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2019 Groundwater Mixing Zone Report for the D-Area Oil Seepage Basin (631-G) (U)

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DISCLAIMER

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EXECUTIVE SUMMARY

The groundwater data presented in this 2019 Groundwater Mixing Zone (GWMZ) Report show that the D-Area Oil Seepage Basin (DOSB) Operable Unit (OU) (631-G) contaminant plume continues to shrink, and concentrations of tetrachloroethylene (PCE), trichloroethylene (TCE), cis-1,2-dichloroethylene and chloroethene (vinyl chloride) (VC) are generally decreasing as compared to previous years. The maximum concentrations of all GWMZ constituents detected were significantly less than the established mixing zone concentration limits (MZCLs). The 2019 groundwater data confirm that the DOSB GWMZ boundaries remain adequate for the detected plume.

Groundwater monitoring requirements are identified in the DOSB GWMZ Application (Revision 1.5), which was approved by the U.S. Environmental Protection Agency Region 4 Office and the South Carolina Department of Health and Environmental Control. The Savannah River Site submits full GWMZ Reports on a biennial basis with letter summary reports submitted during the interim years. The full reports are scheduled for even-numbered years (such as this report submitted in 2020) and the letter reports are submitted during odd-numbered years. The 2019 GWMZ Report results indicate the following:

- The scheduled sampling and chemical analyses were completed for all DOSB OU wells in 2019.
- All volatile organic compounds (VOCs) detected in the boundary compliance wells were below their respective maximum contaminant levels (MCLs).
- All VOCs detected in the plume compliance wells were below their respective MZCLs.
- In the near source “additional” wells, PCE, TCE, and VC concentrations were detected at levels below the specific MZCLs.
- The 2019 water levels were within 0.6 m (2 ft) of the 2018 levels. In 2019, the total rainfall was 3.2 cm (1.25 in.) less than the average rainfall over the last 40 years. Groundwater flow is to the southwest toward the Savannah River.

Overall, the groundwater data presented in this 2019 GWMZ Report show that the DOSB OU contaminant plumes continue to remain below the respective MZCLs and MCLs for each well. The 2019 groundwater data confirm that the existing GWMZ boundaries remain adequate for the DOSB OU plume.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

~	approximate, approximately
aka	also known as
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethylene
cm	centimeter
cm/sec	centimeter per second
CO_2	carbon dioxide
COC	constituent of concern
1,1-DCE	1,1-dichloroethylene
DCE	dichloroethylene
DCM	dichloromethane
DO	dissolved oxygen
DOSB	D-Area Oil Seepage Basin
EQL	estimated quantitation limit
ft	foot (feet)
ft/day	foot (feet) per day
GAU	Gordon Aquifer Unit
GCU	Gordon Confining Unit
GWMZ	groundwater mixing zone
in.	inch(es)
IRA	interim remedial action
km	kilometer(s)
LAZ	lower aquifer zone
LLC	Limited Liability Company
µg/L	micrograms per liter
MCL	maximum contaminant level
m	meter(s)
m/day	meter(s) per day
mg/L	milligram per liter
mi	mile(s)
msl	mean sea level
mV	millivolts
MZCL	mixing zone concentration limit
NA	natural attenuation
ORP	oxidation reduction potential
OU	operable unit

LIST OF ABBREVIATIONS AND ACRONYMS *(Continued/End)*

PCE	tetrachloroethylene
RCRA	Resource Conservation and Recovery Act
RFI/RI	RCRA Facility Investigation/Remedial Investigation
SCDHEC	South Carolina Department of Health and Environmental Control
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
TCE	trichloroethylene
VC	vinyl chloride
VOC	volatile organic compound
USEPA	United States Environmental Protection Agency
UTRAU	Upper Three Runs aquifer unit
WSRC	Washington Savannah River Company
yd	yard(s)
yr	year(s)

1.0 INTRODUCTION

This 2019 Groundwater Mixing Zone (GWMZ) Report has been prepared to support the regulatory reporting requirements for the D-Area Oil Seepage Basin (DOSB) (631-G) Operable Unit (OU). The reporting requirements are specified in the Revision 1.5 GWMZ Application for the DOSB OU (SRNS 2009), which was approved by the United States Environmental Protection Agency (USEPA) and the South Carolina Department of Health and Environmental Control (SCDHEC). In accordance with the GWMZ Application, a report must be submitted on or before July 31 to report and summarize groundwater data and conditions for the previous calendar year. During even-numbered years (as is the case in 2020), a mixing zone report that contains groundwater data tables, contaminant plume maps, and descriptions of groundwater monitoring data and results is submitted. During odd-numbered years, a letter report that summarizes groundwater monitoring data and results is submitted.

1.1 Unit Description and History

The DOSB OU is located within the Savannah River Site (SRS) approximately (~) 1.6-km (1-mi) north of the D-Area Powerhouse and ~3 km (1.9 mi) from the nearest SRS boundary (Figure B-1). The DOSB OU is at an elevation of 45-m (150-ft) above-mean sea level (msl). During 2019, the water table (i.e., lower aquifer zone [LAZ] of the Upper Three Runs aquifer unit [UTRAU]) ranged from ~1.8-m (6-ft) to 3.4-m (11-ft) below ground surface (bgs) in the area of the DOSB OU (Figure B-2). Surface drainage is to the southwest, towards the Savannah River, which is at an elevation ~19.5-m [65-ft] below the elevation of the DOSB OU.

The DOSB was constructed in 1952 as a series of unlined trenches for disposal of waste oil products from A Area and other areas at SRS that were unacceptable for incineration in the 400-D powerhouse boilers. In 1975, the basin was removed from service and backfilled with soil. The DOSB is ~115-m (383-ft) long by 32.4-m (108-ft) wide and 2.4-m (8-ft) deep. The terrain is flat, with no discernible slope or relief, and is surrounded by a mature forest of hardwoods and softwoods.

The closest surface water feature is a Carolina Bay, a natural wetland located ~33 m (28 yd) to the west of DOSB (Figure B-3). The Carolina Bay is dry during the summer months or periods of little to no precipitation but may contain surface water during wet seasons. Other seasonal wetlands exist ~75-m (250-ft) south of the unit and extend across the width of the mixing zone area.

An intermittent stream is located just south of the DOB 15 well cluster within the mixing zone area, which directs surface drainage, when present, southward out of the mixing zone near the distal end of the boundary (Figure B-3). The major local surface water drainage system is the Savannah River (and associated swamps), located ~2.57 km (1.6 mi) to the west of the unit (Figure B-1).

1.2 Regulatory History

The DOSB OU is listed as a Resource Conservation and Recovery Act (RCRA) 3004(u) Solid Waste Management Unit/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) unit in Appendix C of the Federal Facility Agreement for SRS. A preliminary unit evaluation and a unit reconnaissance were performed in August 1988. These evaluations concluded that hazardous substances were associated with buried drums within the unit (WSRC 1995a). The principal threat source material was described as subsurface hazardous liquids including drum contents, pumpable free product, and discernible layers of sludges. Since the DOSB had received hazardous substances, a unit-screening investigation was implemented, and field investigations were conducted between 1988 and 1994.

Groundwater and soil sampling were performed in 1996 as part of the RCRA Facility Investigation/Remedial Investigation (RFI/RI) Work Plan (WSRC 1995b). The investigation revealed that volatile organic compounds (VOCs) were present in deep soil zones and in groundwater. The RFI/RI Report and Baseline Risk Assessment for the DOSB OU (WSRC 1997) identified eight VOCs as final constituents of concern (COCs): benzene, 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethylene, cis-1,2-dichloroethylene (cis-1,2-DCE), dichloromethane (methylene chloride) (DCM), tetra-chloroethylene (PCE), trichloroethylene (TCE), and chloroethene (vinyl chloride) (VC).

An interim remedial action (IRA) was implemented in 1996 to remove drums, debris and principal threat source material. The IRA included testing the efficacy of a bioventing remedial technology for the vadose zone and shallow groundwater. Two horizontal pipes were used to introduce fresh air, nutrients, and tracers into the soil at a depth of ~2.4 m (8 ft) (WSRC 1999b). The tests showed that microbial activity in the basin soil did not respond to further stimulation by air injection.

The selected final remedy for the DOSB OU was no further action for soil and a GWMZ for groundwater. The specific controls associated with the DOSB OU required to prevent unauthorized exposure to the contaminated groundwater include: 1) controlled access to the DOSB OU through existing SRS security gates and SRS perimeter fences and compliance with SRS Site Use/Site Clearance procedures; and 2) control of installation of groundwater wells through existing SRS procedures. The goal of the groundwater remedial action is to decrease the concentration of VOCs in groundwater to levels at or below maximum contaminant levels (MCLs). Groundwater modeling was initially performed as part of the Revision 1.1 GWMZ Application (WSRC 1998) to demonstrate the efficacy of a Natural Attenuation (NA)/GWMZ strategy for DOSB OU groundwater.

In January 2000, a groundwater monitoring and reporting program was implemented to demonstrate compliance with the Mixing Zone Concentration Limits (MZCLs) in plume compliance wells and with the MCLs at the compliance boundary, as required by the GWMZ application. This report is produced to satisfy the requirement of the approved GWMZ application and to provide a biennial report to SCDHEC and USEPA.

A revised GWMZ Application (Revision 1.2) (WSRC 2005) was submitted in June 2005 to address exceedances of the MCLs specified in the Revision 1.1 GWMZ Application. Subsequent revisions (Revision 1.3 and Revision 1.4) were prepared to address regulator comments, and the Revision 1.5 GWMZ Application was submitted in January 2009

(SRNS 2009). The Revision 1.5 GWMZ Application was approved by SCDHEC and the USEPA.

As a result of comments received regarding the Revision 1.2 GWMZ Application, SRS reanalyzed groundwater data and the changing conditions of the DOSB OU. The groundwater data showed that contaminant plumes present at the DOSB OU continue to evolve (i.e., change in composition) over time. The primary source contaminants, PCE, TCE, and waste oils were disposed of in trenches at the DOSB where periodically the wastes were ignited in the trenches. Since the water table was present near the base of the DOSB trenches, the oil served as a ready source of carbon for microbes to biodegrade PCE and TCE in the vadose zone near the source and in shallow groundwater downgradient from the source.

From the actions of the IRA (source removal and bioventing) and the reductive dechlorination that occurred (and other active attenuation processes), concentrations of the chloroethene parents PCE and TCE have decreased, and the degradation products cis-1,2-DCE and VC are present and are undergoing NA. As discussed in Section 3.3 of this document, groundwater geochemical conditions have evolved and the present NA processes include aerobic degradation of VC and physical attenuation (i.e., dispersion and mixing with uncontaminated groundwater).

The paradigm formulated for NA presently occurring at the DOSB OU was incorporated into the Revision 1.5 GWMZ Application. Simulations from the updated model predict that the VC plume will not exceed the MCL at the GWMZ boundary and will continue to shrink to less than the MCL in 7 years (~2027).

2.0 SITE HYDROLOGY

The updated and detailed hydrostratigraphic interpretations of the DOSB OU area were used to formulate the numerical models used in the Revision 1.2 and Revision 1.5 GWMZ Applications (WSRC 2005 and SRNS 2009, respectively).

The Floridan aquifer system is within the DOSB OU area and is divided into two aquifer units (separated by a confining unit). From top to bottom, hydrostratigraphy at the DOSB OU includes the UTRAU, the Gordon Confining Unit (GCU [aka the Green Clay Confining Unit]), and the Gordon Aquifer Unit (GAU) (Figure B-2). The Crouch Branch Confining Unit and the deeper Crouch Branch Aquifer Unit are located beneath the GAU. Only the shallow aquifer zones (i.e., UTRAU and GAU) have been impacted by DOSB OU contamination.

The water table aquifer at the DOSB OU is composed of the sands of Dry Branch, Santee and Clinchfield Formations and is in the LAZ of the UTRAU. Locally, the LAZ of the UTRAU is subdivided into three aquifer zones: AQ1, AQ2, and AQ3. These zones are separated by two "weak" aquitards (designated as AT1 and AT2). The shallowest of these aquitards (AT1) underlies AQ1 at ~3-m (10-ft) bgs. The AT1 is described as a gravelly, clay-rich bed at the base of the Dry Branch Formation, resting on the Santee/Clinchfield Unconformity. The AT1 is ~0.9-m (3-ft) thick and has an irregular surface. The second aquitard (AT2) is ~0.9- to 1.2-m (3- to 4-ft) thick and occurs at a depth of ~7.5 m (25 ft). AT2 is absent beneath the eastern portion of the basin and is not laterally continuous outside the immediate area of the DOSB OU.

Underlying AQ3 and directly beneath the basin is another weak aquitard, designated as "AT-Unnamed" (located about 13.5-m [45-ft] bgs). Downgradient from the DOSB OU, the AT-Unnamed pinches out (near the DOSB GWMZ boundary). Beneath AT-Unnamed is another aquifer zone labeled "AQ-Unnamed". The AQ-Unnamed zone is 1.5-m (5-ft) thick beneath the DOSB OU and thickens to roughly 6 m (20 ft) thick downgradient in the section.

The GCU separates the LAZ of the UTRAU from the GAU. The GCU is ~1.5-m (5-ft) thick and the hydraulic head differential across the GCU is normally about 1.8 to 3.3 m (6 to 11 ft). The hydraulic head gradient across the GCU is south-southwest. The GAU is subdivided into three transmissive zones (GAU-AQ1, GAU-AQ2, and GAU-AQ3) that are separated by aquitards (GAU-AT1 and GAU-AT2). Monitoring wells at the DOSB are installed in GAU-AQ1 and GAU-AQ2 to determine impacts and monitor the vertical extent of the contamination.

According to water levels measured at well clusters DOB 15 and DOB 21, hydraulic heads in the LAZ of the UTRAU exhibit a downward flow potential. At the DOB 15 and DOB 21 well clusters, the head in the AQ3 zone of the LAZ of the UTRAU is normally 0.9- to 3-m (3- to 10-ft) higher than the GAU. The horizontal hydraulic conductivity of the LAZ ranges from 3 to 7.2 m/day (10 to 24 ft/day), while the horizontal hydraulic conductivity from the calibrated groundwater flow model ranges from 0.15 to 30 m/day (0.5 to 100 ft/day) (WSRC 1998).

3.0 REMEDIAL ACTION

3.1 Objectives

The objective of the remedial action for DOSB OU groundwater is to decrease the concentration of contaminants in the groundwater to levels at or below MCLs for the identified COCs. Since the selected remedy is NA/GWMZ with institutional controls, concentrations of approved GWMZ constituents may exist at elevated concentrations above MCLs within the established GWMZ compliance boundary. Groundwater monitoring is performed to ensure that established groundwater concentration limits (MCLs at GWMZ boundaries and MZCLs within the boundaries) are not exceeded.

3.2 Groundwater Mixing Zone Elements

The purpose of compliance monitoring at the DOSB OU is to demonstrate compliance with MCLs at the compliance boundary wells and compliance with the MZCLs at the plume compliance wells as required. The downgradient GWMZ compliance boundary is located ~495-m (1,650-ft) downgradient of the southern perimeter of the OU, placing it slightly beyond the farthest extent of the VOC plume above the MCL when it was characterized in 1996 (Figure B-3).

The approved Revision 1.5 GWMZ Application requires monitoring of 18 wells (Figure B-4) for groundwater quality and indicator parameters. These wells include two background wells (DOB 9 and DOL 1), nine plume compliance wells (DOB 15, DOB 15A, DOB 15D, DOB 15PZ, DOB 16, DOB 19, DOB19A, DOB 23, and DOL 2), and seven boundary compliance wells (DOB 20, DOB 20A, DOB 21, DOB 21A, DOB 21PZ, DOB 22 and DOB 22A). The 'A' wells are usually (but not always) screened in the AQ2 aquifer zone, while the wells without a letter designation are usually screened in the AQ3 aquifer zone. Background well DOB 9 is screened in AQ1/AQ2 aquifer zones, and DOL 1 is screened in AQ3.

The groundwater quality parameters (VOCs) are monitored for compliance with MCLs and MZCLs, while indicator parameters are monitored to evaluate the NA processes occurring in the DOSB OU groundwater. The MCLs and MZCLs or GWMZ constituents are shown in Table 1. A summary of monitoring well sampling and comparison criteria is presented in Table 2.

In addition to the background, plume compliance, and boundary compliance wells, SRS monitors four near source "additional" wells (DOB 11, DOB 12, DOB 13 and DOB 14). These wells are located near the source area and are screened in the AQ2 aquifer zone. SRS also monitors one surface water location (DOBSW1) when sufficient surface water is present.

The DOSB OU plume compliance and boundary compliance wells are sampled on an annual basis. During 2019, they were sampled during the second quarter of the year (2Q2019). Biennial sampling is required for the DOSB OU background wells, they were last sampled in 2Q2018.

3.2.1 Background Wells

The background groundwater quality is used as a baseline to evaluate the extent of attenuation occurring in the plume. The term "background" refers to the data collected from existing background wells DOL 1 and DOB 9.

3.2.2 Plume Compliance Wells

The purpose of plume compliance wells is to verify that contaminants do not exceed MZCLs within GWMZ boundaries. The Revision 1.5 GWMZ Application contains updated MZCLs for PCE, TCE, cis-1,2-DCE and VC. If the concentration of a GWMZ constituent exceeds the MZCL at a plume compliance well, the well will be re-sampled within 30 days of receipt of a valid data report to confirm that the exceedance occurred. If the event is validated by the confirmation sample results, SRS will notify the USEPA and SCDHEC of this occurrence. If directed by the DOSB OU Core Team, SRS will begin implementing the corrective action strategy as outlined in the Conceptual Corrective Action Plan Strategy (WSRC 1999a).

3.2.3 Boundary Compliance Wells

The purpose of boundary compliance wells is to verify that contaminants do not exceed MCLs at the southern edge of the GWMZ boundary. If the concentration of a GWMZ constituent exceeds the standards listed in Regulation 61-58: State Primary Drinking Water Regulations, or the MCL at a boundary compliance well, the well will be re-sampled within 30 days of receipt of a valid data report to confirm that the exceedance occurred. If the event is validated by the confirmation sample results, SRS will notify the USEPA and SCDHEC of this occurrence. If directed by the DOSB OU Core Team, SRS will begin implementing the corrective action strategy as outlined in the Conceptual Corrective Action Plan Strategy (WSRC 1999a).

3.3 Natural Attenuation

As stated in the *Groundwater Mixing Zone Application for the D-Area Oil Seepage Basin (631-G) (U)* (SRNS 2009), reductive dechlorination is not considered a continuous viable process at the DOSB OU. At SRS, groundwater aquifers are normally depleted in natural carbon. However, petroleum hydrocarbons and chlorinated solvents were co-disposed at the DOSB (1952 to 1975), which provided a favorable situation for the reductive dechlorination of PCE and TCE in groundwater. Biodegradation of PCE and TCE likely occurred in the vadose zone, but the water table is shallow at the DOSB OU

(2.4- to 4.5-m [8- to 15-ft] bgs). Thus, the pathway to groundwater is relatively short. Past biogeochemical zonation at the DOSB may have included reductive dechlorination zones near the source, followed by oxidative degradation of VC at some point downgradient. Over time and with the source removal/treatment of the DOSB OU (1995 to 1997), the concentrations of PCE and TCE have significantly declined, as well as the concentrations of the petroleum hydrocarbons.

The co-disposal of petroleum hydrocarbons provided a ready carbon source for biological degraders, and the presence of degradation products (cis-1,2-DCE and VC) in the plume wells suggest that past biodegradation has effectively degraded the parent compounds. Since the source of the carbon has become depleted, groundwater has reverted to natural aerobic conditions in the existing carbon-poor environment. Natural attenuation at the DOSB OU relies mainly on physical processes (dispersion/dilution), except for aerobic degradation of vinyl chloride.

For evaluation, trends for pH, alkalinity, oxidation reduction potential (ORP) and dissolved oxygen (DO) sampled between 2000 and 2006 are compared to 2019 data. Groundwater conditions have evolved overtime back to aerobic conditions so the current conditions are compared to data from 2000 – 2006 when conditions were more anaerobic and suitable for reductive dichlorination."

In terms of pH, wells sampled between 2000 and 2006 had pH values ranging from 3.5 to 7.8 as compared to the 2019 data (Table A-1) with pH values ranging from 4.1 to 7.1. Microbes capable of degrading chlorinated aliphatic hydrocarbons and petroleum hydrocarbons generally prefer pH values ranging from 6 to 8.

Wells sampled between 2000 and 2006 had ORP values ranging from -30 to 600 millivolts (mV), while the 2019 data show ORP values ranging from -21 to 391 mV. The ORP of groundwater is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater containing organic compounds are usually biologically mediated and therefore, the ORP of a groundwater system depends upon and influences rates of biodegradation. In addition, ORP is important because some biological processes operate only within a prescribed ORP range. Reductive dechlorination typically occurs at an ORP range of -200 to 50 mV; however, 20 of the 22 measurements were above this range with the majority of them above 150 mV.

Wells sampled between 2000 and 2006 had DO values ranging from 0 to 8.4 mg/L, while the 2019 data show DO values ranging from 1.31 to 9.37 mg/L. DO is the most thermodynamically favored electron acceptor used by microbes for the biodegradation of organic carbon, whether natural or anthropogenic. Anaerobic bacteria generally cannot function at DO concentrations greater than 0.5 mg/L.

Alkalinity values for wells sampled between 2000 and 2006 ranged from 0 to 180 mg/L, while the 2019 data show alkalinity values range between 0 and 92 mg/L. Seven out of 20 measurements were 0 mg/L. There is a positive correlation between zones of microbial activity and increased alkalinity. Increases in alkalinity result from the dissolution of rock driven by the production of carbon dioxide (CO_2) produced by the metabolism of microorganisms. Alkalinity is important in the maintenance of groundwater pH because it buffers the groundwater against acids generated during both aerobic and anaerobic biodegradation. However, alkalinity does not have a direct effect on reductive dechlorination at the DOSB OU, especially since the 2019 results indicate a decrease in the alkalinity range.

Based on the comparison of data collected in 2019 with known reductive dechlorination parameters, reductive dichlorination is not occurring at the DOSB.

4.0 GROUNDWATER MONITORING

4.1 Monitoring Well Network

The GWMZ monitoring network includes two background wells, nine plume compliance wells, and seven boundary compliance wells (i.e. distal plume monitoring wells). In addition to the approved GWMZ monitoring network, SRS samples four additional wells (near the source) and one surface water location to provide plume detail. The monitoring wells are used to monitor contaminant concentrations in background wells, near the DOSB OU source, beneath the existing plume, in the plume, and at the downgradient compliance boundary. Table 3 provides a list of these 22 wells, the monitoring category, and well screen intervals/aquifer zones monitored.

No changes to the monitoring well network occurred in 2019.

4.2 Sampling and Analysis

During 2019, the scheduled groundwater and surface water sampling were completed for all the DOSB wells. Groundwater samples were analyzed for VOCs (PCE, TCE, 1,1-DCE, cis-1,2-DCE, VC, DCM, and benzene), and field measurements of pH, specific conductance, alkalinity, and NA indicator parameters (ORP and DO) in 2Q2019. The surface water sample (DOSBW1) was analyzed for VOCs and field measurements (pH, specific conductivity and NA indicator parameters) in 2Q2019. Background wells DOB 9 and DOL 1 are sampled biannually and were last sampled in 2018.

4.3 Monitoring Results

No anomalous data were identified for the DOSB OU groundwater or surface water samples. The Groundwater Monitoring Results and Data Review Key are included in Appendix A. Figures are included in Appendix B, hydrographs are included in Appendix C, and the time series plots are included in Appendix D.

4.4 Compliance and Mixing Zone Monitoring

The analyte concentrations and baseline levels for GWMZ monitoring network wells sampled during 2019 are provided in Table A-1. The potentiometric data and the analytical results are depicted in Figures B-5 through B-12. In each table, the sample results are compared with the applicable concentration limits according to the category of the well sampled. Table 2 includes the specific well categories and limits that apply. The 2019 GWMZ Report indicate the following:

- The field measurements in groundwater samples from 2019 for pH, alkalinity, and specific conductance are similar to past results.
- NA indicator parameters ORP and DO in groundwater samples from 2019 are similar to past results.
- There were no exceedances of the MZCLs in the plume compliance wells nor the near source "additional" wells.
- There were no exceedances of the MCLs in the boundary compliance wells nor the surface water sampling point DOBSW1.

4.4.1 Background Wells

Background wells DOL 1 and DOB 9 are sampled on a biannual basis during even numbered years (Figure B-4). DOL 1 and DOB 9 were last sampled during 2Q2018 and were non-detect for all VOCs except methylene chloride, a common laboratory contaminant, detected at DOL 1 (3.4 µg/L).

4.4.2 Plume Compliance Wells

There are nine plume compliance wells: DOB 15, DOB 15A, DOB 15D, DOB 15PZ, DOB 16, DOB 19, DOB 19A, DOB 23, and DOL 2 (Figure B-4). All VOC concentrations detected in the plume compliance wells were below their respective MZCLs (Table A-1). 1,1-DCE and DCM were not detected in any of the plume compliance wells. Benzene and PCE concentrations detected in the plume compliance wells did not exceed their MCL of 5 µg/L.

The maximum VOC concentrations detected in the plume compliance wells were from the same well DOB 15 (PCE at 4.86 µg/L; TCE at 18 µg/L; cis-1,2-DCE at 107 µg/L; and VC at 19.1 µg/L). Well DOB 15D located in the upper portion of the Gordon Aquifer, had low level detections of VOCs below their respective MCLs. VOCs were not detected at well DOB 15PZ, which is ~3-m (10-ft) below where well DOB 15D is screened.

4.4.3 Boundary Compliance Wells

There are seven boundary compliance wells: DOB 20, DOB 20A, DOB 21, DOB 21A, DOB 21PZ, DOB 22, and DOB 22A. 1,1-DCE, benzene, VC, DCM, PCE, and TCE were not detected in any of the boundary compliance wells (Table A-1). Estimated values (i.e., "J" values) of cis-1,2-DCE were detected in boundary compliance wells with the maximum value (0.42 µg/L) detected in well DOB 21 considerably below the MCL (70 µg/L).

4.4.4 Near Source "Additional" Wells

The near source "additional" wells DOB 11, DOB 12, DOB 13, and DOB 14 are monitored for plume definition (Figure B-4). All VOC concentrations detected in these wells were below their respective MZCLs (Table A-1). 1,1-DCE and DCM were non-detect in all four wells.

Concentrations of benzene (0.41 J µg/L), cis-1,2-DCE (8.68 J µg/L) PCE (4.68 µg/L), TCE (25.6 J µg/L), and VC (4.02 µg/L) were detected in well DOB 11. Concentrations of cis-1,2-DCE (3.93 J µg/L), PCE (2.72 µg/L) and TCE (4.13 J µg/L) were detected in well DOB 12. All other VOC concentrations were below detection in wells DOB 11, DOB 12, DOB 13 and DOB 14.

4.4.5 Surface Water Sample

Surface water (DOBSW1) is sampled when sufficient surface water is available (Figure B-4). This location was sampled during 2019. Only cis-1,2-DCE (0.98 J µg/L) and TCE (0.52 J µg/L) were detected in the surface water sample in 2019 at low levels well below their respective MCLs (Table A-1).

4.4.6 Trend Analysis

As shown in Table A-1 and Figures B-6 through B-12, the 2019 monitoring results did not exceed the established limits for any of the DOSB OU wells. The maximum concentrations of PCE (4.86 µg/L), TCE (18 µg/L), VC (19.1 µg/L), and cis-1,2-DCE (107 µg/L) were detected in well DOB 15 (plume compliance well), but below the specific

MZCLs (78 µg/L, 200 µg/L, 147 µg/L, and 1,164 µg/L, respectively). Results from all the wells were significantly less than established limits.

The time-series plots for all DOSB GWMZ wells (1Q1995 to 2Q2019) and the surface water sample (DOBSW1) are provided in Appendix D. The DOSB GWMZ constituents included in the plots are 1,1-DCE, benzene, VC, cis-1,2-DCE, DCM, PCE, and TCE.

For 1,1 DCE, all sampling results at the DOSB OU were non-detect in 2019. Based on the time series plots, there have been no exceedances of the MCL (7 µg/L) for 1,1-DCE in any of the DOSB OU wells. No exceedances of 1,1-DCE have occurred in the surface water location (DOBSW1).

For benzene, all sampling results at the DOSB OU were below the MCL (5 µg/L) in all wells. There have been no exceedances of the MCL for benzene in the plume compliance or boundary compliance wells since sampling began for the GWMZ. Only one of the four near source “additional” wells (DOB 11 in 2003) exceeded the MCL for benzene. No other exceedance of the benzene MCL has occurred in the near source “additional” wells. No exceedances of benzene have occurred in the surface water location (DOBSW1).

For VC, there were no exceedances of the MZCL (147 µg/L) in the plume compliance or near source “additional” wells in 2019. Additionally, there were no exceedances of the MCL (2 µg/L) in the boundary compliance wells in 2019. There have been no exceedances of the MCL for VC in the boundary compliance wells since sampling began for the GWMZ. Only two boundary compliance wells (DOB 21 and DOB 21A) have had detects of VC which occurred in 2005 and were below the MCL (2 µg/L). No exceedances of VC have occurred in the surface water location (DOBSW1).

For cis-1,2-DCE, there were no exceedances of the MZCL (1,164 µg/L) in the plume compliance or near source “additional” wells in 2019. Additionally, there were no exceedances of the MCL (70 µg/L) in the boundary compliance wells in 2019. There have been no exceedances of the MCL for cis-1,2-DCE in the boundary compliance wells since sampling began for the GWMZ. None of the plume compliance wells have exceeded the

MZCL (1,164 µg/L) for cis-1,2-DCE since sampling began for the GWMZ. Only one near source "additional" well (DOB 11) had a detect in 2003 that exceeded the MZCL (1,164 µg/L) for cis-1,2-DCE. All other results for the near source "additional" wells have been below the MZCL for cis-1,2-DCE. No exceedances of cis-1,2-DCE have occurred in the surface water location (DOBSW1).

For DCM, all sampling results at the DOSB were non-detect in 2019. Based on the time series plots, there have been no exceedances of the MCL (5 µg/L) for DCM in any of the DOSB wells. No exceedances of DCM have occurred in the surface water location (DOBSW1).

Based on the long-term results for benzene, 1,1-DCE, and DCM (primarily non-detects), SRS proposes to remove their time series plots from Appendix D.

For PCE, there were no exceedances of the MZCL (78 µg/L) in the plume compliance or near source "additional" wells in 2019. Additionally, there were no exceedances of the MCL (5 µg/L) in the boundary compliance wells in 2019. There have been no exceedances of the MCL (5 µg/L) for PCE in the boundary compliance wells since sampling began for the GWMZ. Likewise, none of the plume compliance wells have exceeded the MZCL (78 µg/L) for PCE since sampling began for the GWMZ. Only one near source "additional" well (DOB 13) had detects that exceeded the MZCL (78 µg/L) for PCE in 2010. All other results from the near source "additional" wells have been below the MZCL for PCE. No exceedances of PCE have occurred in the surface water location (DOBSW1).

For TCE, there were no exceedances of the MZCL (200 µg/L) in the plume compliance or near source "additional" wells in 2019. Additionally, there were no exceedances of the MCL (5 µg/L) in the boundary compliance wells in 2019. There have been no exceedances of the MCL (5 µg/L) for TCE in the boundary compliance wells since sampling began for the GWMZ. Likewise, none of the plume compliance wells have exceeded the MZCL (78 µg/L) for TCE since sampling began for the GWMZ. Two of the near source "additional" wells (DOB 11 in 2003 and DOB 13 in 2010) had detects that exceeded the MZCL (200 µg/L) for TCE. All other results from the near source "additional" wells have been below the MZCL for TCE. No exceedances of TCE have occurred in the surface water location (DOBSW1).

Contaminant transport time estimates for shallow wells suggest that peak concentrations of PCE and TCE should have already occurred within the GWMZ. For PCE and TCE, maximum concentrations in 2006 were 54 µg/L and 100 µg/L, respectively. The highest concentration of PCE and TCE in 2019 was 4.86 µg/L and 18 µg/L, respectively. In general, most VOC concentrations continue to show an overall decreasing trend in the DOSB OU wells. However, VOC concentrations intermittently increase/decrease in various wells, including the "additional" wells (DOB 11 through 14) and plume compliance wells DOB 15A, DOB 15D and DOB 16. This trend may indicate the following: 1) core plume movement downgradient from the original source area; 2) effects of increased/decreased rainfall; and 3) degradation of parent VOC contaminants. Periods of high water levels may correlate with increased contaminant concentrations. Residual vadose zone contaminants may be released into the groundwater as water elevations drop from higher to lower water elevations (Figures 1-4). During times of increased VOC concentrations, contaminant levels in the DOB wells are still far below historical highs and below the MZCLs.

Contaminant trends at the highest concentration well, DOB 15, show steady concentrations of VC, cDCE, and TCE, (Figure D-29, D-52, and D-144, respectively). As for the dispersion/dilution of VOCs, it is speculated that VOCs are being retarded by the aquitards and clayey zones and/or restricted groundwater flow zones through tighter aquifer zones. Wells DOB 15, DOB 16 and DOL 2 are located within or below clayey zones in which VOCs may be sorbing to those clays thereby prolonging the physical attenuation process (dispersion) as well as slowing the transport vertically. Figure B-12 shows the VC plume in cross-section and vertical well distribution. The amount of aerobic degradation of cDCE and VC at these locations may be less than the amount being physically transported from previously higher concentrated areas located above and upgradient of those zones, as well as, what is desorbing from clayey zones. As shown in Appendix D, trends of parent and daughter VOCs at wells DOB 11 (source), DOL 2 (near source), and DOB 15 (intermediately located) show that there has not been much divergence of contaminant trends (increases of degradation products compared to parent products) to indicate that degradation is occurring at a significant rate after the source removal action.

Contaminant levels in wells downgradient of well cluster DOB 15 (wells DOB 19 and DOB 19A) display decreasing trends (Appendix D). Modeling had indicated that an increase in VC may occur around 2016; however, due to trends shown in DOB 15, it appears that contaminant transport has more retardation than modeling indicated. Additionally, further downgradient boundary compliance wells (well clusters DOB 20, DOB 21, and DOB 22) and surface water concentrations continue to be below MCLs or remain non-detect; therefore, the DOSB OU GWMZ is performing adequately.

5.0 GROUNDWATER FLOW DIRECTION AND RATE

5.1 Water Elevation Measurements

Water-level data have been used to prepare a potentiometric surface map (Figure B-5) for AQ1/AQ2, AQ3, and GAU. The hydrographs in Appendix C include the water elevation history for all the wells sampled during 2019.

The maps and hydrographs provide information to calculate the groundwater flow direction and flow rate, as well as the effectiveness of the well network and GWMZ boundaries. The existing well network and GWMZ boundaries are adequate for the DOSB OU plume as the plume is contained within the boundaries and the distribution of monitoring wells defines the horizontal and vertical extent of the existing plume.

Although the spatial distribution of the potentiometric data is limited, the characterization data for the contaminant plumes and the DOSB OU numerical modeling studies to support the GWMZ Application indicate primary groundwater flow and contaminant transport pathways. The DOSB OU monitoring wells are located in-line with primary transport pathways and provide a representative sample of the DOSB OU plume in groundwater.

5.2 Horizontal and Vertical Flow Rates

The horizontal groundwater flow rate (or average linear groundwater velocity) is calculated using the following equation:

$$\text{Flow (ft/day)} = \frac{\text{Hydraulic Conductivity, } K_h \text{ (ft/day)}}{\text{Effective Porosity (unitless)}} \times \frac{dh \text{ (ft)}}{dl \text{ (ft)}}$$

The value *dh* is the difference in head, and *dl* is the length of the flow path shown on the map. The ratio *dh/dl* is the horizontal gradient. A porosity of 0.3 was assumed for the calculations, which is consistent with porosity values used at other SRS OUs. The groundwater flow velocity is directly related to the hydraulic gradient. A gradient of 0.0005 to 0.0030 was calculated based on data collected between October 1994 and March 1995 (WSRC 1998). The average (2019) hydraulic (horizontal) gradient is 0.002 in the AQ1/AQ2 zones, 0.003 in the AQ3 zone, and 0.0057 in the GAU. Based on slug test results, the horizontal hydraulic conductivity for the combined AQ1/AQ2 zones ranges from 3.4 x 10^{-3} to 8.5 x 10^{-3} cm/sec (10 to 24 ft/day). For the purposes of this calculation, the mid-point of the range, 6.0 x 10^{-3} cm/sec (17 ft/day) was used. The hydraulic conductivity for AQ3 was calculated at 1.4 x 10^{-3} cm/sec (3.9 ft/day), approximately four times lower than the combined AQ1/AQ2 zones (WSRC 1998). The hydraulic conductivity for GAU was not calculated because of the effectiveness of the GCU and because the head distribution represents an upward potential, limiting the vertical migration of contaminants (WSRC 1998). The estimated horizontal gradients and groundwater flow rates are shown in Table 4.

Based on the 2Q2019 water elevation data, the difference in hydraulic head (comparing AQ1/AQ2 water level measurements with GAU-AQ1 measurements in DOB 15 and DOB 21) range between +1.7 and 2.9 m (+5.7 and +9.6 ft). The head difference across the GCU (i.e., hydraulic head difference between the UTRAU/Unnamed-AQ and the GAU) is typically 1.8 to 3.3 m (6 to 11 ft). The vertical gradients for the DOB 15 and DOB21 wells are 0.52 ft/ft and 0.44 ft/ft, respectively. Using the vertical conductivity of the DOSB OU sediments as= 1.0E-5 cm/sec (0.028 ft/day) and porosity as= 0.3, the estimated vertical groundwater flow rate is about 4.9 m/yr (16 ft/yr).

In AQ1/AQ2, the estimated horizontal groundwater flow rate for 2Q2019 is ~2.5 times as much as the estimated vertical flow rate. In AQ3, the vertical flow rate is approximately the same as the estimated 2Q2019 horizontal flow rate. This indicates that in 2019 the horizontal flow was approximately the same as the vertical flow in AQ3. The groundwater beneath the DOSB OU flows to the southwest towards the Savannah River and the GWMZ boundaries are adequate for the DOSB OU plume.

5.3 Recharge and Precipitation Measurements

The groundwater recharge rate can be estimated using site-specific precipitation data. Typically, the amount of precipitation that enters groundwater as recharge is 25% of the total measured precipitation. Table 5 is a summary of rainfall over the last four decades (1979 to 2019). The meteorological data was taken from the meteorological station in C Area beginning in November 2012. During 2019, the total rainfall in C Area was 115.9cm (45.63 in.), close to the average rainfall rate over the last 40 years (119.08 cm [46.88 in.]). Based on the annual precipitation rate for the year 2019, the recharge to the water table aquifer was ~28.96 cm (11.4 in.) compared with 37.47 cm (14.75 in.) in 2018 and 32.59 (12.83 in.) in 2017. The average groundwater recharge over the last 40 years was 29.77 cm (11.72 in.).

6.0 CONCLUSIONS

The scheduled sampling and chemical analyses were completed for all DOSB OU wells in 2019. The groundwater data presented in this 2019 GWMZ Report show that the DOSB OU contaminant plume continues to remain below the MZCLs for the plume compliance and near source “additional” wells and below the MCLs for the boundary compliance wells. The maximum concentrations of all GWMZ constituents detected were significantly less than the established criteria. Additionally, there were no detections of VOCs in the surface water location (DOBSW1).

Along with the chemical analysis, all the DOSB OU well samples were analyzed for NA indicator parameters in 2019. The 2Q2019 results for pH, alkalinity, ORP and DO indicate that the groundwater conditions are too aerobic to support reductive dechlorination. Natural attenuation at the DOSB OU relies mainly on physical processes (dispersion/dilution) except for possible aerobic degradation of VC depending on the availability of carbon.

The 2019 water levels in individual wells are within 0.6 m (2 ft) of the 2018 levels (Appendix C). Groundwater flow remains to the southwest toward the Savannah River.

Overall, the groundwater data presented in this 2019 GWMZ Report show that the DOSB OU contaminant plumes continue to remain below the respective MZCLs and MCLs for each well. Based on these results, the 2019 groundwater data confirm that the existing GWMZ boundaries remain adequate for the DOSB OU plume.

As agreed to in the comment response for the DOSB OU letter report submitted in 2019, a Core Team meeting will be held in 2020 to discuss the trends in the DOSB OU plumes, the overall effectiveness of the NA/GWMZ remedy, and whether or not conditions at the DOSB OU warrant future action.

