicator of the overall environmental performance of the facility, as the waters that accumulate in this pond reflect the net contribution remobilization and attenuation processes that occur within the Tailings Pond, tailings porewater, and in underlying substrates.

Time series profiles of major ions for the Tailings Seepage Pond show trends of increasing concentration for TDS, SO₄ and Ca from 2011 to maxima in 2014, with values decreasing over the last half of 2014 and 2015 (Figure 12). These trends are not mirrored in the Tailings Pond, which typically shows trends of decreasing concentration for most salinity proxies (Figure 6). These observations suggest the trends in TDS, SO₄ and Ca in the Seepage Pond reflect processes within the tailings mass. This is supported by increasing values for SO₄ and Ca in some monitoring wells since 2010, including MW09-1, MW09-21 and MW09-22. As outlined above, increasing values for SO₄ and Ca may indicate the early stages of enhanced sulfide mineral oxidation.

Alkalinity and pH in the Seepage Pond show variable, though stable conditions (Figure 12). Sodium shows a progressive decline in concentration in the Seepage Pond since 2010 (Figure 12). Sodium is positively correlated with SCN, suggesting the Na decrease reflects the progressive flushing of residual cyanide mill reagents (added as NaCN). This trend is consistent with generally decreasing Na values in the Tailings Pond (Figure 6).

Inspection of redox-related parameters for the Seepage Pond shows evidence of changing redox conditions within the tailings facility. Specifically, dissolved Fe shows a pronounced increase in concentration from <5 mg/L (2010) to a maximum of 20 mg/L in early 2015 (Figure 13). Dissolved Mn also shows evidence of modest increasing concentrations, with maximum values observed in late 2014 and early 2015. Given the neutral pH conditions of seepage waters, such increases are interpreted to represent the enhanced reductive dissolution of Mn(IV)- and Fe(III)-oxide phases within the tailings mass.

The onset to more vigorous Mn(IV) and Fe(III) reduction may result from decreased availability of NO₃-N, which has shown a pronounced decrease in concentration since 2011 (maximum of 5.5 mg/L) to 2015 values ≤ 1 mg/L (Figure 13). In reduction-oxidation (redox) reactions in tailings porewaters, NO₃ will serve as a preferential electron acceptor over Mn(IV) and Fe(III) as dictated by thermodynamics. Specifically, redox conditions in saturated tailings are governed by a series of microbially-mediated redox reactions in which reduced carbon compounds (e.g., dissolved organic carbon - DOC) serve as electron donors to various oxidants that serve as terminal electron acceptors. The reaction sequence proceeds in an order which is determined by the net free energy yield, with aerobic oxidation (oxygen reduction) being the most favourable. In the absence of oxygen, nitrate presents the next most favourable reaction. Following nitrate reduction (denitrification), the redox sequence proceeds via Mn(IV)-oxide reduction, Fe(III)-oxyhydroxide reduction, sulfate reduction, and methanogenesis (CO₂ reduction) (Froelich et al., 1979).

Within the context of the tailings facility, the Seepage Pond data potentially illustrate a transition in redox conditions towards less denitrification and greater reduction of Mn(IV)- and Fe(III)-oxides. Specifically, the data suggest the tailings system has entered a stage of nitrate limitation, whereby other redox reactions are now favoured. This conclusion is supported by groundwater data, which show increasing trends for dissolved Mn and Fe in several wells. The absence of a notable increase in Mn concentration in the Seepage Pond as compared to Fe may relate to the higher Mn values in the Tailings Pond (up to ~10 mg/L) (i.e., the higher Tailings Pond values may overwhelm the signature associated with reductive dissolution reactions within the tailings mass).

The transition towards more suboxic conditions within the tailings area is further supported by the data for dissolved As (Figure 14) which show an increase very similar to that of Fe. Indeed, the two parameters are strongly correlated ($r^2 = 0.73$). Arsenic shows a strong affinity to Fe oxides, and the congruent nature of their concentration profiles strongly suggest that As is being remobilized via the reductive dissolution of As-bearing Fe-oxyhydroxides.

Dissolved Zn concentrations show a pronounced increase in Seepage Pond waters in 2015 and 2016, from pre-2015 values of <0.02 mg/L to maxima of 0.09 mg/L (February 2015) and 0.12 mg/L (February 2016) (Figure 14). In both 2015 and 2016, the Zn peaks occur in the winter low-flow period when inputs to the Seepage Pond will be minimally diluted with surface runoff. This implies the Zn increases can be attributed to processes occurring within the tailings facility, and input to the pond via seepage pathways. The Zn increase in 2015 does not correlate with Fe and As, nor with concentration trends in the Tailings Pond, suggesting other process contribute to the observed increases. Evidence for enhanced sulfide mineral oxidation (as shown by data for SO₄, Ca and alkalinity in groundwater), and elevated Zn values in groundwater well MW09-1, may imply the Seepage Pond increases are linked to sulfide oxidation and acid generating reactions within the tailings mass.

Dissolved Cd also shows a peak in concentration in 2015, on the same day as observed for Zn (February 16, 2015), suggesting the behaviour of both elements are governed by similar controls. From a remobilization perspective, both Zn and Cd are predicted to be hosted in common sulfide phases in the tailings (e.g., co-occurrence in sphalerite), and therefore sulfide mineral oxidation processes would affect both elements. From an attenuation perspective, both Cd and Zn will be predicted to also share similar behaviours (e.g., removal as secondary sulfide phases).

Other possible explanations to account for the dramatic increases in Zn concentration in 2015 and 2016 may include (as outlined in SLR, 2015a): 1) non-steady-state feature condition associated with the breakthrough of a water parcel with elevated Zn (as supported by elevated Zn values in some wells); 2) reduction in Zn attenuation processes within tailings porewaters and/or underlying organic substrate; and 3) changes in flow patterns, permafrost distribution, and attenuation processes associated with warming temperatures. In SLR (2015a), no specific anomalies in the site snow/ice and hydrology data were identified that could account for the increase in Zn concentrations in the Seepage Pond.

In terms of other trace elements, dissolved Cu, Ni and Cr show progressively decreasing concentrations since 2010. The sharp transition in Cr values is interpreted to reflect a change in analytical protocols, given that the decrease observed on April 17, 2013 overlaps with similar jumps in concentration for Ni and Se.

2.3 Lower Dome Creek

Water quality trends for the Tailings Seepage Pond were compared to data for Lower Dome Creek (DC-U and DC-R) to assess the magnitude of downstream water quality impacts:

- DC-U: Lower Dome Creek, approximately 250 m downstream of the Seepage Pond and immediately downstream of the Dome Creek diversion channel;
- DC-R: Lower Dome Creek at road, approximately 1,500 m downstream of Seepage Pond;

As outlined in Section 2.2, several parameters show recent increases in concentration in the Seepage Pond (SO₄, Fe, Mn, Zn, Cd), while NO₃-N concentrations have been decreasing. The increase in SO₄ concentration observed between 2012 and 2014 is evident in lower Dome Creek at both DC-U and DC-R (Figure 15). With respect to redox-sensitive parameters, the dissolved Mn peak in the Seepage Pond in 2014 is congruent with peak values at DC-U (Figure 16). However, evidence for increasing trends in Mn concentrations over time is not apparent further downstream at DC-R. Comparison of Mn data between DC-U and DC-R suggest a slight effect of dilution downstream similar to SO₄. In contrast, the relative effect of dilution on Fe is markedly different as Fe concentrations show seasonal increase between DC-U and DC-R. Further, the progressive rise in dissolved Fe concentrations in the Seepage Pond since 2010 is not evident at

DC-U nor DC-R (Figure 16), suggesting that Fe is not behaving conservatively downstream of the Seepage Pond.

The data for dissolved Mn and Fe suggest both elements are being attenuated in lower Dome Creek via the precipitation of Fe-Mn oxyhydroxides. The dissolved Fe data specifically imply that a large proportion of the Fe attenuation occurs upstream of DC-U, while for Mn, the spatial scales of attenuation extend further downstream. It is possible these contrasts in behaviour relate to differences in reaction kinetics. Specifically, the kinetics of Fe oxidation/precipitation are very rapid (Davison, 1993), and would therefore expect Fe attenuation processes to occur within close proximity to the Seepage Pond. In contrast, the oxidation/precipitation kinetics for Mn can be slow, which could explain why Mn behaves relatively conservatively (e.g., similar to SO_4) in comparison to Fe.

With respect to trace elements, the elevated values observed for As, Cd, and Zn in the Seepage Pond in recent years are not clearly manifested in lower Dome Creek (Figure 17), suggesting commensurate attenuation of these elements with Mn and Fe. Comparison of downstream trends at DC-U and DC-R is somewhat hindered by the less frequent sampling collection at these sites. This is particularly evident for location DC-R, which has been sampled less frequently in the winter due to glaciation. The progressive decrease in $\text{NO}_3\text{-N}$ values since 2011 is evident in lower Dome Creek at both DC-U and DC-R (Figure 16).

Assuming attenuation products are accumulating in lower Dome Creek, the potential for their remobilization must be considered. The precipitation of secondary Fe/Mn-oxide phases within and downstream of the Seepage Pond presents a leading candidate to explain the attenuation of As, Cd and Zn in lower Dome Creek. The potential for the remobilization of these elements will therefore relate to the potential for the remobilization of the secondary Fe-oxide phases, which in turn requires suboxic conditions. The potential for suboxia may be affected by both spatial and temporal factors. On a spatial scale, the progressive burial of Fe oxides phases may promote the development of suboxia below the sediment-water interface. In a temporal context, suboxic conditions are more likely to develop during the winter period, when ice-cover may restrict water-atmospheric interaction.

2.4 Victoria Creek

Water quality data for Victoria Creek (2010-2015) were examined for the following locations to assess the magnitude of mine-related water quality impacts:

- VC-UMN: Victoria Creek downstream of Dome Creek, and upstream of Minnesota Creek;
- VC-R: Victoria Creek at road, downstream of Dome Creek and downstream of Minnesota Creek;

- VC-U: Victoria Creek control, 20 m upstream of Back Creek confluence. This location is predicted to be influenced by Back Creek only during very high freshet flows (e.g., April and May of 2015); and
- VC-DBC: Victoria Creek downstream of Back Creek confluence, but upstream of Dome Creek.

Time series profiles for VC-UMN and VC-R show a high level of congruency, illustrating the minimal influence of Minnesota Creek on water quality in Victoria Creek (Figure 18). Downstream of the Dome Creek confluence, mine-related signatures are evident in Victoria Creek with respect to SO₄, Fe, Mn, As, Cd and Zn (Figure 18), as illustrated by the data for VC-UMN and VC-R in comparison to upstream values (VC-U).

In terms of temporal trends, increases in SO₄ since 2010 have been evident at both VC-UMN and VC-R (Figure 18). At VC-R, the mean annual SO₄ concentration increased from 22 mg/L in 2010 to 39 mg/L in 2015. Inspection of the SO₄ data for Victoria Creek upstream of the Dome Creek confluence (VC-U and VC-DBC) also shows evidence of increasing values (Figure 19). However, the magnitude of SO₄ values at VC-U and VC-DBC is not sufficient to account for the increases downstream of Dome Creek, suggesting that the recent increases in SO₄ concentration at VC-UMN and VC-R can be linked to the higher values observed since 2010 in the Seepage Pond and Lower Dome Creek (i.e., tailings-related source).

For other parameters of interest (e.g., As, Cd, Fe, Mn and Zn), the water quality data for Victoria Creek downstream of Dome Creek (VC-UMN and VC-R) do not reveal any temporal trends, with the possible exception of dissolved Cd, which shows evidence of decreasing values since 2010 (Figure 18). This perceived decrease cannot be attributed to changes upstream, since data for both VC-U and VC-DBC show higher Cd values in recent years (Figure 19).