7.0 REFERENCES

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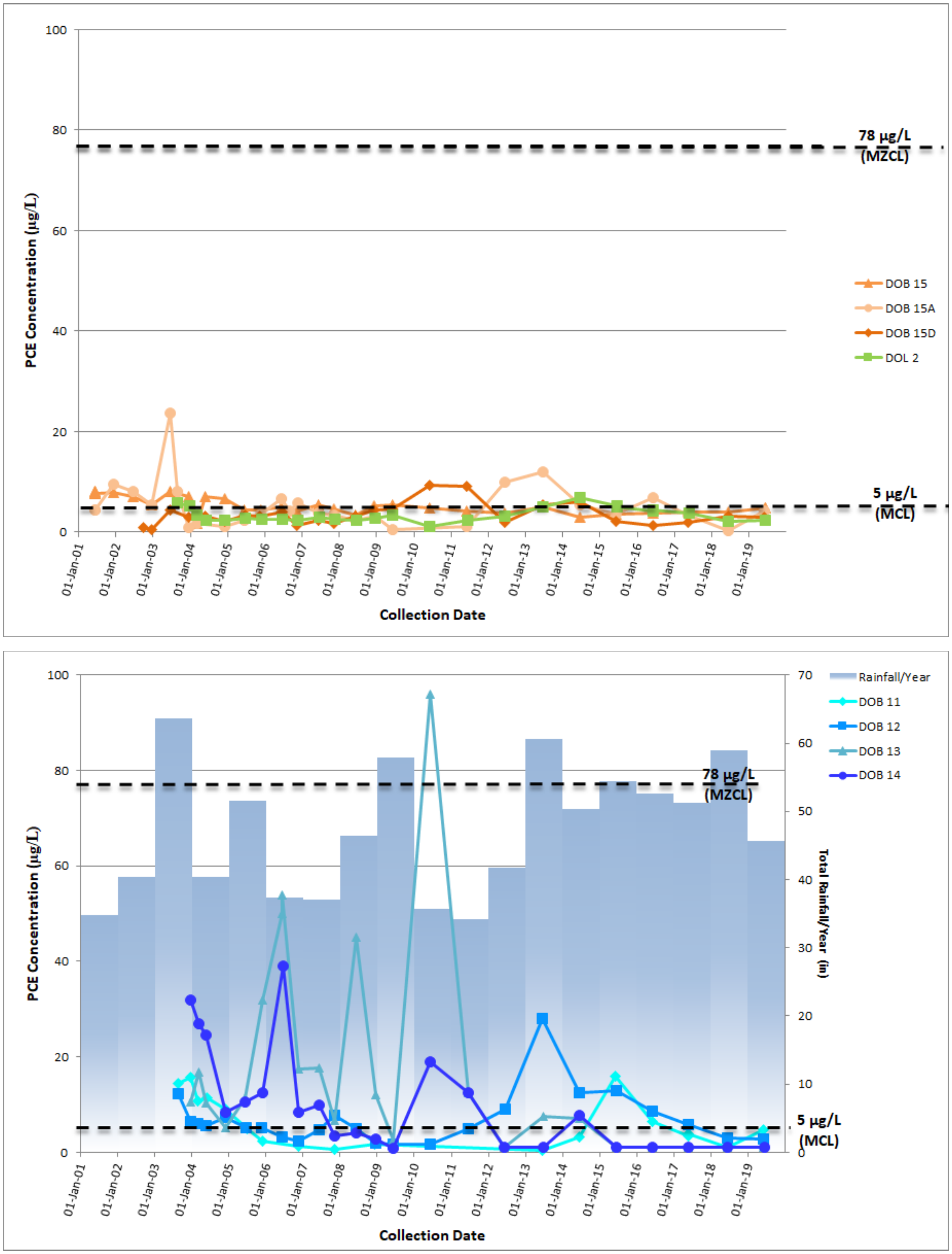
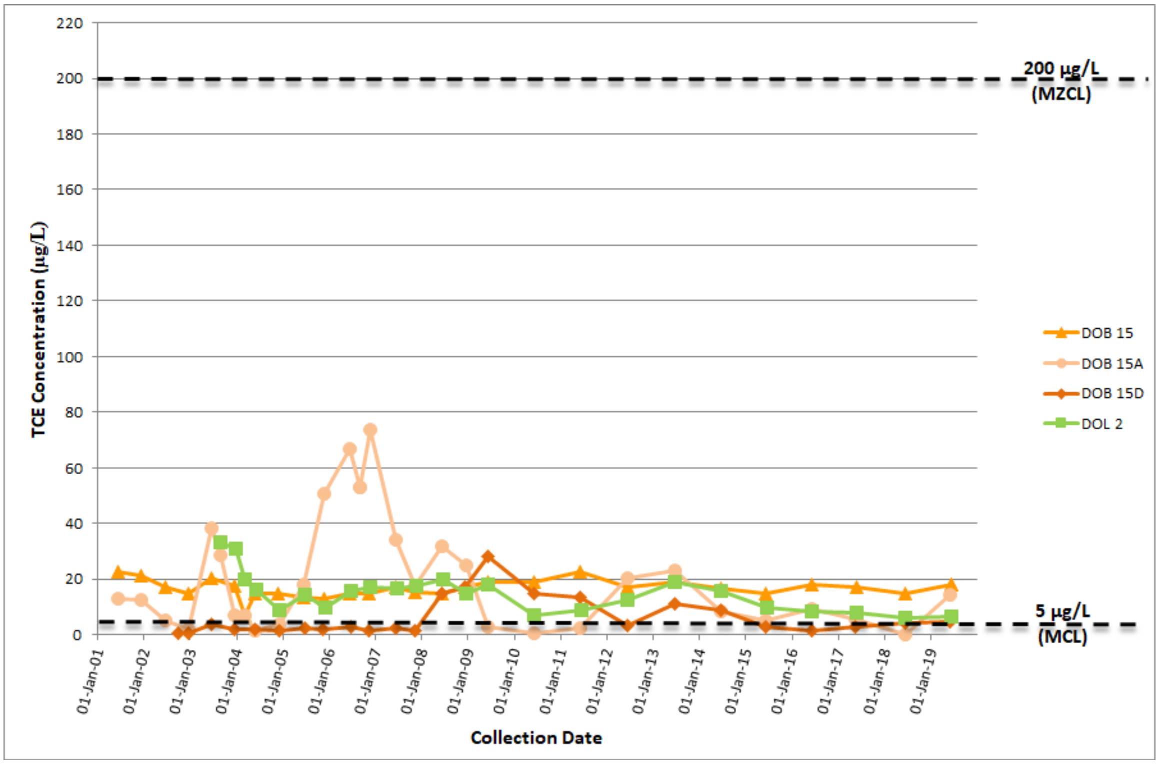


Figure 1. PCE Concentrations Vs. Rainfall at Plume Compliance Wells (DOB 15, 15A, 15D and DOL 2) and Additional Wells (DOB 11, 12, 13 and 14) at the DOSB OU



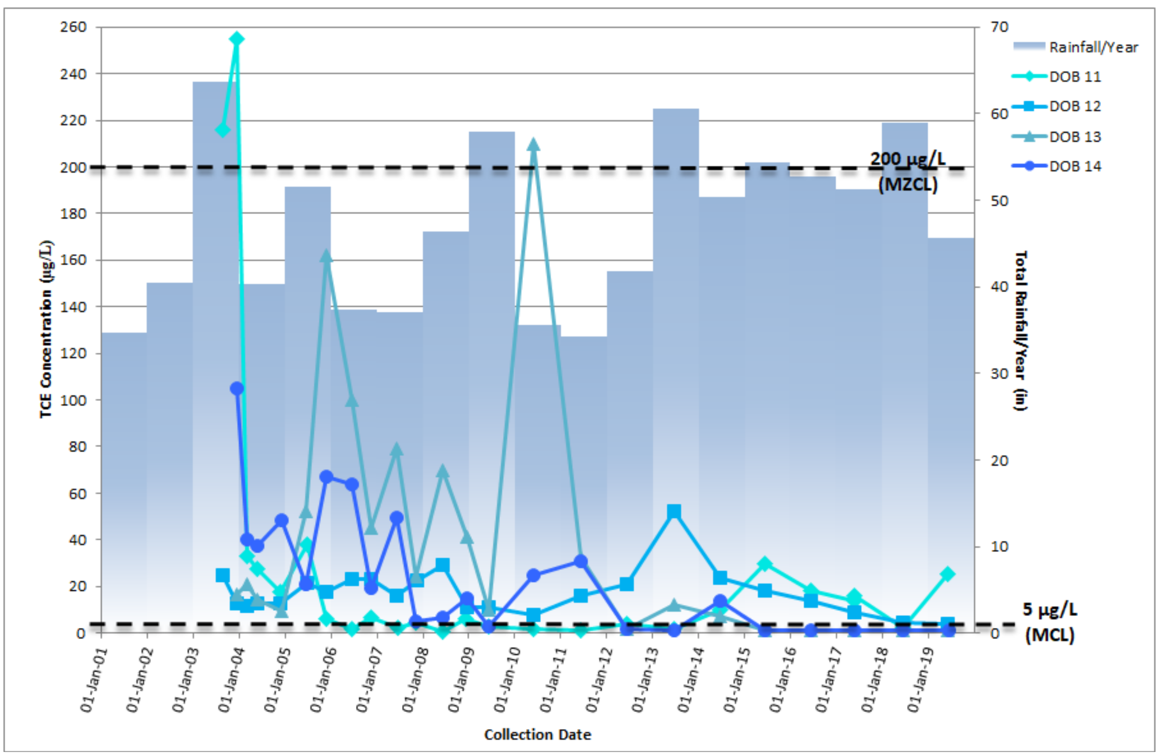


Figure 2. TCE Concentrations Vs. Rainfall at Plume Compliance Wells (DOB 15, 15A, 15D and DOL 2) and Additional Wells (DOB 11, 12, 13 and 14) at the DOSB OU

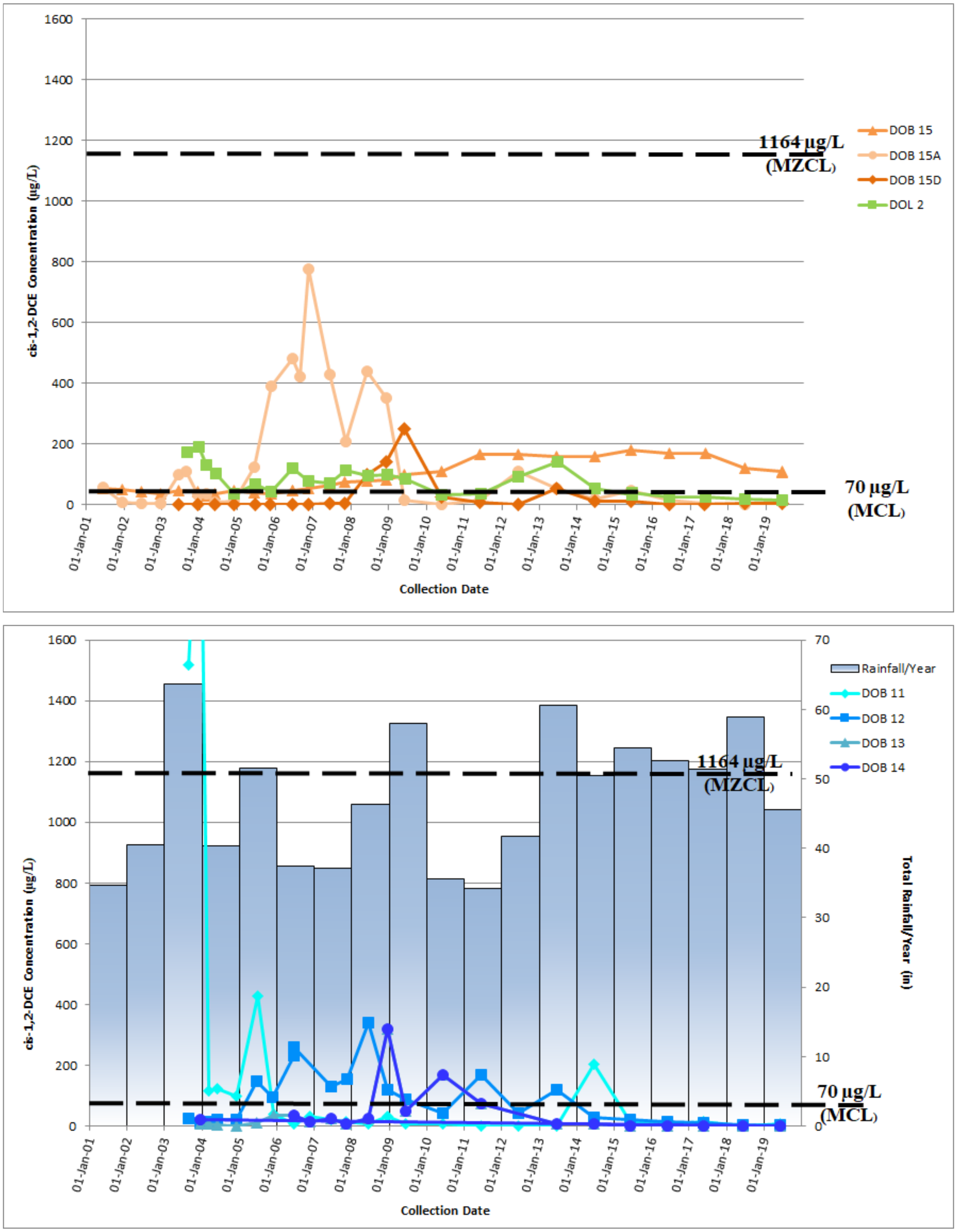


Figure 3. **cis-1,2-DCE Concentrations Vs. Rainfall at Plume Compliance Wells (DOB 15, 15A, 15D and DOL 2) and Additional Wells (DOB 11, 12, 13 and 14) at the DOSB OU**

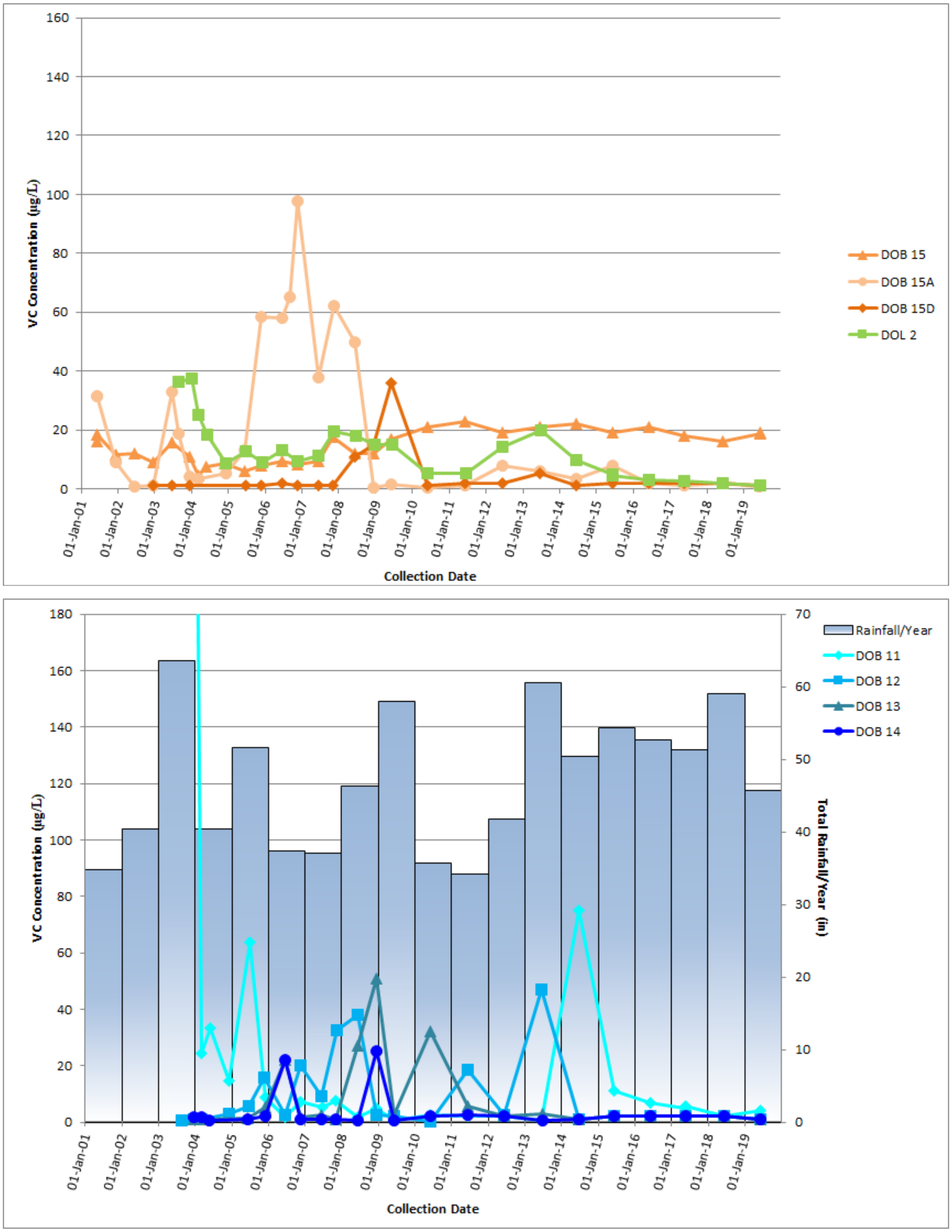


Figure 4. **VC Concentrations Vs. Rainfall at Plume Compliance Wells (DOB 15, 15A, 15D and DOL 2) and Additional Wells (DOB 11, 12, 13 and 14) at the DOSB OU**

Table 1. Comparison Criteria for GWMZ Constituents

GWMZ Constituents	Baseline Value from Background Wells (DOL 1 and DOB 9)	MCL ($\mu g/L$)	MZCL ($\mu g/L$)
Tetrachloroethylene (PCE)	<EQL	5	78
Trichloroethylene (TCE)	<EQL	5	200
Cis-1,2-Dichloroethylene (cis-1,2-DCE)	<EQL	70	1,164
1,1-Dichloroethylene (1,1-DCE)	<EQL	7	7
Vinyl Chloride (VC)	<EQL	2	147
Benzene	<EQL	5	5
Dichloromethane (DCM)	<EQL	5	5

Table 2. Monitoring Well Sampling

Well Identification	Constituents Analyzed	Comparison Criteria[1]	Sampling Frequency
Background Wells: DOB 9, DOL 1	GWMZ Constituents, Field Parameters[2]	Baseline	Biennial (2Q)
Plume Compliance Wells DOB 15, DOB 15A, DOB 15D, DOB 15PZ, DOB 16, DOB 19, DOB 19A, DOB 23, DOL 2	GWMZ Constituents, Field Parameters[2]	MZCLs	Annual (2Q)
Boundary Compliance Wells DOB 20, DOB 20A, DOB 21, DOB 21A, DOB 21PZ, DOB 22, DOB 22A	GWMZ Constituents, Field Parameters[2]	MCLs	Annual (2Q)
Additional Wells DOB 11, DOB12, DOB13, DOB14	GWMZ Constituents, Field Parameters[2]	MZCLs	Annual (2Q)
Surface Water DOBSW1	GWMZ Constituents, Field Parameters[3]	MCLs	Annual (2Q)

1 - See Table 1
2 - Field parameters are alkalinity, pH, specific conductance, temperature, turbidity, oxidation reduction potential, dissolved oxygen, volume purged and water level measurements
3 - Field parameters are oxidation reduction potential, dissolved oxygen, pH, specific conductance, and turbidity

Table 3. Details of DOSB Monitoring Wells and Surface Water Location

Well	Monitoring Category	Screen Zone Top *(ft msl)*	Screen Zone Bottom *(ft msl)*	Aquifer Zone
DOL 1	Background Well	119.2	109.2	AQ3
DOB 9	Background Well	148.5	128.5	AQ1/2
DOB 11	Additional Well	131.1	126.1	AQ2
DOB 12	Additional Well	138.8	133.8	AQ2
DOB 13	Additional Well	131.0	126.0	AQ2
DOB 14	Additional Well	137.6	132.6	AQ2
DOL 2	Plume Compliance Well	123.6	113.6	AQ3
DOB 15	Plume Compliance Well	115.7	110.6	AQ3
DOB 15A	Plume Compliance Well	132.7	122.7	AQ2
DOB 15D	Plume Compliance Well	72.35	62.3	GAU-AQ1
DOB 15PZ	Plume Compliance Well	54.8	49.8	GAU-AQ2
DOB 16	Plume Compliance Well	108.2	103.0	AQ-Unnamed
DOB 19	Plume Compliance Well	114.5	104.5	AQ3
DOB 19A	Plume Compliance Well	129.5	119.5	AQ2
DOB 23	Plume Compliance Well	81.02	76.0	GAU-AQ1
DOB 20	Boundary Compliance Well	112.7	102.7	AQ3
DOB 20A	Boundary Compliance Well	129.5	119.5	AQ2
DOB 21	Boundary Compliance Well	113.3	103.4	AQ3
DOB 21A	Boundary Compliance Well	128.9	118.9	AQ2
DOB 21PZ	Boundary Compliance Well	46.3	41.3	GAU-AQ2
DOB 22	Boundary Compliance Well	111.8	101.8	AQ3
DOB 22A	Boundary Compliance Well	127.5	117.5	AQ2
DOBSW1	Surface Water	NA	NA	NA

NA = Not Applicable

Table 4. Horizontal Groundwater Flow Rate Summary

Aquifer Zones	Sample Period	Horizontal Gradient	Flow Rate *(ft/day)*	Flow Rate *(ft/yr)*
AQ1/AQ2, LAZ of the UTRAU	2Q2019	0.002	0.118	43.2
AQ3, LAZ of the UTRAU	2Q2019	0.003	0.0417	15.2

Table 5. Rainfall Measurements at 400-D (in), 1979 to 2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1979	3.48	9.49	3.06	4.54	7.45	1.37	5.57	7.14	6.13	0.82	6.38	2.35	57.78
1980	4.23	3.05	11.1	2.45	4.15	4.5	0.97	1.65	7.51	2.05	1.73	2.71	46.1
1981	0.72	3.8	4.16	2.64	3.7	4.96	4.56	6.18	0.06	3.04	0.66	8.86	43.34
1982	4.48	4.89	3.17	4.98	3.64	5.82	3.36	3.12	3.2	3.71	1.68	6.08	48.13
1983	4.09	7.12	5.36	5.43	2.4	3.44	1.63	5.32	2.54	2.42	4.35	4.03	48.13
1984	3.22	5.65	5.3	4.91	5.39	6.07	8.81	1.97	0.73	0.38	1.15	1.34	44.92
1985	2.64	5.71	1.01	1.53	1.79	6.25	8.9	4.15	0.2	5.53	7.16	2.7	47.57
1986	1.14	2.8	3.07	0.48	2.48	5.01	1.66	8.13	0.52	2.52	4.7	3.96	36.47
1987	6.49	6.65	3.85	0.28	1.39	4.69	2.45	1.73	4.64	0.19	2.34	1.27	35.97
1988	3.55	5.3	2.04	6.18	1.56	6.94	1.76	5.04	5.06	2.45	1.81	1.15	42.84
1989	1.78	3.17	4.56	4.72	2.42	5.73	7.39	0.23	5.11	4.57	2.61	2.37	44.66
1990	2.05	3.51	3.19	0.29	1.1	1.22	4.8	5.23	0.44	17.12	1.26	1.67	41.88
1991	7.49	2	7.15	4.9	3.09	2.58	9.11	8.59	1.52	0.53	1.01	3.34	51.31
1992	3.59	4.86	3.27	2.48	2.15	7.55	7.29	6.27	3.58	3.91	6.64	1.95	53.54
1993	7.92	2.55	9.7	1.3	2.24	8.65	1.85	3.06	6.42	0.87	1.84	2.25	48.65
1994	4.71	4.49	6.72	1.29	1.66	7.33	6.08	3.62	2.33	8.98	2.86	4.71	54.78
1995	5.28	6.06	2.47	0.17	2.28	7.24	4.2	6.86	3.95	2.11	2.49	4.47	47.58
1996	2.6	2.05	6.26	1.69	1.6	3.65	4.89	7.93	3.72	1.98	1.5	2.74	40.61
1997	4.14	5.1	1.98	3.42	1.69	6.82	6.54	1.37	5.41	4.74	4.29	7.93	53.43
1998	7.76	6.26	7.86	7.14	4.2	2.86	7.53	2.98	6.33	0.65	0.57	1.89	56.03
1999	6.9	2.26	2.98	2.12	2.59	7.37	6.36	5.46	3.45	2.18	0.65	0.91	43.23
2000	5.11	0.77	4.26	1.62	0.21	5.85	3.86	4.15	9.11	0.06	3.33	1.61	39.94
2001	2.69	3.05	7.28	1.43	3.24	6.54	2.19	3.14	3.31	0.18	1.12	0.57	34.74
2002	2.04	2.23	4	1.59	1.63	3.9	4.41	4.55	3.72	4.57	3.94	3.86	40.44
2003	2.07	5.31	8.07	8.64	6.81	9.18	10.14	3.96	2.63	3.39	1.19	2.26	63.65
2004	2.7	7.11	0.86	1.28	2.79	7.83	2.91	1.96	7.05	0.59	2.74	2.54	40.36
2005	2.35	4.43	6.07	1.26	4.12	9.57	5.19	4.64	2.07	2.95	2.53	6.4	51.58
2006	3.19	2.61	1.35	2.29	2.34	6	5.26	1.59	2.81	1.77	3.76	4.4	37.37
2007	3.18	2.87	1.7	2.48	1.23	5.42	4.97	3.04	0.91	1.47	0.14	9.67	37.08
2008	4	5.89	4.66	2.35	2.42	0.27	6.82	6.86	0.57	4.47	2.93	5.13	46.37
2009	2.03	0.8	4.25	5.86	8.21	1.72	4.47	7.67	5.74	2.89	4.56	9.75	57.95
2010	4.9	2.62	2.5	1.71	1.34	7.29	2.39	7.04	2.51	0.48	1.45	1.41	35.64
2011	2.2	4.95	5.67	3.53	1.17	2.81	2.5	2.54	2.38	1.86	2.68	1.91	34.2
2012*	1.91	1.59	3.07	1.43	6.96	3	5.27	9.85	1.55	0.54	1.51	5.1	41.78
2013*	0.92	9.89	3.65	5.17	3.17	10.87	11.44	7.39	1.06	0.51	1.58	4.92	60.57
2014*	3.21	5.31	3.08	3.45	2.57	5.63	7.34	3.28	6.27	.75	4.99	4.54	50.42
2015*	3.44	4.64	3.61	5.39	0.99	6.31	5.19	3.83	5	5.9	5.74	4.37	54.41
2016*	2.8	4.8	3.45	3.51	5.58	6.87	4.06	5	6	4.8	0.26	5.54	52.67
2017*	9.21	1.47	2.56	6.04	4.26	4.51	6.49	3.25	5.79	1.55	1.35	4.84	51.32
2018*	2.46	1.86	3.72	3.49	6.55	4.96	6.14	5.22	4.43	4.52	7.8	7.83	58.98
2019*	5.03	1.18	2.4	3.67	2.64	7.49	1.63	4.83	1.2	3.74	3.46	8.36	45.63
Average	3.75	4.15	4.26	3.15	3.10	5.51	5.08	4.63	3.58	2.87	2.80	3.99	46.38
Max	9.21	9.89	11.10	8.64	8.21	10.87	11.44	9.85	9.11	17.12	7.80	9.75	63.65
Min	0.72	0.77	0.86	0.17	0.21	0.27	0.97	0.23	0.06	0.06	0.14	0.57	34.20

* Beginning in Nov 2012, 100-C rain gauge used for rainfall measurement data because of issues with the D-Area rain gauge.

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APPENDIX A

DOSB 2019 GROUNDWATER MONITORING RESULTS TABLES
AND
DATA REVIEW KEY

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LIST OF FIGURES

Appendix A Figures **Page**

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Key to Reading the Tables
The following abbreviations may appear in the data tables:

Constituents

1,2,3,4,6,7,8-HPCDD	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin
1,2,3,4,6,7,8-HPCDF	1,2,3,4,6,7,8-heptachlorodibenzo-p-furan
1,2,3,4,7,8-HXCDD	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin
1,2,3,4,7,8-HXCDF	1,2,3,4,7,8-hexachlorodibenzo-p-furan
Lindane	gamma-benzene hexachloride
PCB	polychlorinated biphenyl
1,2,3,7,8-PCDD	1,2,3,7,8-pentachlorodibenzo-p-dioxin
1,2,3,7,8-PCDF	1,2,3,7,8-pentachlorodibenzo-p-furan
Sp. conductance	specific conductance
TCDD	tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzo-p-furan

Laboratories

ARS	ARS/David and Floyd
EBL	Environmental Bioassay Laboratory (SRS)
GEL	General Engineering Laboratories, Inc.
MCR	Microseeps
TAL	Test America Laboratory

Nomenclature

AZ	Aquifer Zone
CBAU	Crouch Branch Aquifer Unit (previously Black Creek)
CBCU	Crouch Branch Confining Unit
GAU	Gordon Aquifer Unit
GCU	Gordon Confining Unit
GCCZ	Green Clay Confining Zone
LAZ	Lower Aquifer Zone
LLAZ	Lost Lake Aquifer Zone
LLLAZ	Lower Lost Lake Aquifer Zone (previously Lower Congaree)
MAAZ	M-Area Aquifer Zone (previously Water Table)
MSAZ	Middle Sand Aquifer Zone (previously Ellenton Sand)
PZ	Perched Zone
UAZ	Upper Aquifer Zone
ULLAZ	Upper Lost Lake Aquifer Zone (previously Upper Congaree)
UNK	Unknown
UTRAU	Upper Three Runs Aquifer Unit

Sampling Codes

B	blank sample was collected
C	well was pumping continuously
D	well was dry
E	equipment blank was collected
I	well went dry during sampling; insufficient water to collect all samples
L	well went dry before sampling began; only depth to water can be determined
N	well was not stabilized before sampling began
P	inaccessibility or mechanical failure prevented sample collection and field analysis of the water
S	no water in standpipe; for water level events only
T	samples were collected, but some samples were not sent to the laboratory due to high turbidity
W	unable to sample well because of stabilization or sampling equipment failure; water-level measurements were obtained
X	well went dry during purging; samples collected after well recovered

Sampling Methods – ("Pump" column)

B	sample collected using an open-bucket bailer
O	sample collected by method other than bailer or pump
P	sample collected using a bladder pump
S	sample collected using a single-speed centrifugal downhole pump
V	sample collected using a variable-speed pump

Units

deg. C	degrees Celsius
Deg N	Degrees North
Deg W	Degrees West
E	East
ft	feet
mg/L	milligrams per liter
mV	millivolts
msl	mean sea level
N	North
nM	nanomoles
NTU	nepholometric turbidity unit
pCi/L	picocuries per liter
pCi/mL	picocuries per milliliter
pH	pH unit
μg/L	micrograms per liter
μS/cm	microsiemens per centimeter

Other

CLP	USEPA Functional Guideline Codes
CS	carbon steel
DF	dilution factor column in data tables
E	exponential notation (e.g., 1.1E–09 = 1.1 x 10^{-9} = 0.0000000011)
STORET	USEPA STORET result qualifiers
Filt.	Data results after application of the Data Usability filter
GWPS	groundwater protection standard
MCS	monitoring constituent standard
Mod	modifier column in data tables
NDD	"not decision data"
PDWS	primary drinking water standard
PVC	polyvinyl chloride
ST	exceeded the GWPS or MCS column in data tables
TOC	top of casing
<EQL	less than the sample-specific estimated quantitation limit

Results Below Detection

If the analyte is not detected, the sample-specific estimated quantitation limit (EQL) is entered into the result field and is reported with a less than [<] sign. The EQL is defined as the lowest concentration that can be achieved reliably within specified limits of precision and accuracy during routine laboratory operating conditions. The sample-specific EQL is modified for sample concentration or dilution or unusual aliquot size that affects analytical sensitivity.

Uncertainty and Data Usability

In April 1998, the South Carolina Department of Health and Environmental Control (SCDHEC) accepted guidance proposed by Savannah River Site (SRS) to apply a method for minimizing uncertainty in compliance decisions potentially affecting long-term monitoring or remediation (SCDHEC 1998). The method is applied by processing or "filtering" the data, using the United States Environmental Protection Agency (USEPA) Functional Guideline Codes (USEPA 1994; USEPA 1999) applied by the laboratories to qualify the analytical results. By removing all data with a result qualifier of "L", "R", "U", and "J" from consideration, groundwater data users can ensure that only quantified numerical results are applied to the decision process. The output of the filtering process populates the "Filt" column as follows:

1) "Null" or "blank" – Data not remarked. The analytical result is acceptable for use as reported, and the result is not greater than an associated concentration limit for the analyte.

Rationale: The best result would be one without qualifiers, so the preferred choice would be the maximum result that did not have any qualifiers.

2) "J", "L", "N", "NJ", or "JL" – "J" identifies that the analyte was positively identified; the associated numerical value is an estimated concentration of the analyte in the sample. "L" Indicates the sample result is off scale high. "JL" Indicates an estimated quantity of a sample that is off scale high. "N" is used for all TIC (tentatively identified compounds) and indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification. "NJ" means the presence of an analyte that has been tentatively identified and the associated numerical value represents its approximate concentration.

   Rationale: an estimate can still provide useful information. Although there may be a range of uncertainty around the actual value, the value itself may still grossly exceed a regulatory standard. However, an estimated value is less certain than an unqualified result. Therefore, this would be labeled as "NDD" (not decision data).

3) "U" - material analyzed for, but not detected. The analyte concentration is less than the sample specific Estimated Quantitation Limit and labeled "<EQL".

   Rationale: a result above the detection limit would be chosen before a result below detection so that the process is not biased toward false negatives.

4) "UJ" - result is not above the reported sample quantitation limit, but the reported quantitation limit itself is approximate, and may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

   Rationale: the additional qualifiers make this result less reliable for use than the "U" without qualifiers. These results would be labeled "<EQL".

5) "Rejected" **–** The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.

   Rationale: the only value in providing this result in the report is to indicate that the lab attempted to analyze the sample. If there are any other results available, the result with the "R" qualifier should not be reported. If it is reported, it is definitely "NDD" (not decision data).

Holding Times

Standard analytical methods include a limit (i.e., holding time) on the maximum elapsed time between sample collection and extraction or analysis by the laboratory. In the data tables, the result qualifier Q in the "EPA" column indicates that holding time was exceeded. Analyses performed beyond holding times may not yield valid results.

SCDHEC allows only 15 minutes elapsing between sampling and analysis for pH. Thus, only field pH measurements can meet the holding time criterion; laboratory pH analyses always will exceed it.

The laboratory procedure used for the determination of specific conductance allows one day elapsing between sampling and analysis. Thus, laboratory specific conductance measurements may exceed the holding time criterion.

Data Qualification

The contract laboratories submit sample- or batch-specific quality assurance/quality control information either at the same time as analytical results or in a quarterly summary. Properly defined and used, data qualifiers can be a key component in assessing data usability. The USEPA Functional Guideline Codes (USEPA 1994; EPA 1999) used by the analytical laboratories are shown in the CLP result qualifier column are defined below. These modifiers appear in the data tables under the column *CLP*. EPA STORET codes appear in the data tables under the column labeled *EPA*.

"CLP" Qualifiers - USEPA Functional Guidelines Codes (USEPA 1994 and USEPA 1999)

(Blank)	Data not remarked. The analytical result is acceptable for use as reported.
J	The analyte was positively identified; the associated numerical value is an estimated concentration of the analyte in the sample.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification. Used for all TIC results.
R	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence of absence of the analyte cannot be verified. Assignment of *R* requires approval by the appropriate WSRC data validation coordinator.
U	Material analyzed for but not detected. Analytical result reported is less than the sample quantitation limit.
N J	The analysis indicates the presence of an analyte that has been tentatively identified and the associated numerical value represents its approximate concentration.
U J	The analyte was not detected above the reported sample quantitation limit. The reported quantitation limit is approximate, and may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Note: These are only some of the qualifiers present in the database. All modifiers associated with the data are published in the official repository of the data.

"EPA" Qualifiers – USEPA STORET Codes

(Blank)	Data not remarked
C	The result is calculated.
I	The result is less than the ssEQL, but equal to or greater than the MDL. Always reported with an associated EPA functional Guideline Code qualifier of *J*.
K	The actual concentration is known to be less than the reported result.
L	The actual concentration is known to be less than the reported result.
O	Sample received by laboratory, but the analysis was lost or not performed.
Q	Sample was held beyond normal holding time prior to analysis.
V	The analyte was detected in both the method blank and the sample.
Y	The result is from an unpreserved or incorrectly preserved sample; the data may not be accurate.

Note: These are only some of the qualifiers present in the database. All modifiers associated with the data are published in the official repository of the data.

APPENDIX A - REFERENCES

SCDHEC, 1998. *RE: Groundwater Data Reporting Change at SRS*, Letter, G. K. Taylor (SCDHEC) to J. W. Cook (EPD/WSRC); April 21, 1998

USEPA, 1994. *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*, 9240.1-05-01, PB 94-963502, EPA540/R-94/013, U.S. Environmental Protection Agency, Washington, DC

USEPA, 1999. *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*, OSWER 9240.1-05A-P, PB99-963506, EPA540/R-99/008, U.S. Environmental Protection Agency, Washington, DC

Table A-1. DOSB Groundwater Monitoring Results, 2019

Station	Well Use	Aquifer Zone	SAMPLE COLLECTION DATE	DEPTH TO WATER	OXIDATION/REDUCTION POTENTIAL	OXYGEN	PH	PHENOLPHTHALEIN ALKALINITY (AS CACO3)	SAMPLING EVENT WATER ELEVATION	SPECIFIC CONDUCTANCE	SYNCHRONOUS MEASUREMENT DATE	SYNCHRONOUS WATER ELEVATION	TOTAL ALKALINITY (AS CACO3)	TURBIDITY	VOLUME PURGED	WATER TEMPERATURE	FIELD CONDITIONS	Compliance Comparison	DOSB Constituents of concern: 1,1-DICHLOROETHYLENE	BENZENE	CHLOROETHENE (VINYL CHLORIDE)	CIS-1,2-DICHLOROETHYLENE	DICHLOROMETHANE (METHYLENE CHLORIDE)	TETRACHLOROETHYLENE (PCE)	TRICHLOROETHYLENE (TCE)
																		Unit	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
																		Limit for Plume Compliance Wells - MZCL	7	5	147	1164	5	78	200
																		Limit for Plume Boundary Wells - MCL	7	5	2	70	5	5	5
Station	Well Use	Aquifer Zone	day-month-year	ft	mV	mg/L	pH	mg/L	ft	uS/cm	day-month-year	ft msl	mg/L	NTU	gal	degC		Limit for Each Well							
DOB 11	Additional	AQ2	05-Jun-2019	9.5	99	1.55	6.6	0	142.09	220	05-Jun-2019	142.09	92	3.3	7	19.6	No Comments	NR	<EQL (1)	[0.41]	4.02	[8.68]	<EQL (5)	4.68	[25.6]
DOB 12	Additional	AQ2	05-Jun-2019	10.8	198	2.26	5.4	0	141.95	60	05-Jun-2019	141.95	4	0.7	8	21.6	No Comments	NR	<EQL (1)	<EQL (1)	<EQL (1)	[3.93]	<EQL (5)	2.72	[4.13]
DOB 13	Additional	AQ2	05-Jun-2019	10.4	283	9.37	5.6	0	142.2	64	05-Jun-2019	142.2	7	0.5	7	19.6	No Comments	NR	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 14	Additional	AQ2	10-Jun-2019	9.91	183	4.67	4.7	0	142.54	58	05-Jun-2019	142.25	0	4.4	4	19.7	No Comments	NR	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 9	Background Well	AQ1/2	NS	NS	NS	NS	NS	NS	NS	NS	06-Jun-2019	143.49	NS	NS	NS	NS	No Comments	MCL	NS	NS	NS	NS	NS	NS	NS
DOL 1	Background Well	AQ3	NS	NS	NS	NS	NS	NS	NS	NS	06-Jun-2019	143.35	NS	NS	NS	NS	No Comments	MCL	NS	NS	NS	NS	NS	NS	NS
DOB 20	Boundary Compliance	AQ3	06-Jun-2019	10.73	182	2.84	7.1	0	138.95	205	06-Jun-2019	138.95	46	0.8	13	20.6	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 20A	Boundary Compliance	AQ1/2	06-Jun-2019	10.61	238	4.52	4.7	0	139.02	52	06-Jun-2019	139.02	0	1.7	7	19.2	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 21	Boundary Compliance	AQ3	06-Jun-2019	9.78	56	5.31	6.4	0	139.08	164	06-Jun-2019	139.08	65	0.1	14	19.3	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	[0.42]	<EQL (5)	<EQL (1)	<EQL (1)
DOB 21A	Boundary Compliance	AQ1/2	06-Jun-2019	9.82	298	4.18	4.8	0	139.17	50	06-Jun-2019	139.17	0	0.6	9	18.3	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 21PZ	Boundary Compliance	GAU	06-Jun-2019	19.36	182	5.35	5.1	0	129.46	38	06-Jun-2019	129.46	1	0.1	31	18.9	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 22	Boundary Compliance	AQ3	11-Jun-2019	8.88	48	3.58	6.2	0	138.85	132	06-Jun-2019	138.37	26	0.5	13	21.6	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 22A	Boundary Compliance	AQ1/2	06-Jun-2019	8.48	177	5.18	5.2	0	138.99	51	06-Jun-2019	138.99	6	0.3	8	19.1	No Comments	MCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 15	Plume Compliance	AQ3	10-Jun-2019	8.53	182	1.31	4.4	0	142.06	203	06-Jun-2019	141.55	0	1.6	11	19.9	No Comments	MZCL	<EQL (1)	[0.61]	19.1	107	<EQL (5)	4.86	18
DOB 15A	Plume Compliance	AQ2	06-Jun-2019	8.2	205	4.3	5.7	0	141.46	130	06-Jun-2019	141.46	6	0.3	8	17.8	No Comments	MZCL	<EQL (1)	<EQL (1)	[0.71]	12.5	<EQL (5)	4.27	14.4
DOB 15D	Plume Compliance	GAU	06-Jun-2019	11.3	236	4.7	5.1	0	138.97	33	06-Jun-2019	138.97	0	0.4	26	18.6	No Comments	MZCL	<EQL (1)	<EQL (1)	<EQL (1)	5.1	<EQL (5)	2.85	4.76
DOB 15PZ	Plume Compliance	GAU	06-Jun-2019	13.9	228	4.1	5	0	135.78	52	06-Jun-2019	135.78	0	0.3	31	18.7	No Comments	MZCL	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (1)	<EQL (5)	<EQL (1)	<EQL (1)
DOB 16	Plume Compliance	AQ_Unnamed	11-Jun-2019	9.14	-21	3.53	6.3	0	141.95	256	06-Jun-2019	141.37	52	2.7	12	21.9	No Comments	MZCL	<EQL (1)	<EQL (1)	2.22	20.2	<EQL (5)	1.07	3.73
DOB 19	Plume Compliance	AQ3	06-Jun-2019	6.6	133	2.72	6.1	0	140.36	172	06-Jun-2019	140.36	12	0.9	13	19.5	No Comments	MZCL	<EQL (1)	<EQL (1)	<EQL (1)	4.03	<EQL (5)	<EQL (1)	[0.87]
DOB 19A	Plume Compliance	AQ2	06-Jun-2019	6.24	117	2.73	6.1	0	140.32	153	06-Jun-2019	140.32	14	0.3	8	19.2	No Comments	MZCL	<EQL (1)	<EQL (1)	<EQL (1)	4.33	<EQL (5)	<EQL (1)	1.28
DOB 23	Plume Compliance	GAU	06-Jun-2019	8.17	190	4.89	5.5	0	138.3	42	06-Jun-2019	138.3	8	0.5	21	19.9	No Comments	MZCL	<EQL (1)	<EQL (1)	<EQL (1)	1.28	<EQL (5)	<EQL (1)	[0.37]
DOL 2	Plume Compliance	AQ3	11-Jun-2019	10.77	391	1.84	4.1	0	142.23	212	06-Jun-2019	142.56	0	0.7	9	19.6	No Comments	MZCL	<EQL (1)	<EQL (1)	<EQL (1)	16.8	<EQL (5)	2.26	6.65
DOBSW1	Surface Water	AQ1/2	10-Jun-2019	NS	-32	1.09	5.4	NS	NS	86	NS	NS	NS	430	0	20.7	No Comments	NR	<EQL (1)	<EQL (1)	<EQL (1)	[0.98]	<EQL (5)	<EQL (1)	[0.52]

* No MPV exists for cis-1,2-dichloroethylene. There for the MPV for total 1,2-Dichloroethylene was applied to cis-1,2-dichloroethylene for comparison purposes

Explanation

	Explanation
[##]	EPA Functional Guideline Code of 'J' was applied to the result, indicating an estimated quanity.
<EQL(##)	Constituent was below detection. The sample-specific Estimated Quantitation Limit is in parentheses.
(red)	Result exceeds applicable limit.
(orange)	Result is above the Baseline (ssEQL), and without EPA Functional Guideline qualifiers.
REJ	Result Rejected.
(white)	Result is less than the applicable limit and without EPA Functional Guidline qualifiers.
NS	Not sampled
Blue Text	Not a required sample analysis.