3.0 Conclusions and Recommendations

3.1 Conclusions

- Time series data for DC-DX+105 illustrate pronounced mine-related signatures with respect to major ions (SO₄, Ca and alkalinity) and several trace elements (Mn, As, Cd and Zn). Contaminant levels cannot be linked to values in mill-area groundwater wells, illustrating the likely importance of adit-related seepage inputs to the surface water system (e.g., Huestis Adit).
- In terms of temporal trends, values for SO₄, Ca and alkalinity at DC-DX+105 have remained relatively constant since 2012. In contrast, the time series profiles for As, Cd and Zn show evidence of decreasing values.

- Data for major ions (e.g., SO₄ and Ca) in Upper Dome Creek show generally higher values downstream at DC-D1b in comparison to DC-D1 and DC-DX+105, likely relating to seepage inputs from historic mine wastes deposited downgradient of the mill area.
- With respect to redox-related parameters in Upper Dome Creek, dissolved Fe and Mn show the highest values at DC-B. Given the circum-neutral pH conditions, the elevated levels of Fe and Mn are predicted to reflect the input of suboxic waters to the creek system.
- The data for dissolved Cd and Zn in upper Dome Creek show strong parallels, illustrating that similar processes govern their remobilization and attenuation. For both parameters, the highest values are observed upstream at DC-DX+105, with progressively lower values occurring with distance downstream to minima at DC-B. Such trends may be explained in part by dilution but are contradicted by increasing trends in SO₄ downstream. The evidence therefore suggests considerable attenuation of Cd and Zn within the creek system.
- The Cd and Zn concentrations measured at DC-B are lower than values measured in the Tailings Pond and Tailings Seepage Pond as well as downstream at DC-U and DC-R, indicating that Upper Dome Creek (DC-B) contributes negligibly to the Cd and Zn signatures in Lower Dome Creek (DC-U and DC-R).
- Tailings Pond waters have shown a progressive decline in salinity proxies (e.g., SO₄, Ca, TDS), several trace elements (Co, Cu and Ni) and NO₃-N since 2010. In contrast, As, Cd, and Zn do not show any definitive inter-annual trends in recent years.
- In tailings facility groundwater, SO₄ shows evidence of increasing concentrations in some wells since 2010, and in some cases, accompanied by commensurate increases in dissolved Ca and decreases in total alkalinity. These data may indicate the early stages of enhanced sulfide oxidation within the tailings mass. (*i.e.*, pyrite oxidation and associated release of sulfate, acidity and associated trace elements).
- Inspection of redox-related parameters shows evidence for increasing Mn and Fe values in several tailings wells since 2010. These observations may indicate a trend towards more reducing conditions in tailings porewaters, and is supported by observations from the Seepage Pond which include observations of denitrification and subsequent increasing trends in Fe (and to a lesser degree Mn) concentrations.
- The Tailings Seepage Pond shows a trend of increasing concentration for TDS, SO₄ and Ca from 2011 to maxima in 2014. These trends are not mirrored in the Tailings Pond, suggesting the trends reflect *in situ* processes within the tailings mass (possibly linked to enhanced sulfide mineral oxidation).
- Inspection of redox-related parameters for the Seepage Pond shows evidence of changing redox conditions within the tailings facility, as illustrated by a pronounced increase in the

concentration of dissolved Fe since 2010. Dissolved Mn also shows evidence of increasing concentrations in late 2014 and early 2015. These observations are indicative of a shift in redox pathways from NO₃ reduction to Fe/Mn-oxide reduction, in response to decreased NO₃-N values in seepage waters since 2011. This conclusion is supported by groundwater data which show increasing trends for dissolved Mn and Fe in several wells.

- The transition towards more reducing conditions within the tailings area is further supported by the Seepage Pond data for dissolved As, which shows a similar pattern of increase to that of Fe.
- Dissolved Zn and Cd also show a pronounced increase in Seepage Pond waters in 2015-2016. The Zn and Cd peaks, however, do not correlate with Fe and As, nor with concentration trends in the Tailings Pond, suggesting other process contribute to the observed increases in the Seepage Pond (possibly via enhanced sulfide mineral oxidation and/or early onset of localized acid mine drainage, as illustrated by data for SO₄, Ca and alkalinity in groundwater).
- The SO₄ increase observed for the Seepage Pond between 2012 and 2014 is evident in lower Dome Creek at both DC-U and DC-R. With respect to redox-sensitive parameters, the dissolved Mn peak in the Seepage Pond in 2014 is congruent with peak values at DC-U, although not evident further downstream at DC-R. The rise in dissolved Fe concentrations in the Seepage Pond since 2010 is not manifested at any of the downstream stations, which can likely be attributed to the attenuation of dissolved Fe in close proximity to the tailings facility.
- With respect to trace elements, the elevated values observed for As, Cd, and Zn in the Seepage Pond in recent years are not clearly manifested at downstream stations, illustrating their likely co-attenuation with Mn/Fe-oxides.
- Downstream of the Dome Creek confluence, mine-related signatures are evident in Victoria Creek with respect to SO₄, Fe, Mn, As, Cd and Zn. Increases in SO₄ concentrations since 2010 cannot be linked to upstream inputs to Victoria Creek. Rather, such increases are consistent with the higher values observed over the same time period in the Seepage Pond and Lower Dome Creek, suggesting a tailings-related source.
- No discernible inter-annual trends are evident for other parameters (e.g., As, Fe, Mn, Zn, NO₃-N, etc.) in Victoria Creek since 2010, with the possible exception of dissolved Cd, which shows evidence of decreasing values.


Closure

We trust that this memorandum meets your expectations at this time. Please contact the undersigned with any questions or comments.

Respectfully submitted,
Lorax Environmental Services Ltd.



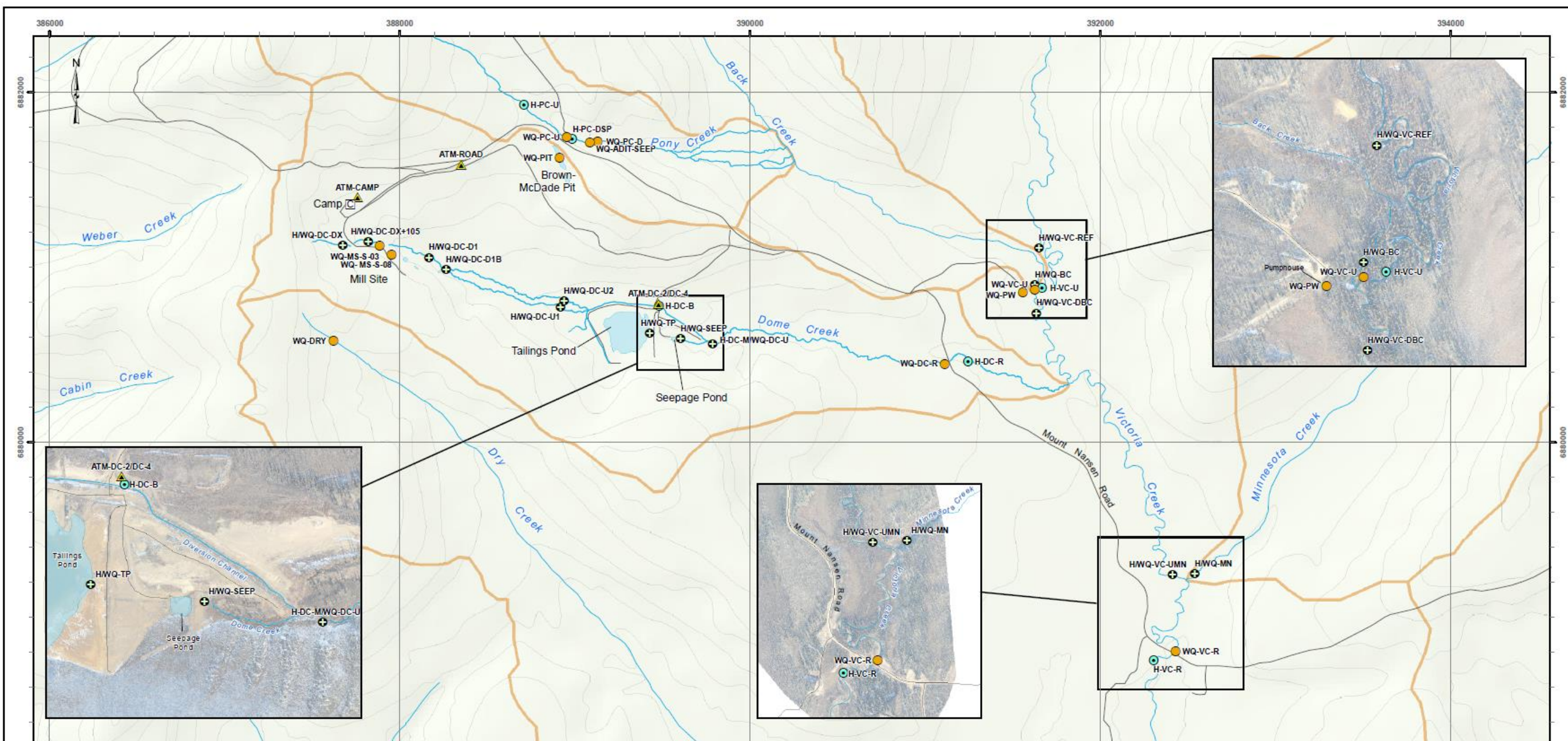
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Senior Hydrogeochemist

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- SLR 2015b. Mount Nansen – Assessment of Zinc Concentrations in the Dome Creek at WC-DX+105. Memorandum from Leslie Gomm (SLR Consulting Ltd.) to Government of Yukon (AAM), April 24, 2015.



Mount Nansen Site: Hydrometric Stations and Water Quality Sites

Legend

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|--|--|--|------------------------|
| | Atmospheric Station (label ex: ATM-DC-2) | | Unpaved Road/Access |
| | Hydrometric Station and Water Quality Site (label ex: H/WQ-VC-UMN) | | Drainage Areas (Local) |
| | Hydrometric Station (label ex: H-VC-R) | | |
| | Water Quality Site (label ex: WQ-PC-U) | | |

1:50,000 and 1:250,000 Topographic Spatial Data provided by Geomatics - Yukon Government via online source (Corporate Spatial Warehouse) www.geomatics.yukon.ca.

Digital Elevation Model provided by Geomatics - Yukon Government via online source (Corporate Spatial Warehouse) www.geomatics.yukon.ca.

Watercourse, drainage areas and Mount Nansen Road layers digitized / modified by EDI (2011) using orthophotos provided by Yukon Government, Energy, Mines and Resources (2011).

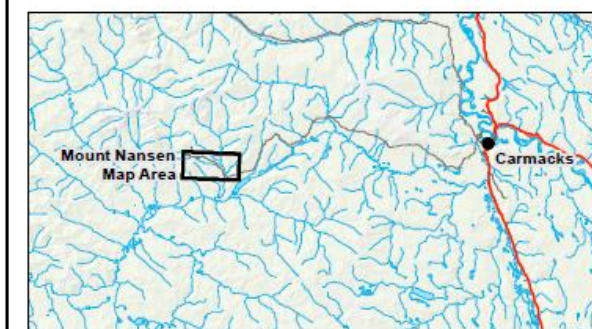
Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. (2011) was obtained using Garmin GPS technology.

This document is not an official land survey and the spatial data presented is subject to change.



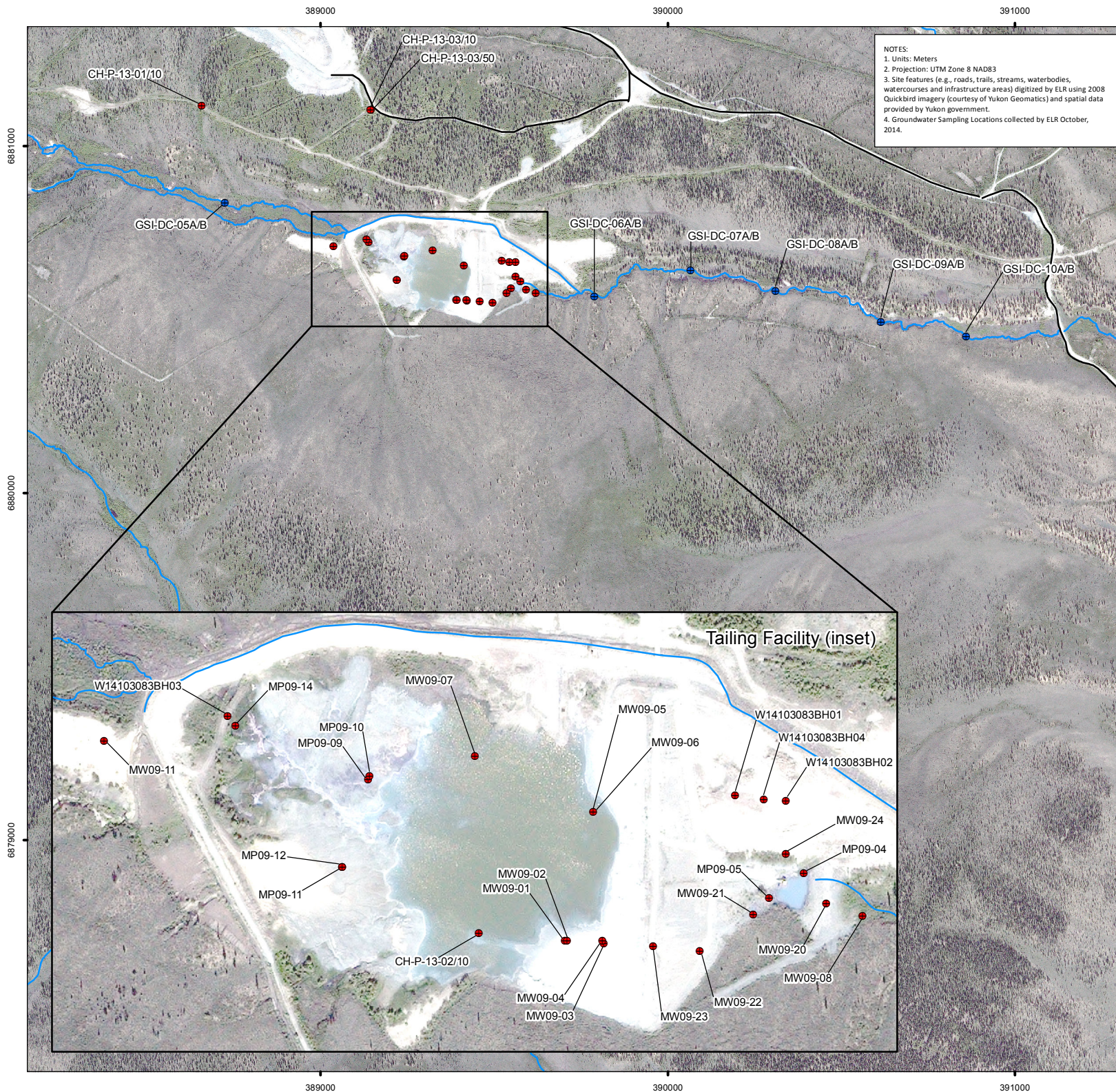
Map Scale = 1:22,000 (printed on 11 x 17)
Map Projection: North American Datum 1983 UTM Zone 8N

Drawn: LG	Checked: MM	FIGURE 1	Date: 28/10/2013
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Yukon

EDI



Mount Nansen Site Groundwater Monitoring Program



Client:



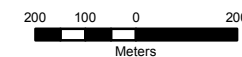
Legend

Groundwater Sample Locations

- Drive Points
- Monitoring Wells
- Watercourses



Scale: 1:15,000



January, 2015

Hemerra Project: 1343-005.05

FIGURE 2

Groundwater Sampling Locations
Dome Creek and Tailings Facility

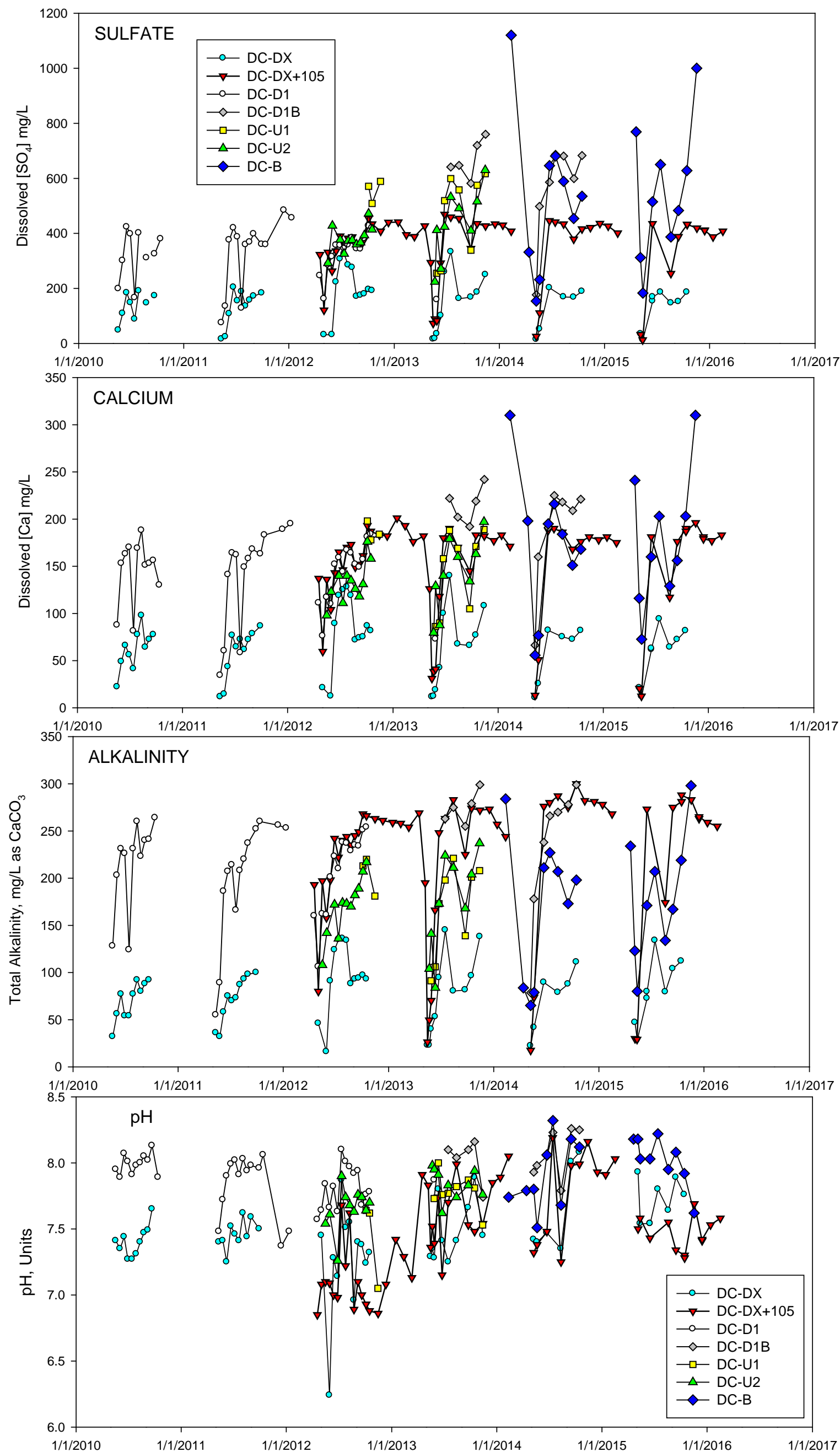


Figure 3: Time series profiles for major ions and pH for surface water stations in Upper Dome Creek (2009-2015 data).

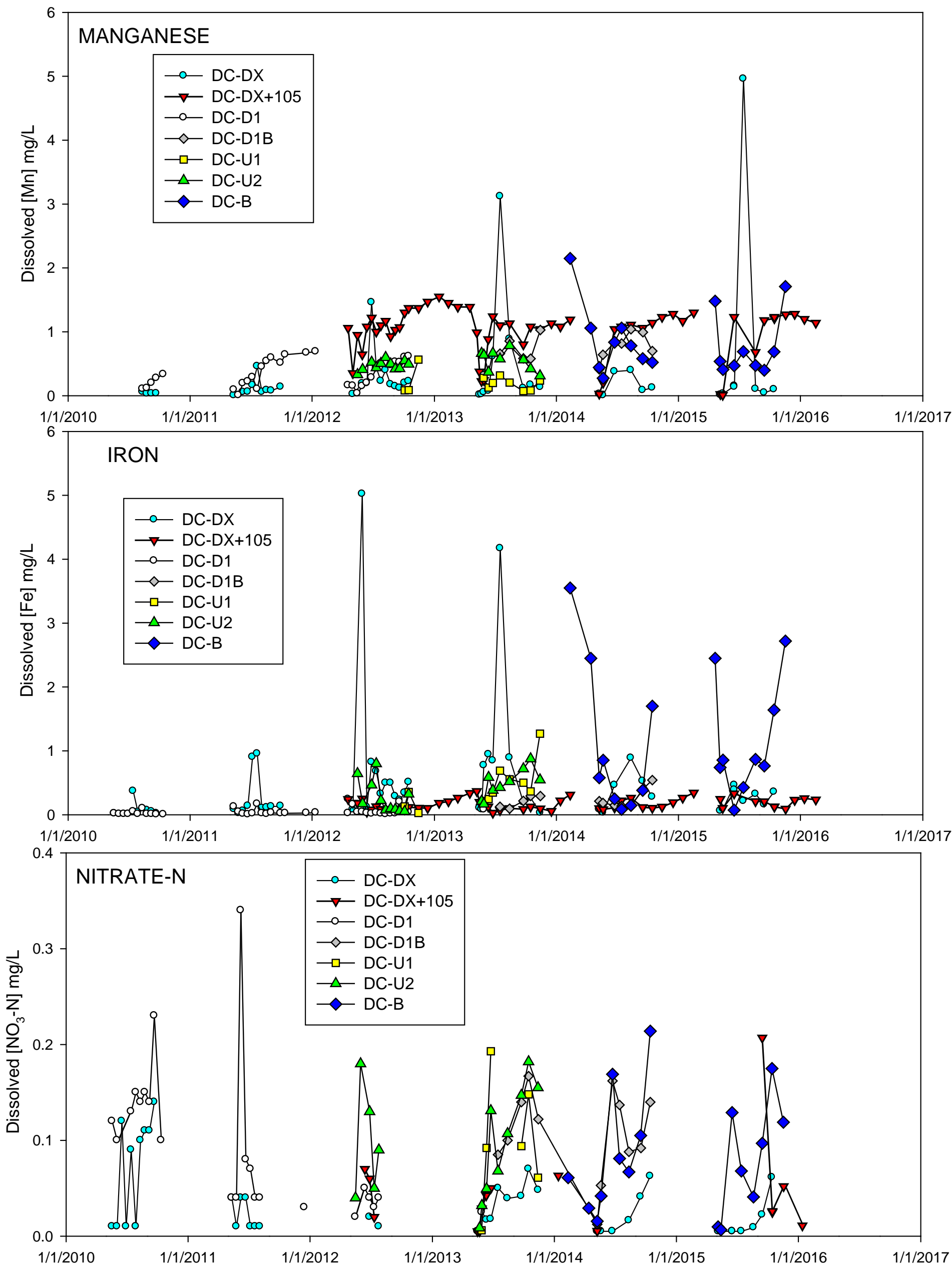


Figure 4: Time series profiles for redox-related parameters for surface water stations in Upper Dome Creek (2009-2015 data).