Figure A-1. DOSB Groundwater Monitoring Results, 2Q2019

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APPENDIX B

DOSB 2019 FIGURES

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LIST OF FIGURES

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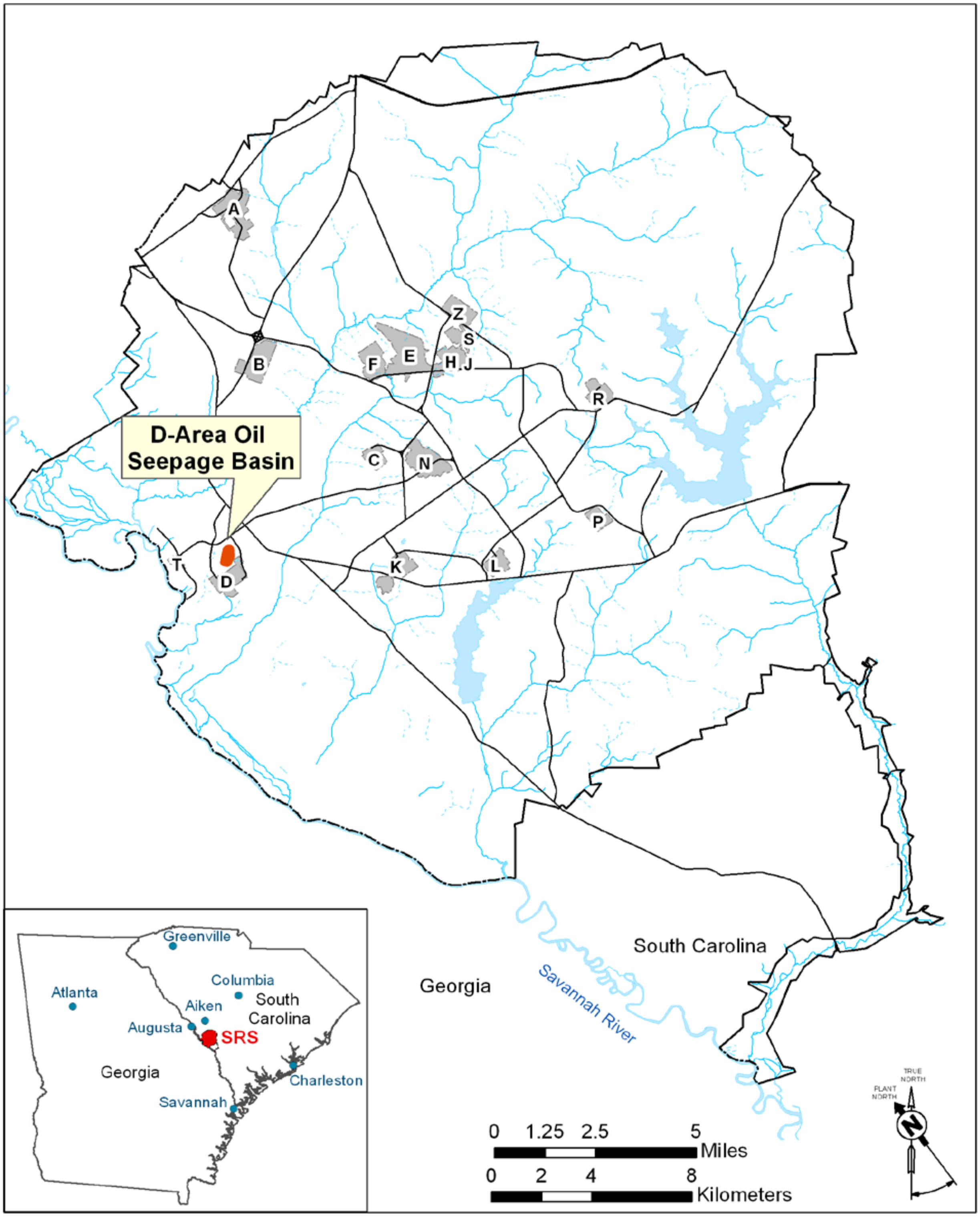

Figure B-1. Location of D-Area Oil Seepage Basin (DOSB) at the Savannah River Site

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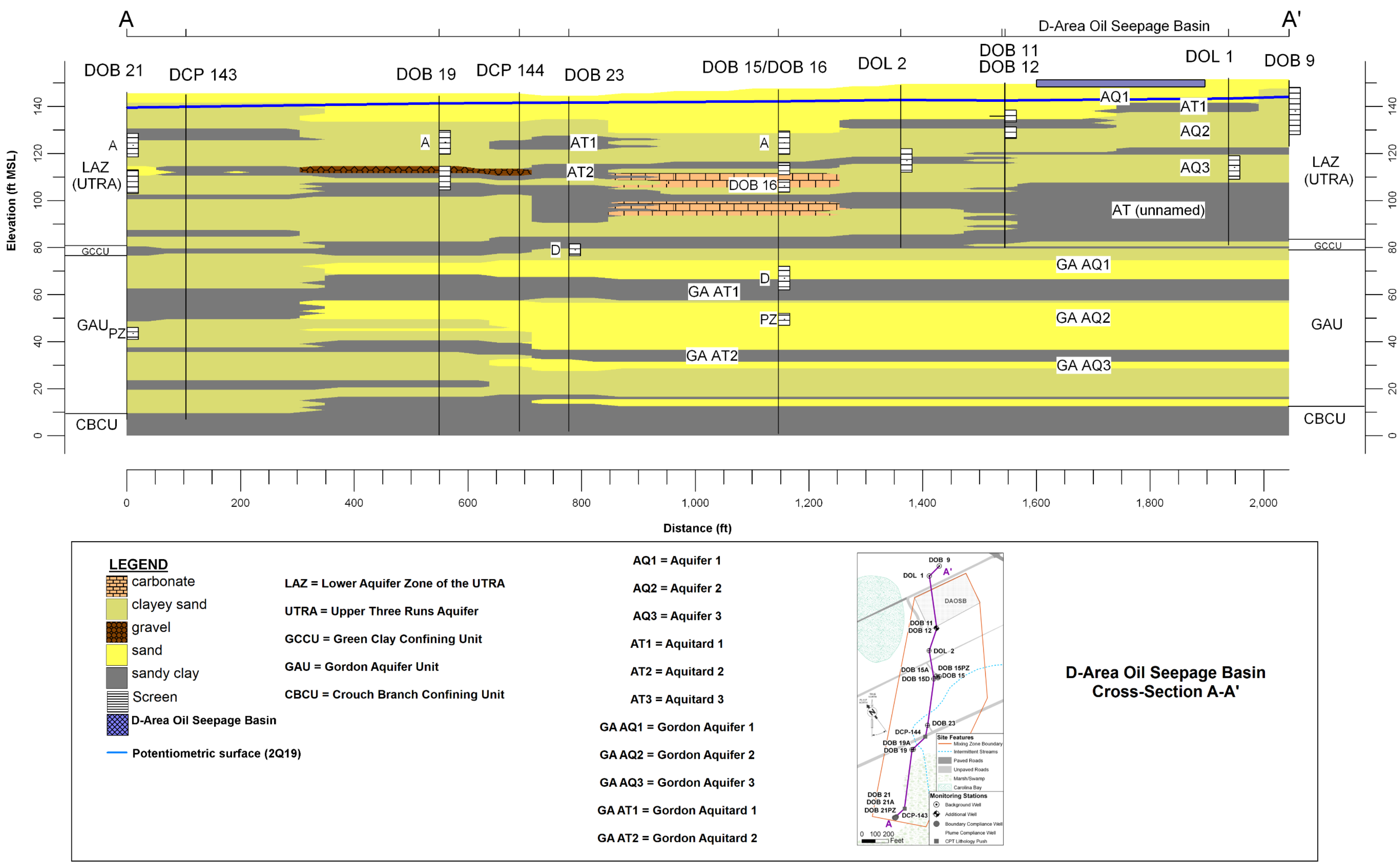

Figure B-2. DOSB Conceptual Cross-Section A-A’

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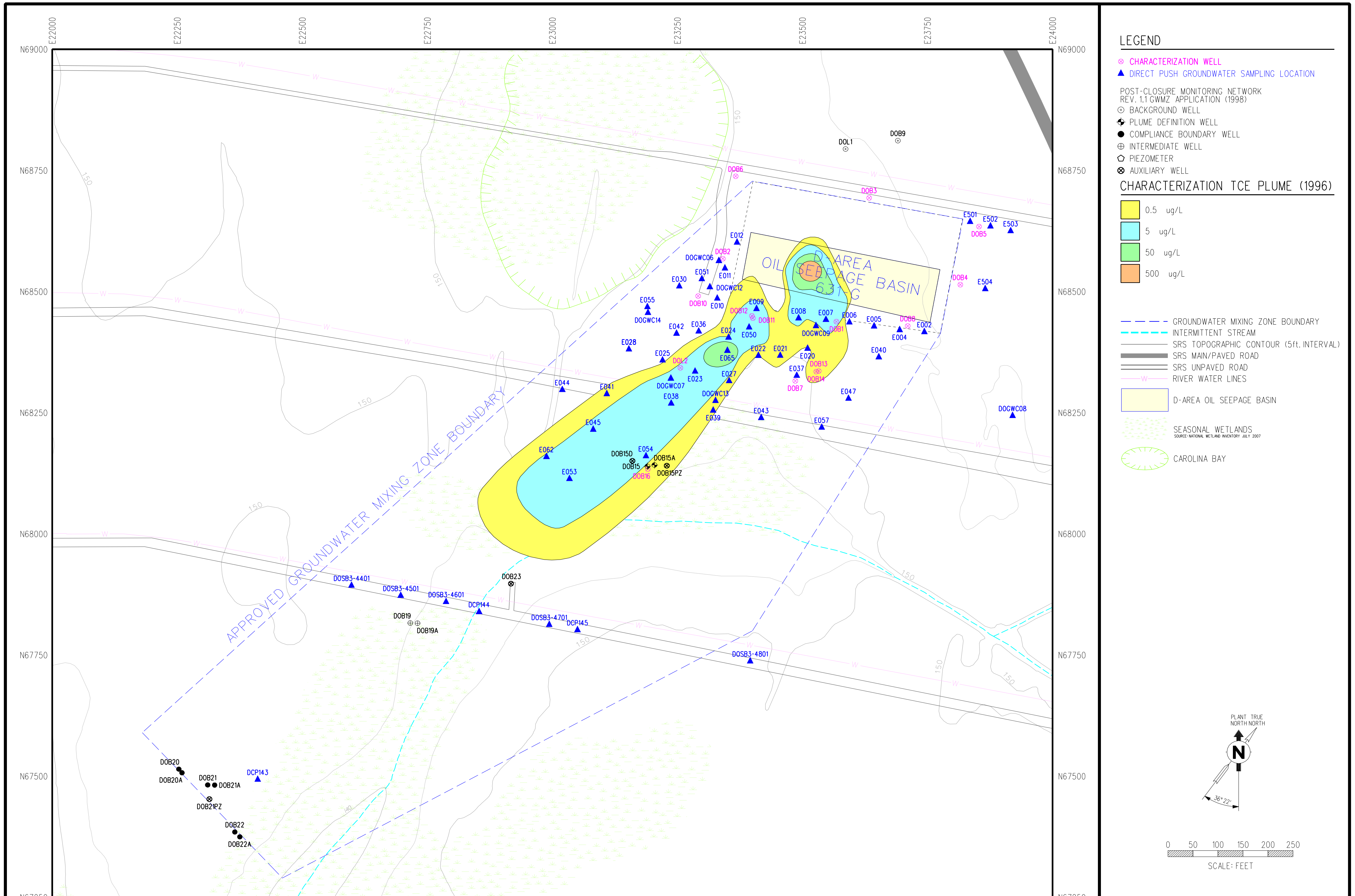

FIGURE B-3. POST-CLOSURE MONITORING WELL NETWORK DESIGNED FOR PLUME CONFIGURATION BASED ON CHARACTERIZATION EFFORTS

Figure B-3. Post-Closure Monitoring Well Network Designed for Plume Configuration Based on Characterization Efforts

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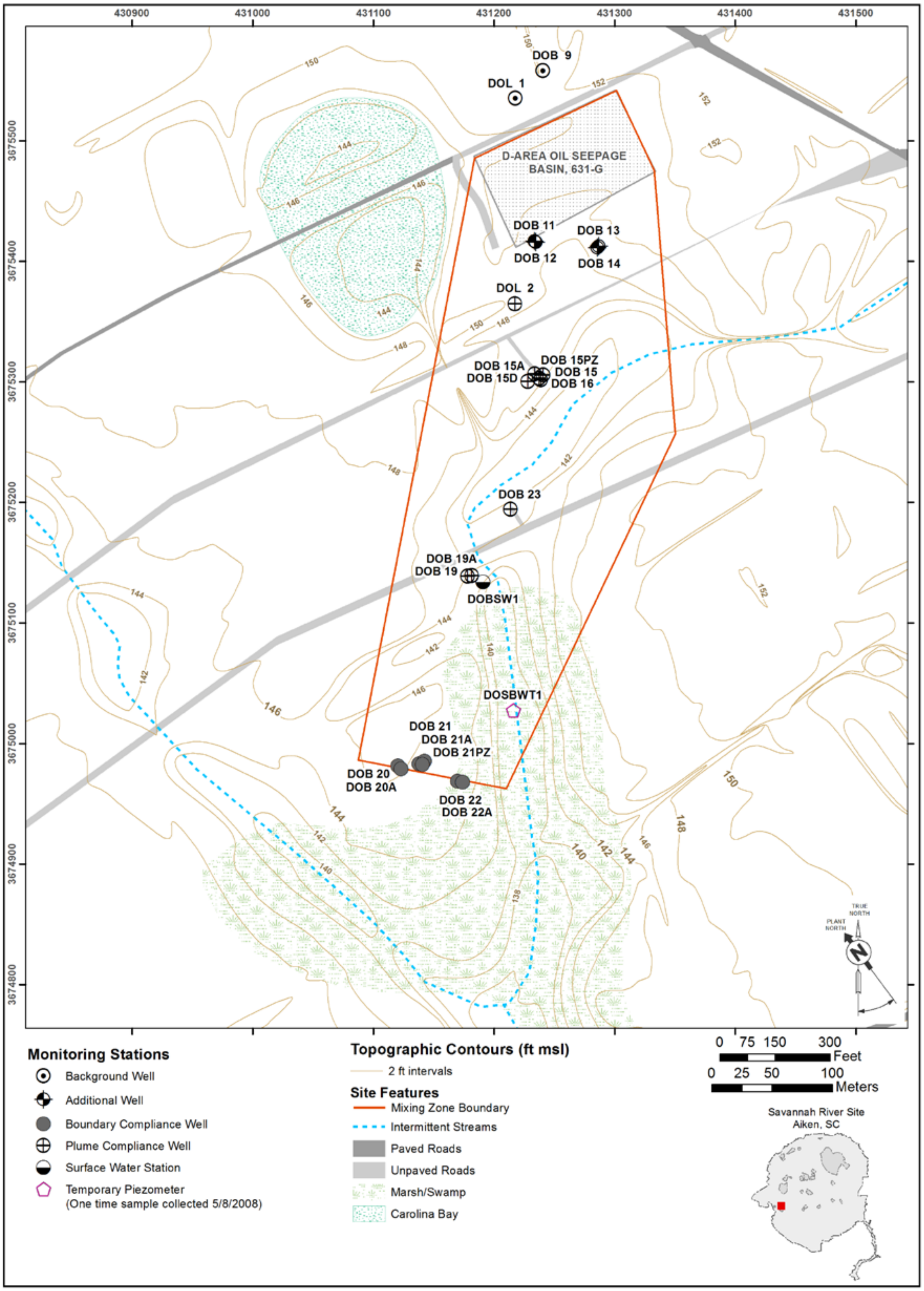

Figure B-4. DOSB Monitoring Well Network

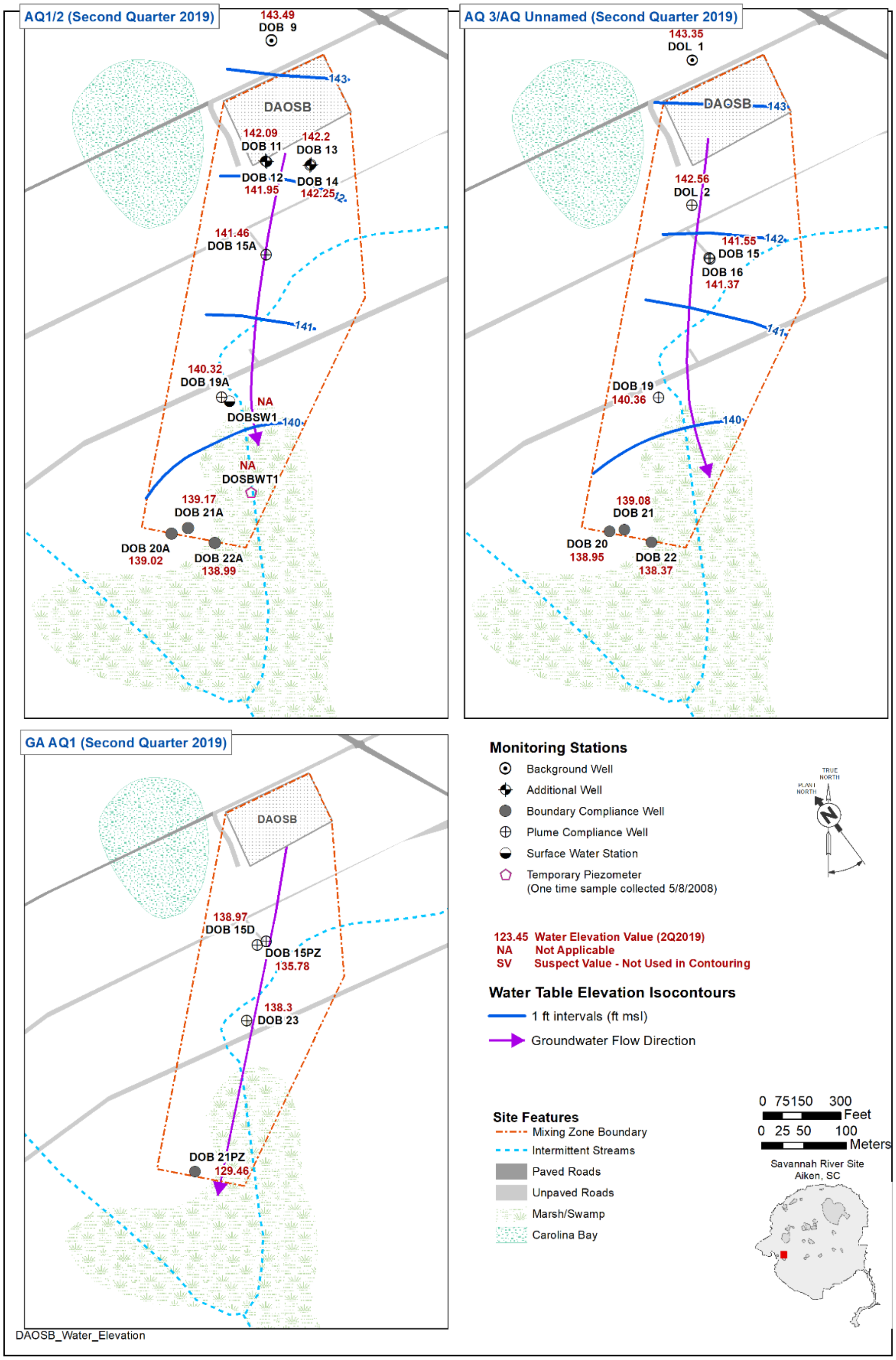

Figure B-5. DOSB Potentiometric Data – AQ1/2, 3 and GAU AQ1, 2019

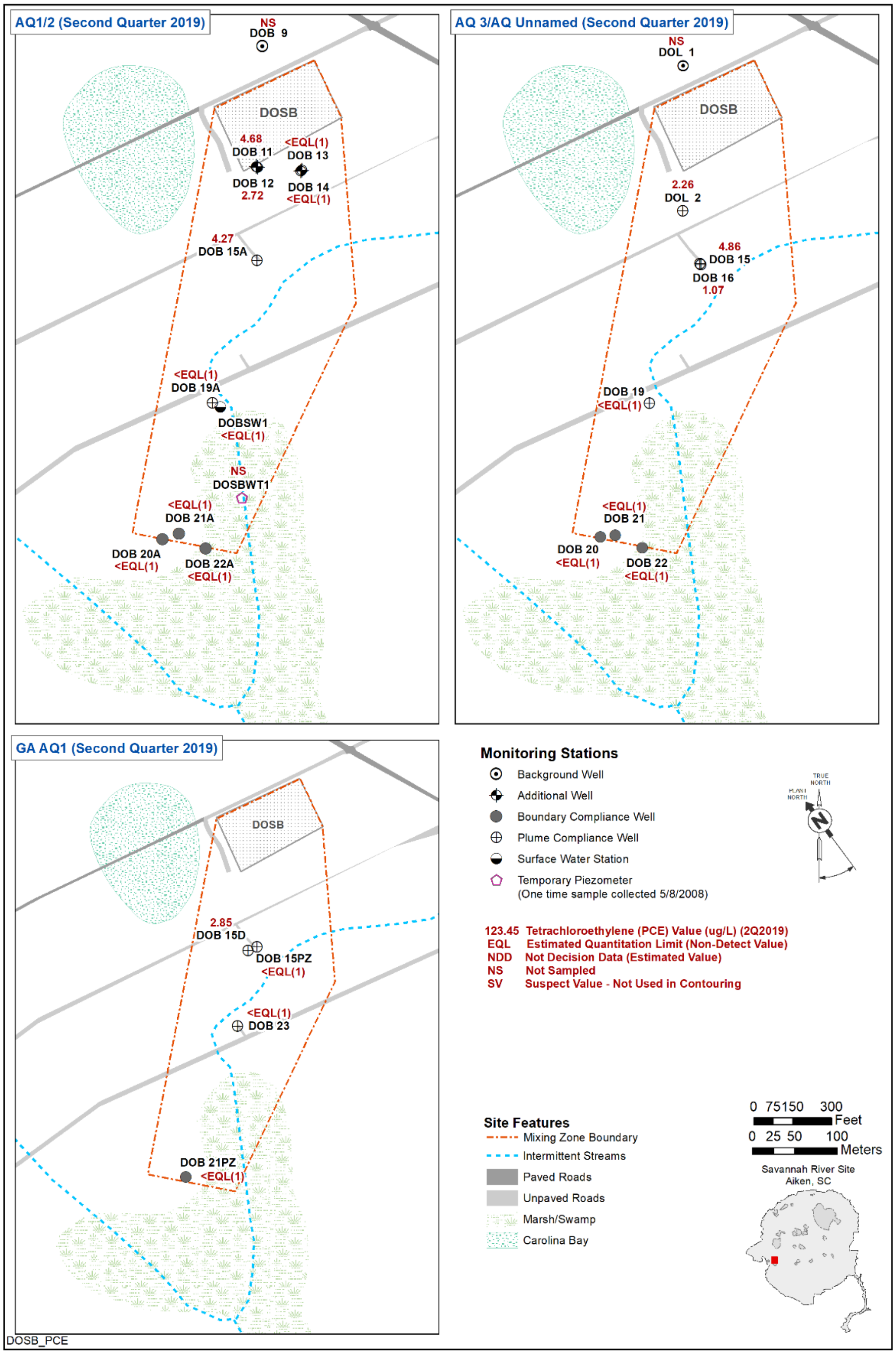

Figure B-6. DOSB PCE Concentrations in AQ1/2, 3 and GA AQ1, 2019

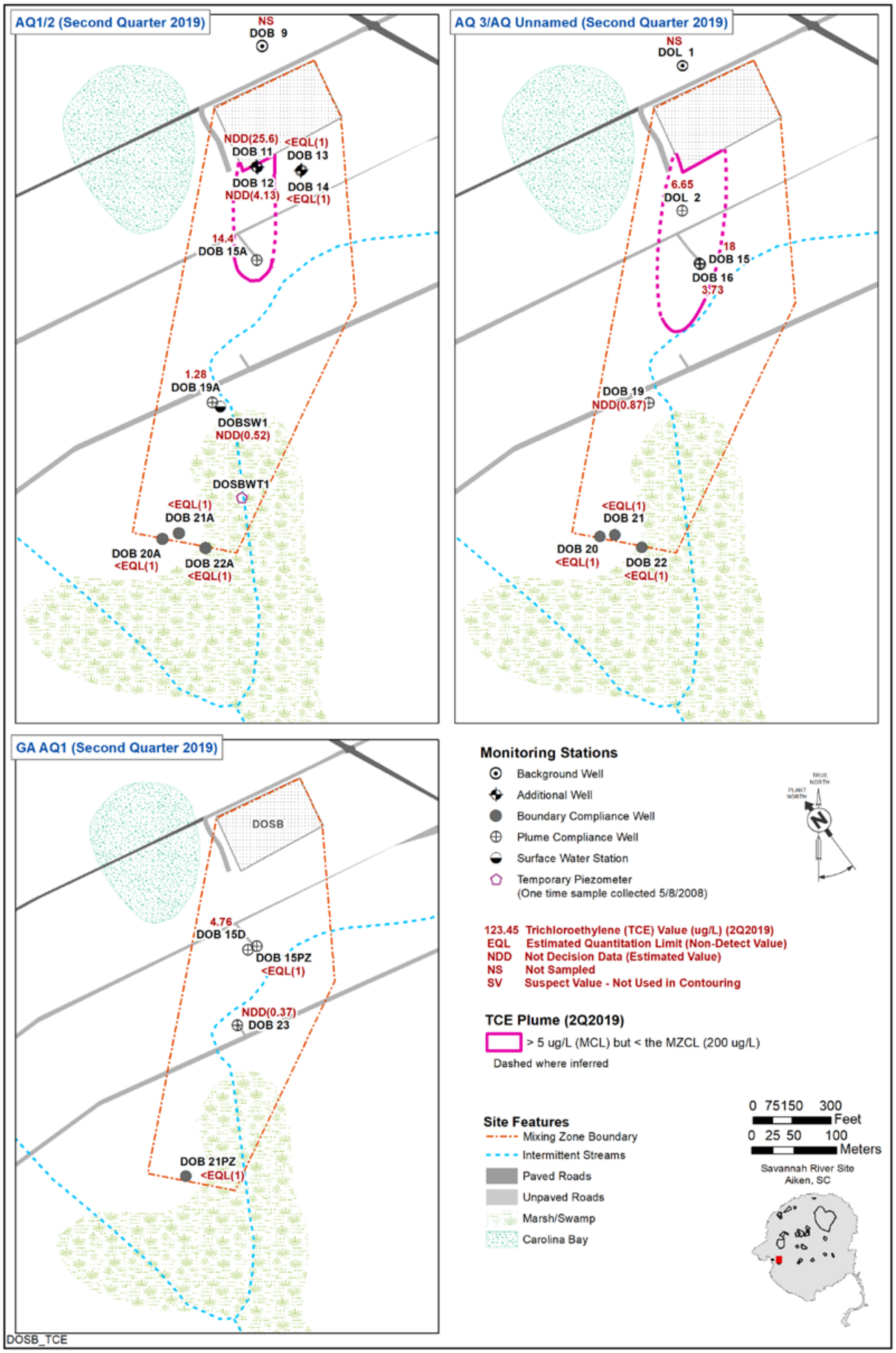

Figure B-7. DOSB TCE Concentrations in AQ1/2, 3 and GA AQ1, 2019

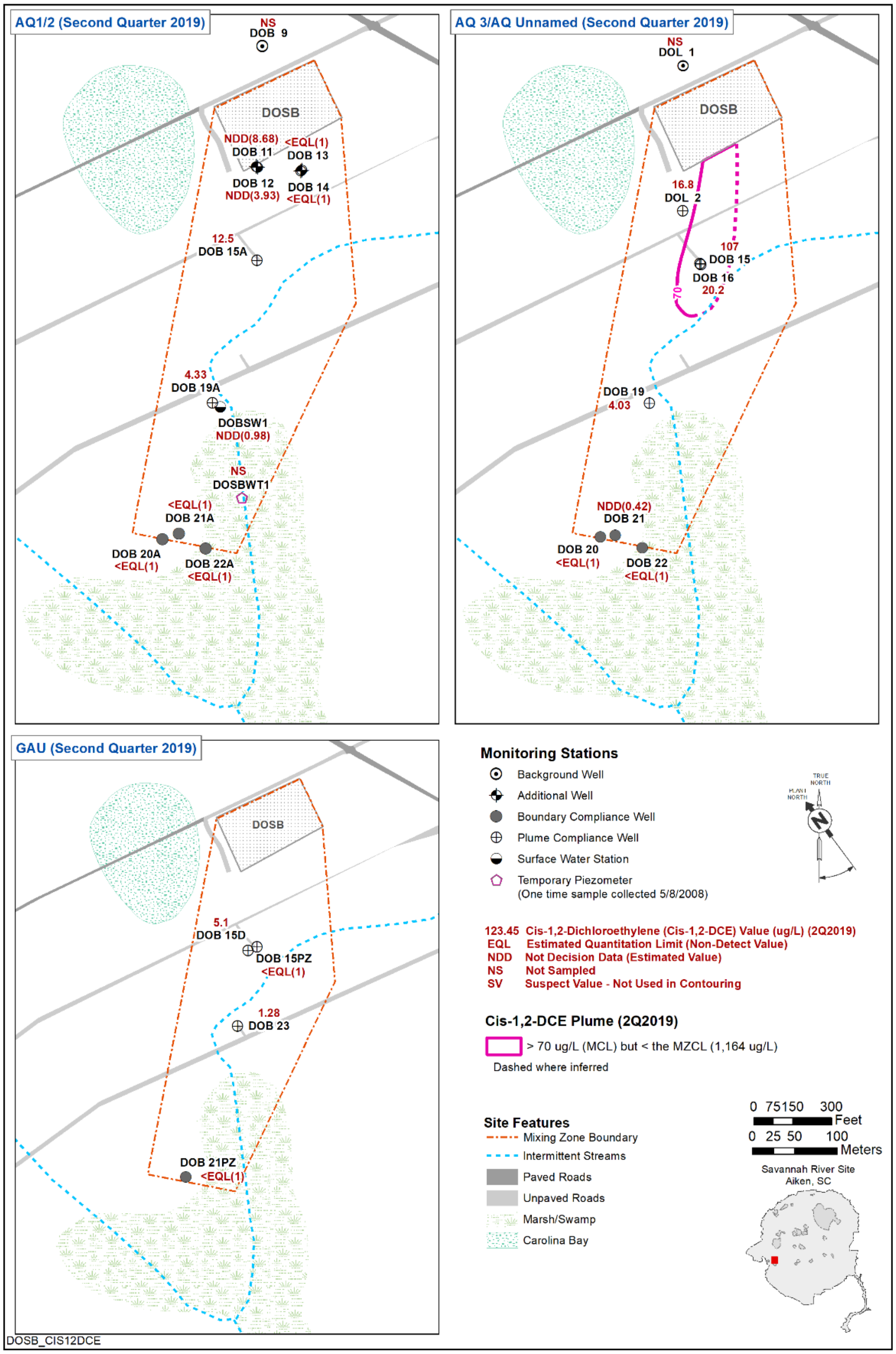

Figure B-8. DOSB cis-1,2-DCE Concentrations in AQ1/2, 3 and GA AQ1, 2019

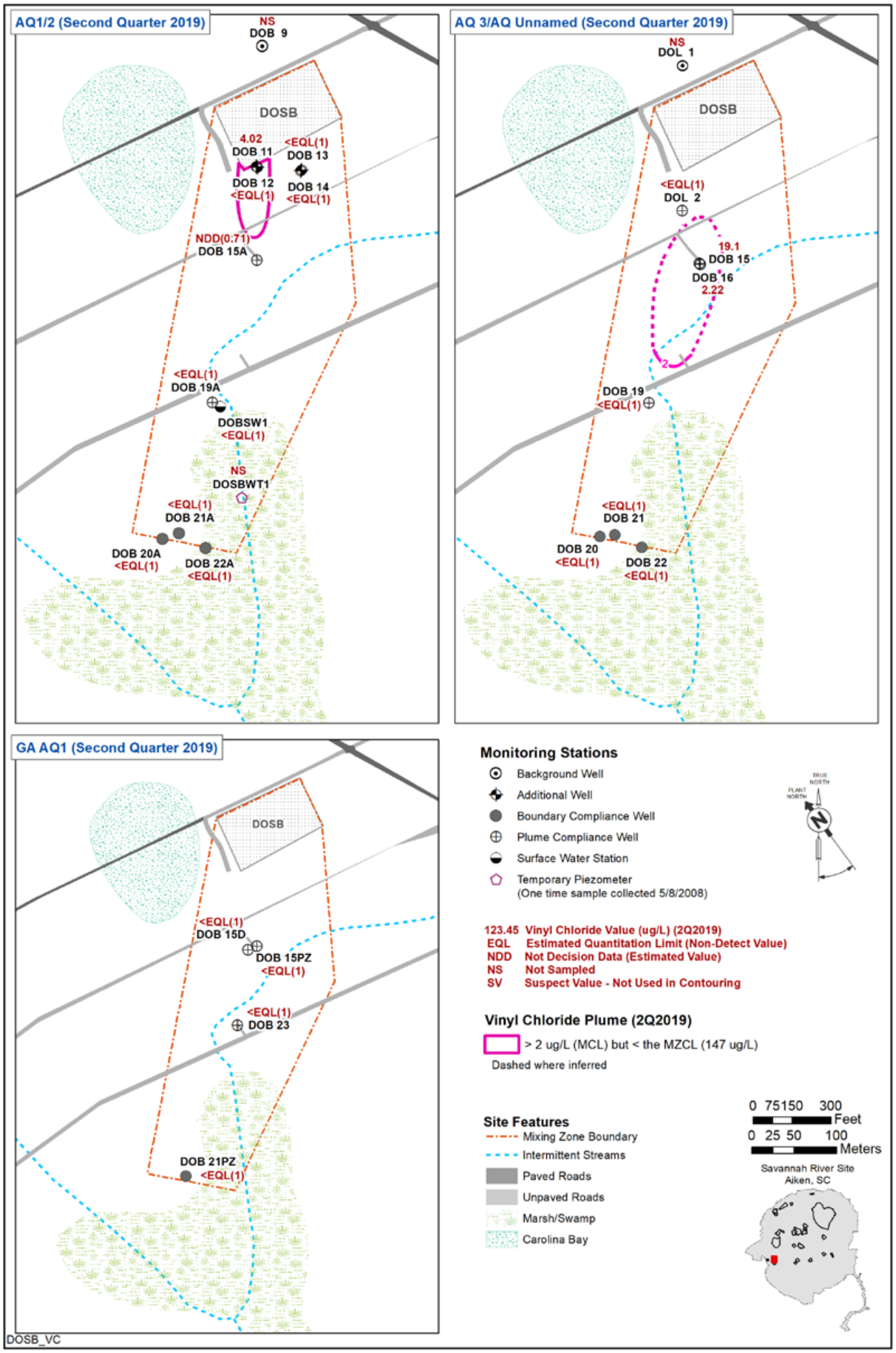

Figure B-9. DOSB Vinyl Chloride in AQ1/2, 3 and GA AQ1, 2019

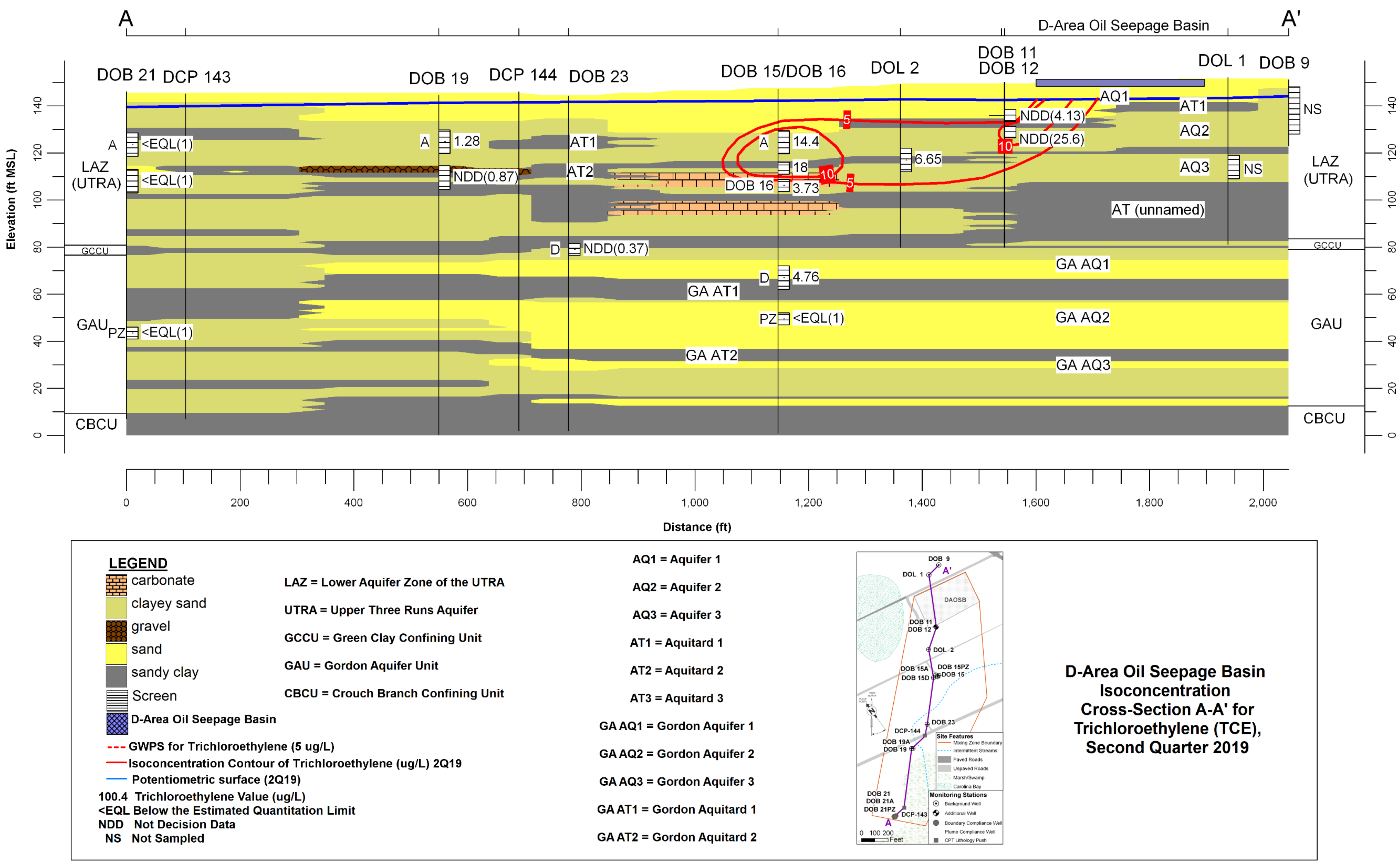

Figure B-10. DOSB Isoconcentration Cross-Section A-A' for TCE, 2Q2019

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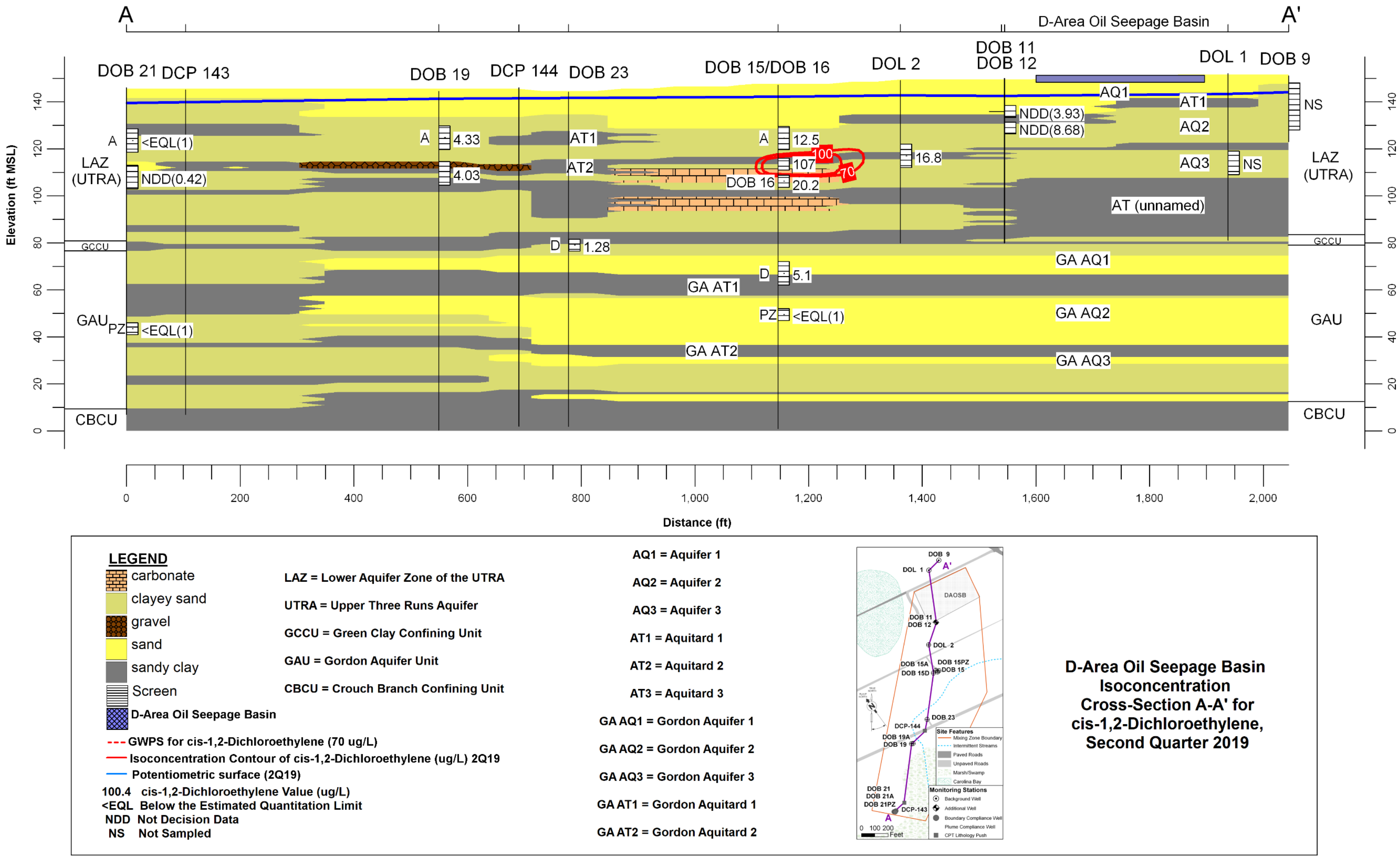

Figure B-11. DOSB Isoconcentration Cross-Section A-A' for cis-1,2-DCE, 2Q2019

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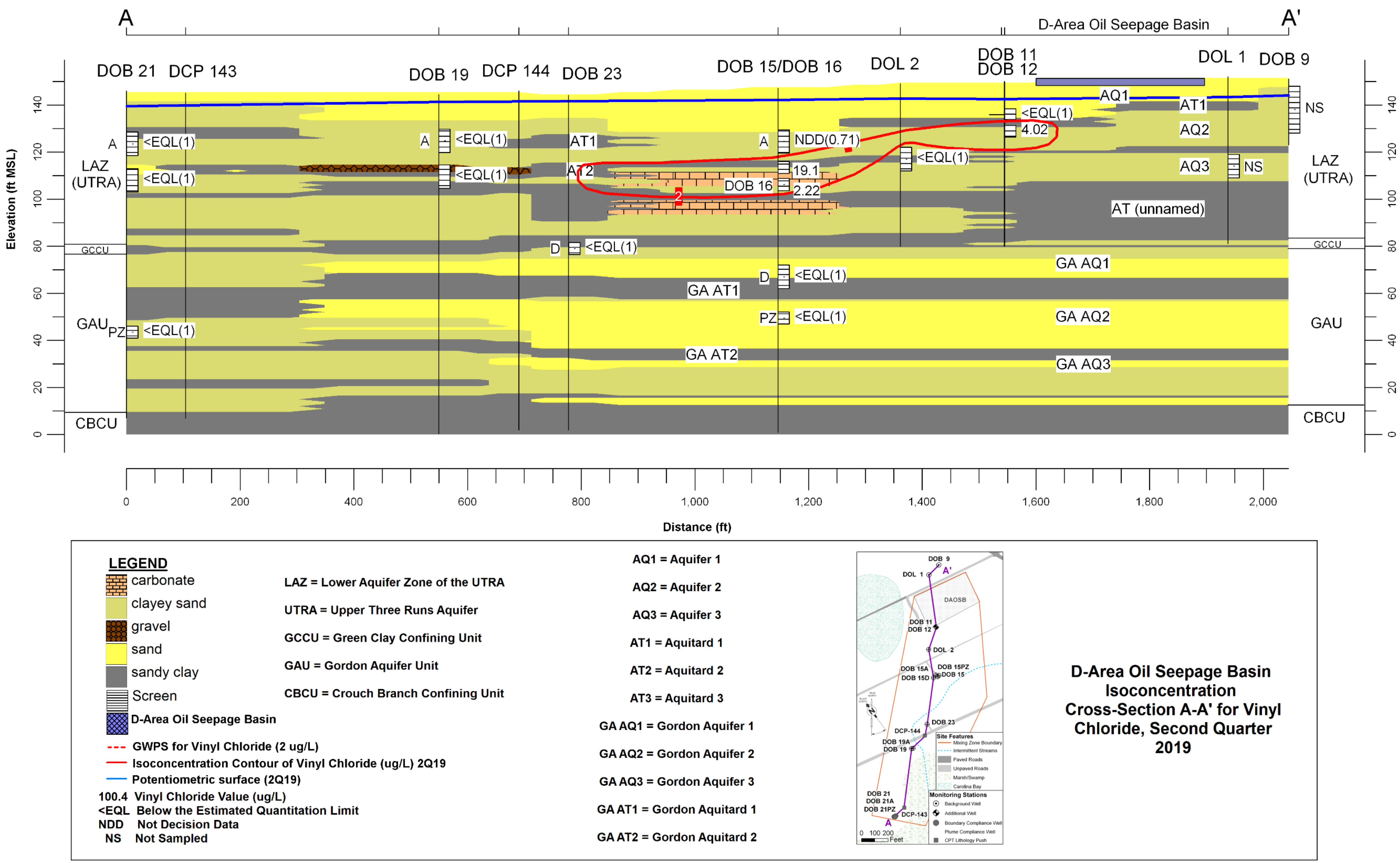

Figure B-12. DOSB Isoconcentration Cross-Section A-A' for Vinyl Chloride, 2Q2019

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APPENDIX C

DOSB HYDROGRAPHS

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LIST OF FIGURES

Appendix C Figures **Page**

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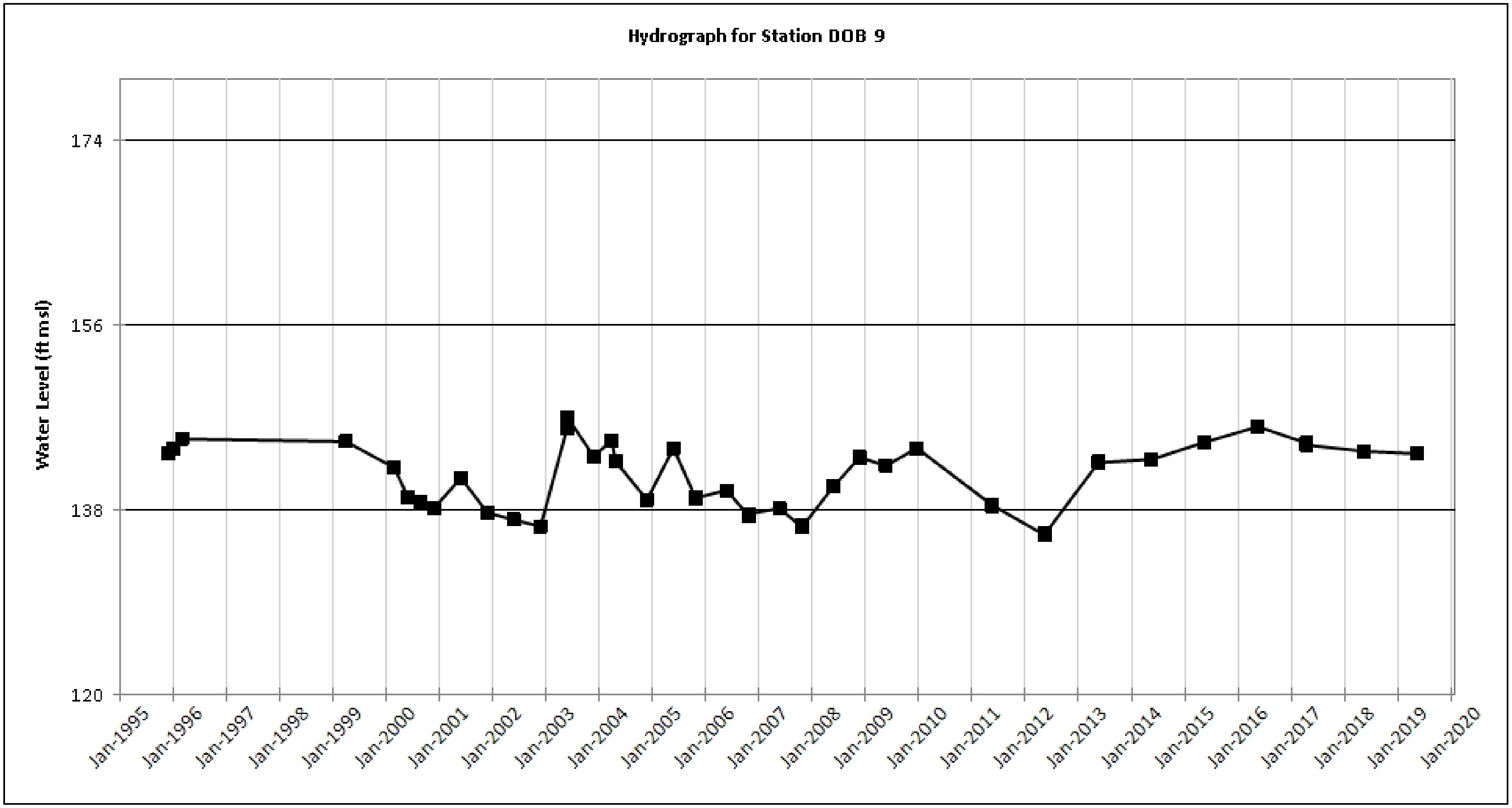
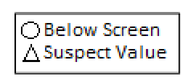