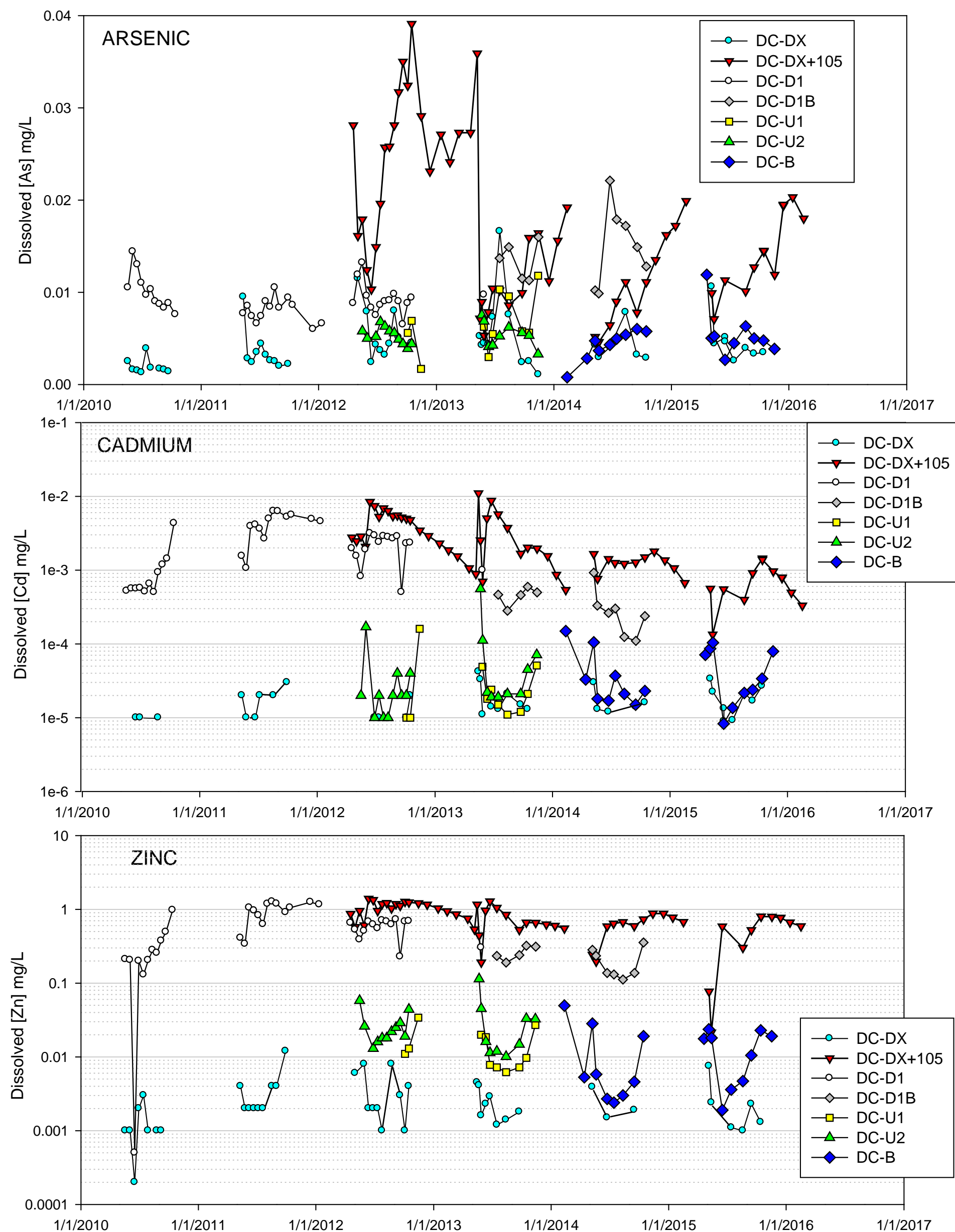


Figure 5: Time series profiles for dissolved As, Cd and Zn for surface water stations in Upper Dome Creek (2009-2015 data). Note log scales on Y axes for Cd and Zn.

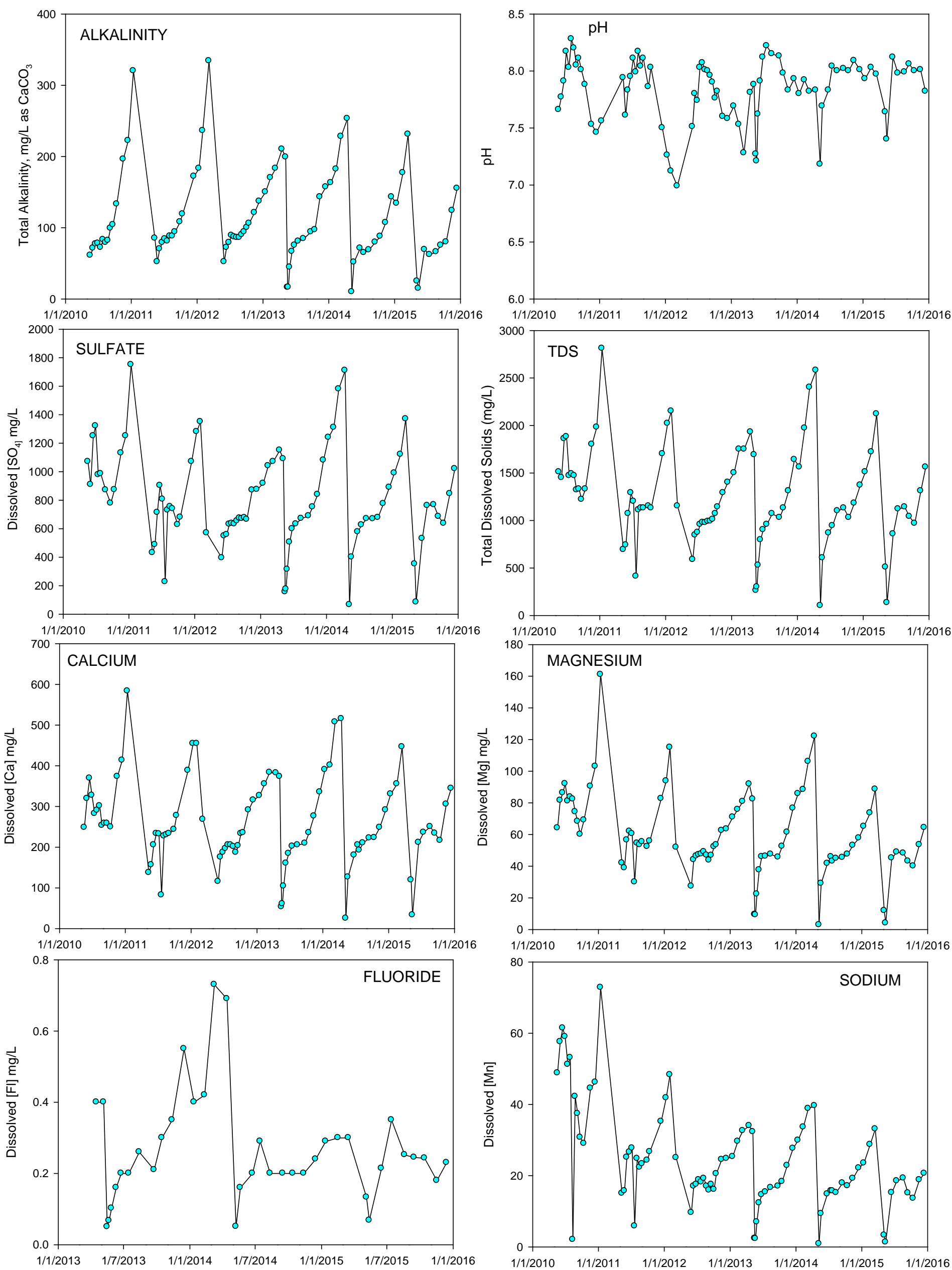


Figure 6: Time series profiles for major ions, TDS and pH for the Tailings Pond.

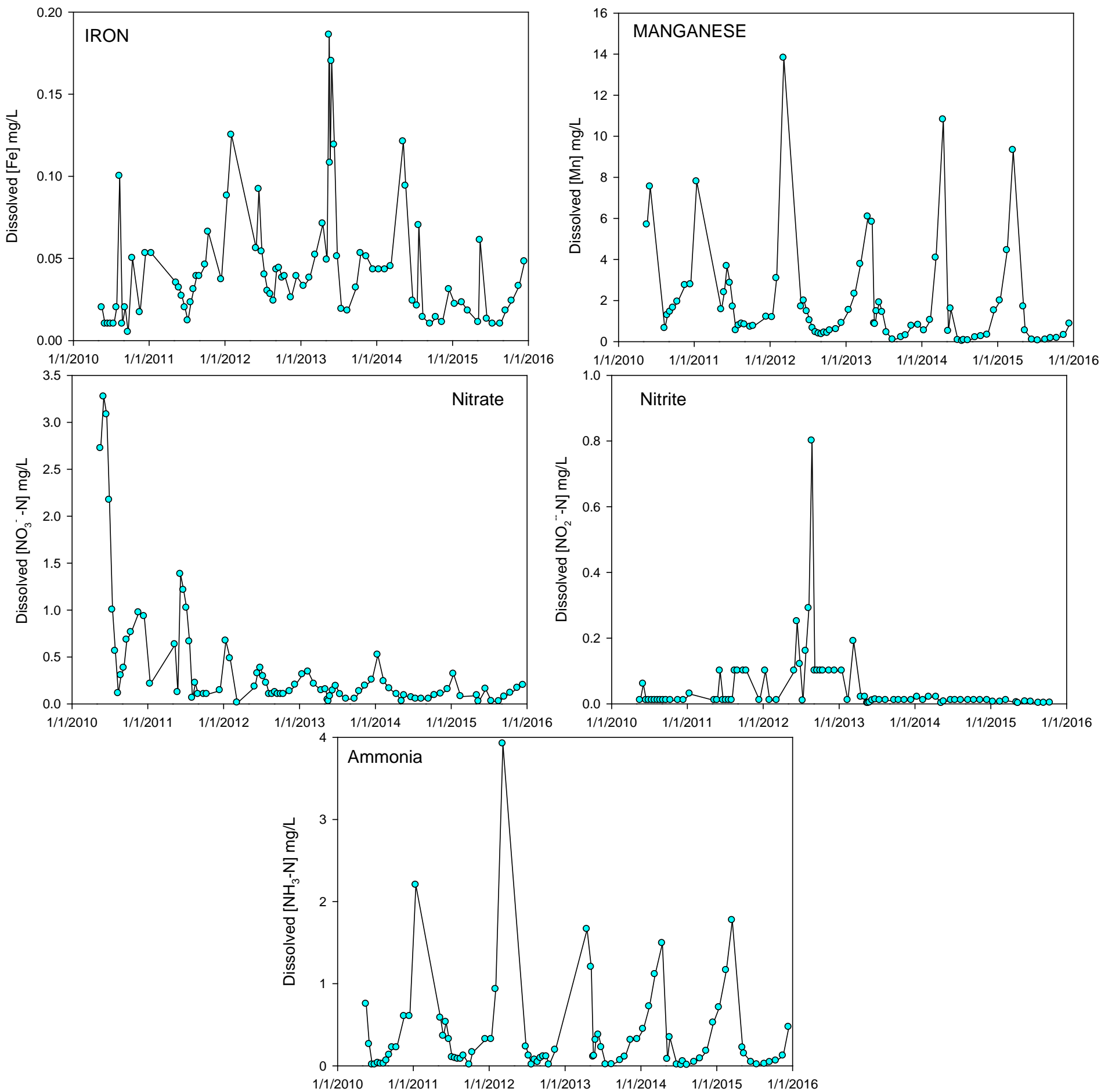


Figure 7: Time series profiles for redox-related parameters for the Tailings Pond.