Figure C-1. Hydrograph for Station DOB 9



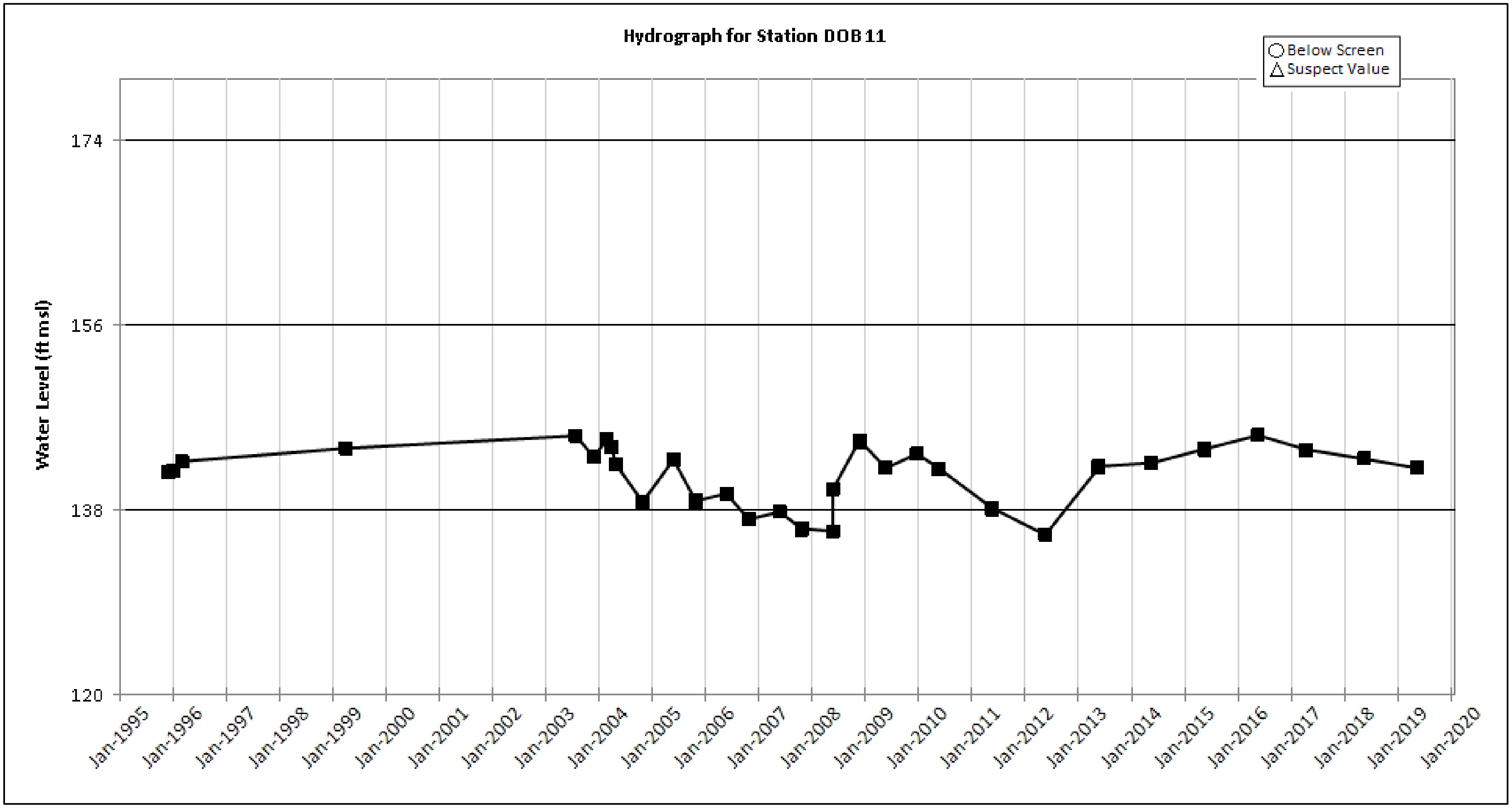


Figure C-2. Hydrograph for Station DOB11

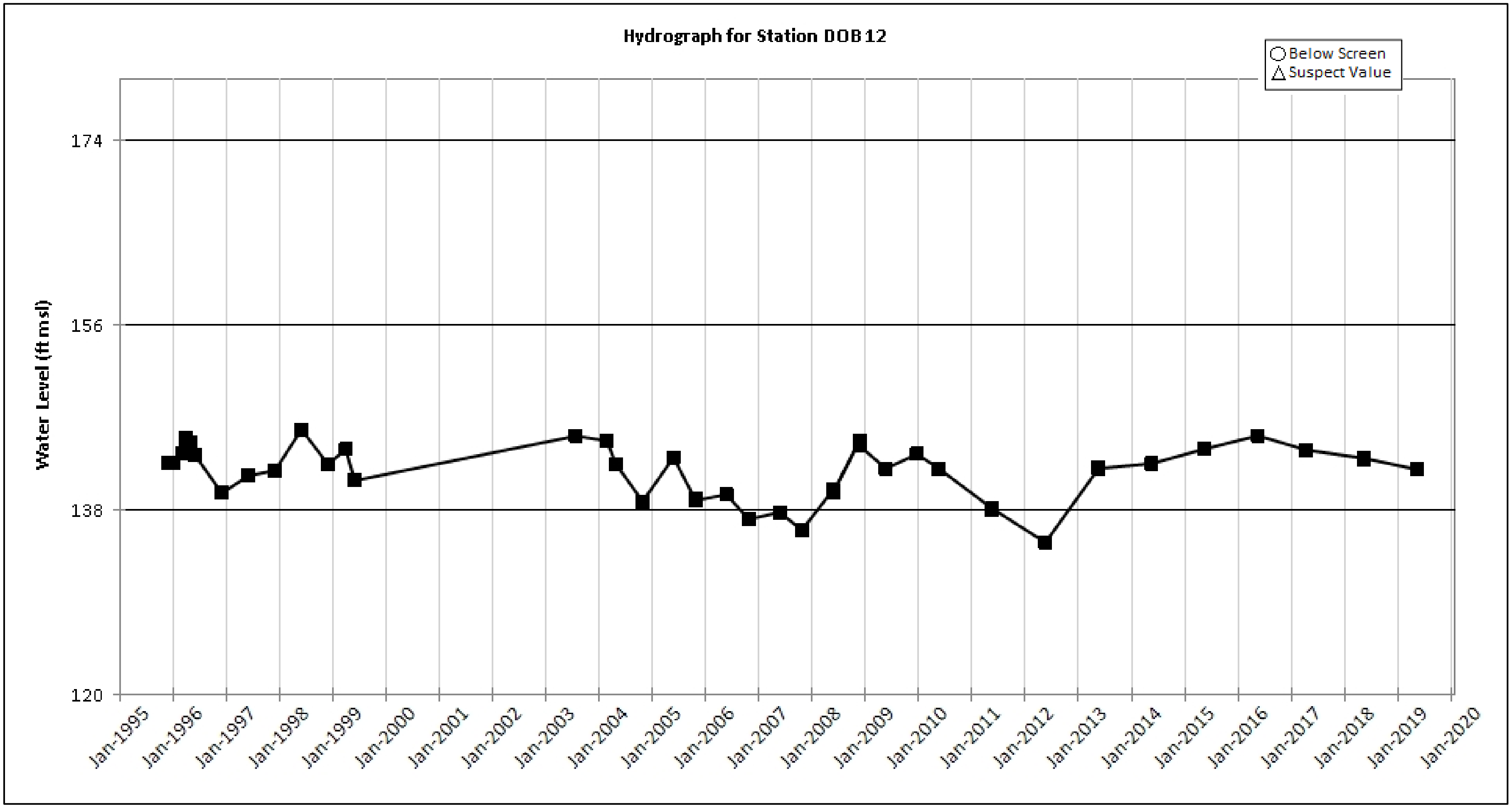


Figure C-3. Hydrograph for Station DOB12

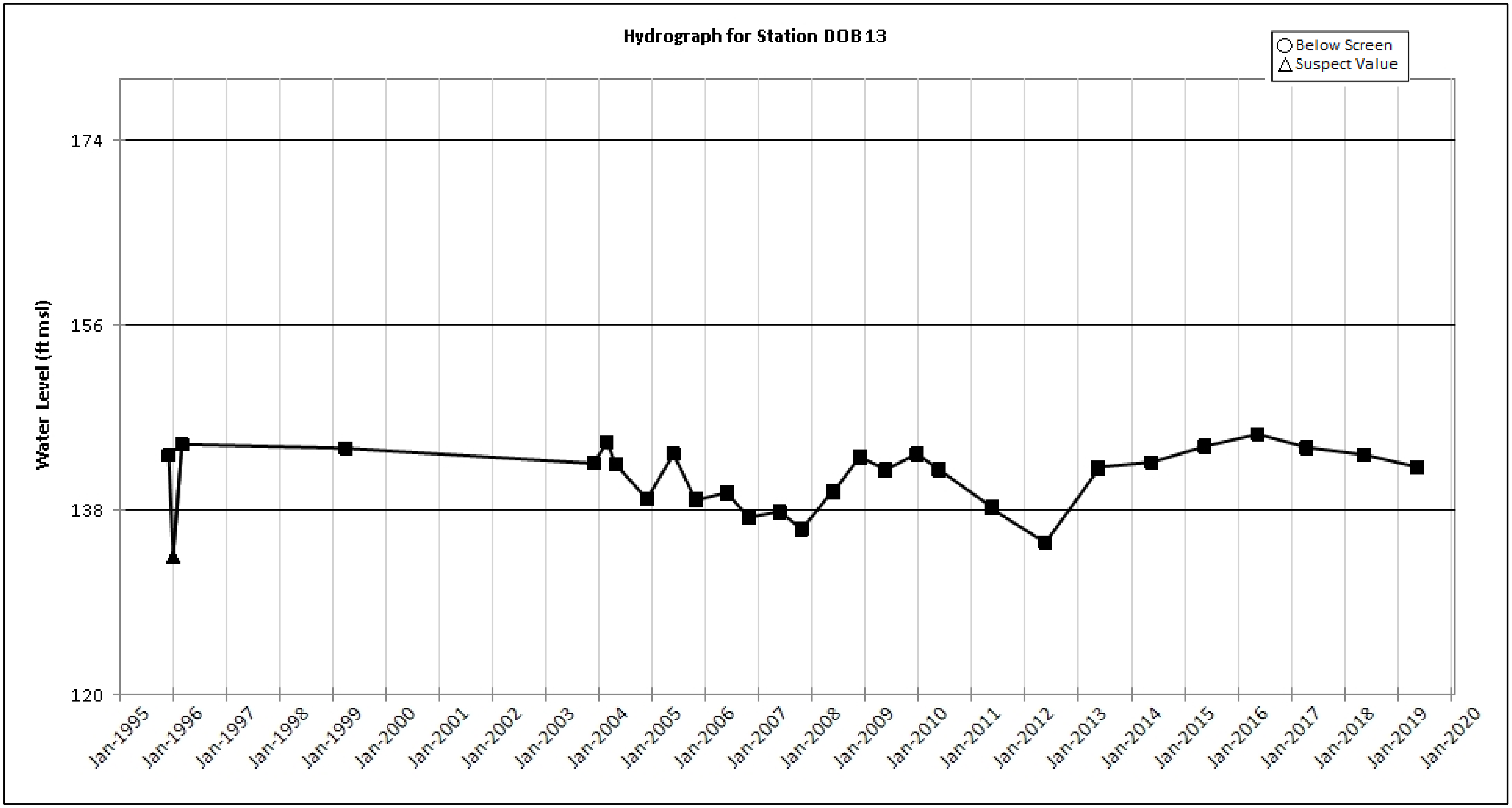


Figure C-4. Hydrograph for Station DOB13

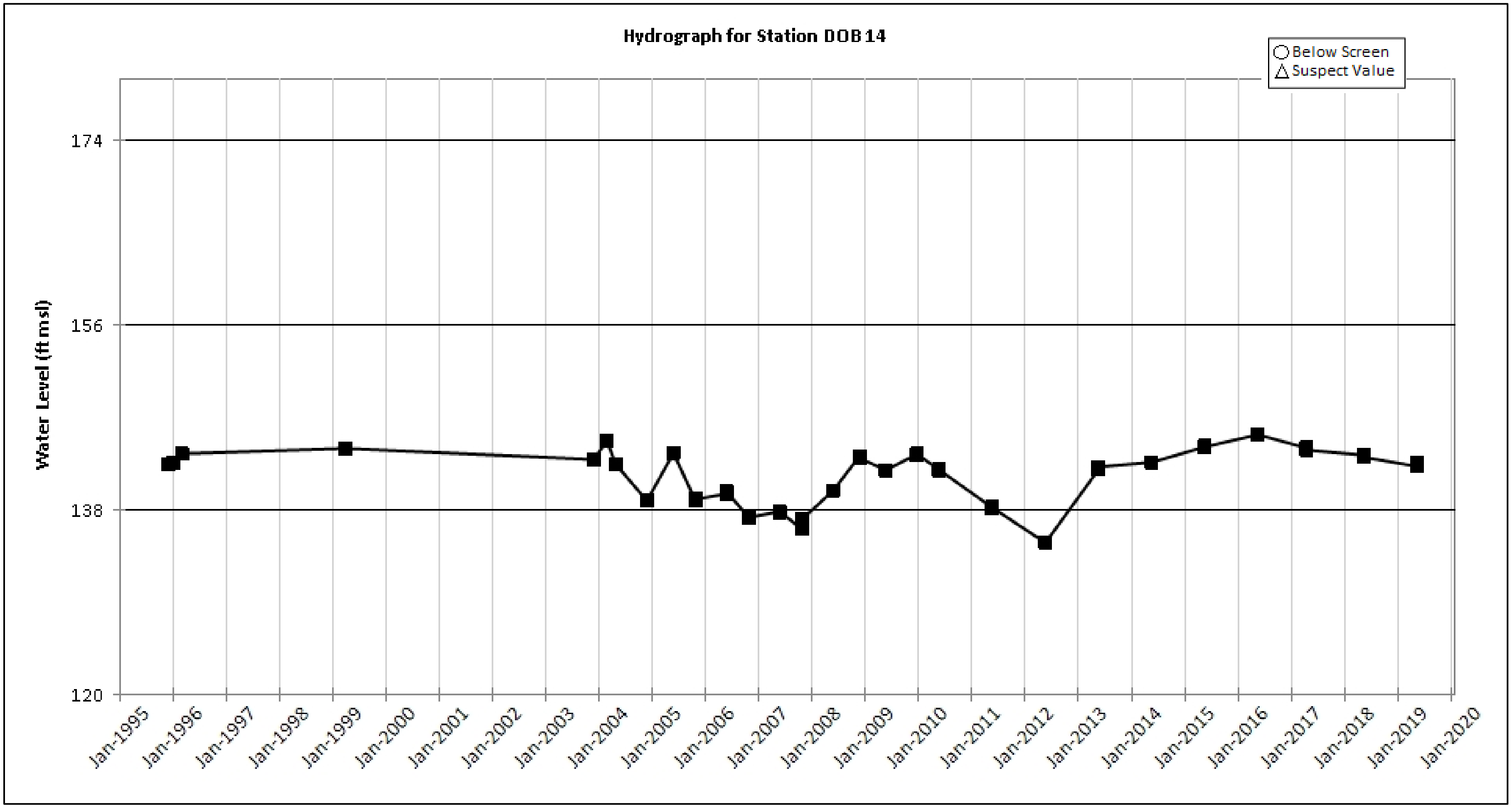


Figure C-5. Hydrograph for Station DOB14

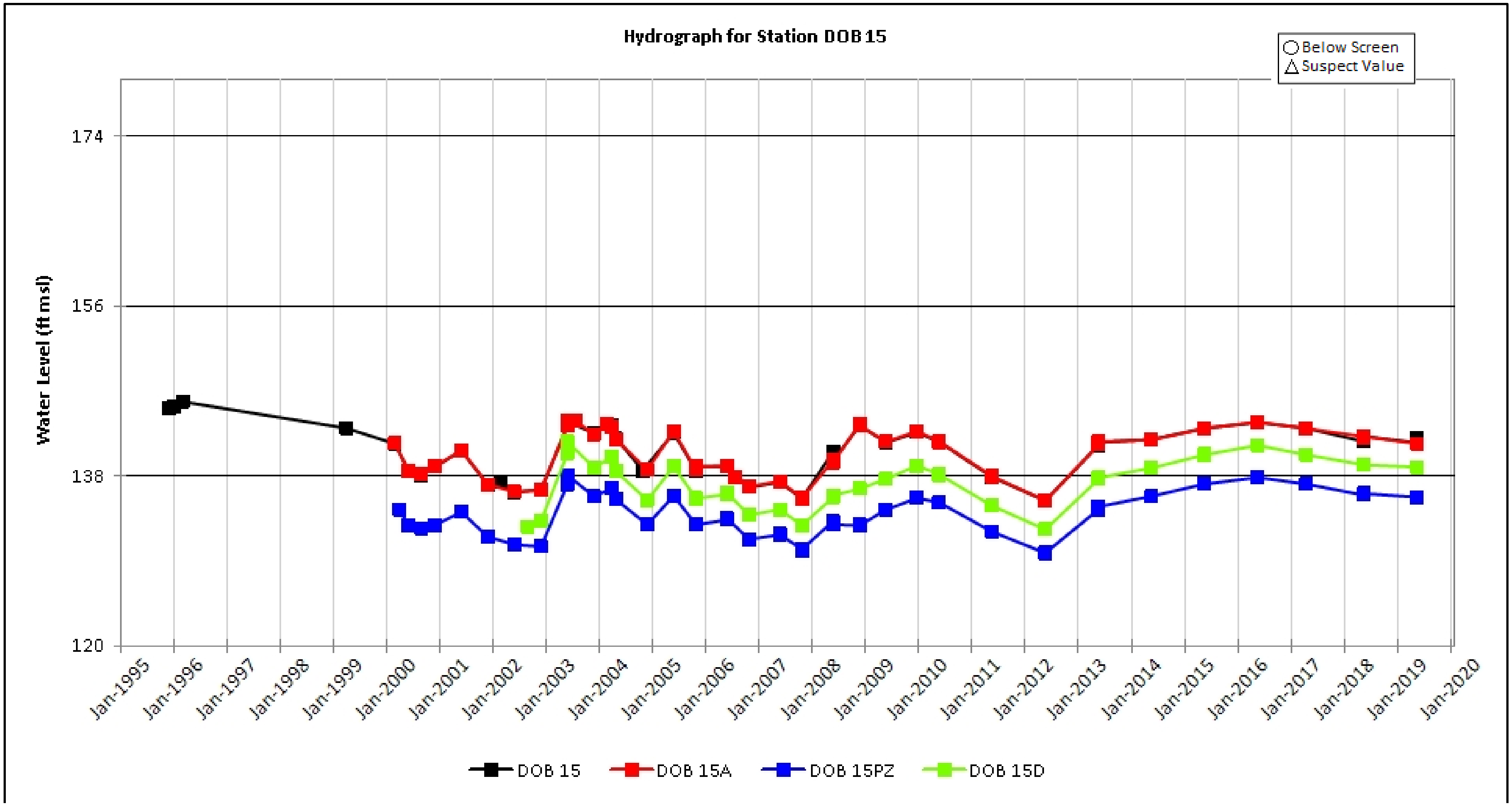


Figure C-6. Hydrograph for Station DOB15

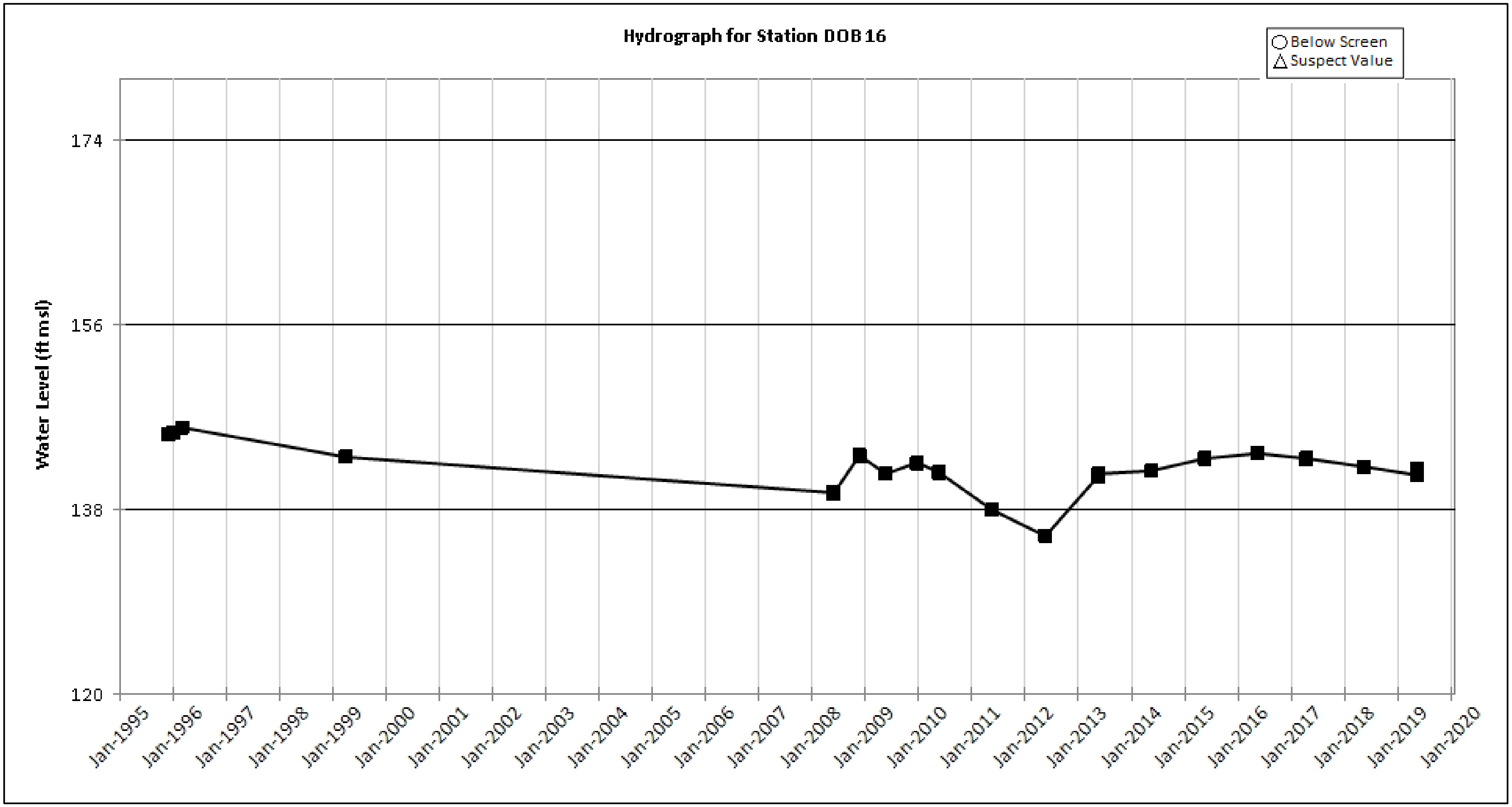


Figure C-7. Hydrograph for Station DOB16

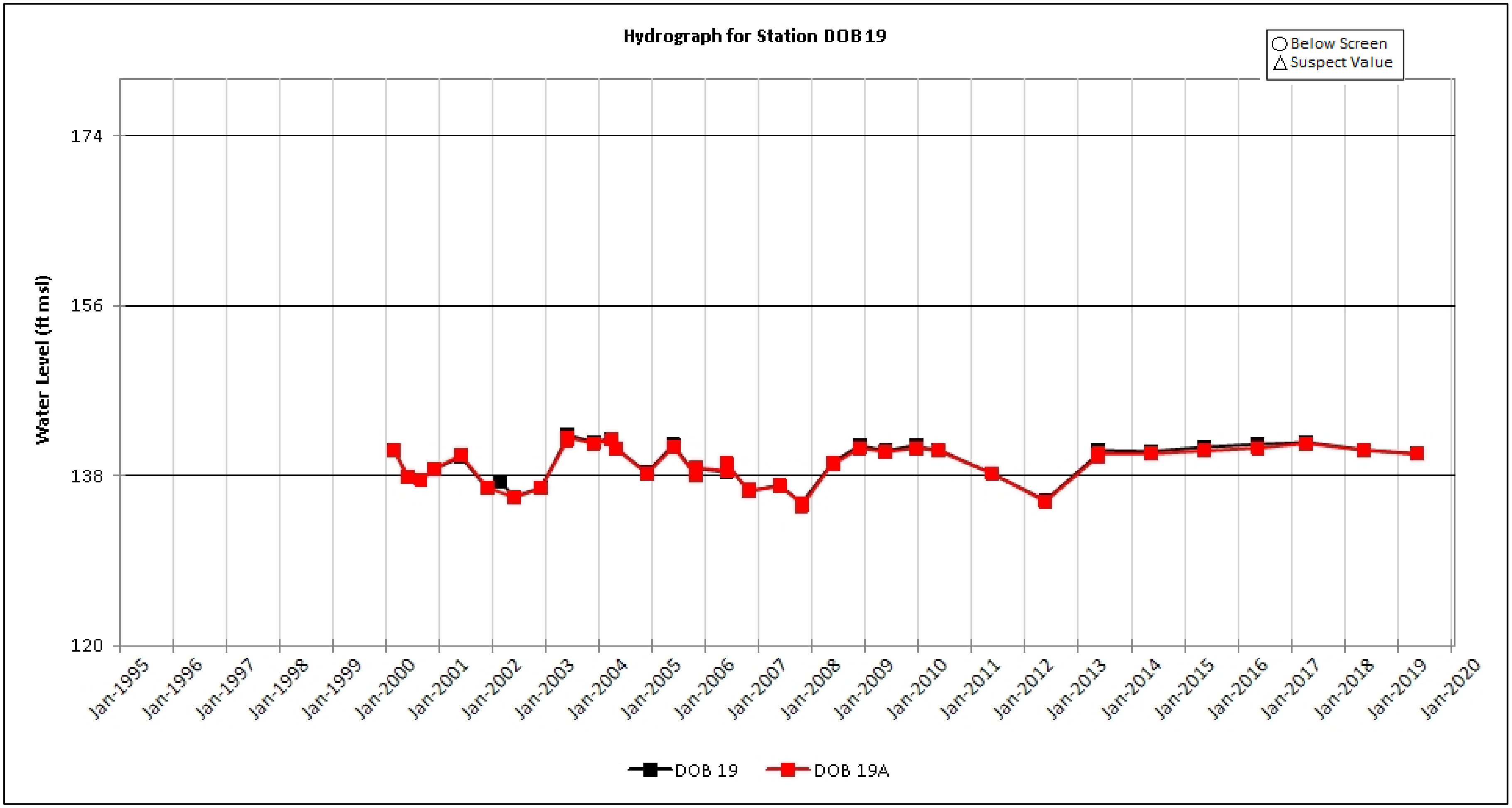


Figure C-8. Hydrograph for Station DOB19

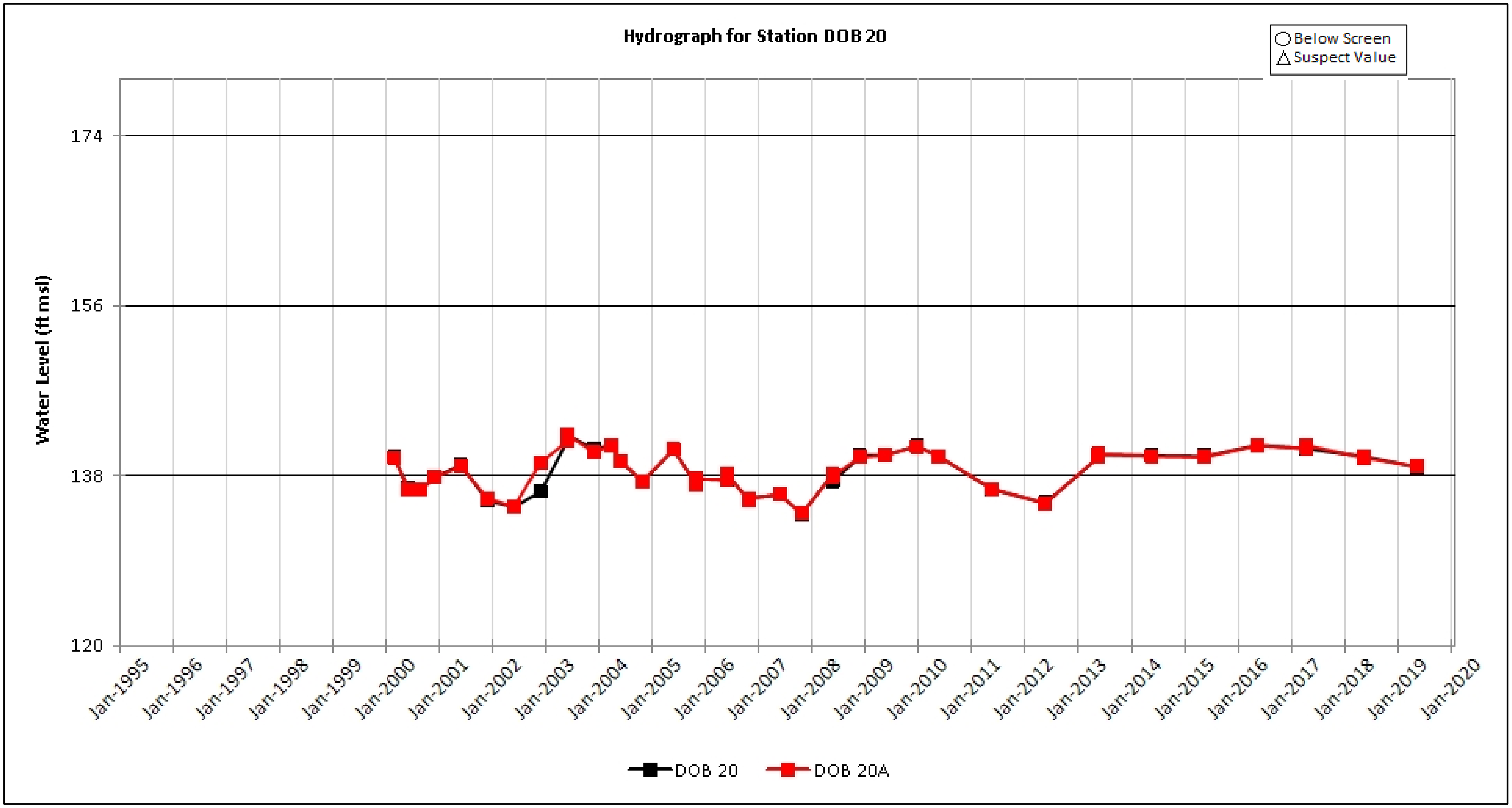


Figure C-9. Hydrograph for Station DOB20

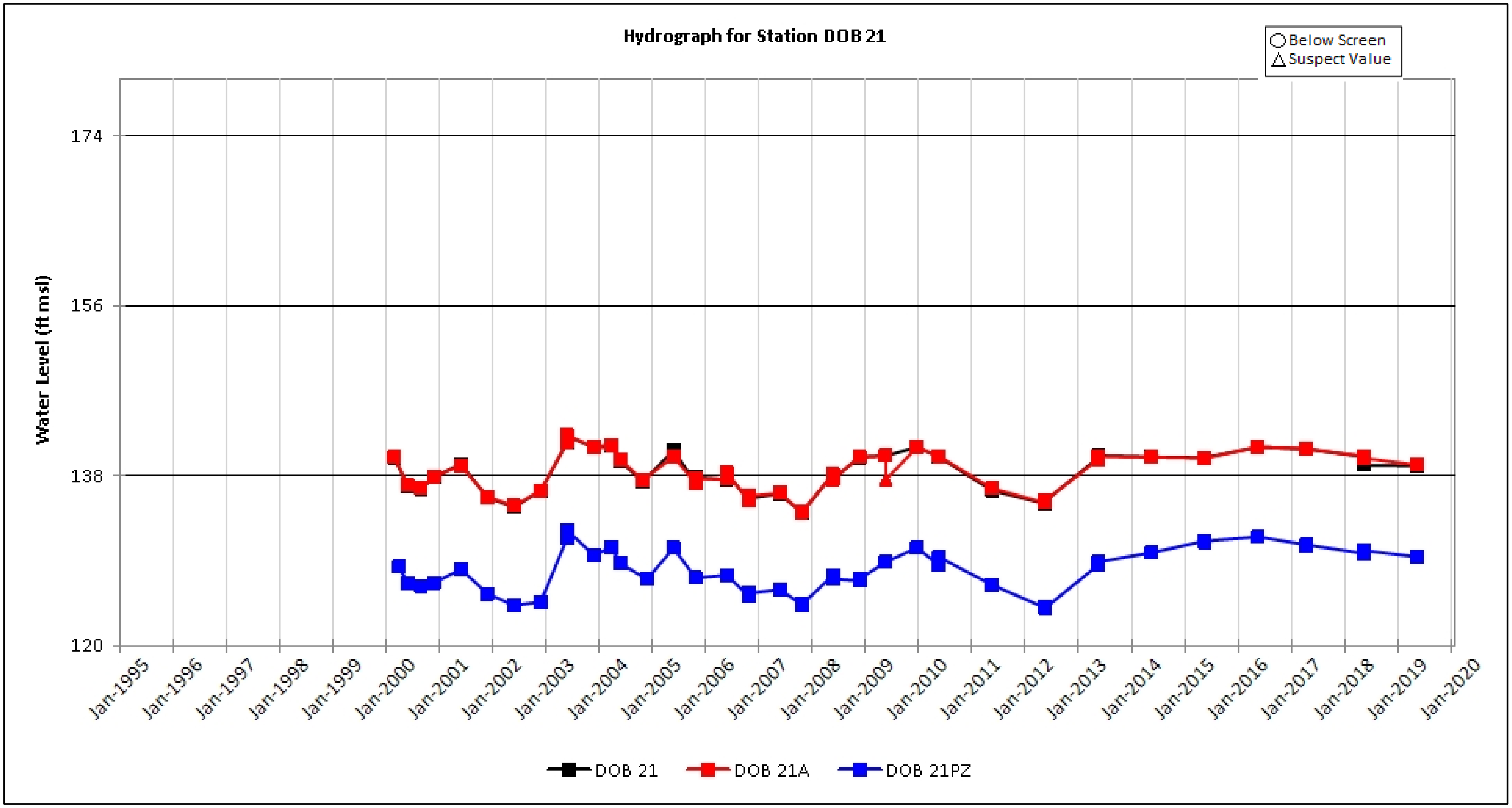


Figure C-10. Hydrograph for Station DOB21

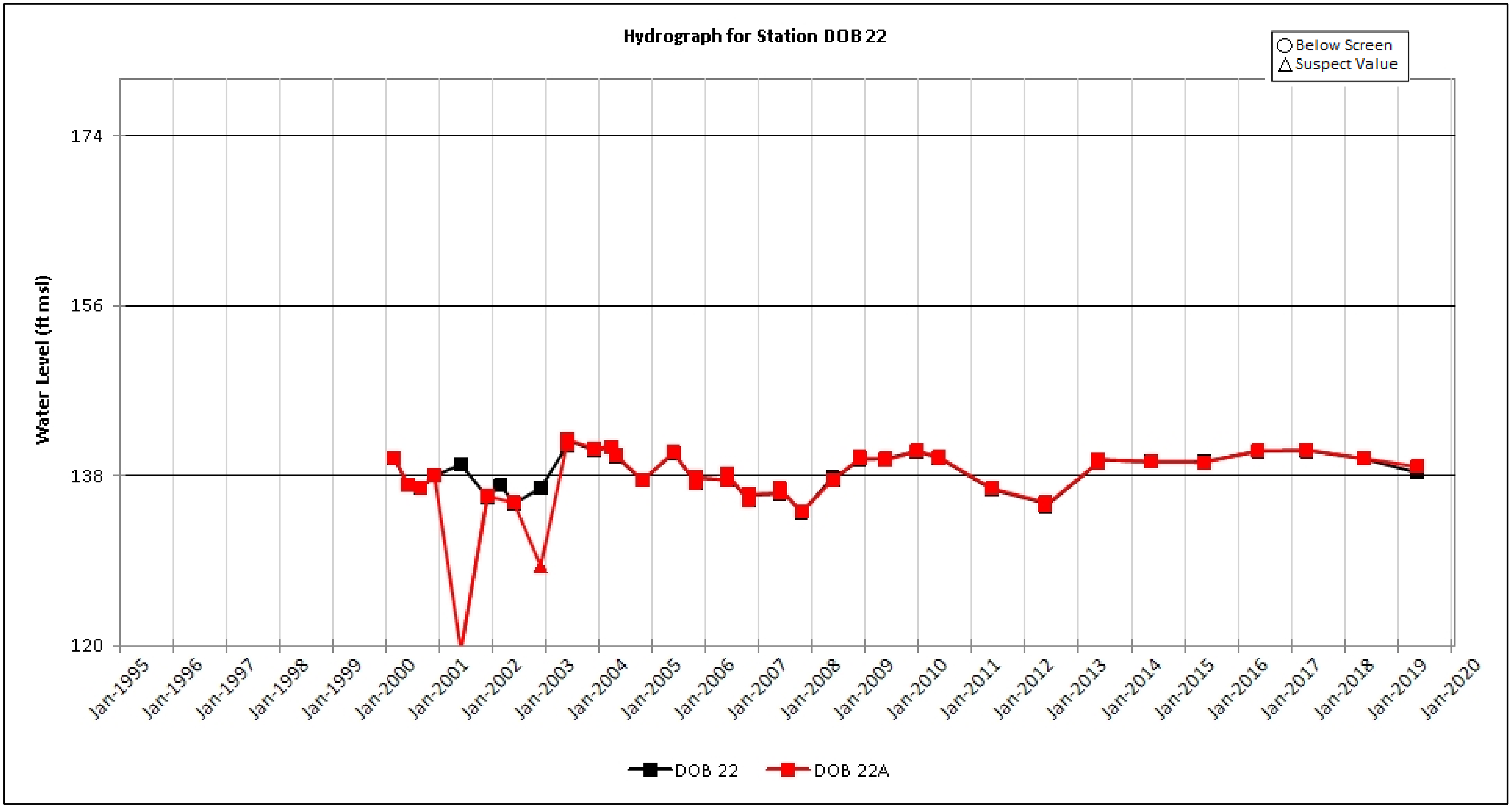


Figure C-11. Hydrograph for Station DOB22

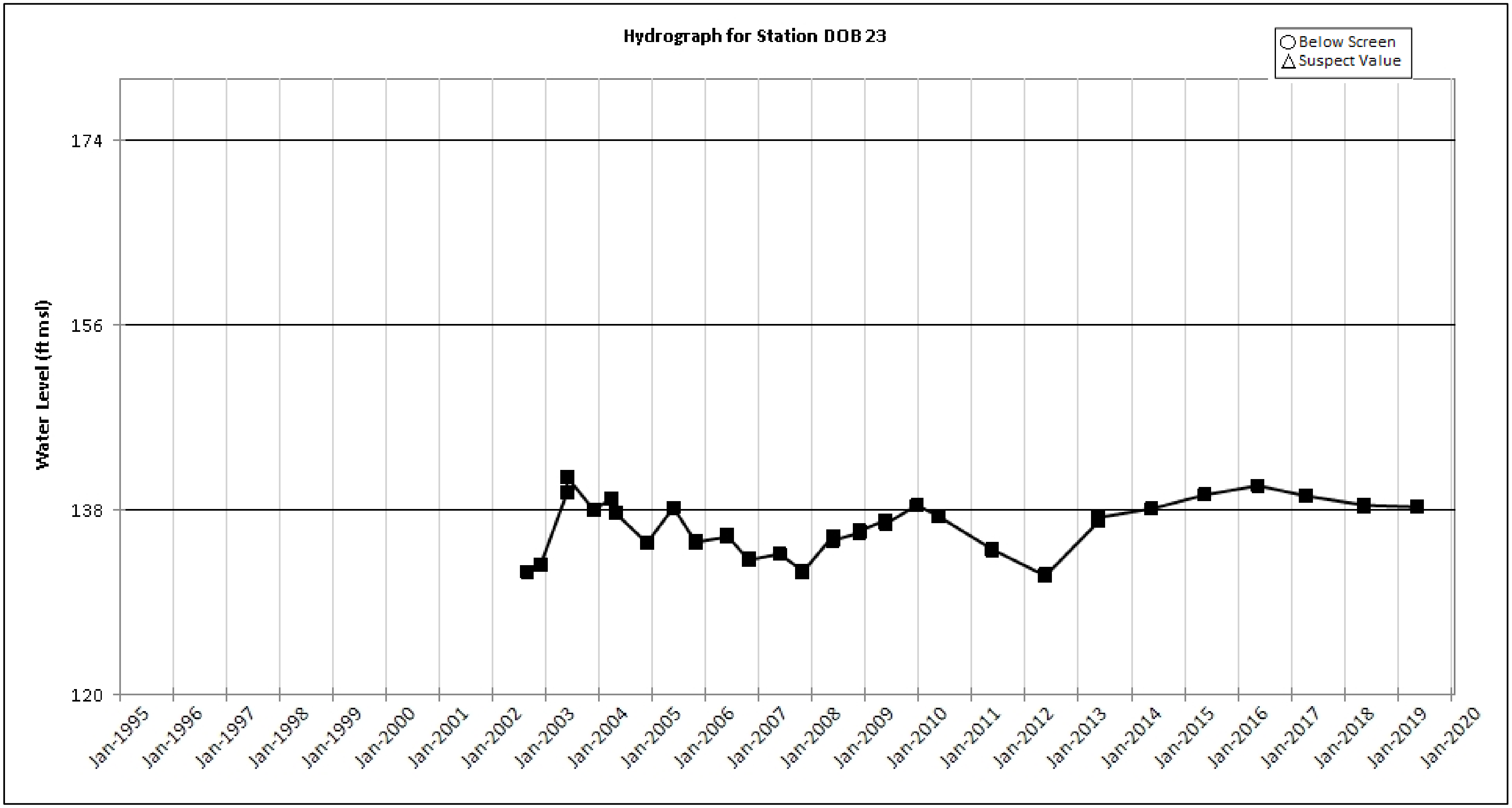


Figure C-12. Hydrograph for Station DOB23

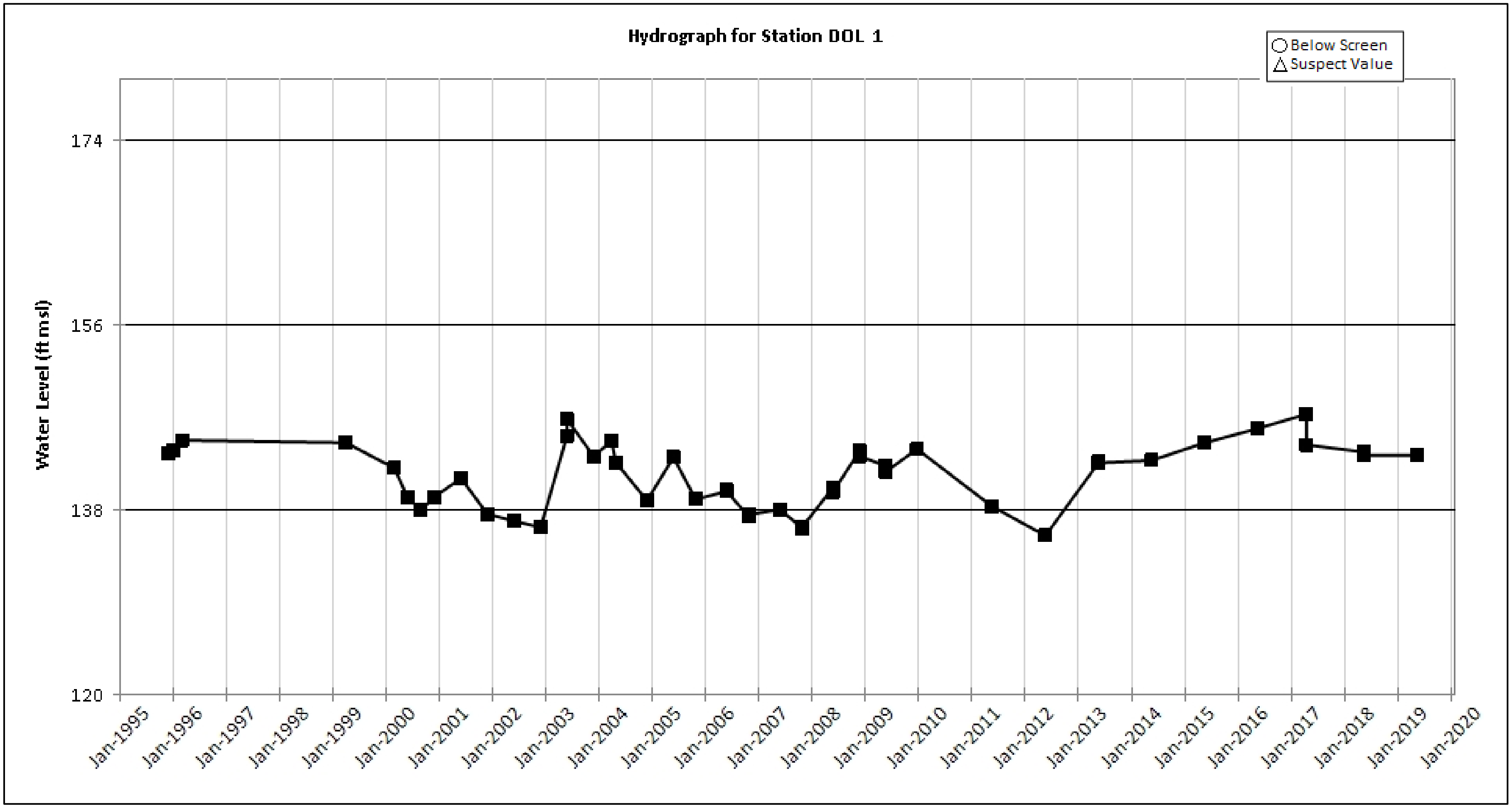


Figure C-13. Hydrograph for Station DOL 1

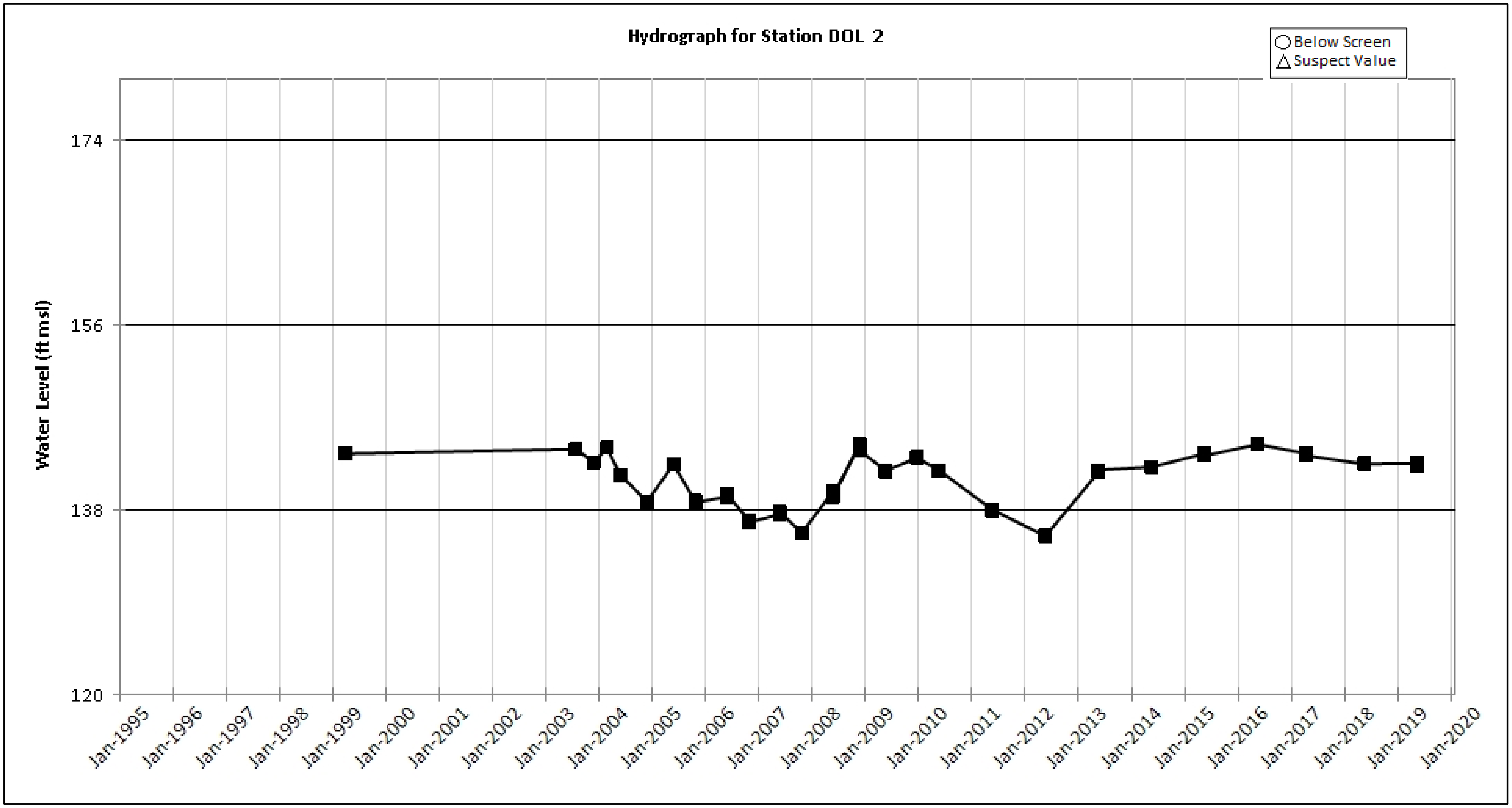


Figure C-14. Hydrograph for Station DOL 2

APPENDIX D

DOSB 2019 TIME SERIES PLOTS

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LIST OF FIGURES

LIST OF FIGURES *(Continued)*

LIST OF FIGURES *(Continued)*

Appendix D, Figures **Page**

LIST OF FIGURES *(Continued)*

Appendix D, Figures **Page**

LIST OF FIGURES *(Continued)*

Appendix D, Figures **Page**

LIST OF FIGURES *(Continued)*

Appendix D, Figures **Page**

LIST OF FIGURES *(Continued)*

Appendix D, Figures **Page**

LIST OF FIGURES *(Continued/End)*

Appendix D, Figures **Page**

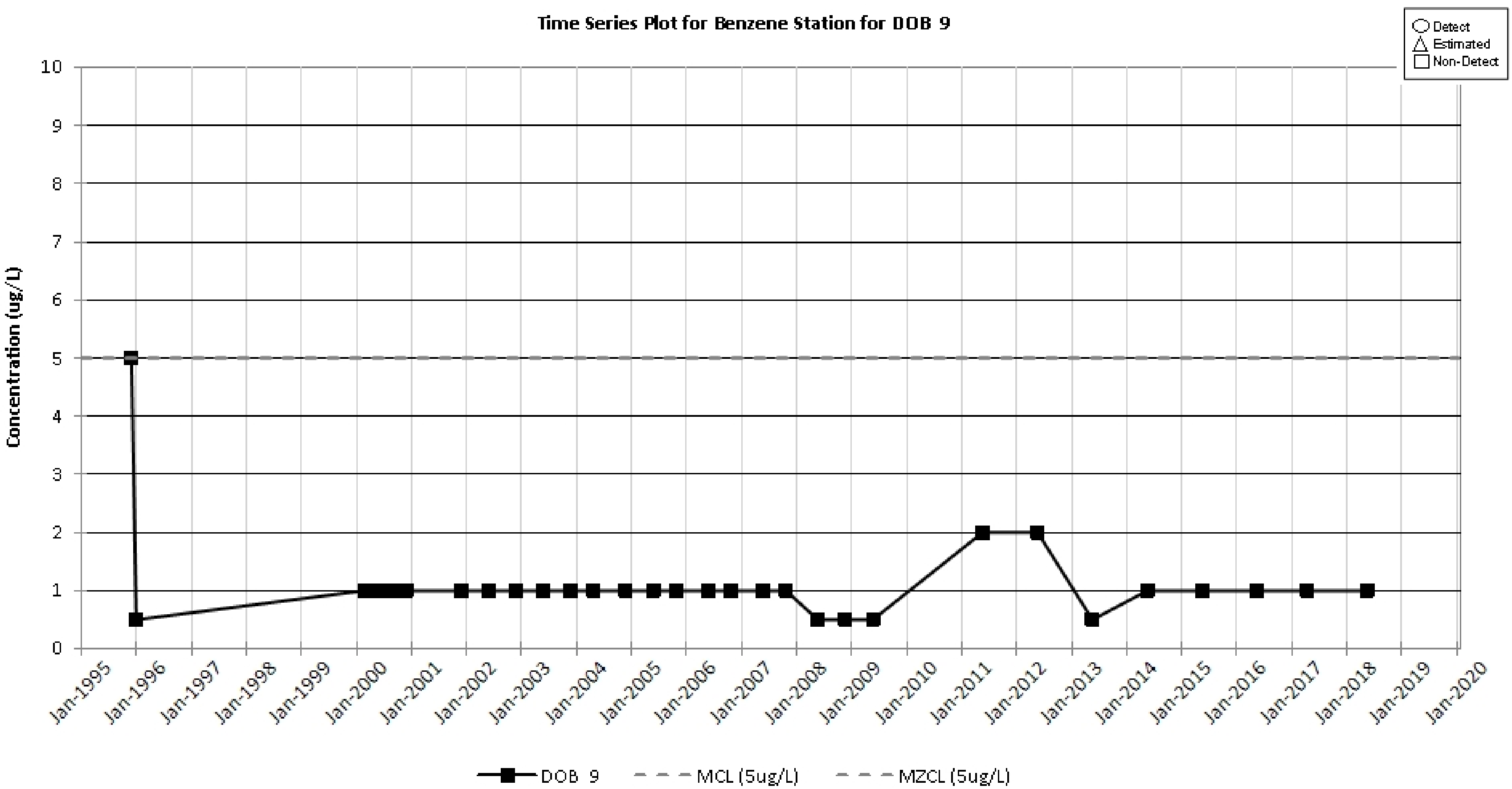


Figure D-1. Time Series Plot for Benzene Station for DOB 9

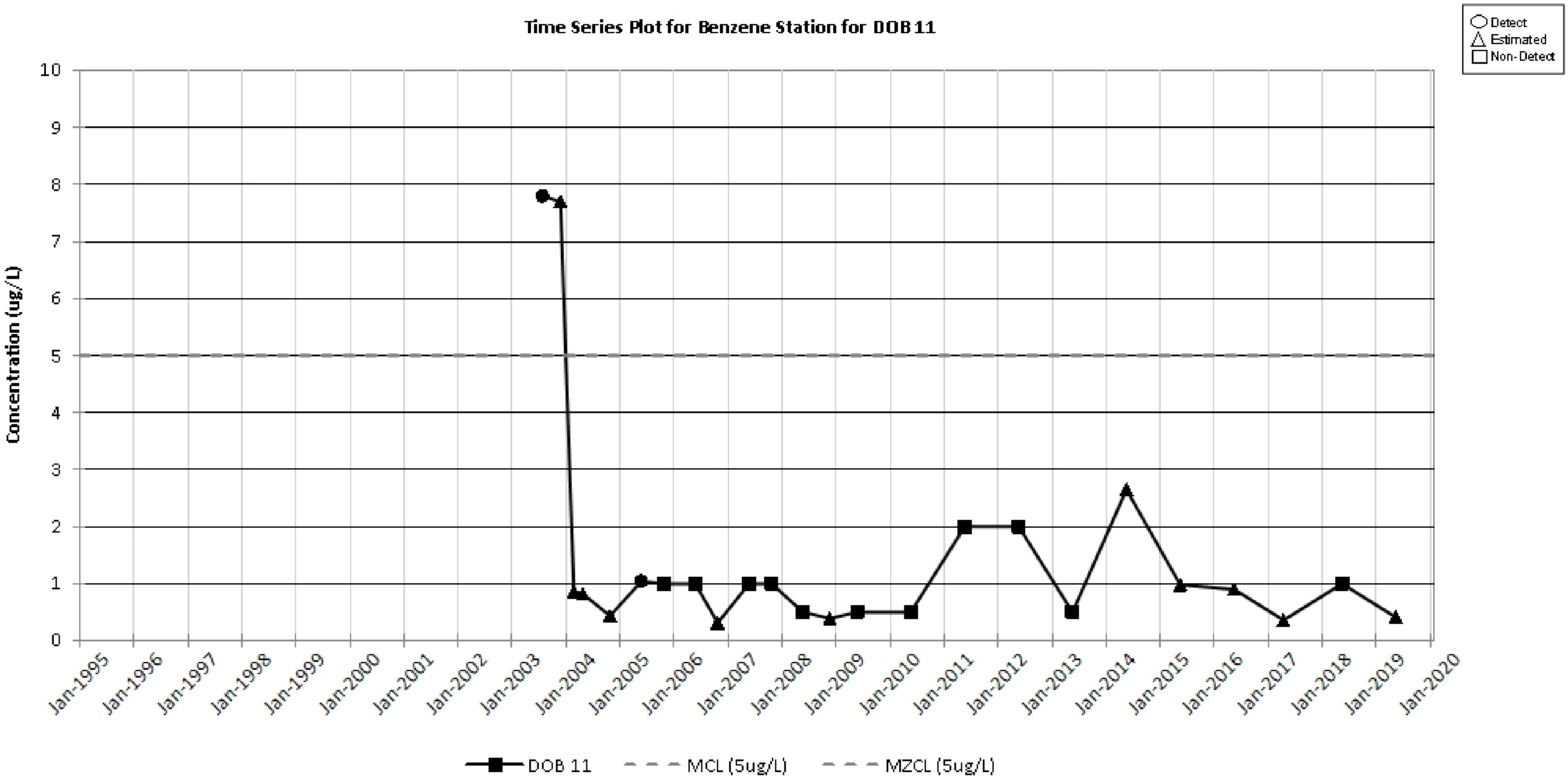


Figure D-2. Time Series Plot for Benzene Station for DOB 11

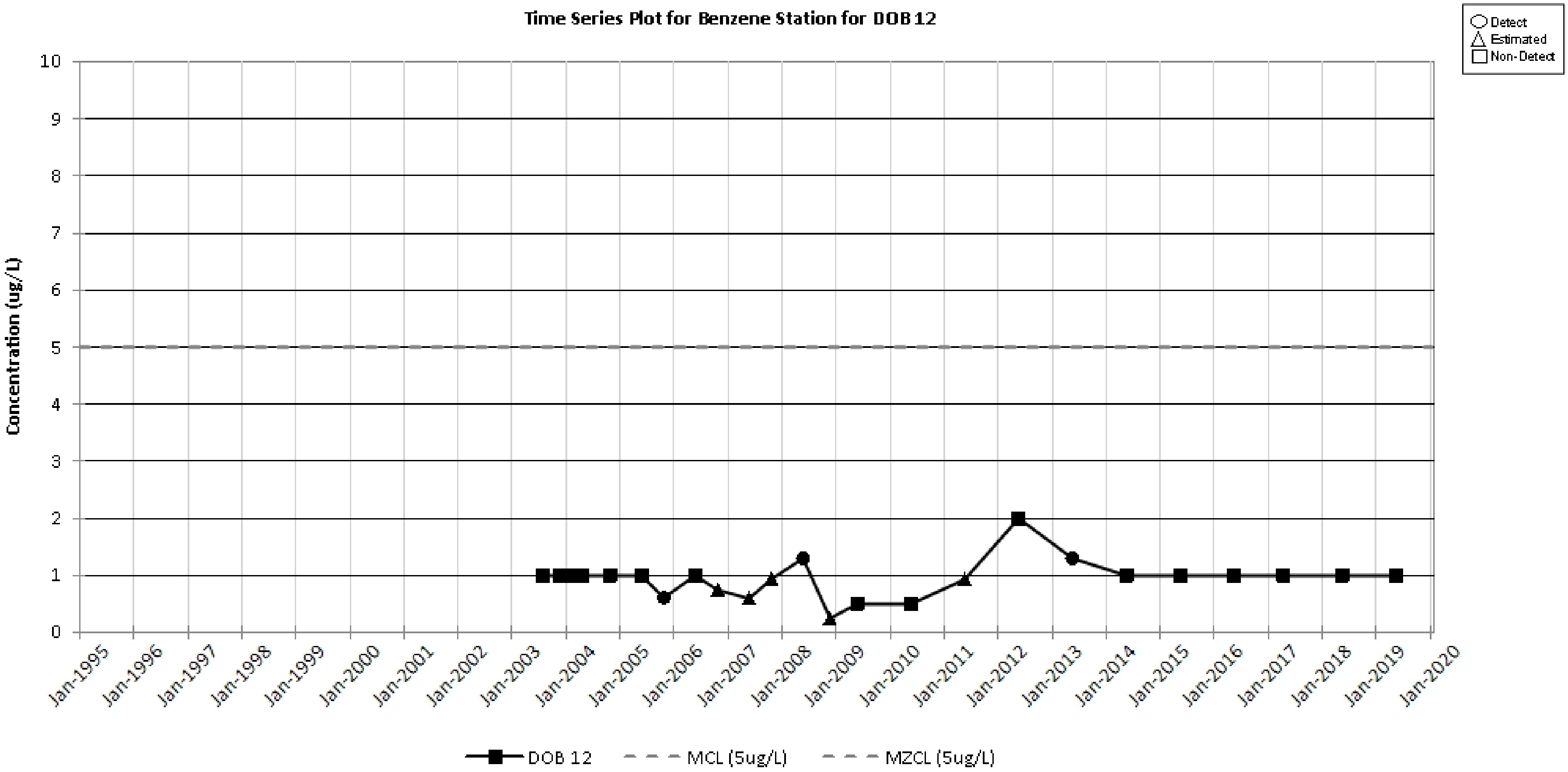


Figure D-3. Time Series Plot for Benzene Station for DOB 12

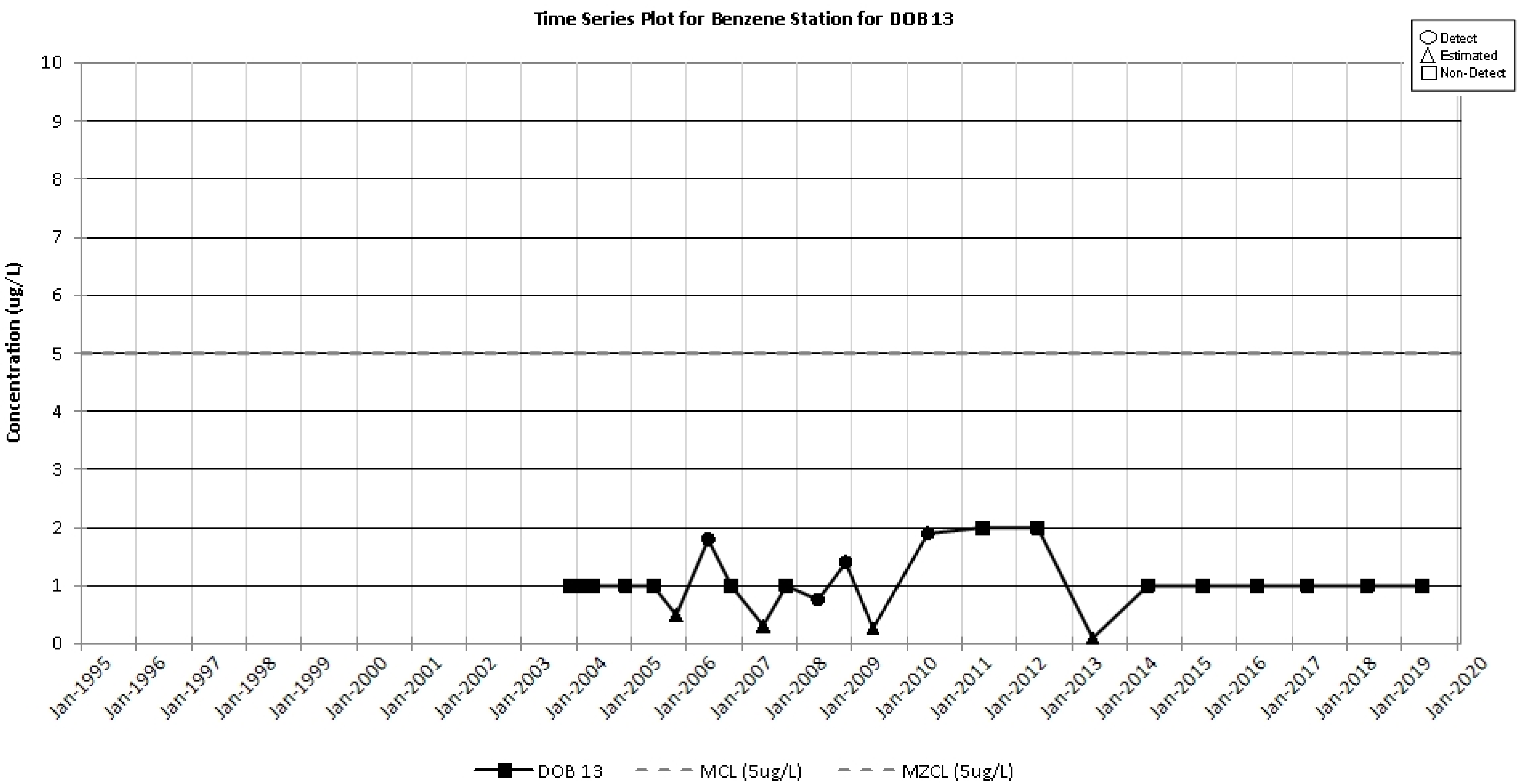


Figure D-4. Time Series Plot for Benzene Station for DOB 13

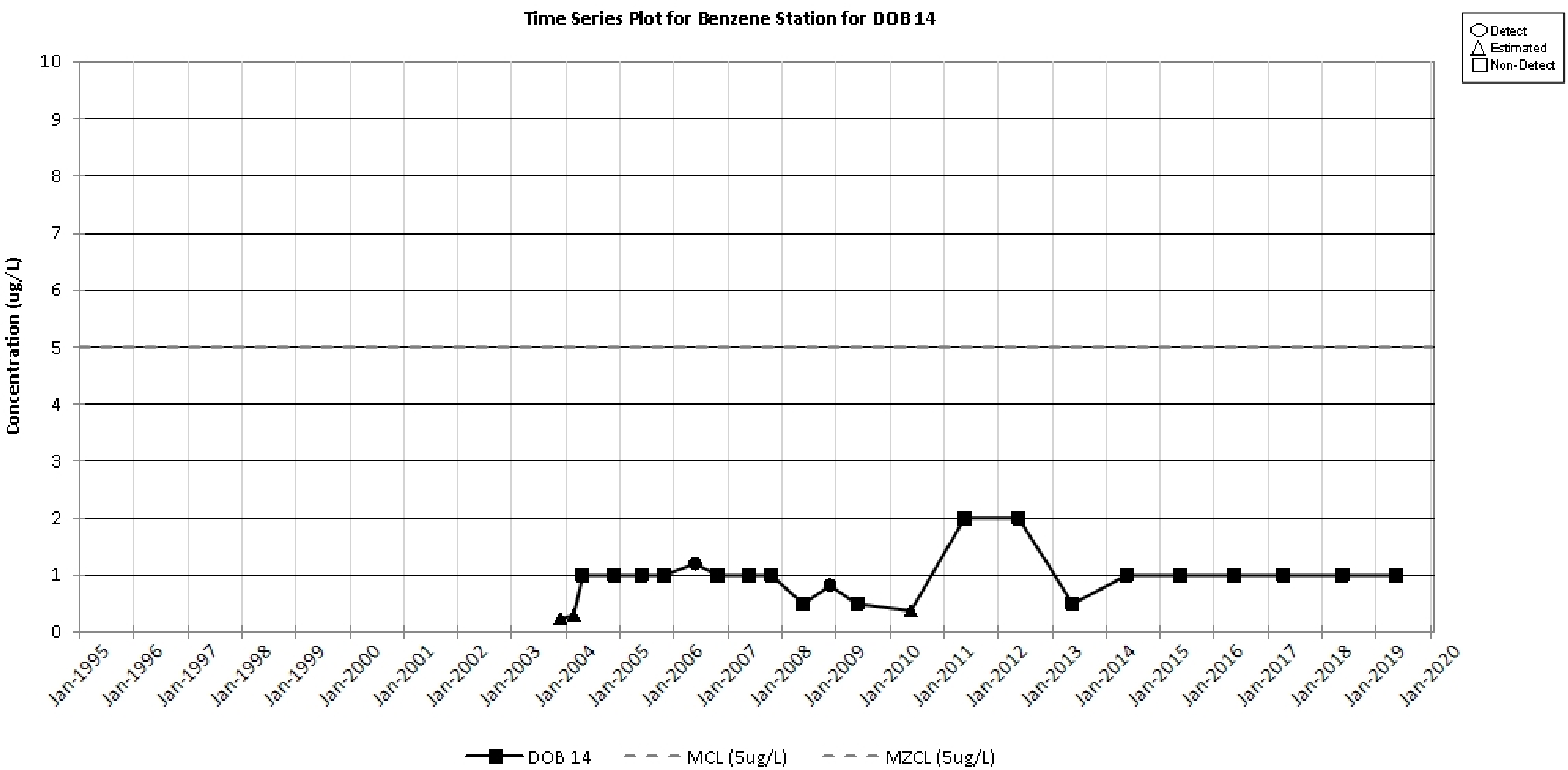


Figure D-5. Time Series Plot for Benzene Station for DOB 14

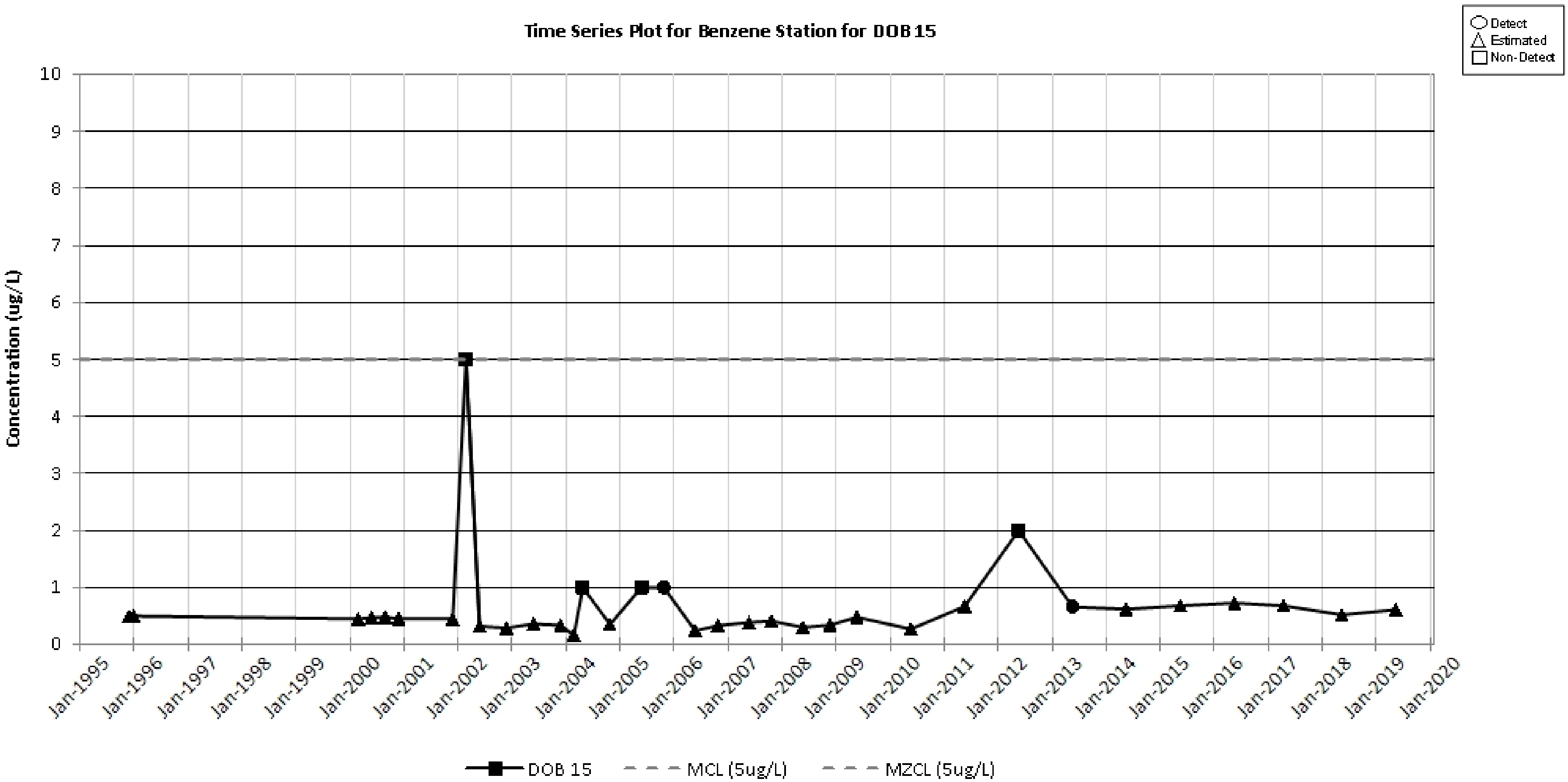


Figure D-6. Time Series Plot for Benzene Station for DOB 15

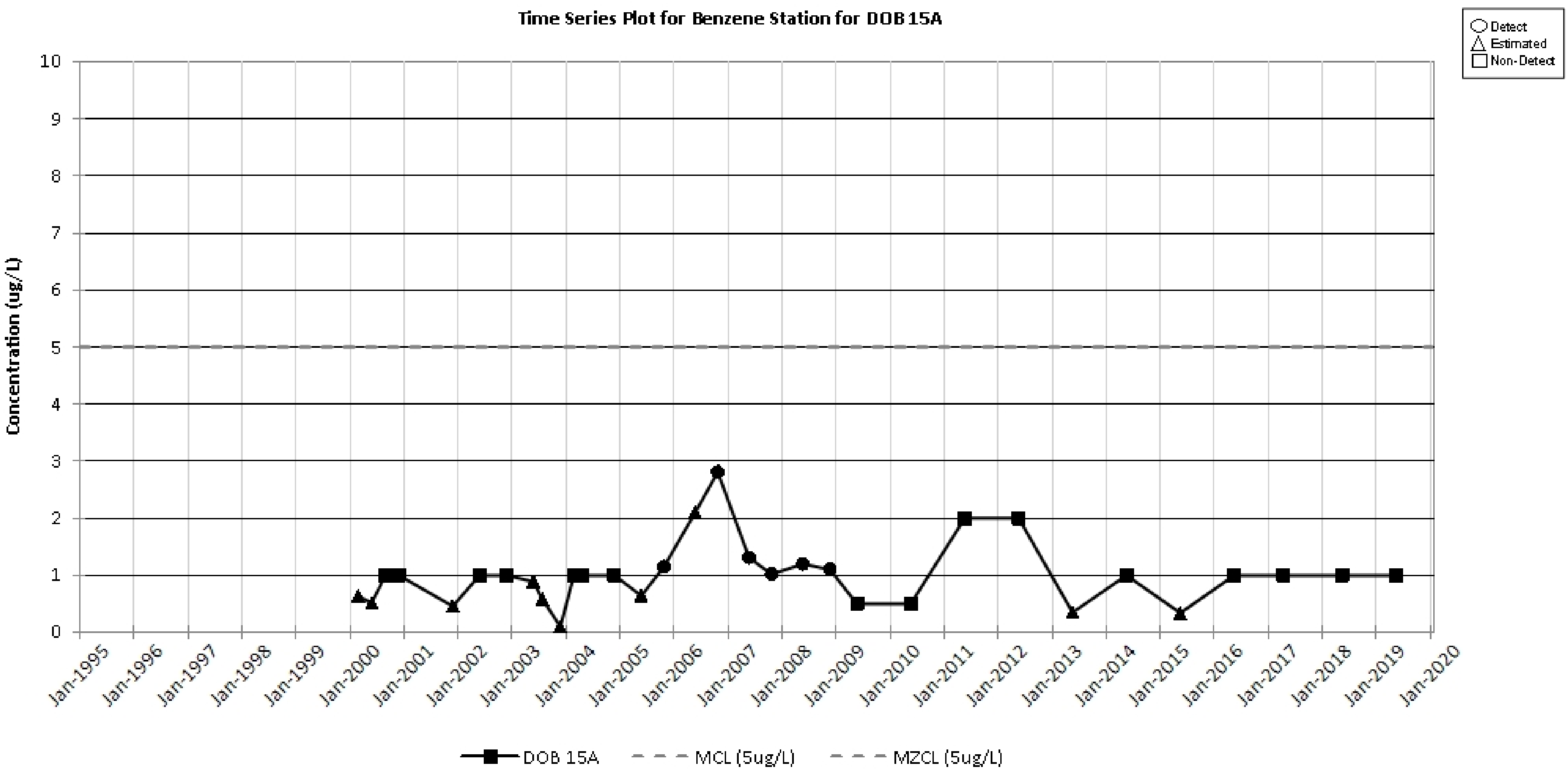


Figure D-7. Time Series Plot for Benzene Station for DOB 15A

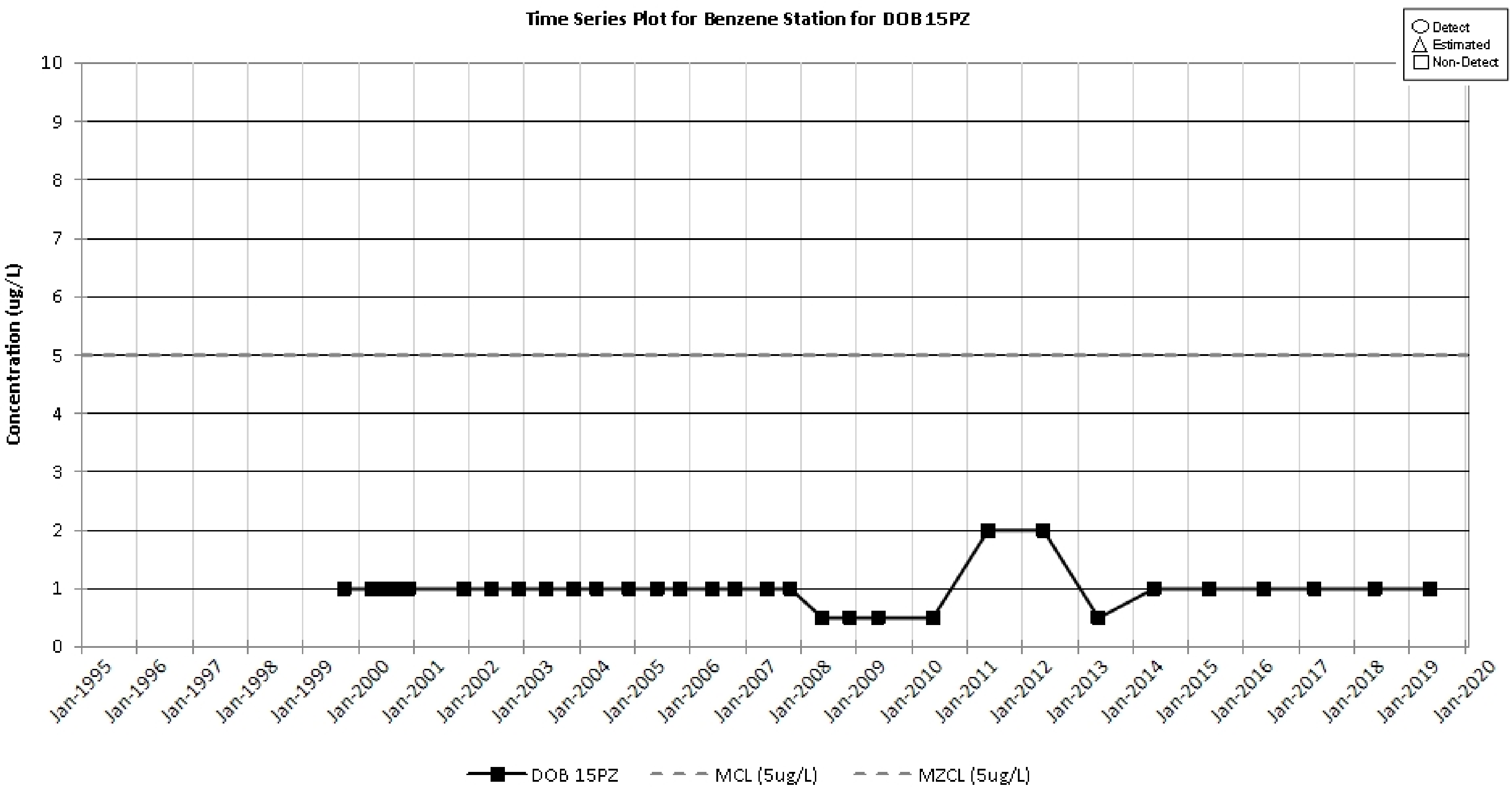


Figure D-8. Time Series Plot for Benzene Station for DOB 15PZ

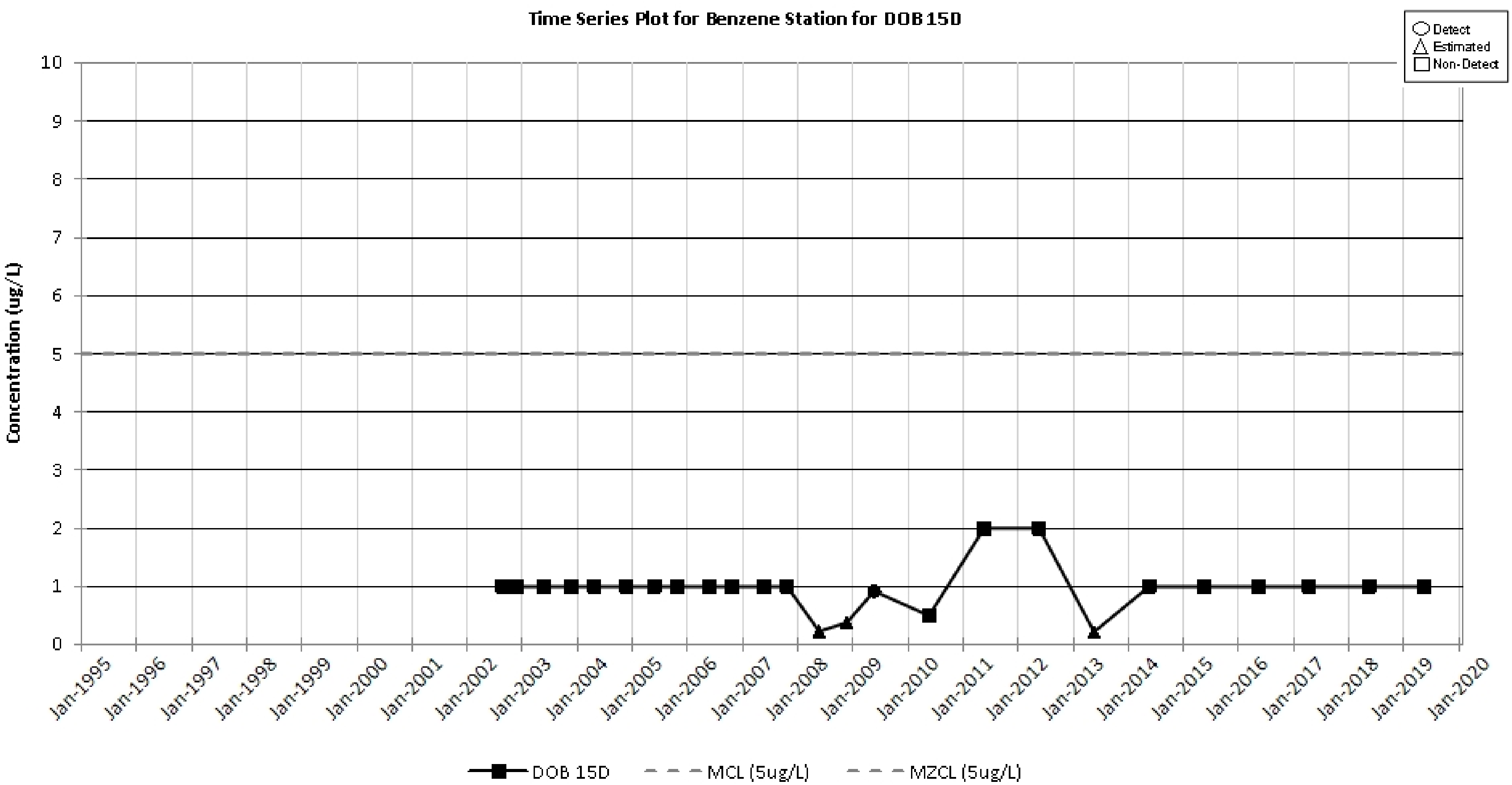


Figure D-9. Time Series Plot for Benzene Station for DOB 15D

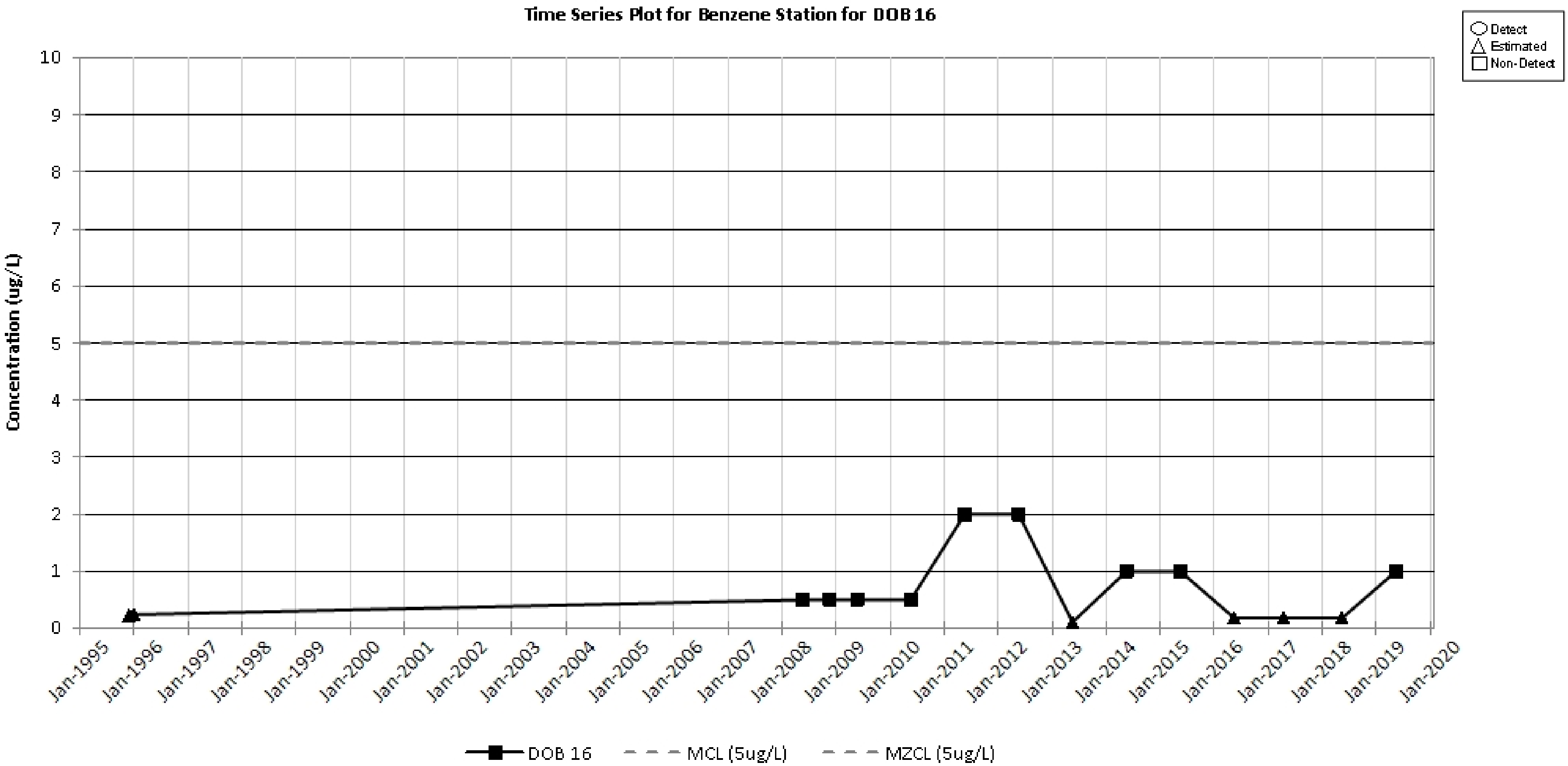


Figure D-10. Time Series Plot for Benzene Station for DOB 16

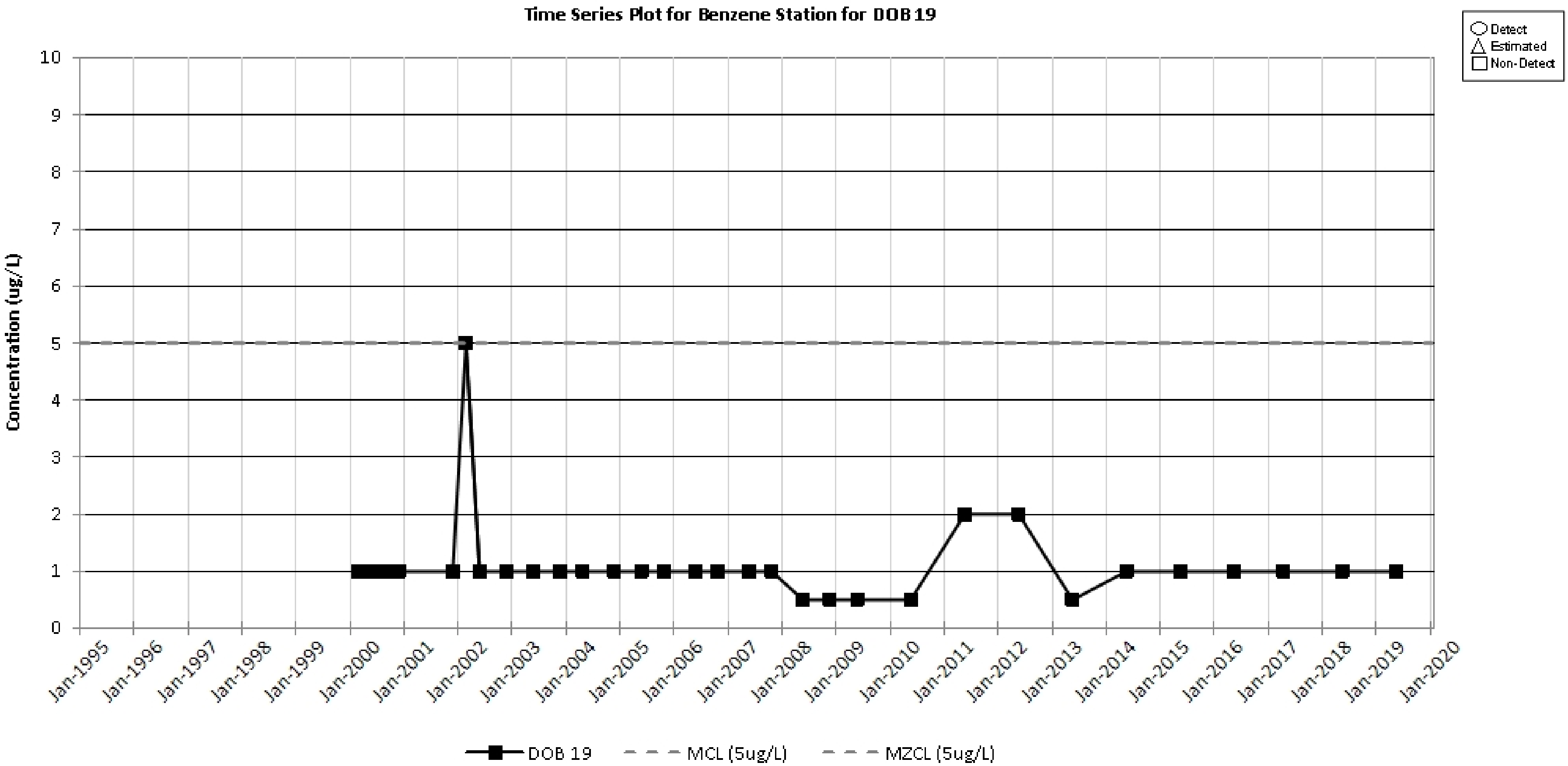


Figure D-11. Time Series Plot for Benzene Station for DOB 19

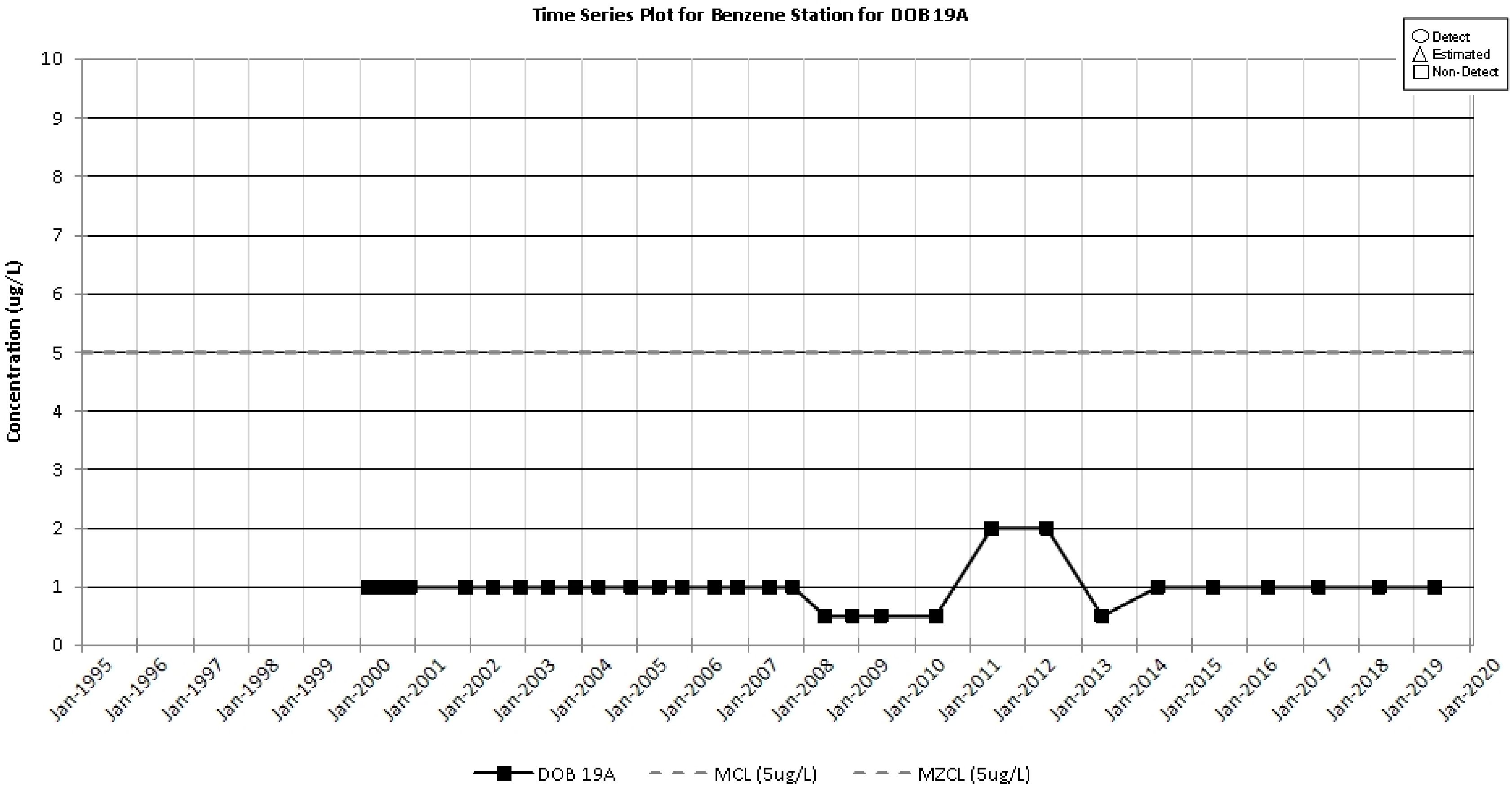


Figure D-12. Time Series Plot for Benzene Station for DOB 19A

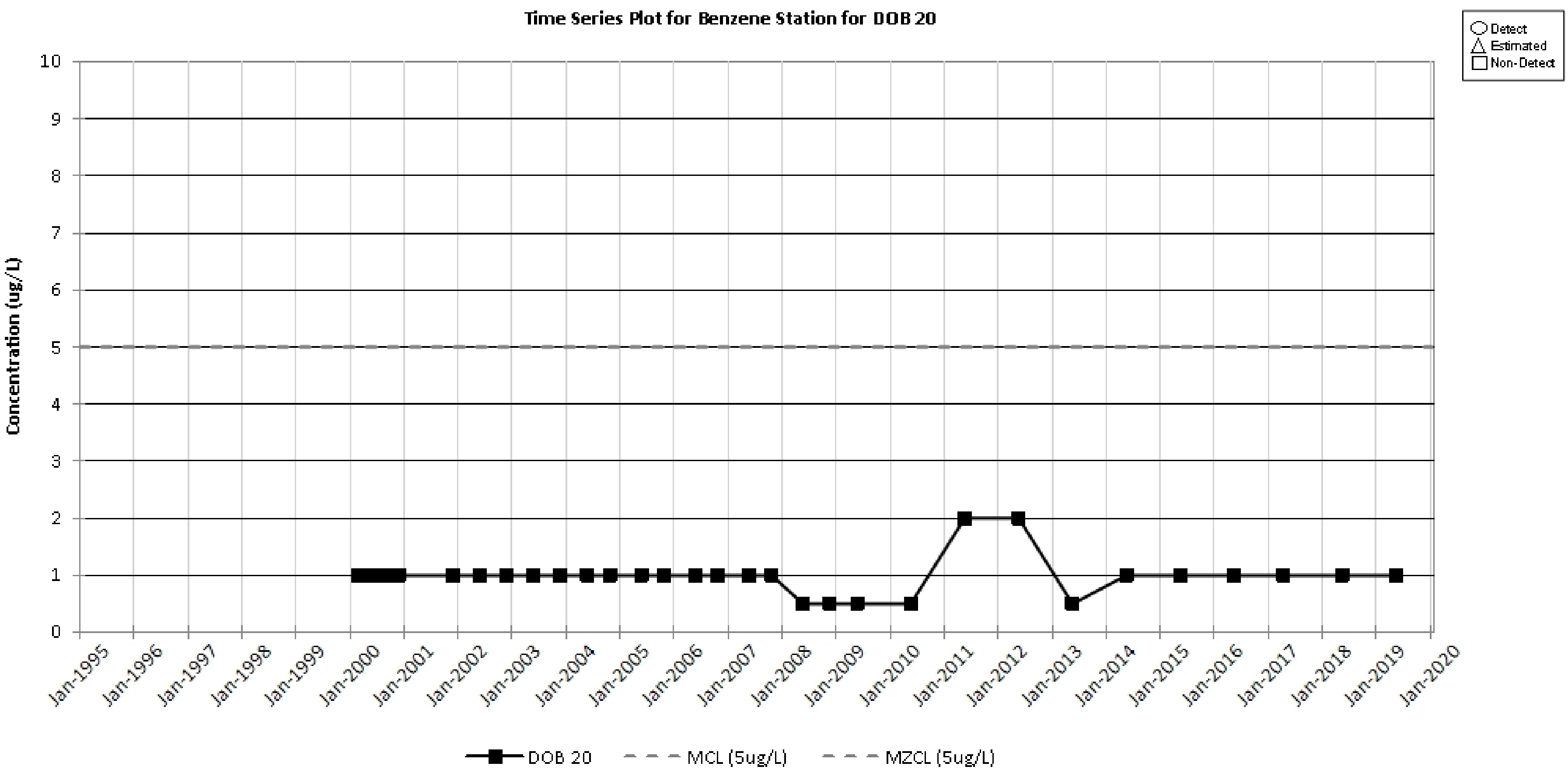
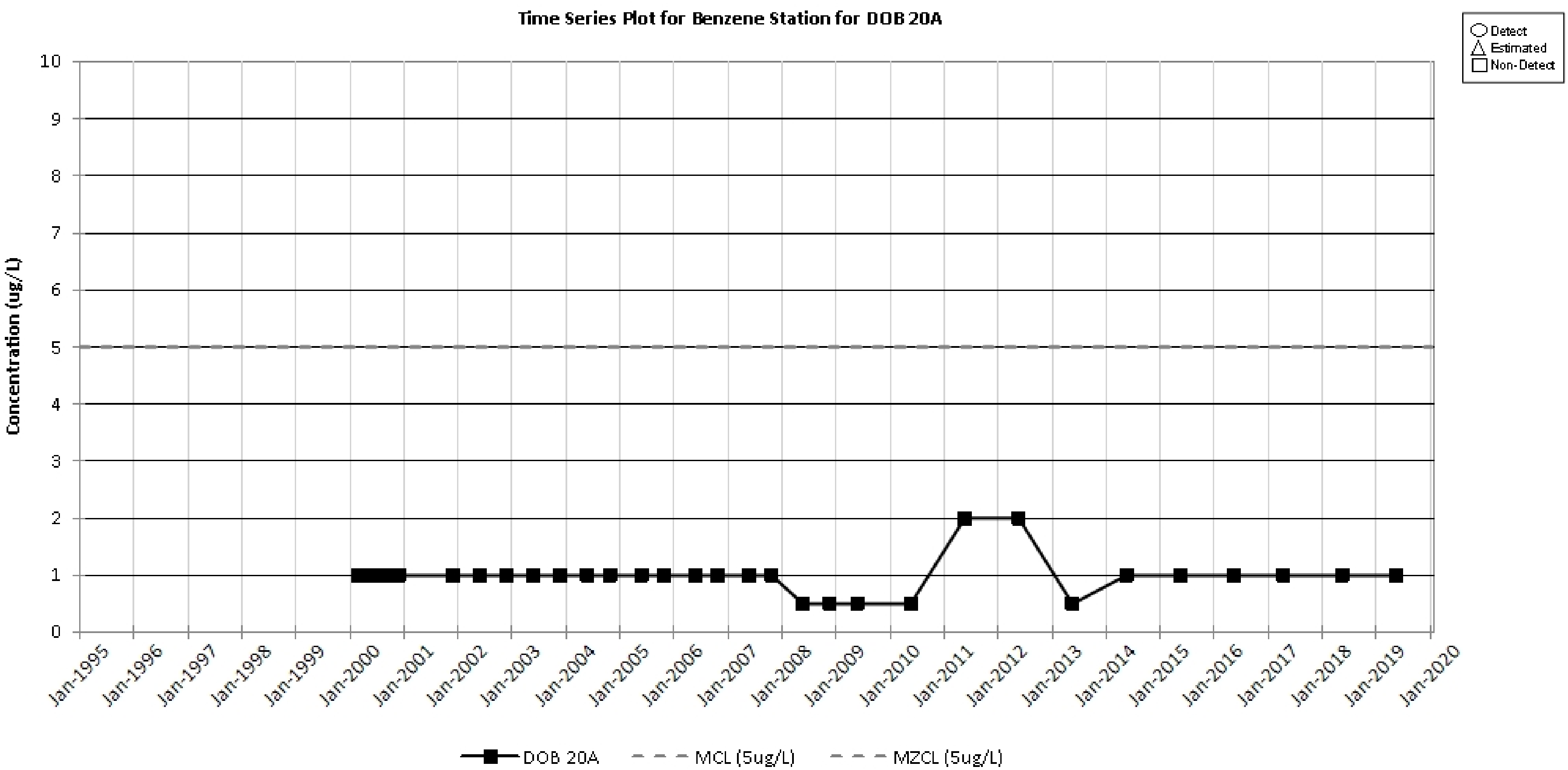


Figure D-13. Time Series Plot for Benzene Station for DOB 20



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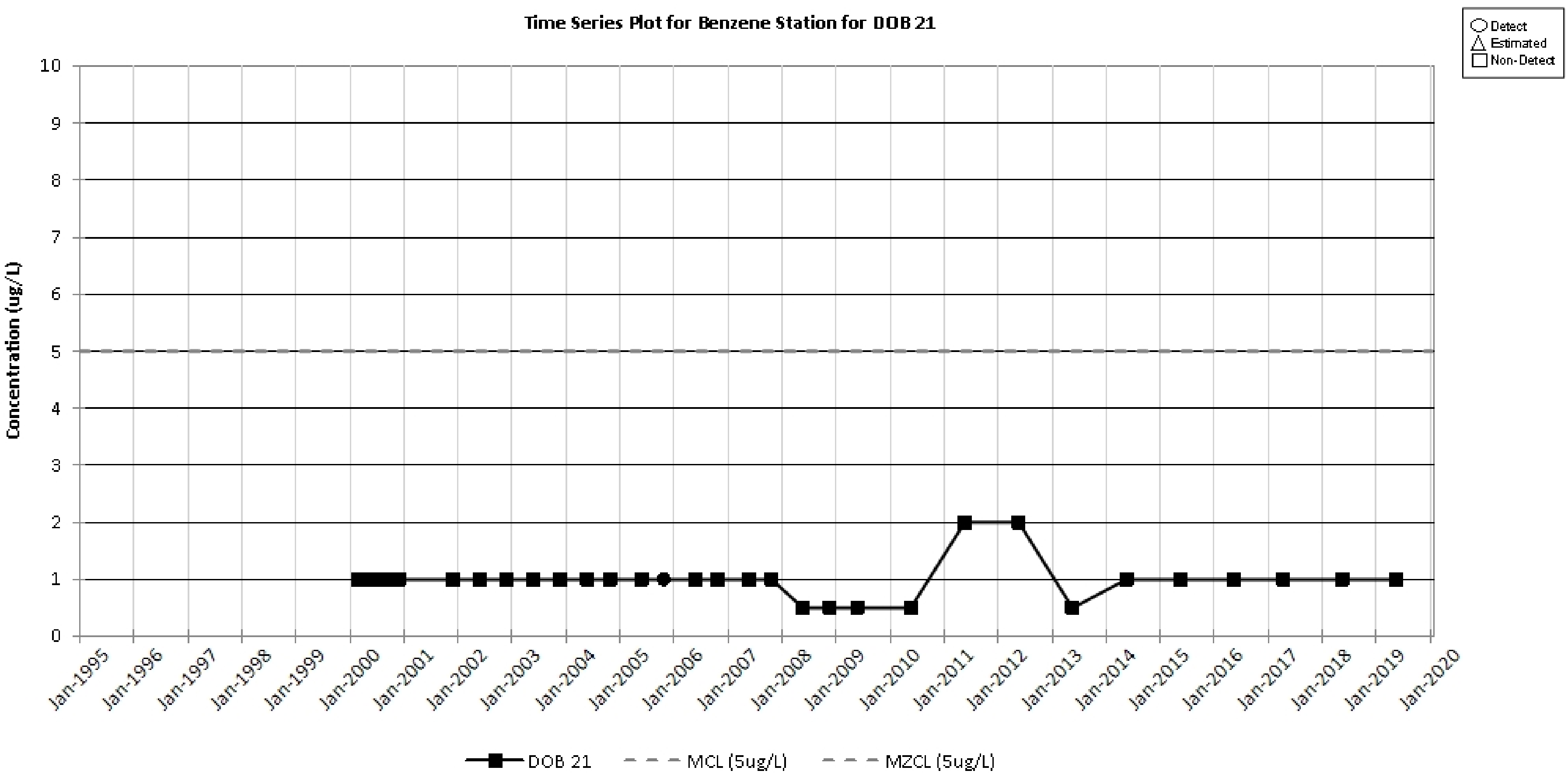


Figure D-15. Time Series Plot for Benzene Station for DOB 21

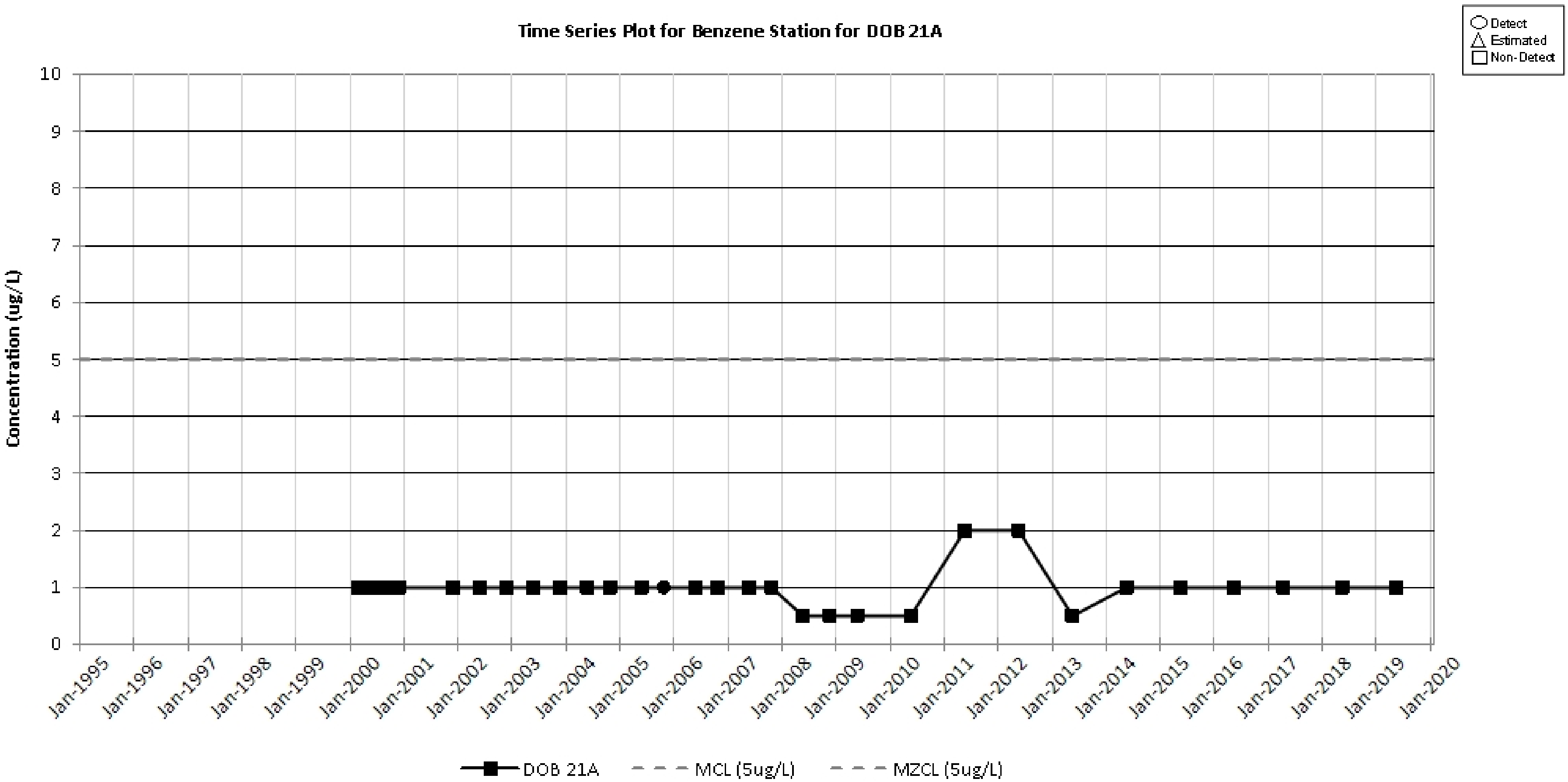
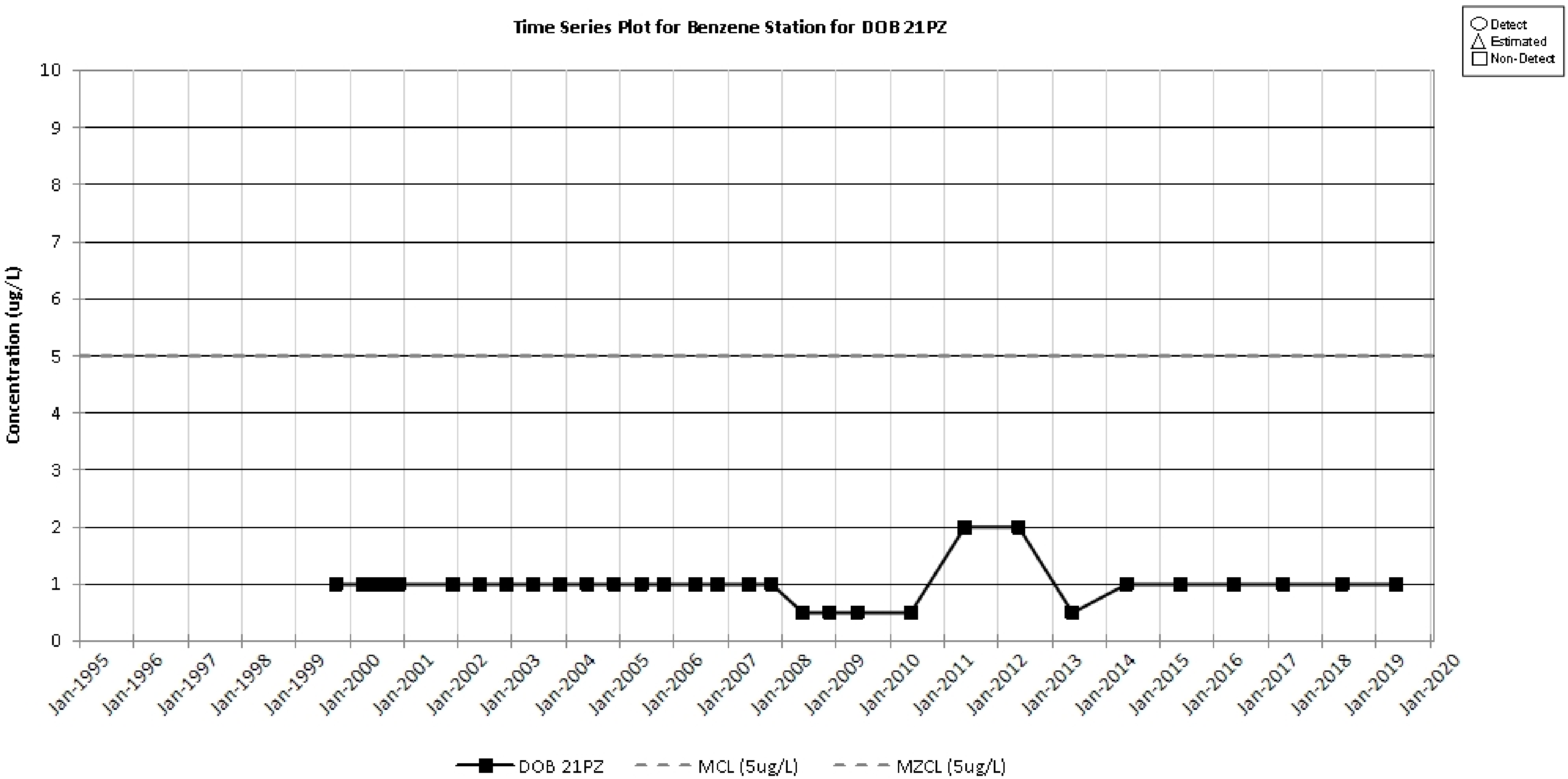


Figure D-16. Time Series Plot for Benzene Station for DOB 21A



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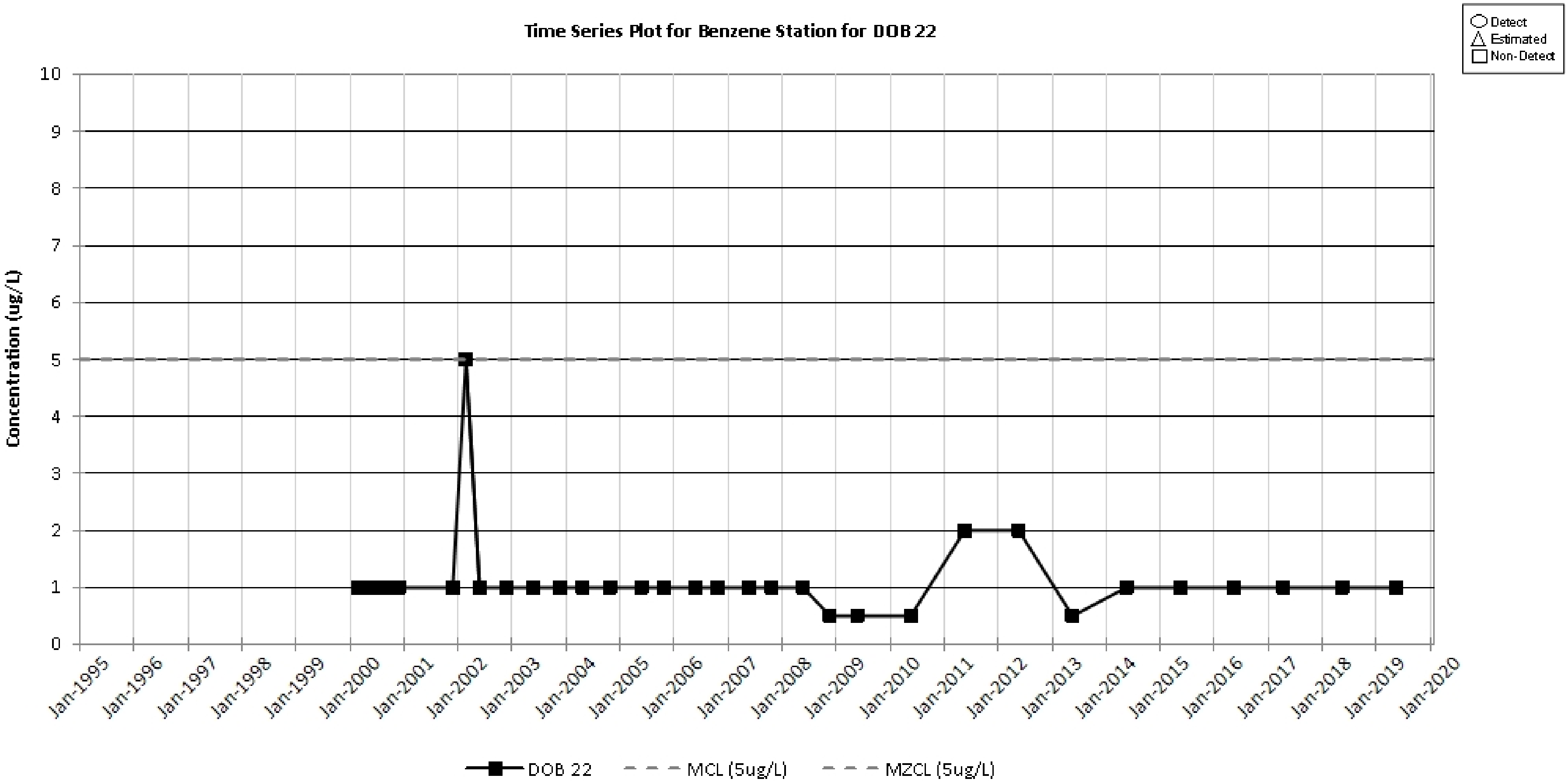