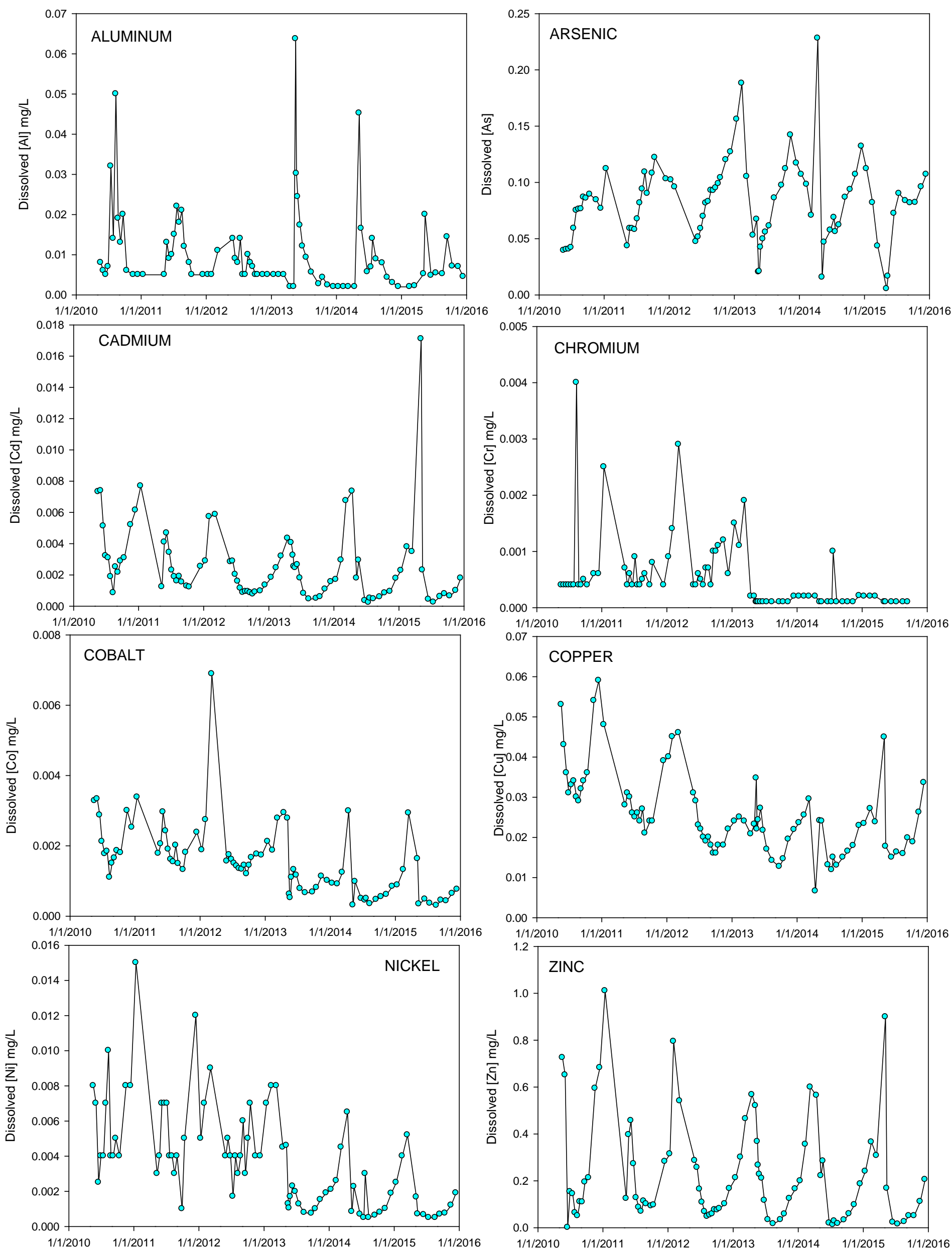


Figure 8: Time series profiles for trace elements for the Tailings Pond.

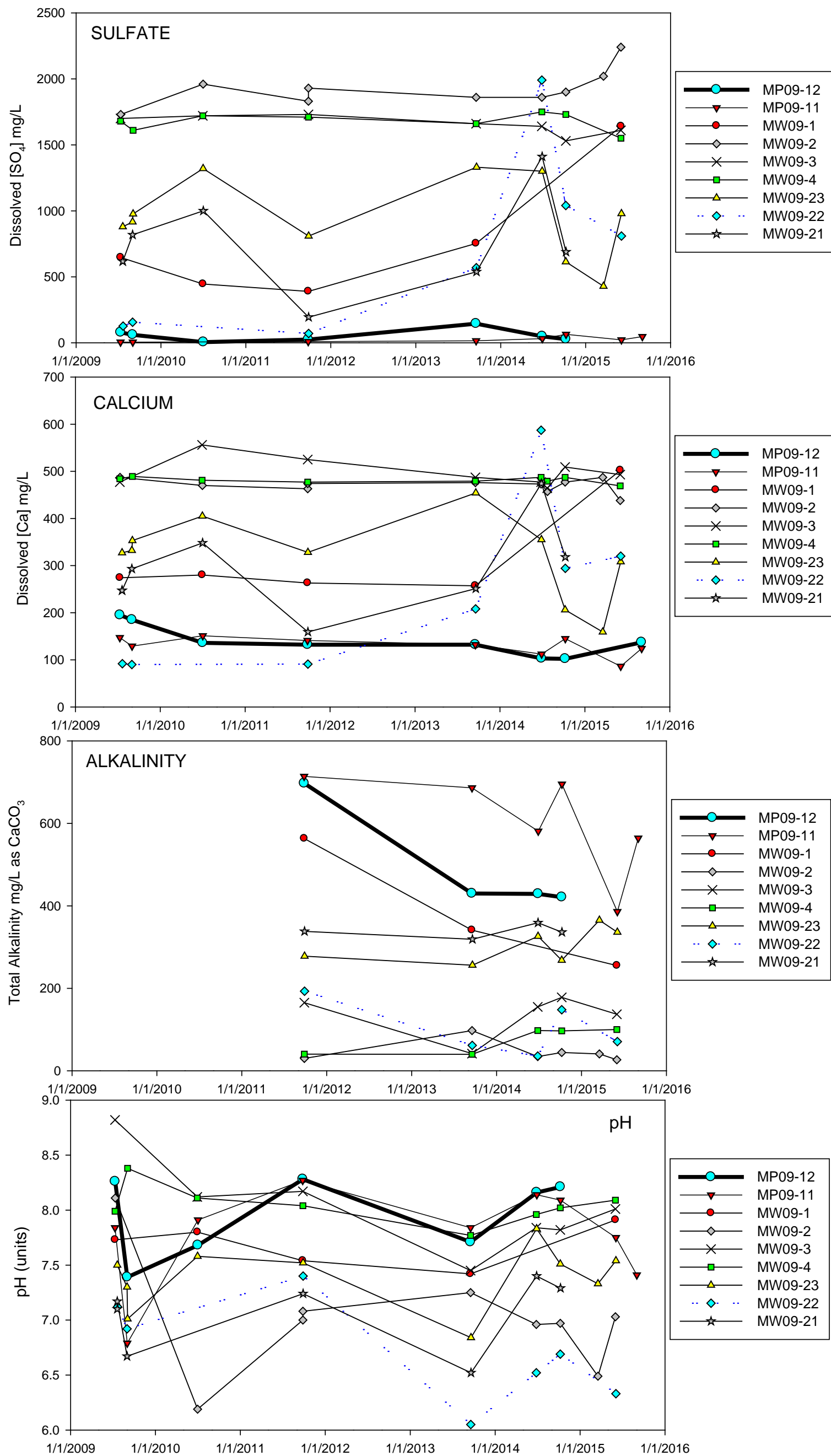


Figure 9: Time series profiles for major ions and pH for Tailings Management Area groundwater wells.

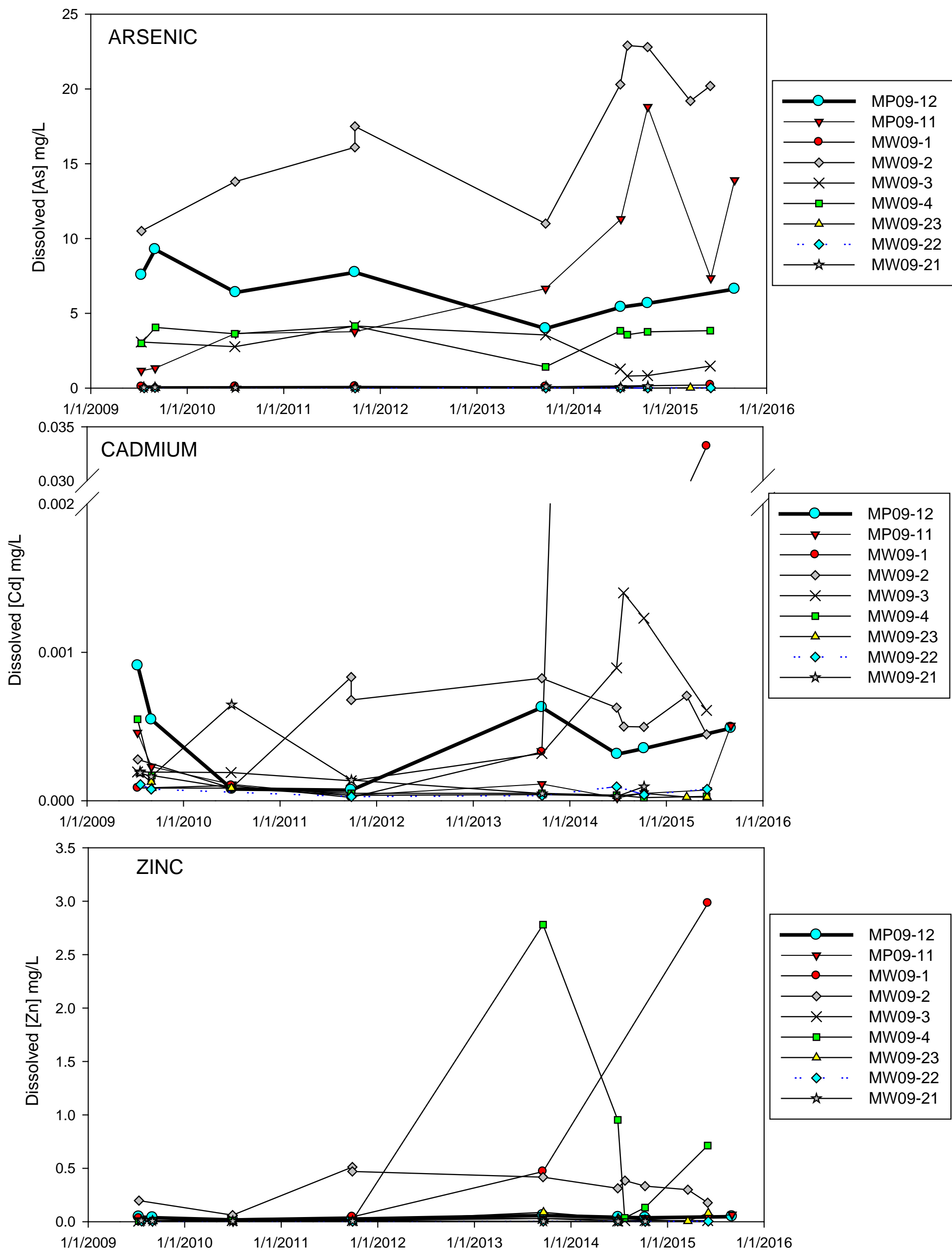


Figure 10: Time series profiles of dissolved As, Cd and Zn for Tailings Management Area groundwater wells. Note break in scale for Cd on Y-axis.