Figure D-18. Time Series Plot for Benzene Station for DOB 22

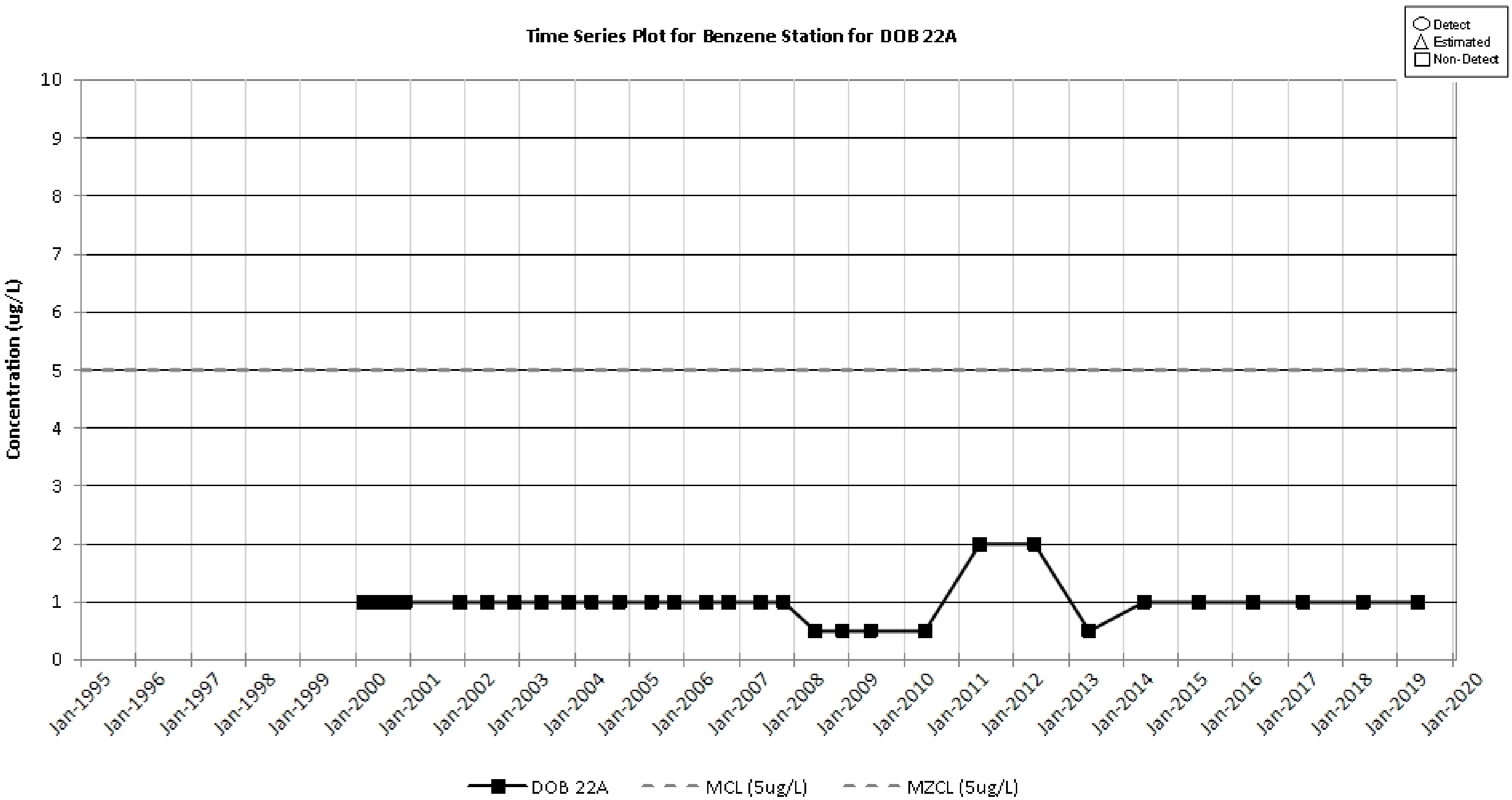


Figure D-19. Time Series Plot for Benzene Station for DOB 22A

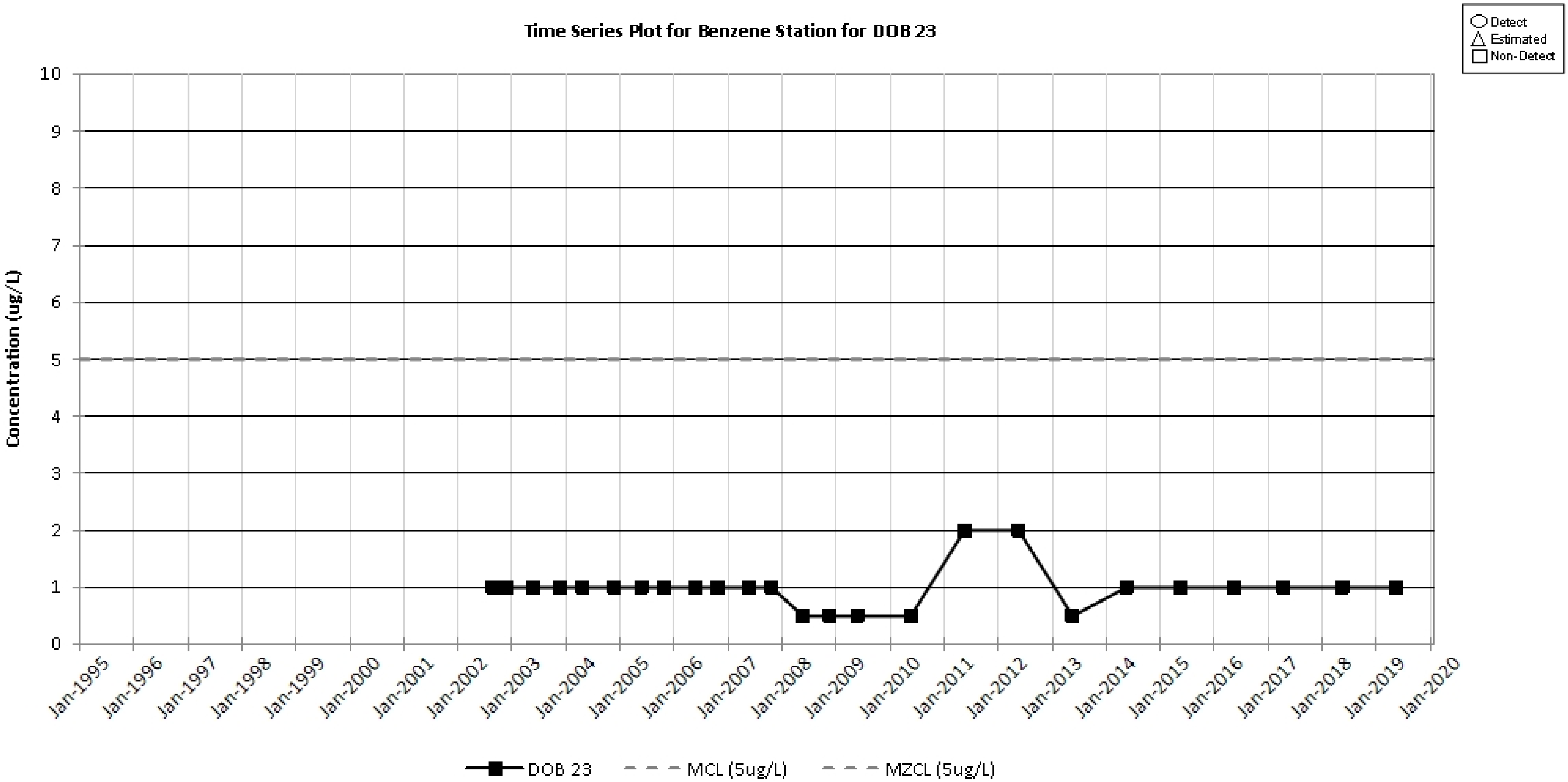


Figure D-20. Time Series Plot for Benzene Station for DOB 23

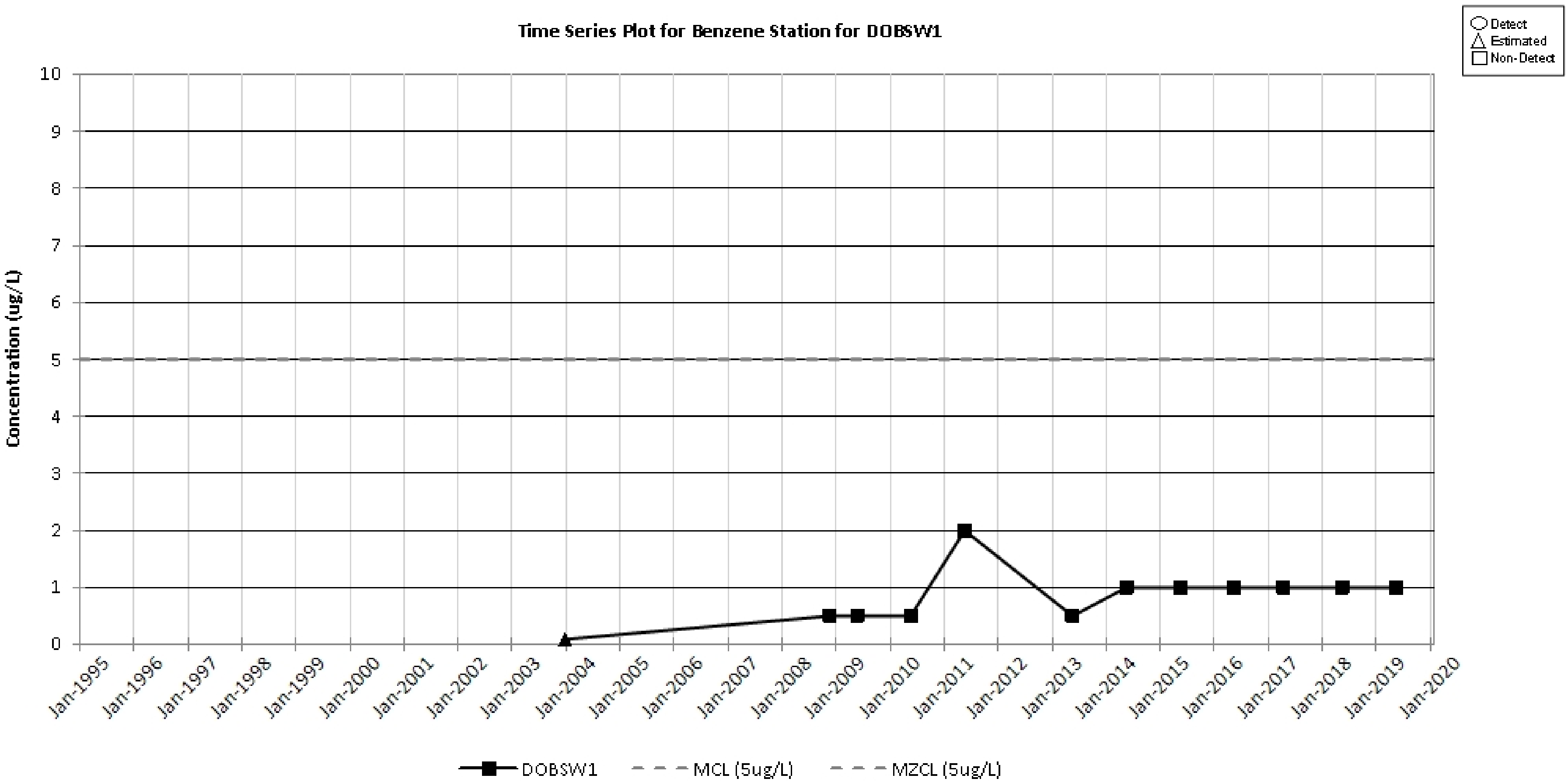


Figure D-21. Time Series Plot for Benzene Station for DOB SW1

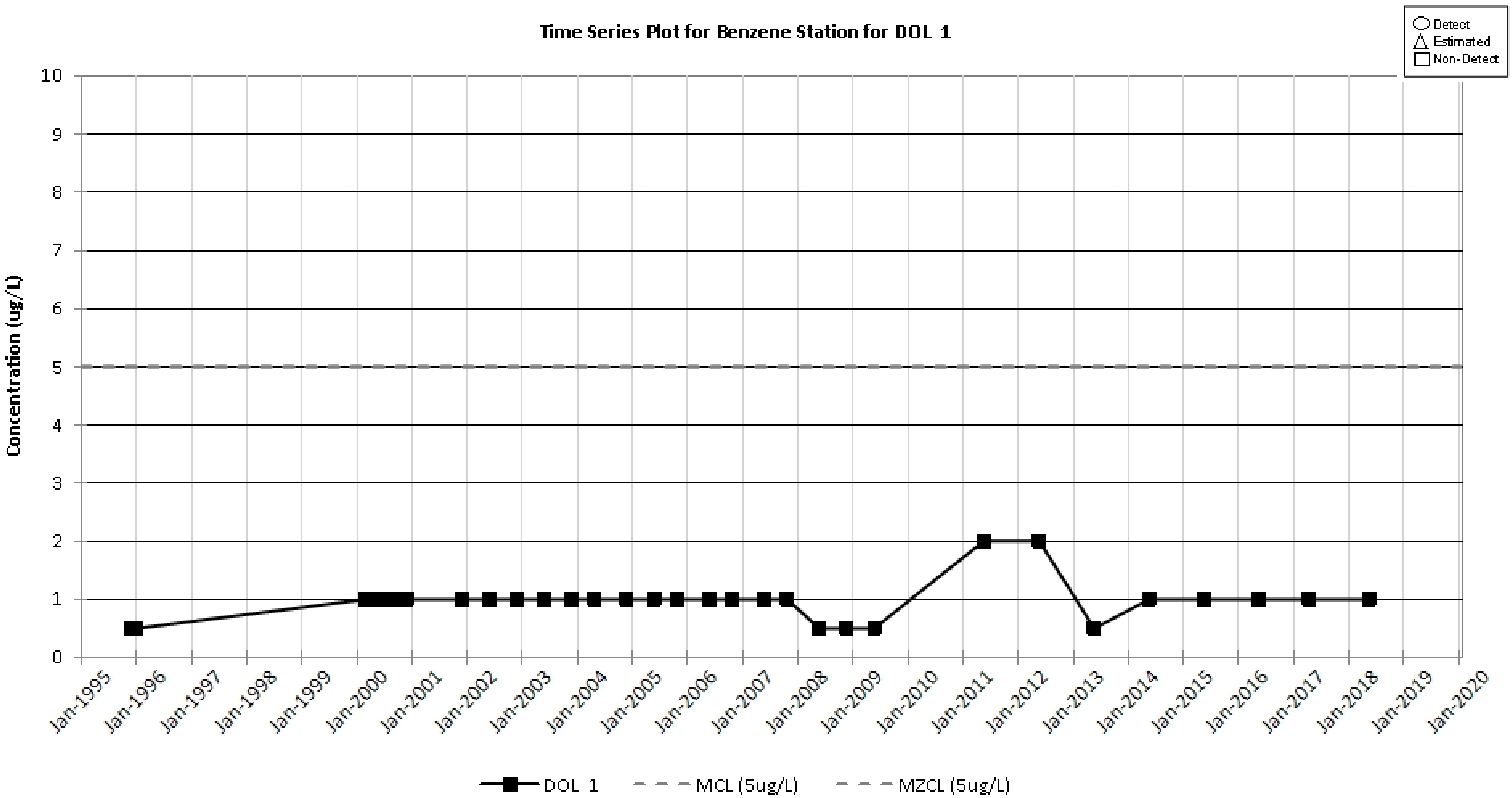


Figure D-22. Time Series Plot for Benzene Station for DOL 1

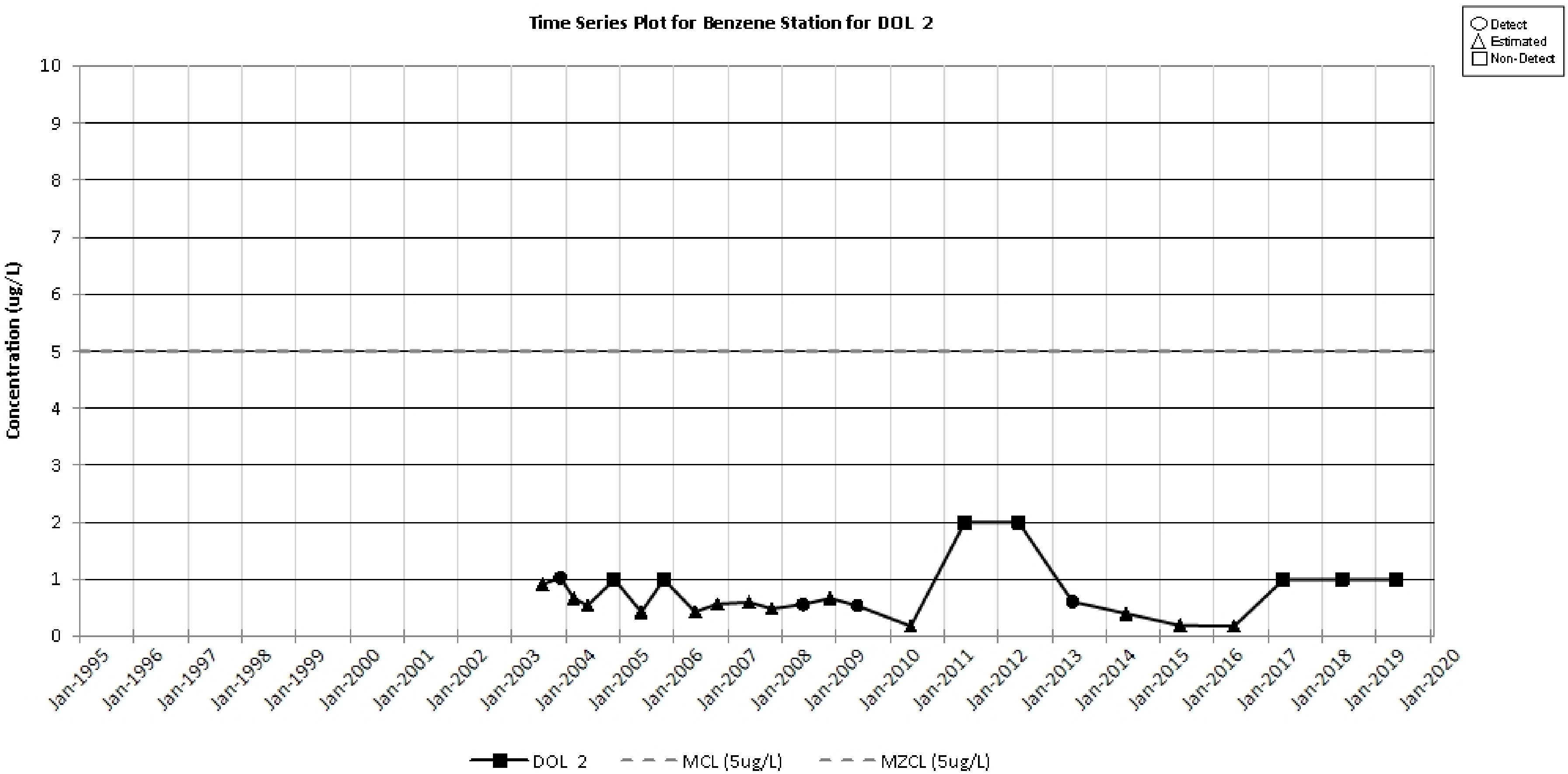


Figure D-23. Time Series Plot for Benzene Station for DOL 2

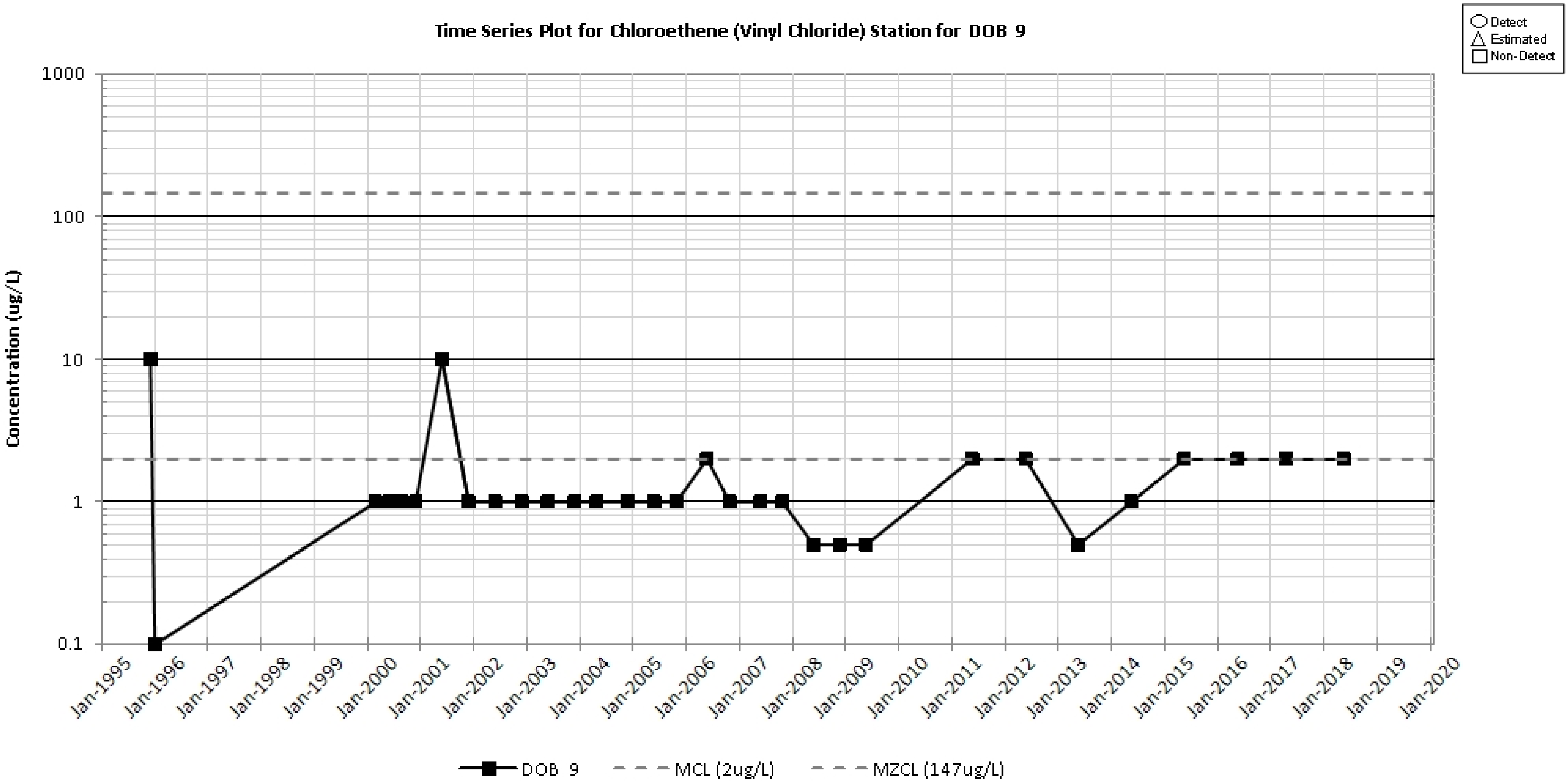


Figure D-24. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 9

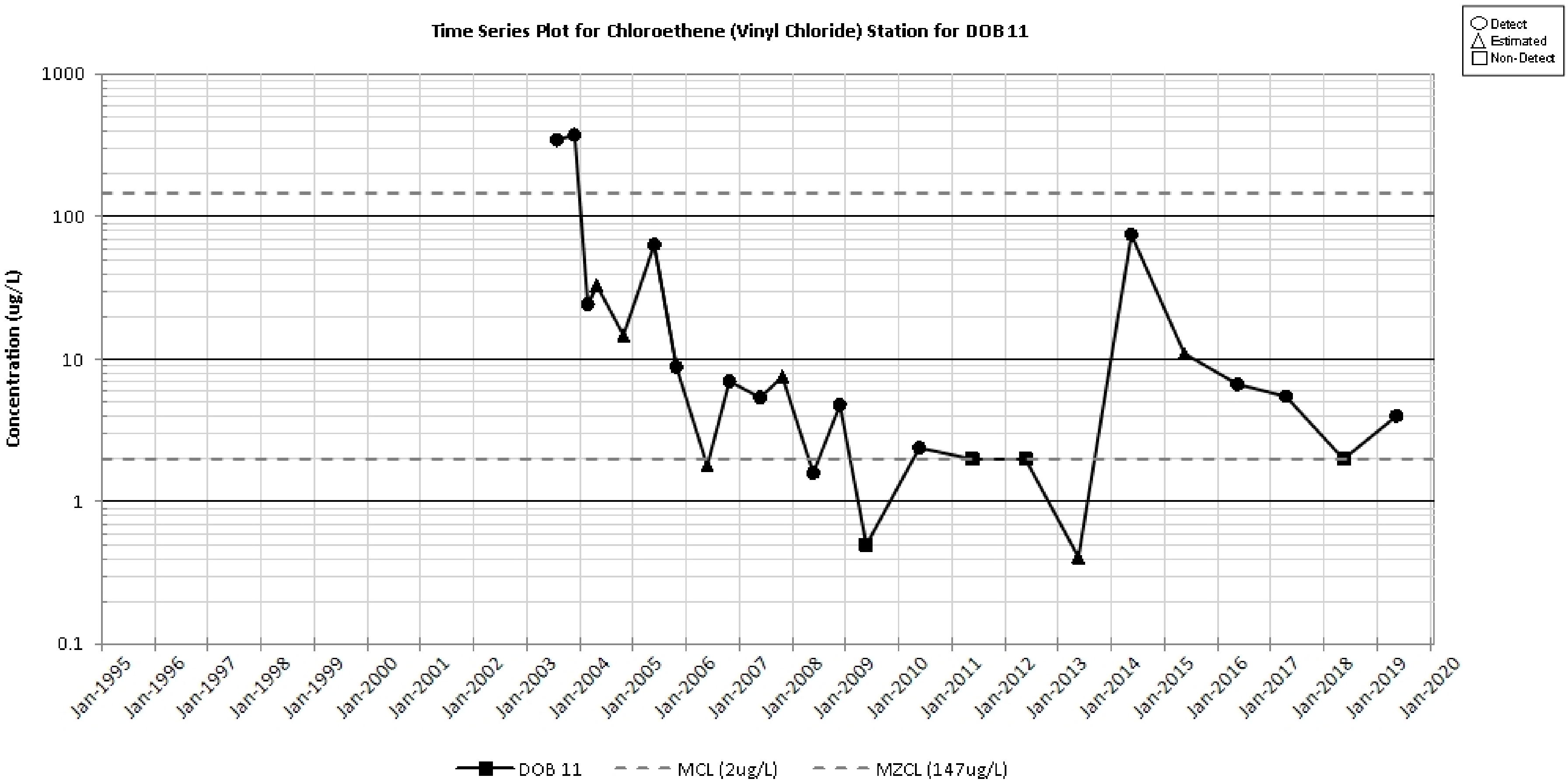


Figure D-25. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 11

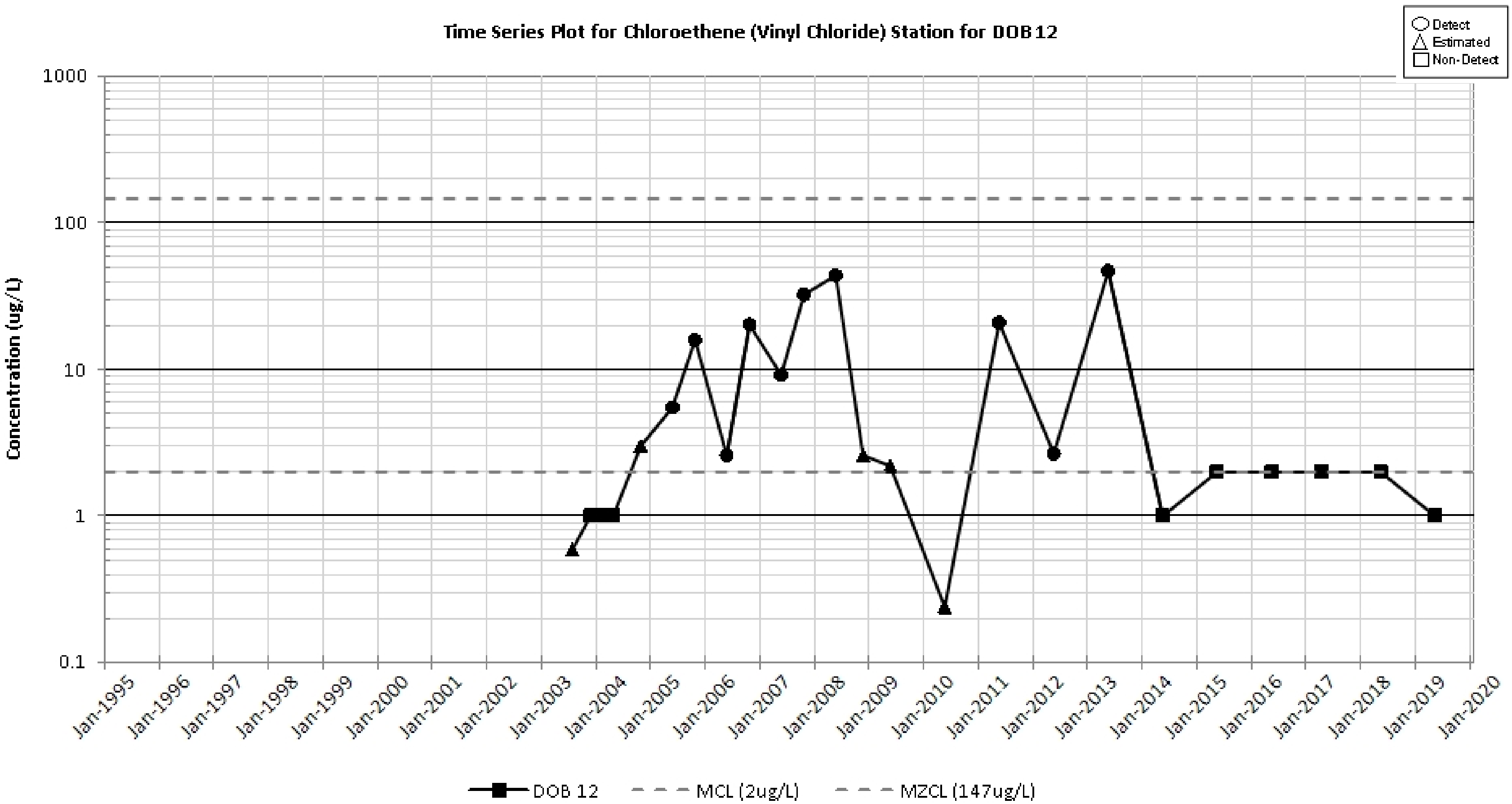


Figure D-26. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 12

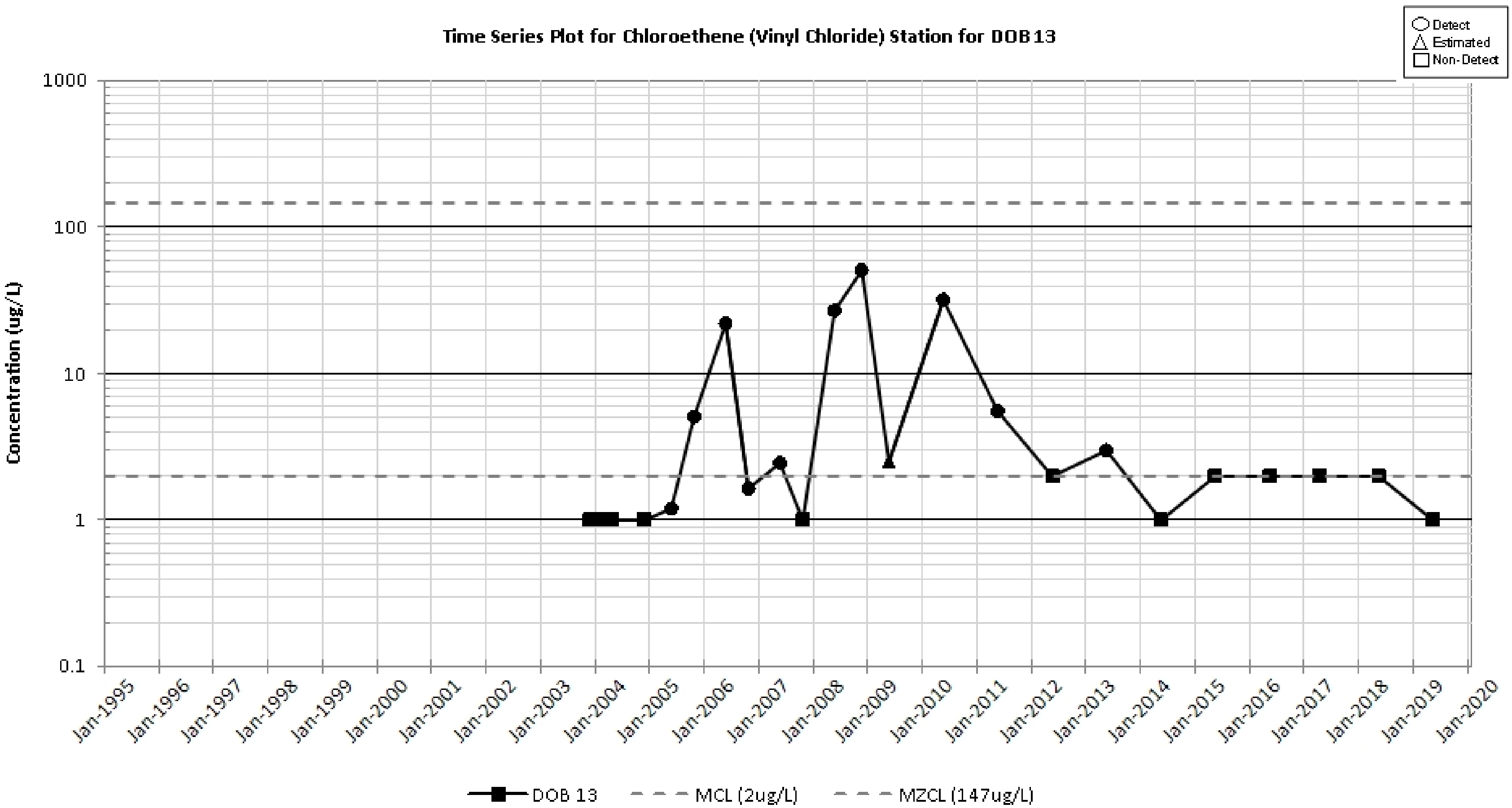


Figure D-27. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 13

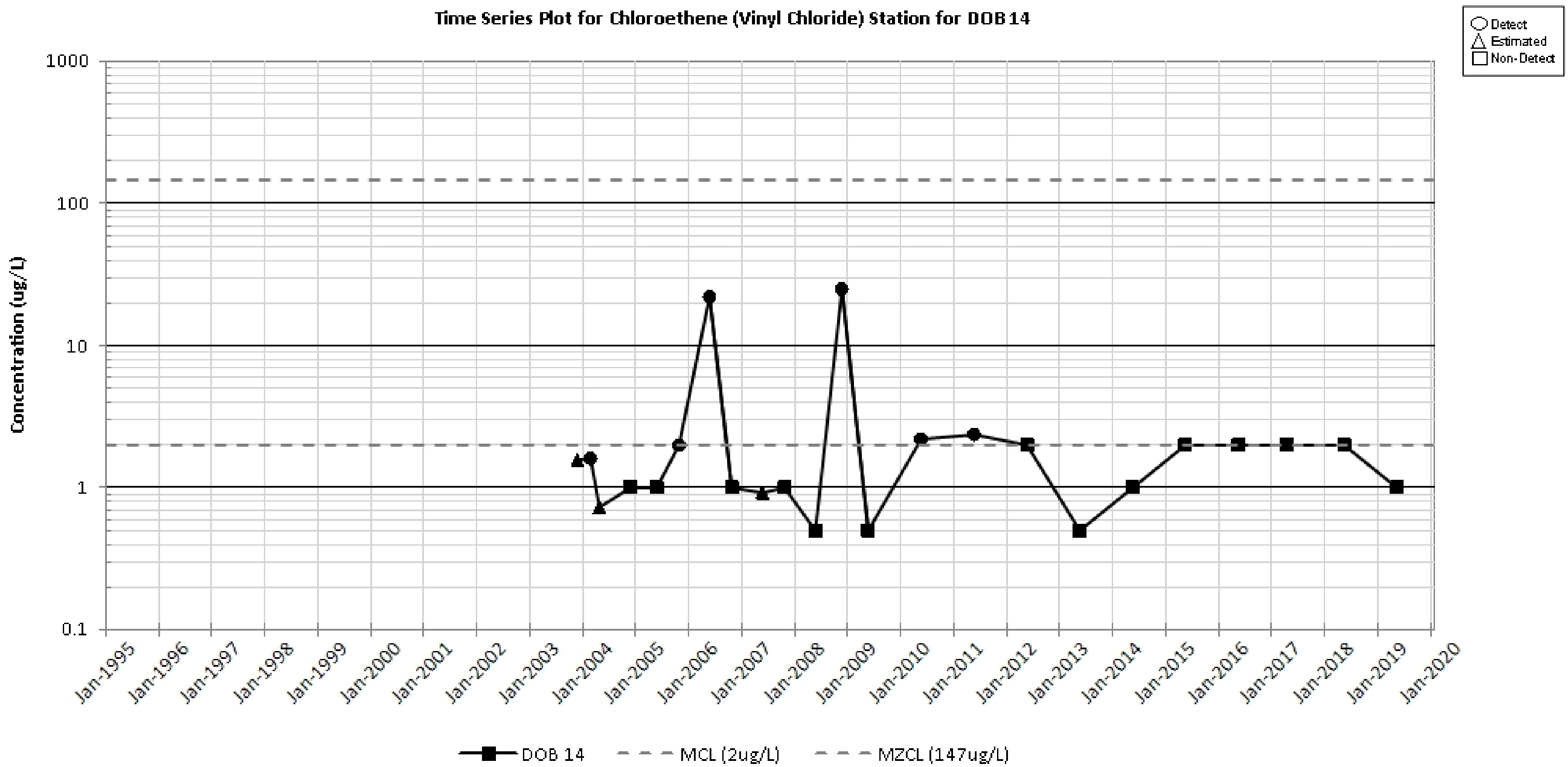


Figure D-28. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 14

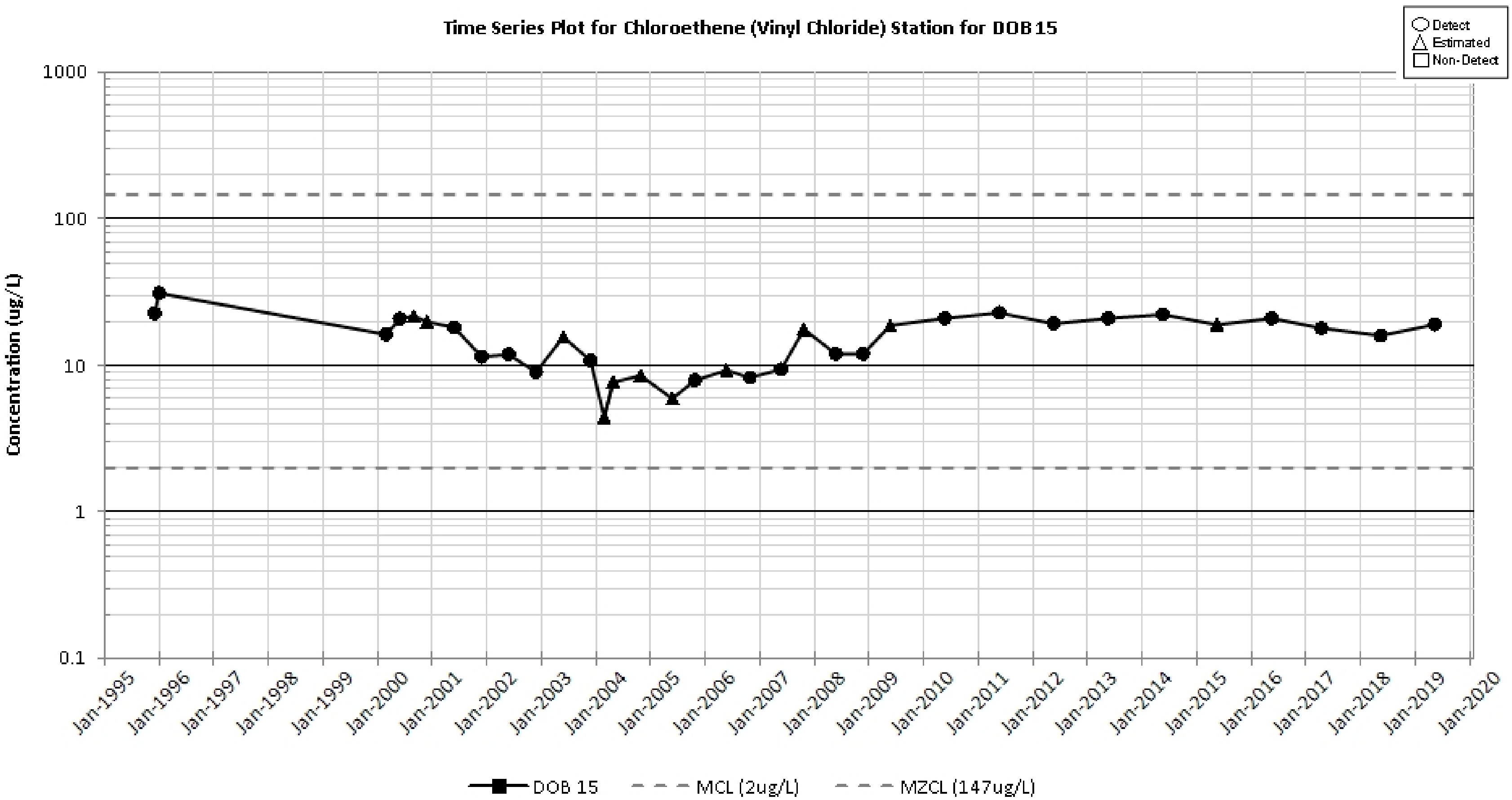


Figure D-29. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 15

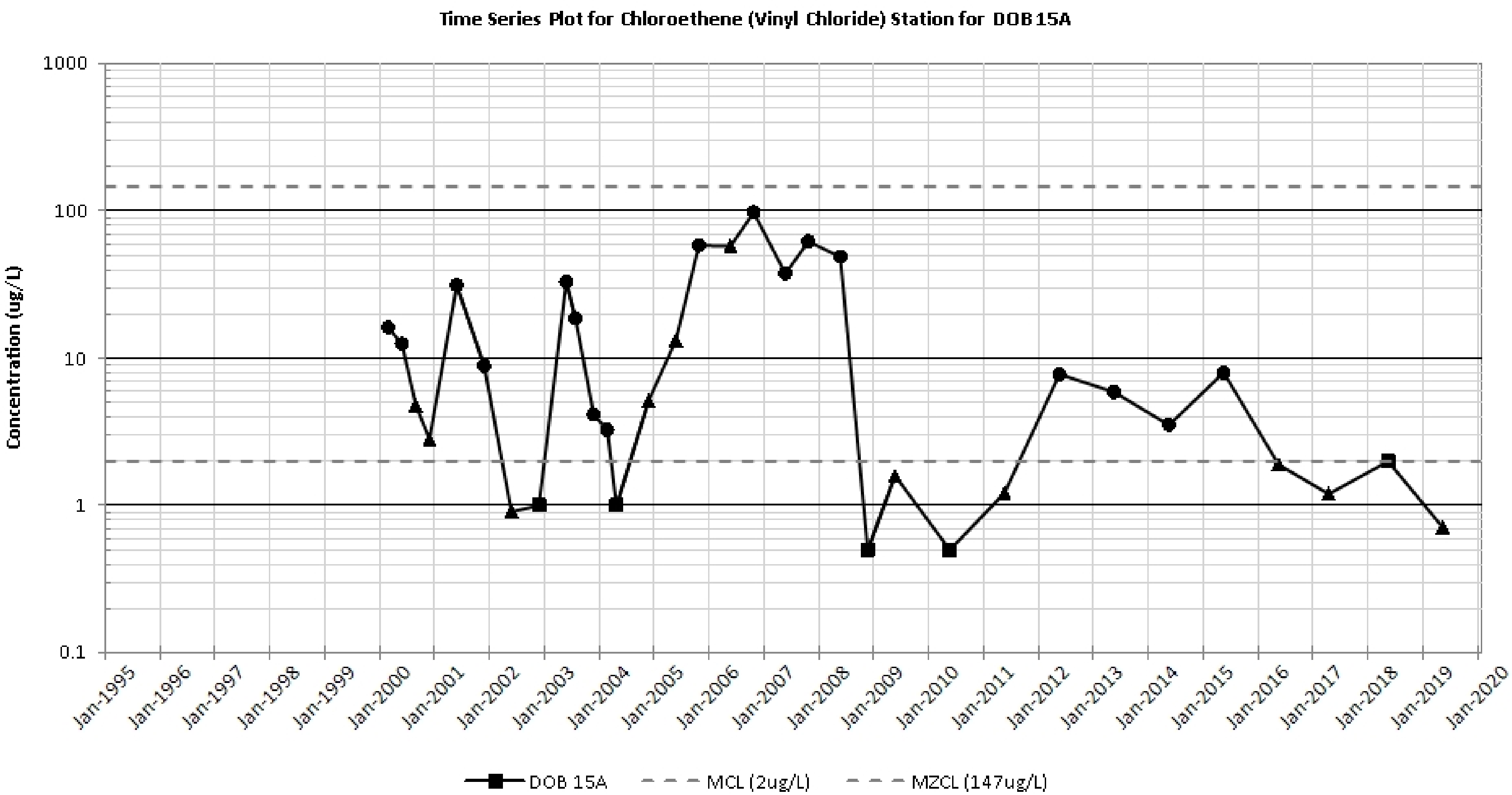
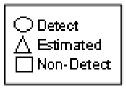