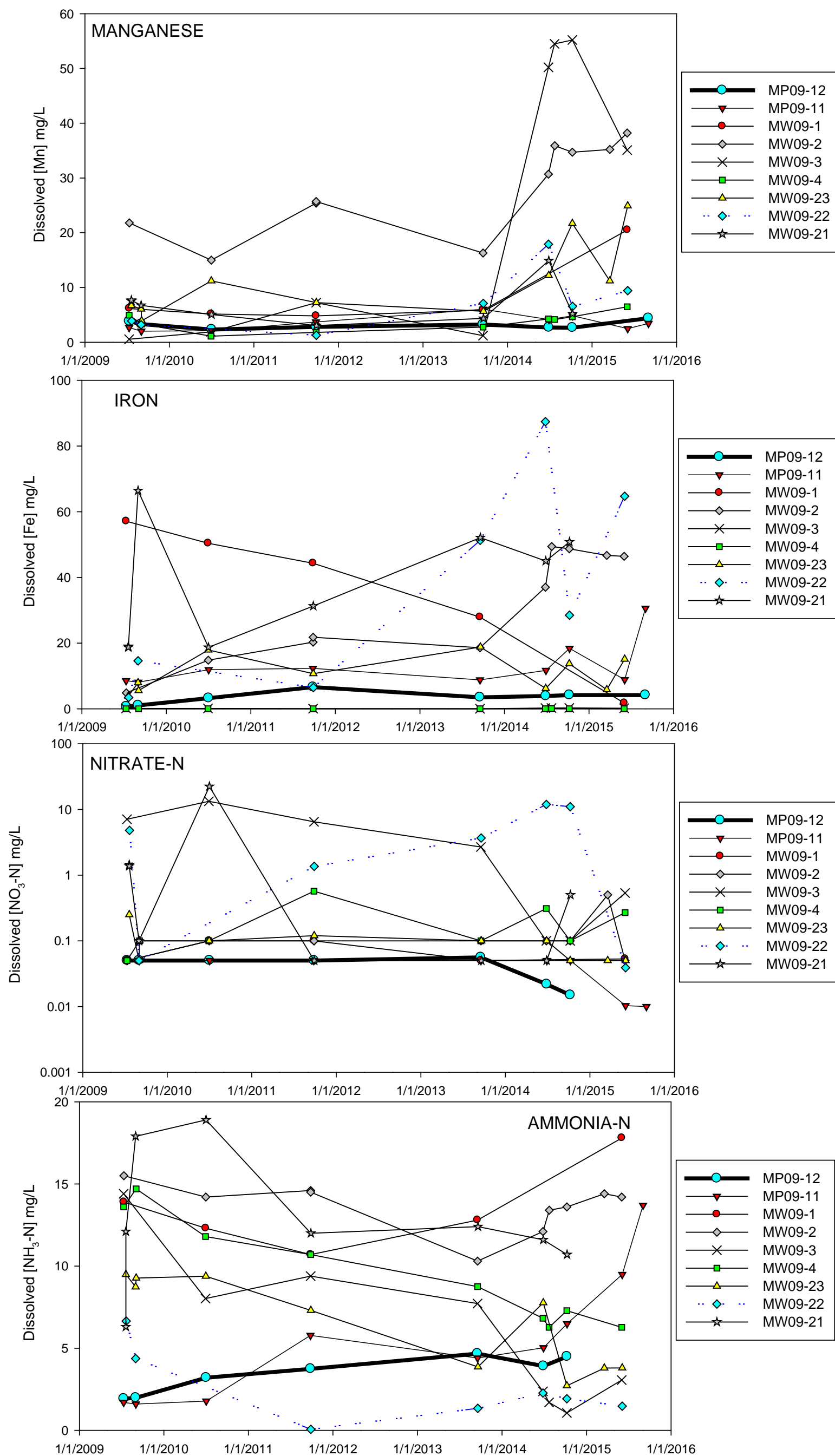


Figure 11: Time series profiles of redox-related parameters for Tailings Management Area groundwater wells.

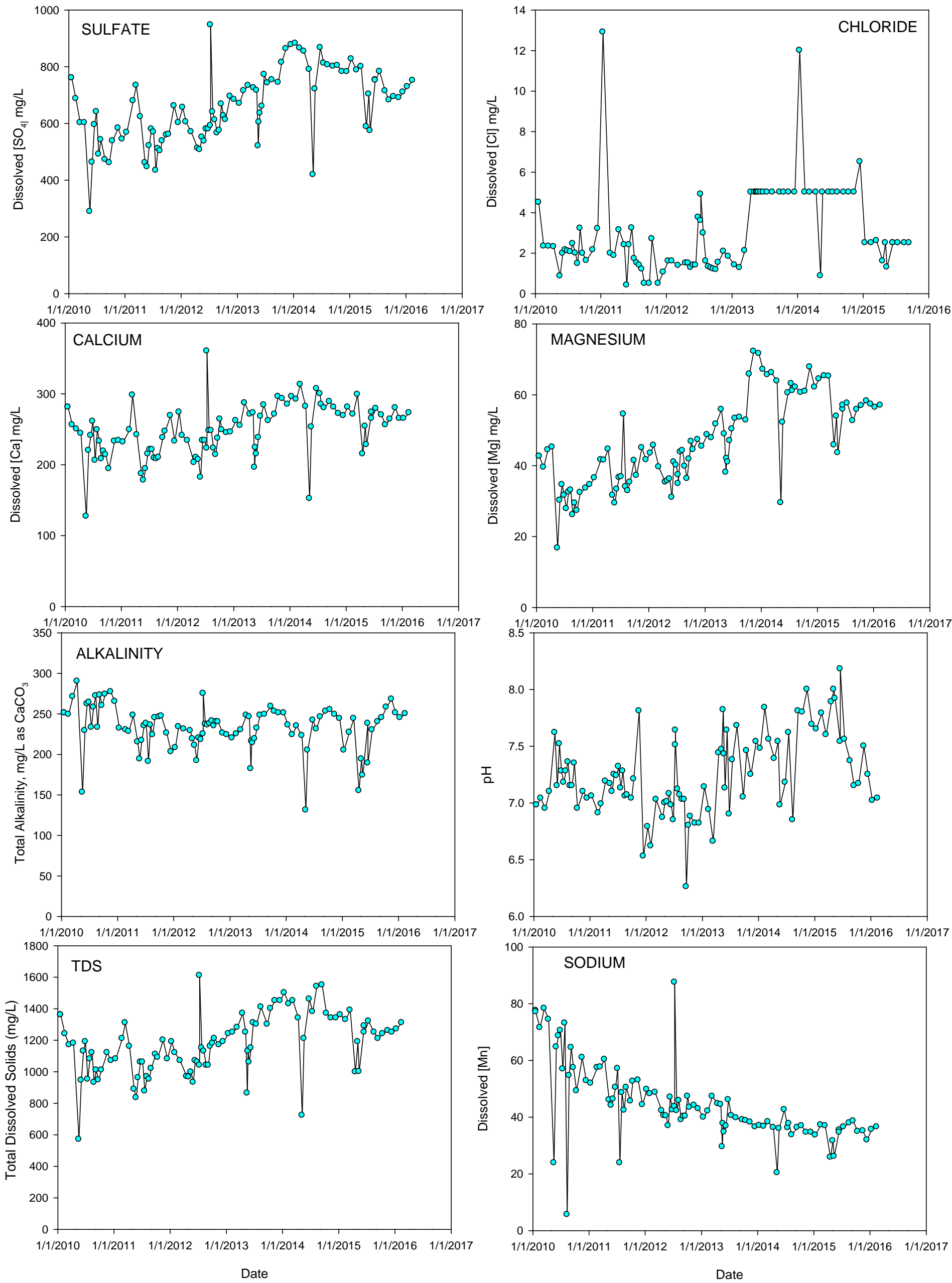


Figure 12: Time series profiles for major ions and pH for the Seepage Pond (2010-February 2016 data).

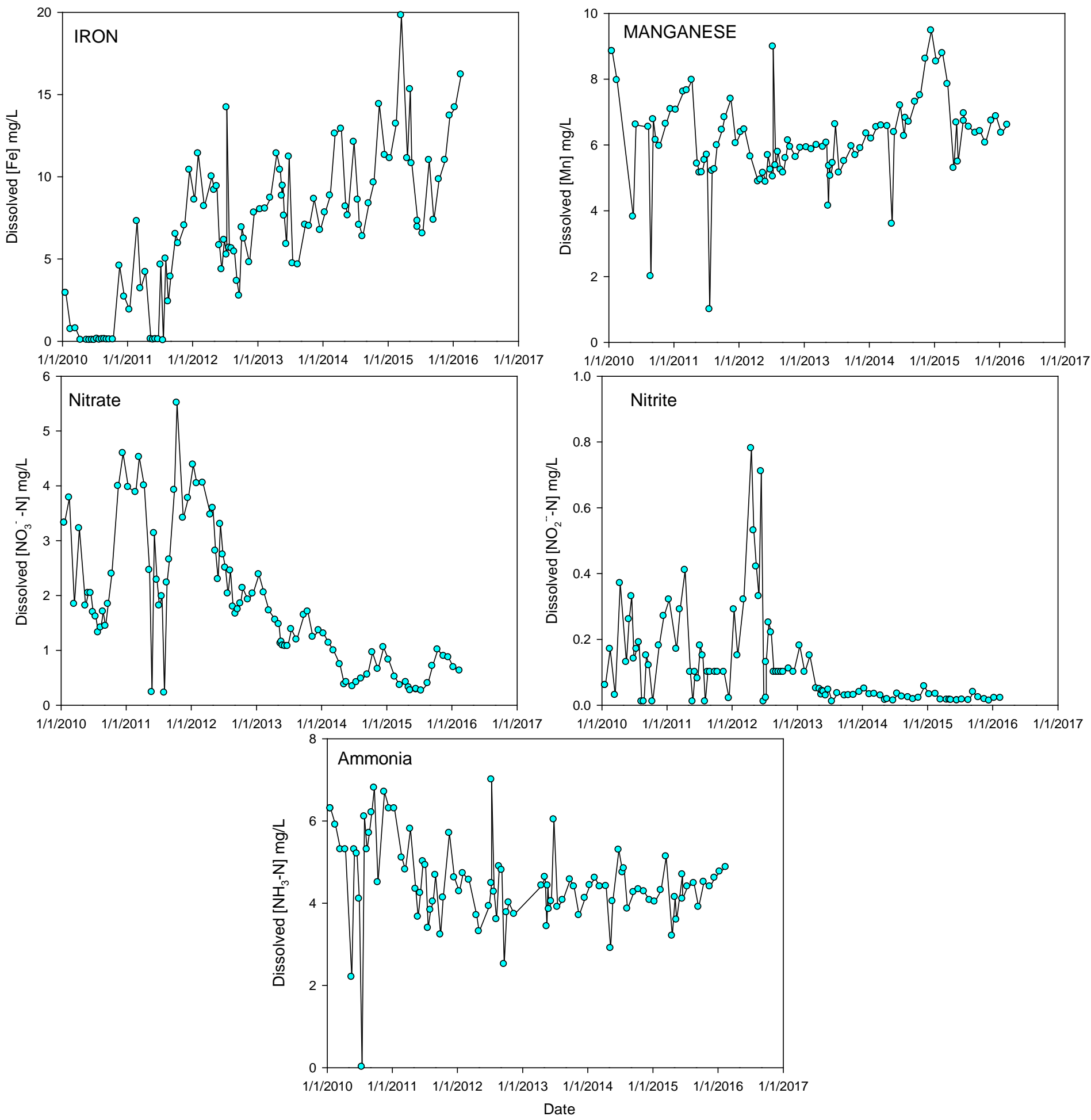


Figure 13: Time series profiles for redox-related parameters for the Seepage Pond (2010-February 2016 data).

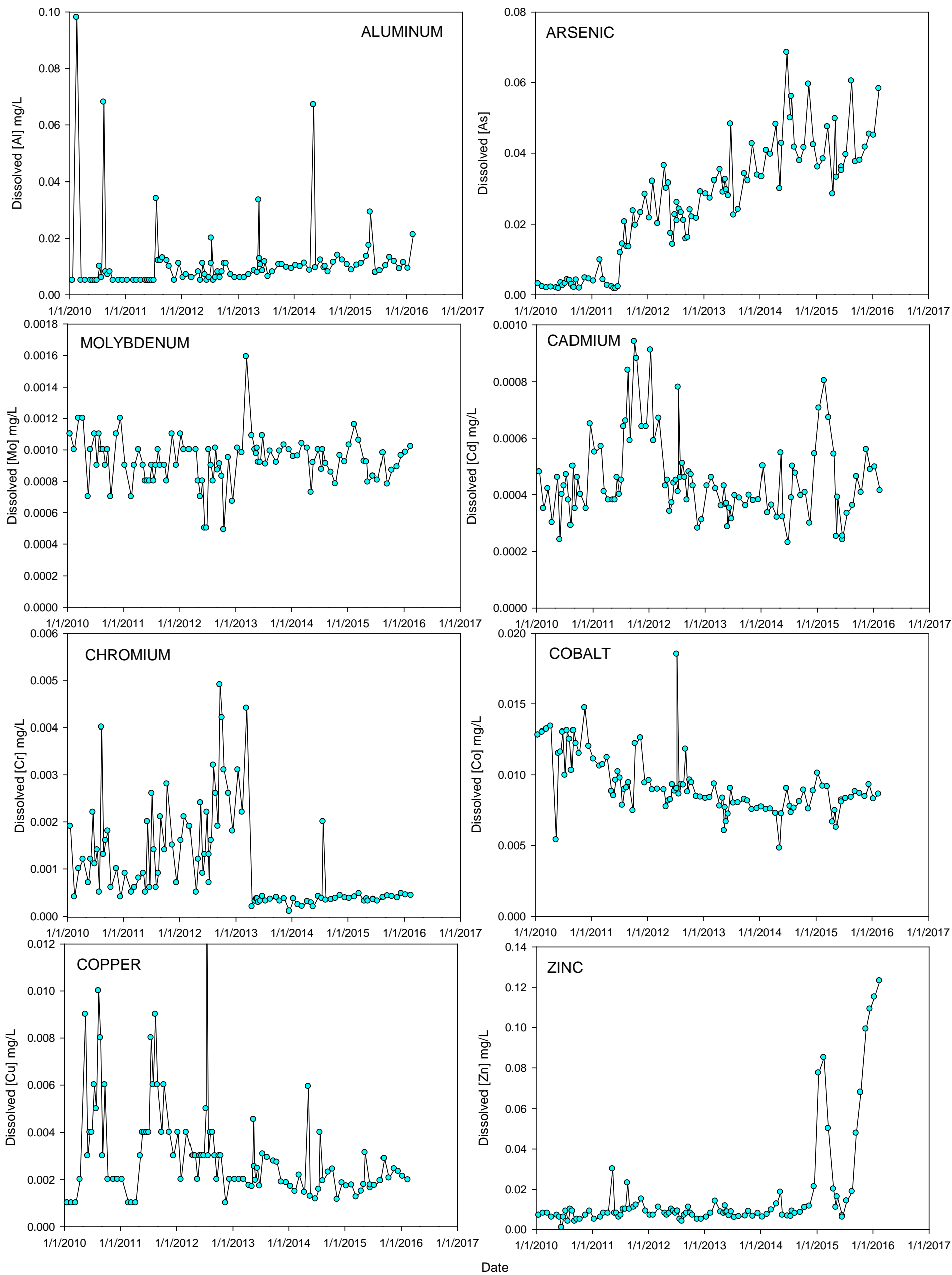


Figure 14: Time series profiles for trace elements for the Seepage Pond (2010-February 2016 data).

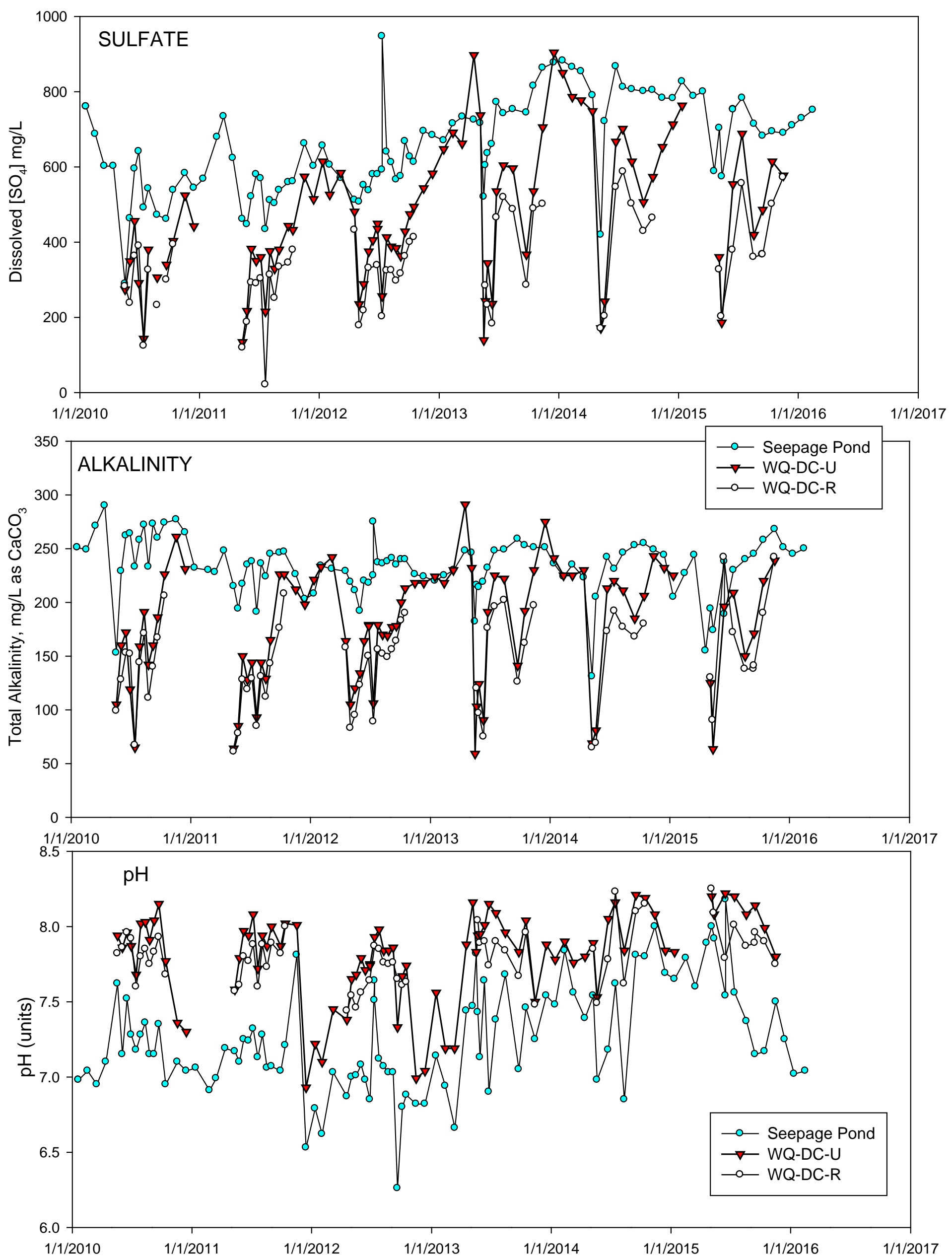


Figure 15: Time series profiles for SO4, alkalinity and pH for Seepage Pond and Lower Dome Creek (2010-2015 data).

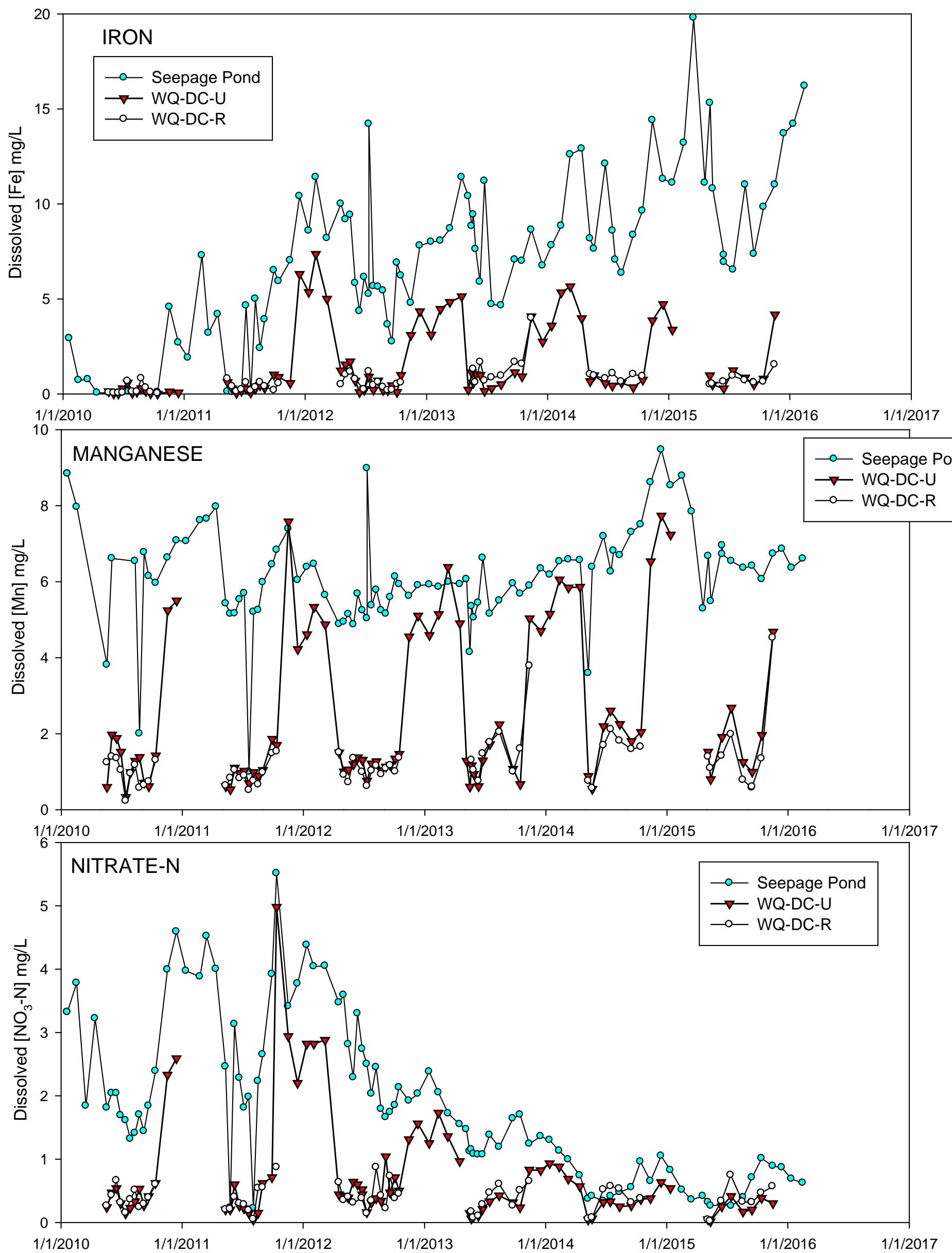


Figure 16: Time series profiles for redox-related parameters for Seepage Pond and Lower Dome Creek (2010-2015 data).

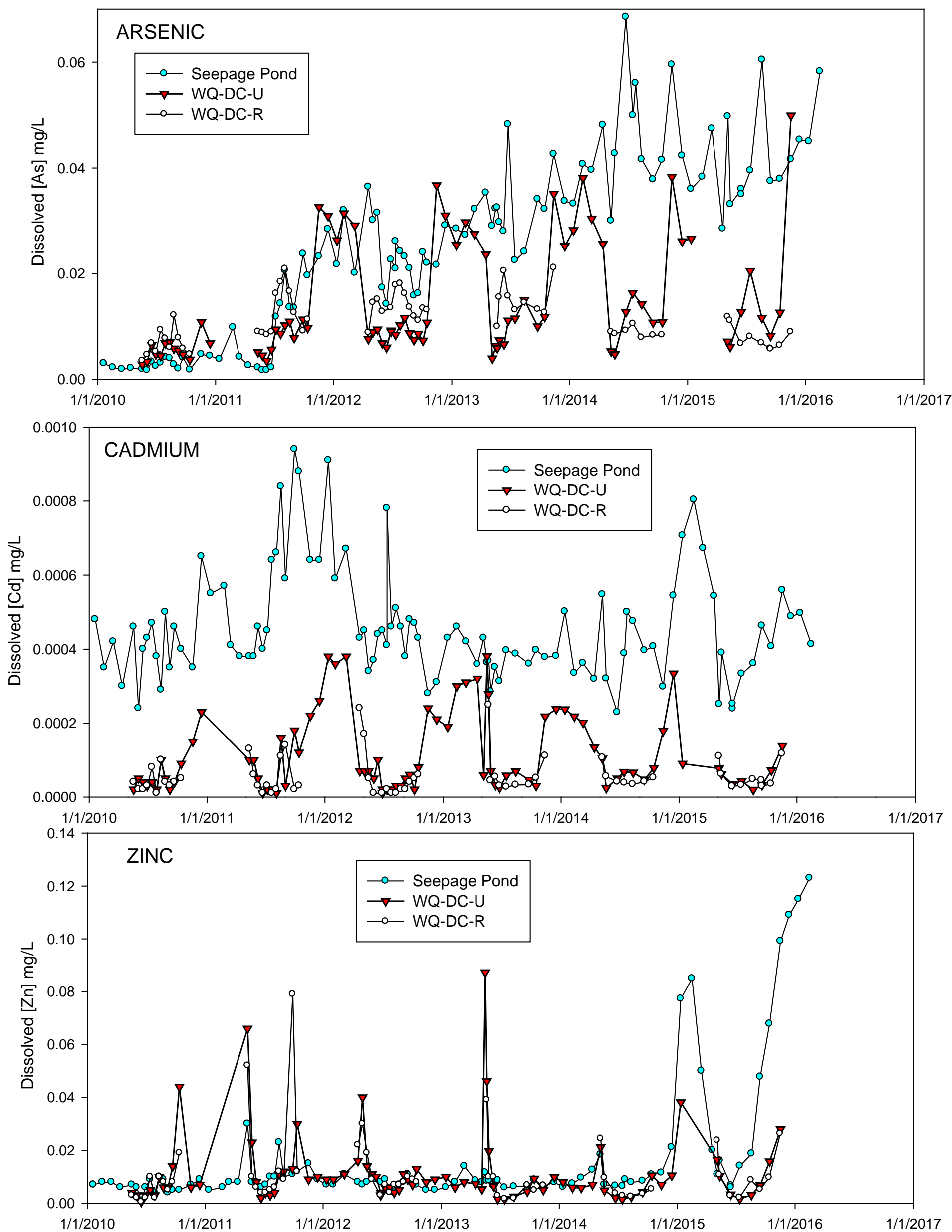


Figure 17: Time series profiles for dissolved As, Cd and Zn for Seepage Pond and Lower Dome Creek (2010-2015 data).

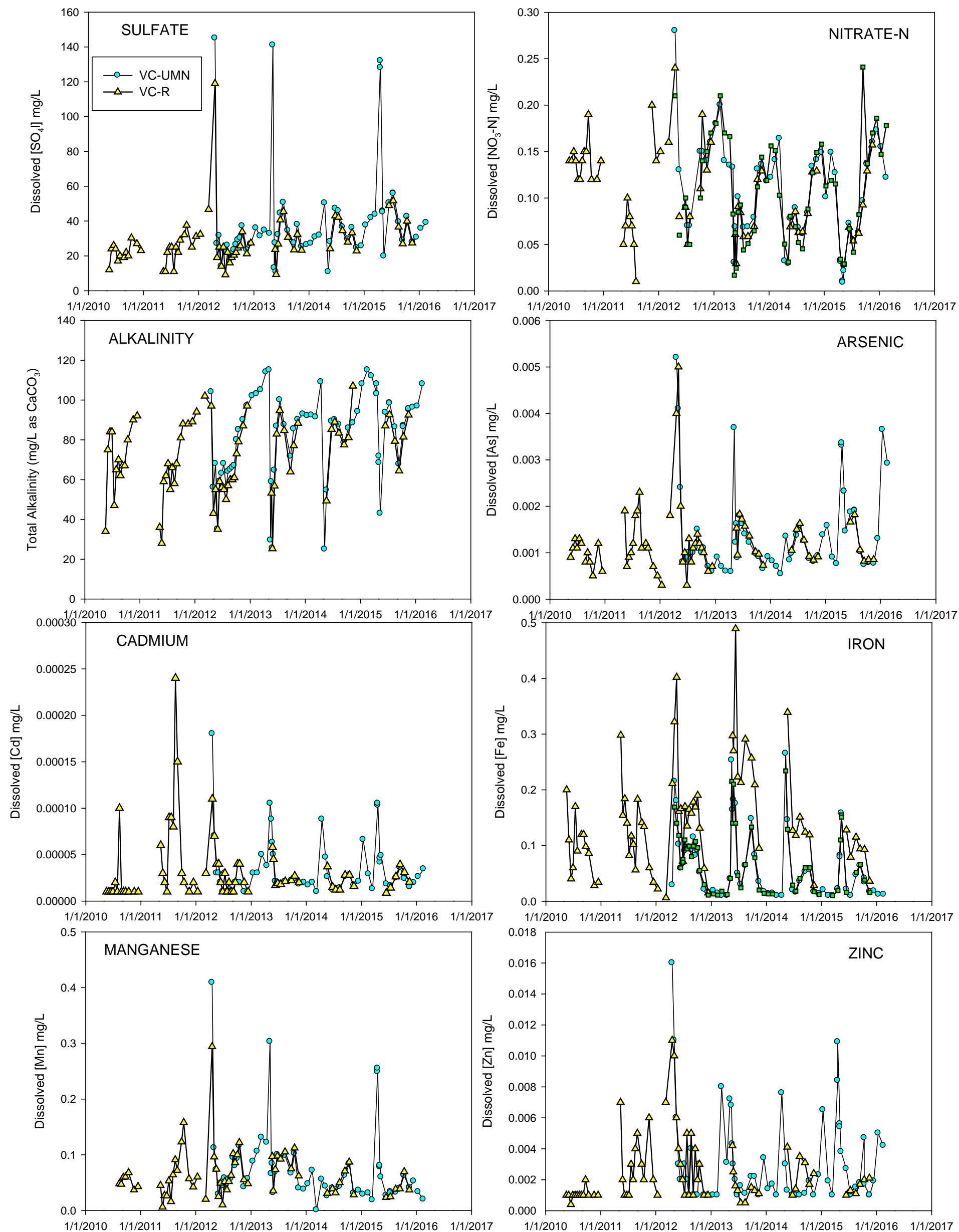


Figure 18: Time series profiles for dissolved sulfate, nitrate-N, alkalinity and various trace elements (As, Cd, Fe, Mn and Zn) for Victoria Creek downstream of Dome Creek confluence, both upstream (VC-UMN) and downstream (VC-R) of Minnesota Creek. Data compared to control site VC-U.

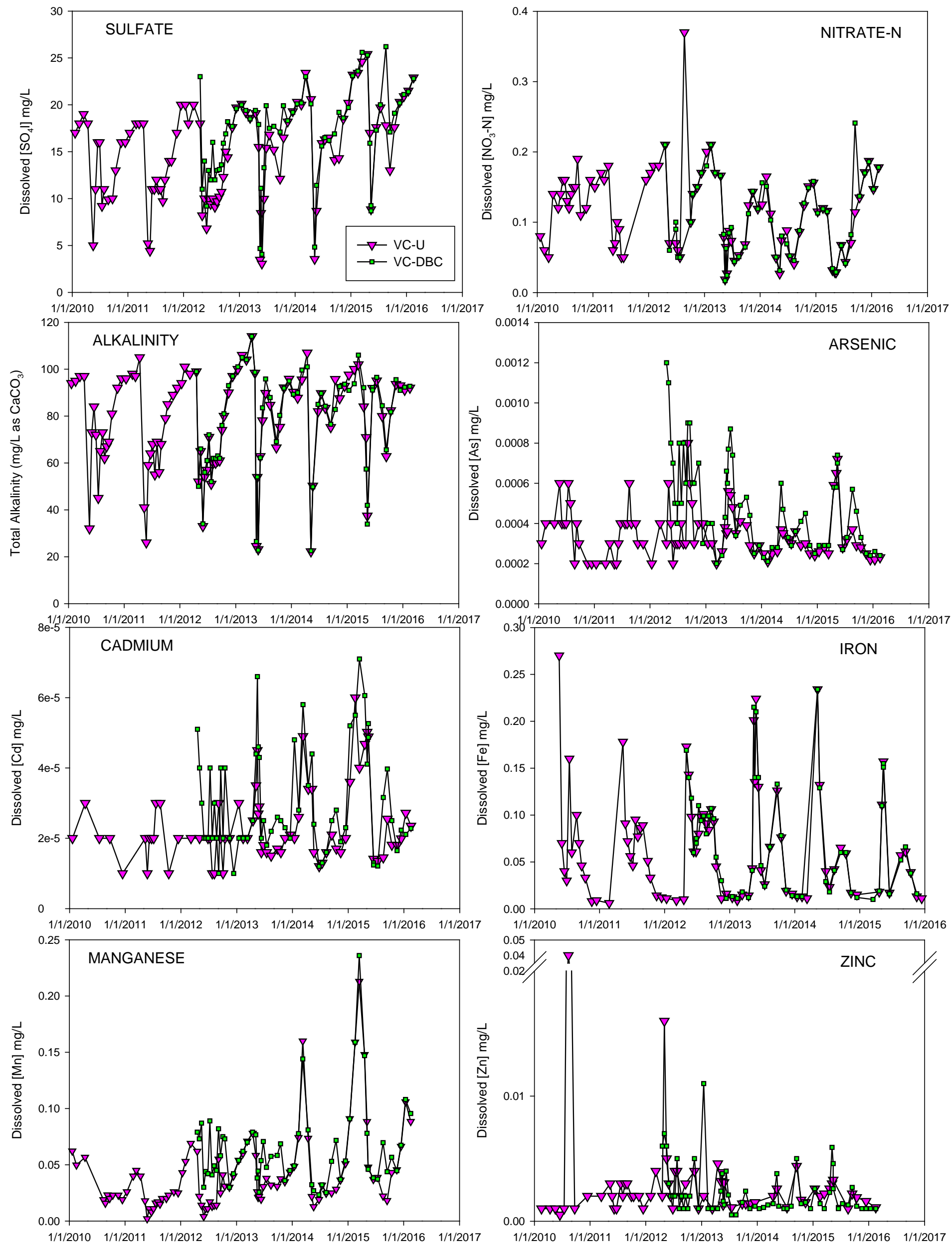


Figure 19: Time series profiles for dissolved sulfate, nitrate-N, alkalinity and various trace elements (As, Cd, Fe, Mn and Zn) for Victoria Creek upstream of Dome Creek confluence, both upstream (VC-U) and downstream (VC-DBC) of Back Creek.