Figure D-30. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 15A



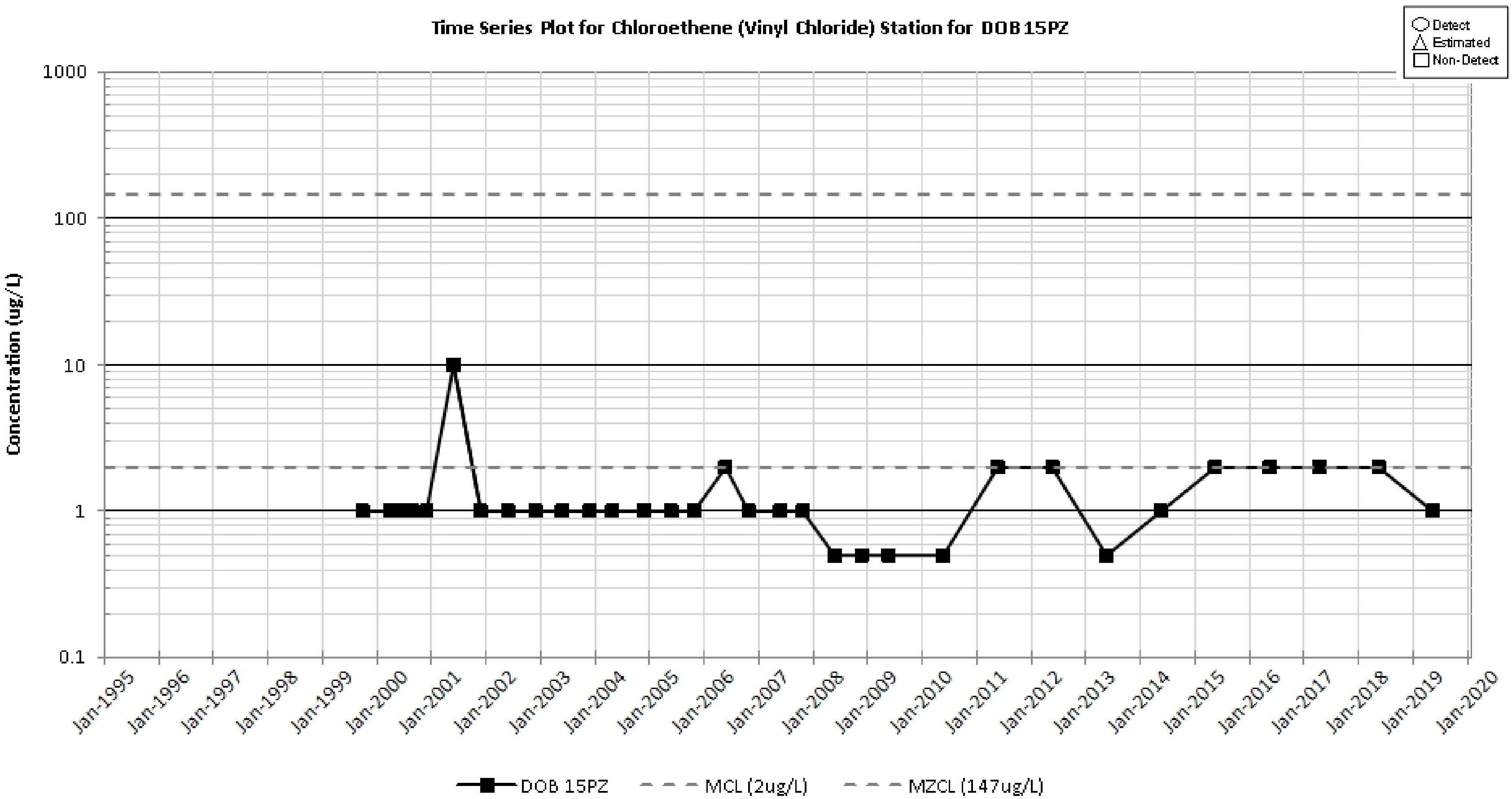


Figure D-31. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 15PZ

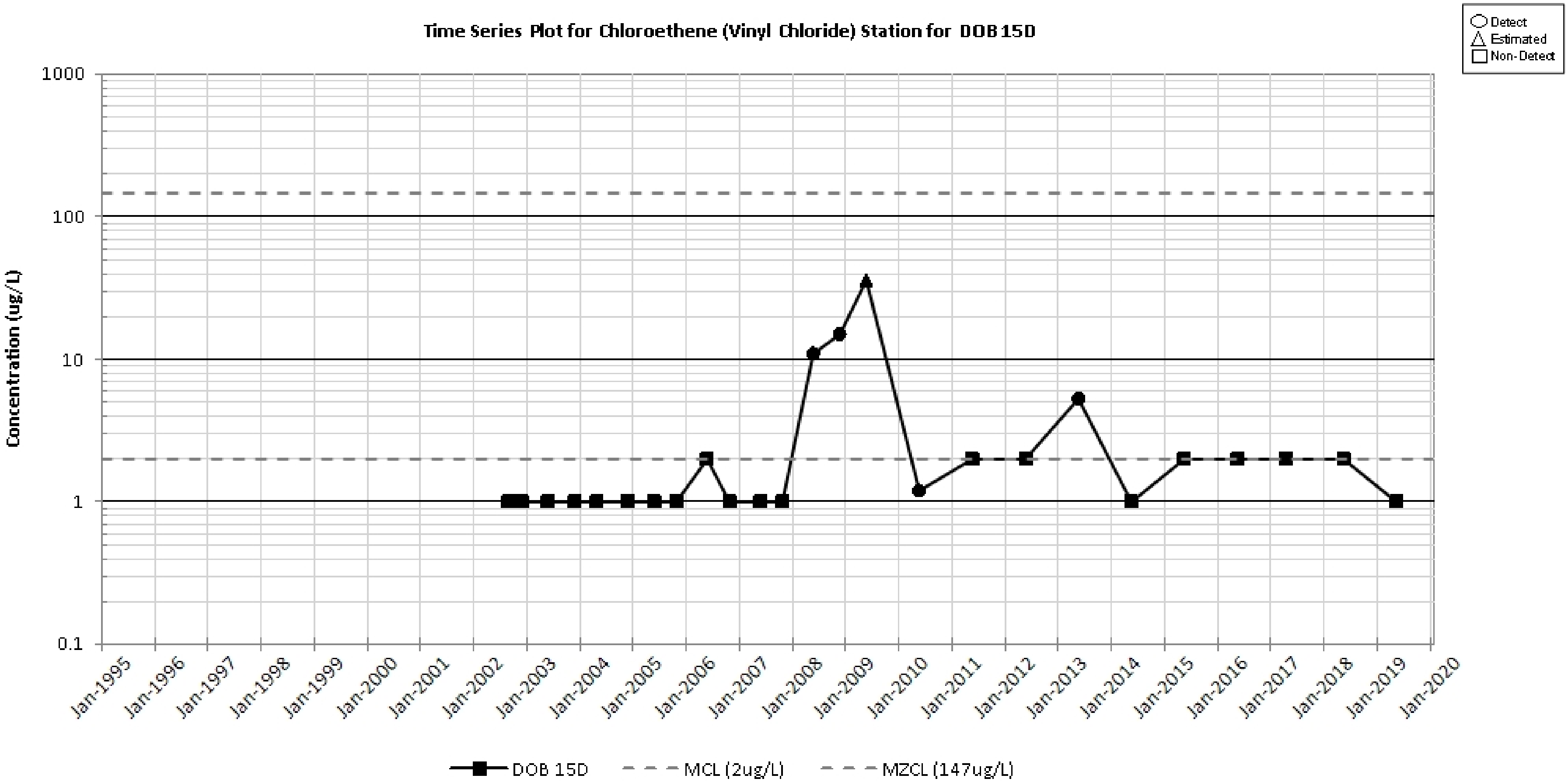


Figure D-32. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 15D

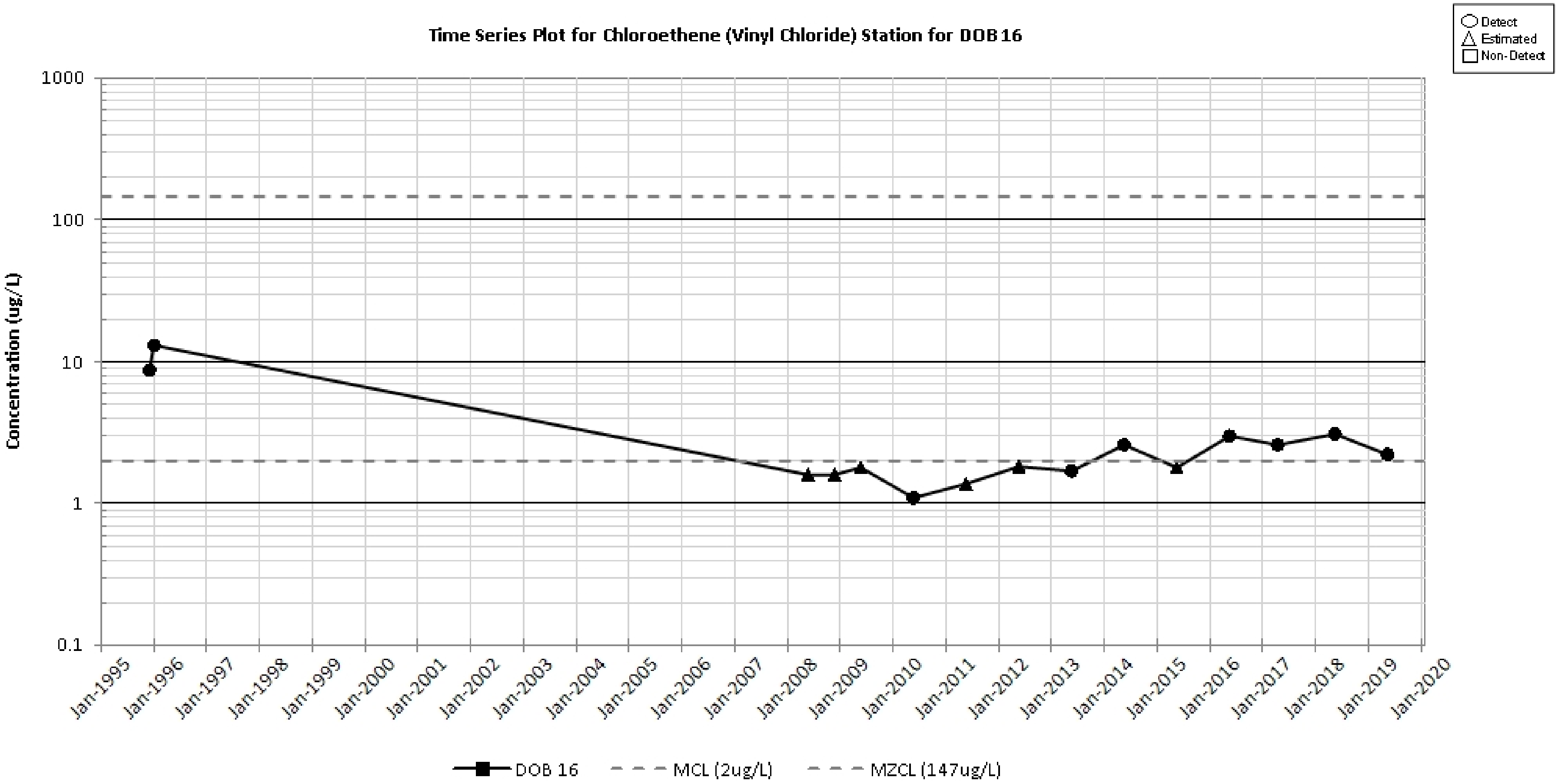


Figure D-33. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 16

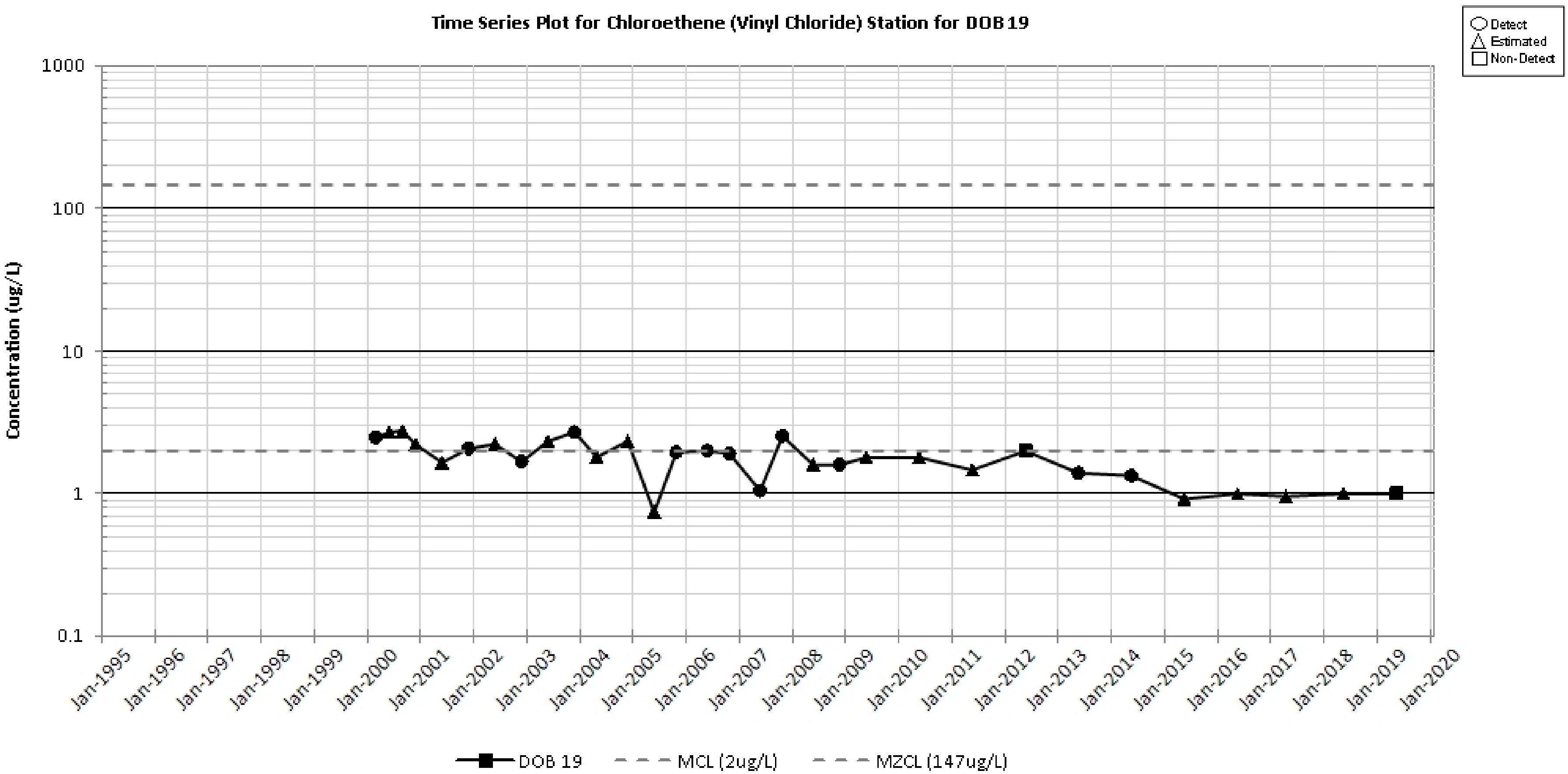


Figure D-34. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 19

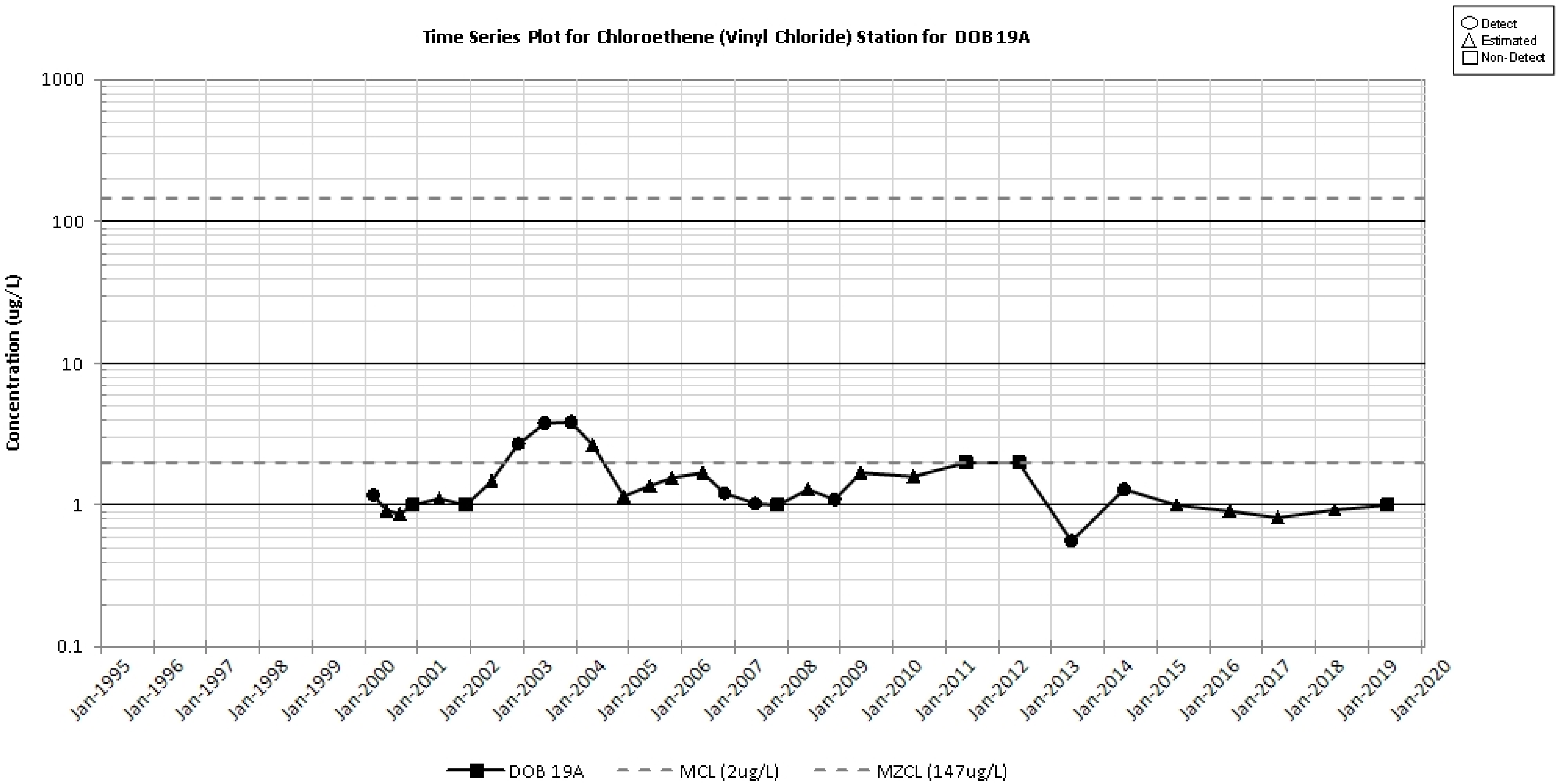


Figure D-35. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 19A

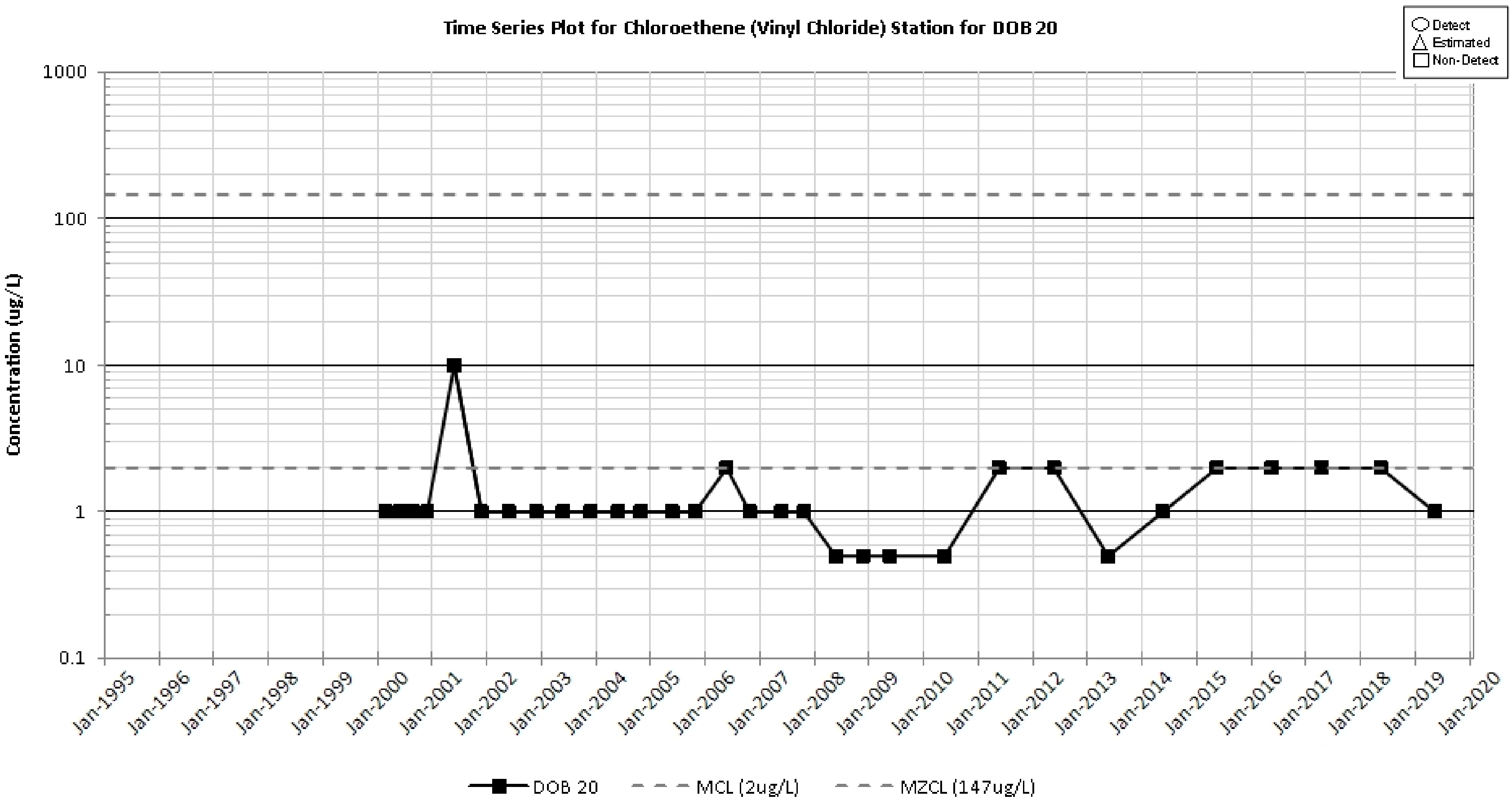


Figure D-36. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 20

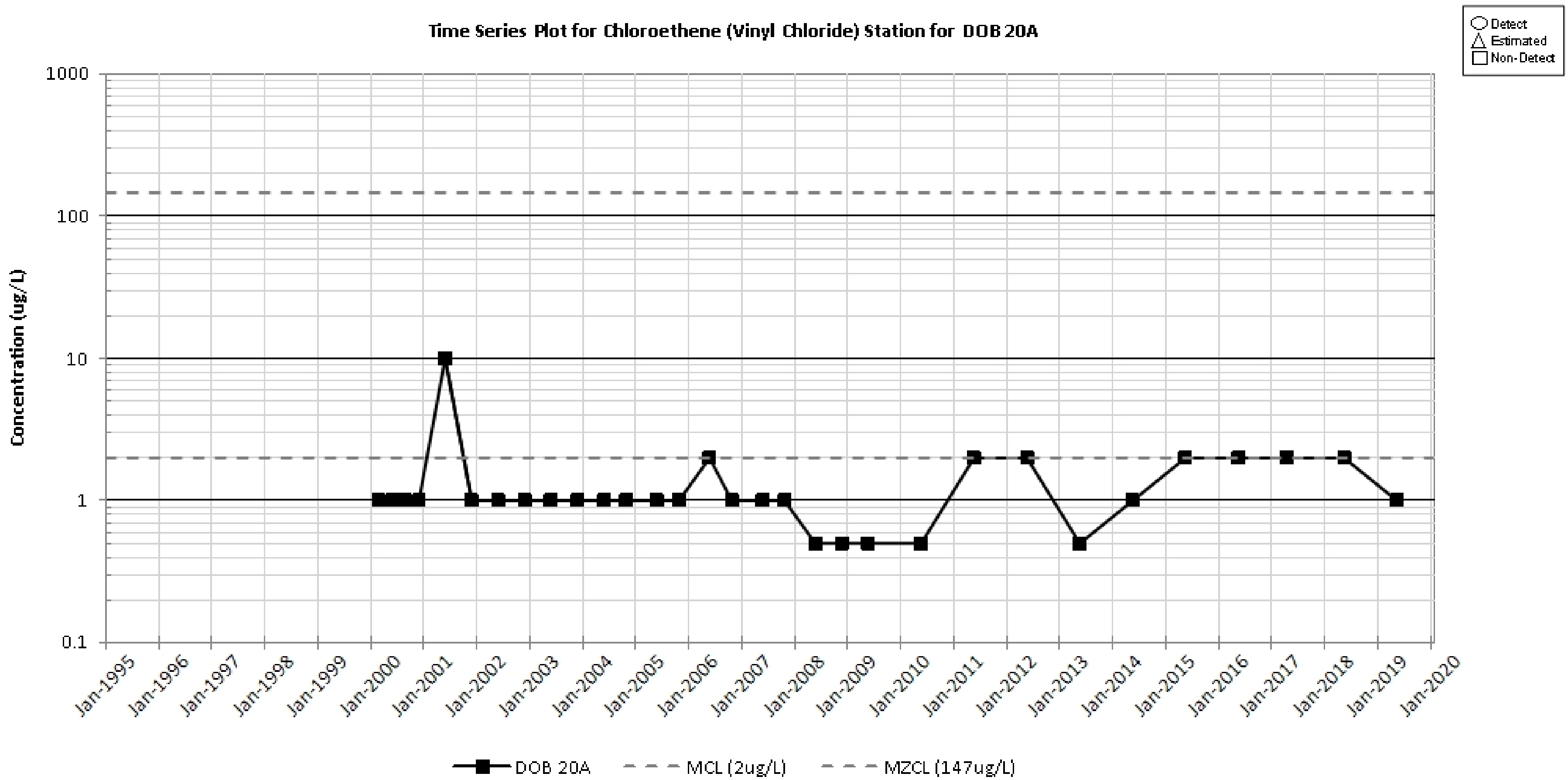


Figure D-37. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 20A

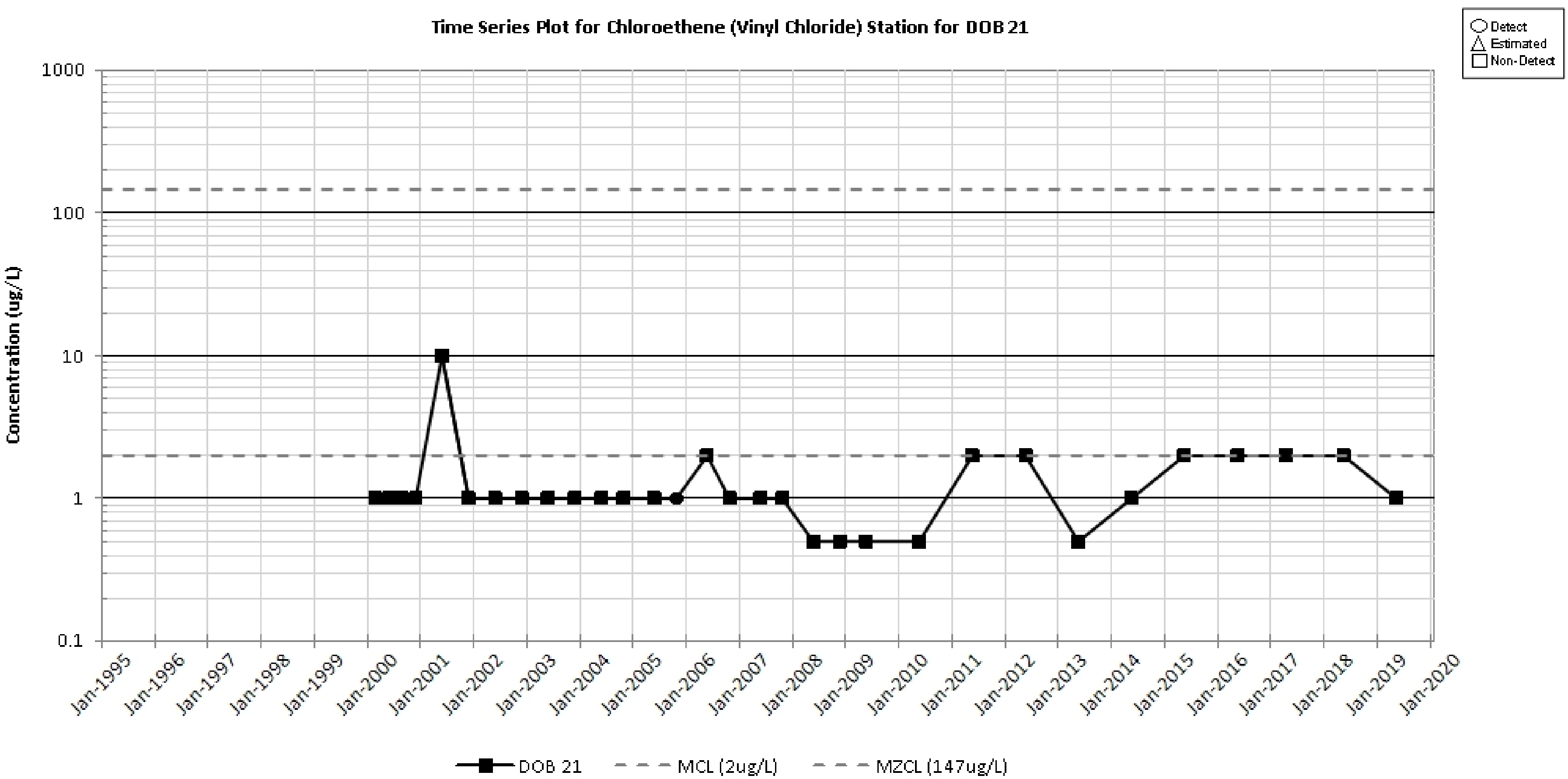


Figure D-38. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 21

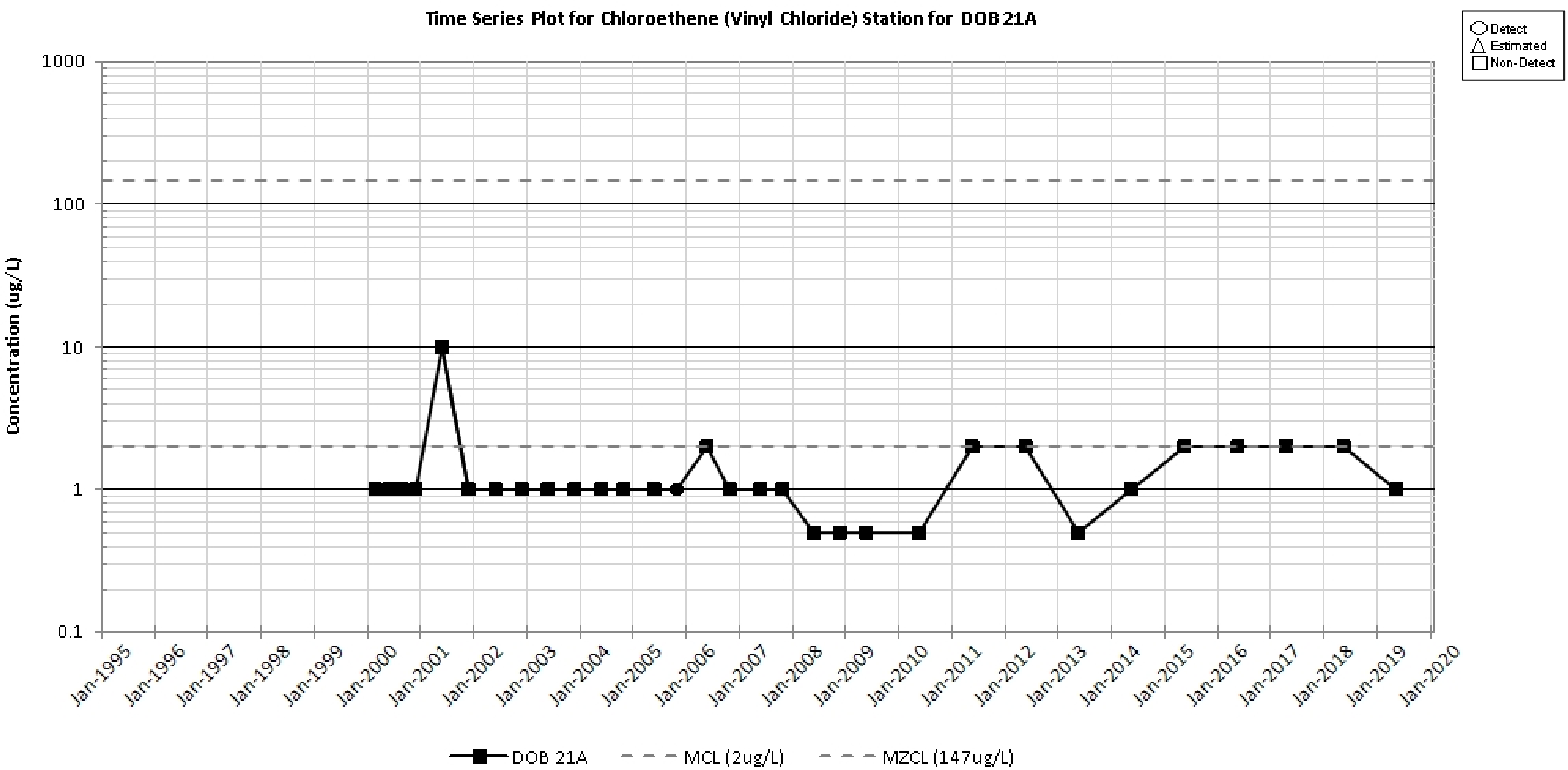


Figure D-39. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 21A

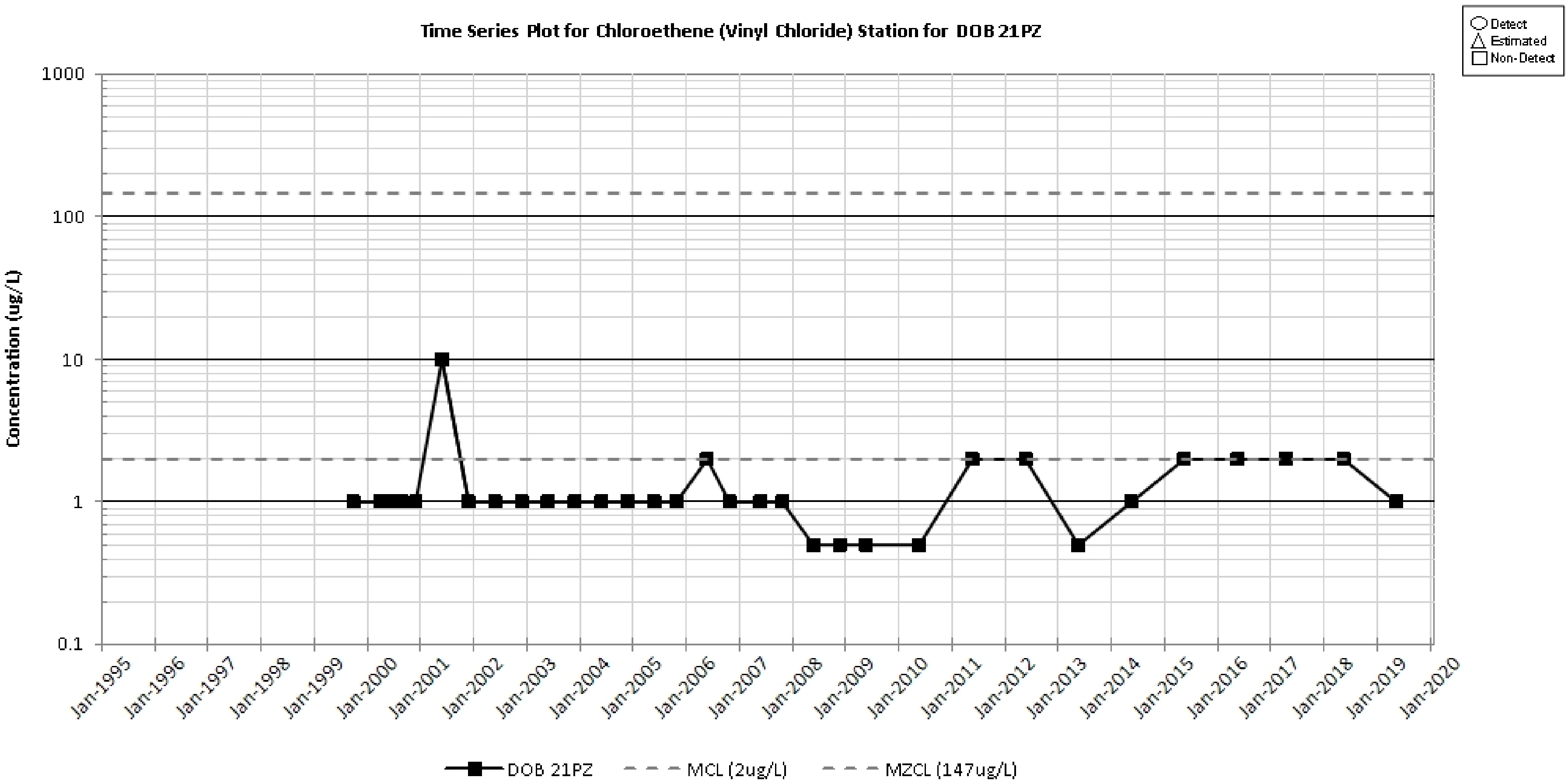


Figure D-40. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 21PZ

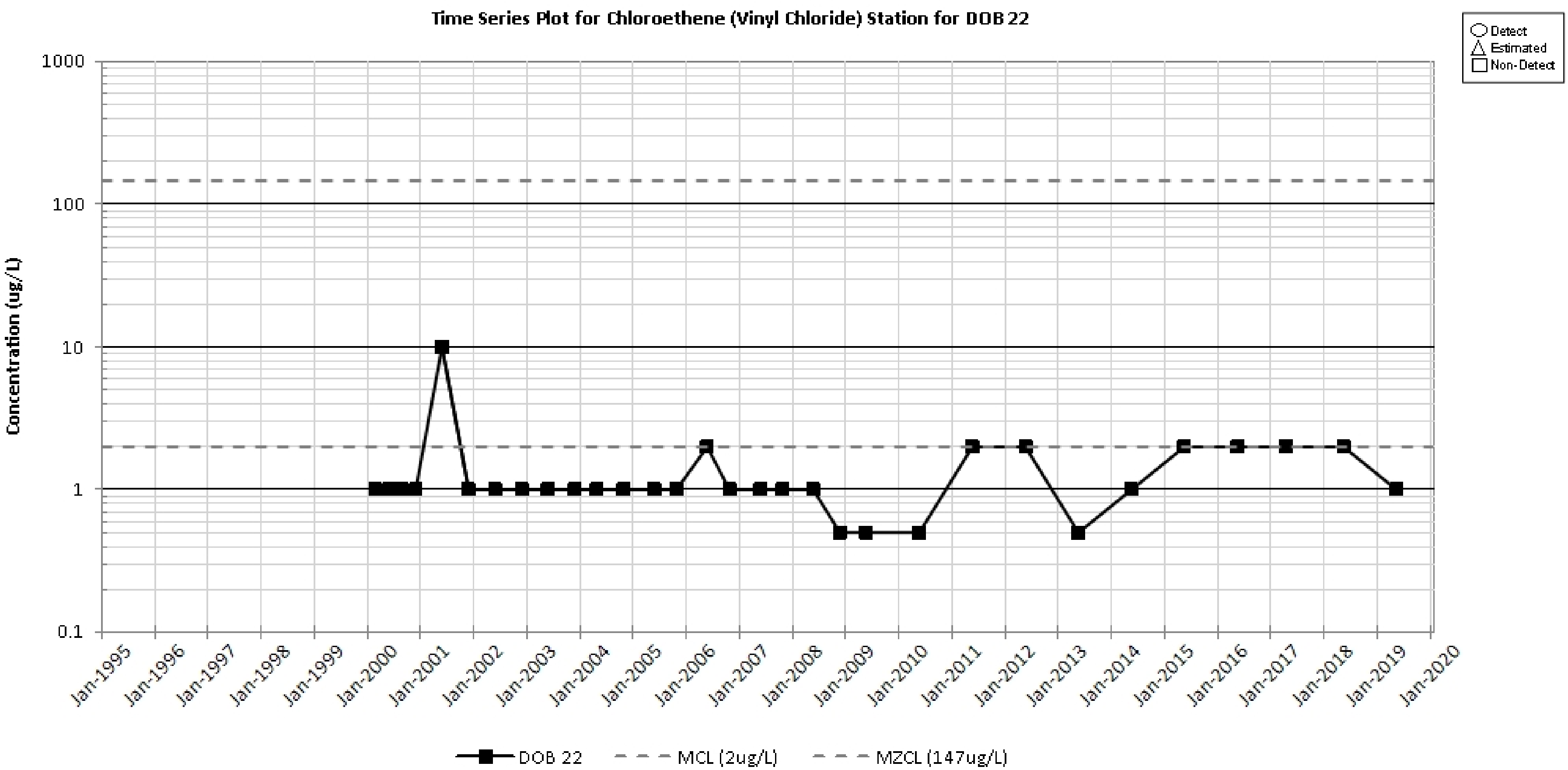


Figure D-41. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 22

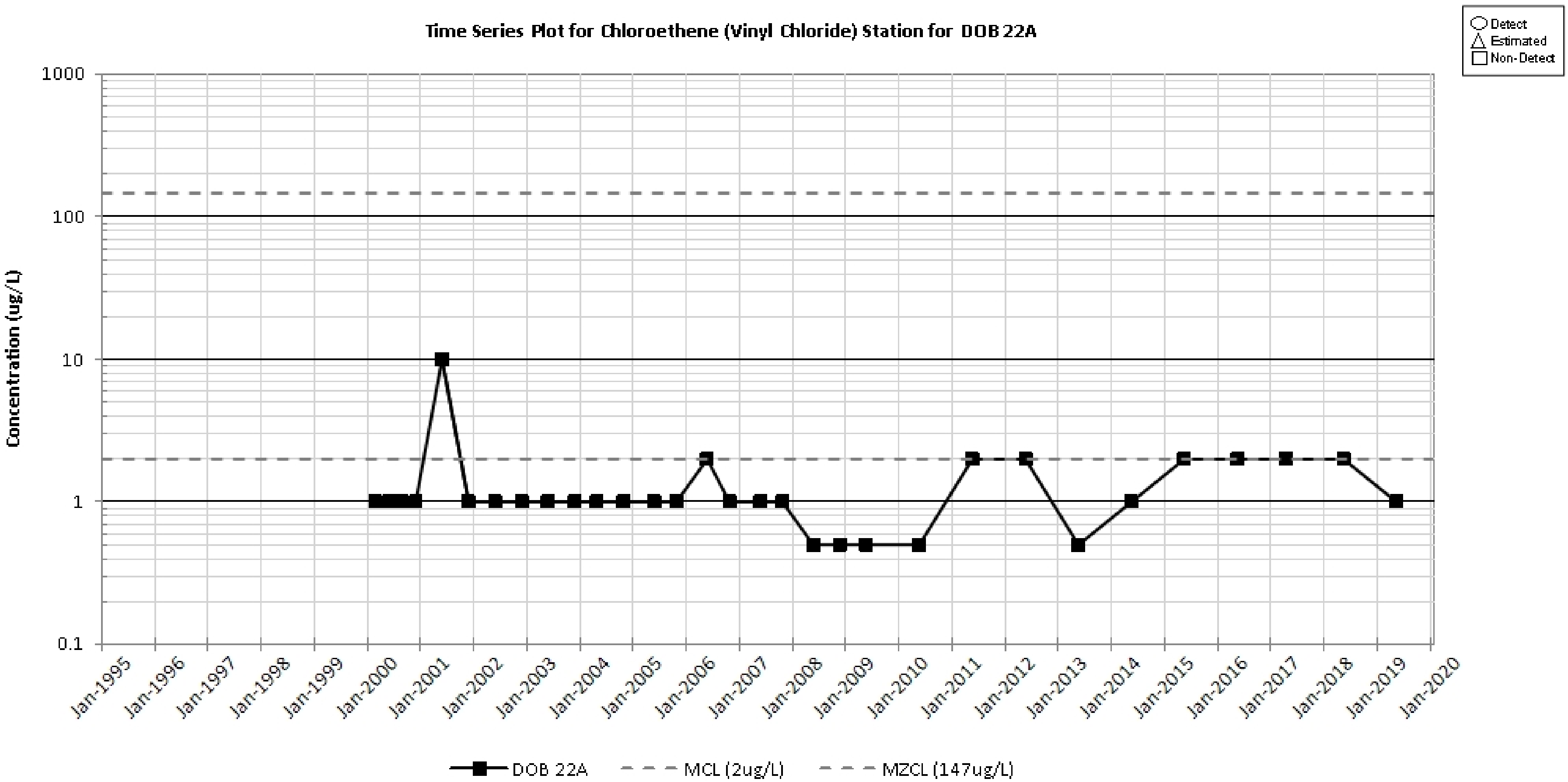


Figure D-42. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 22A

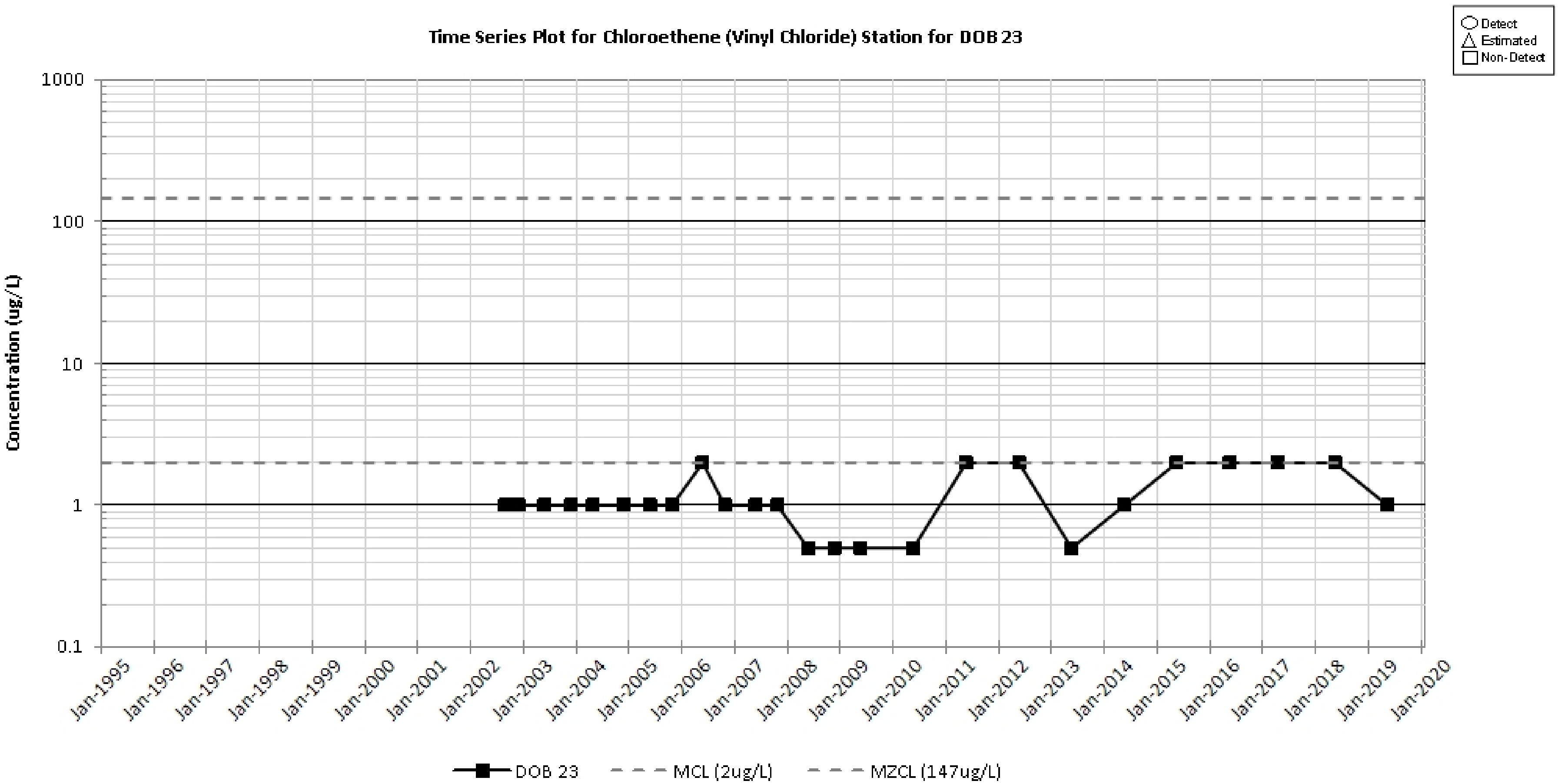


Figure D-43. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB 23

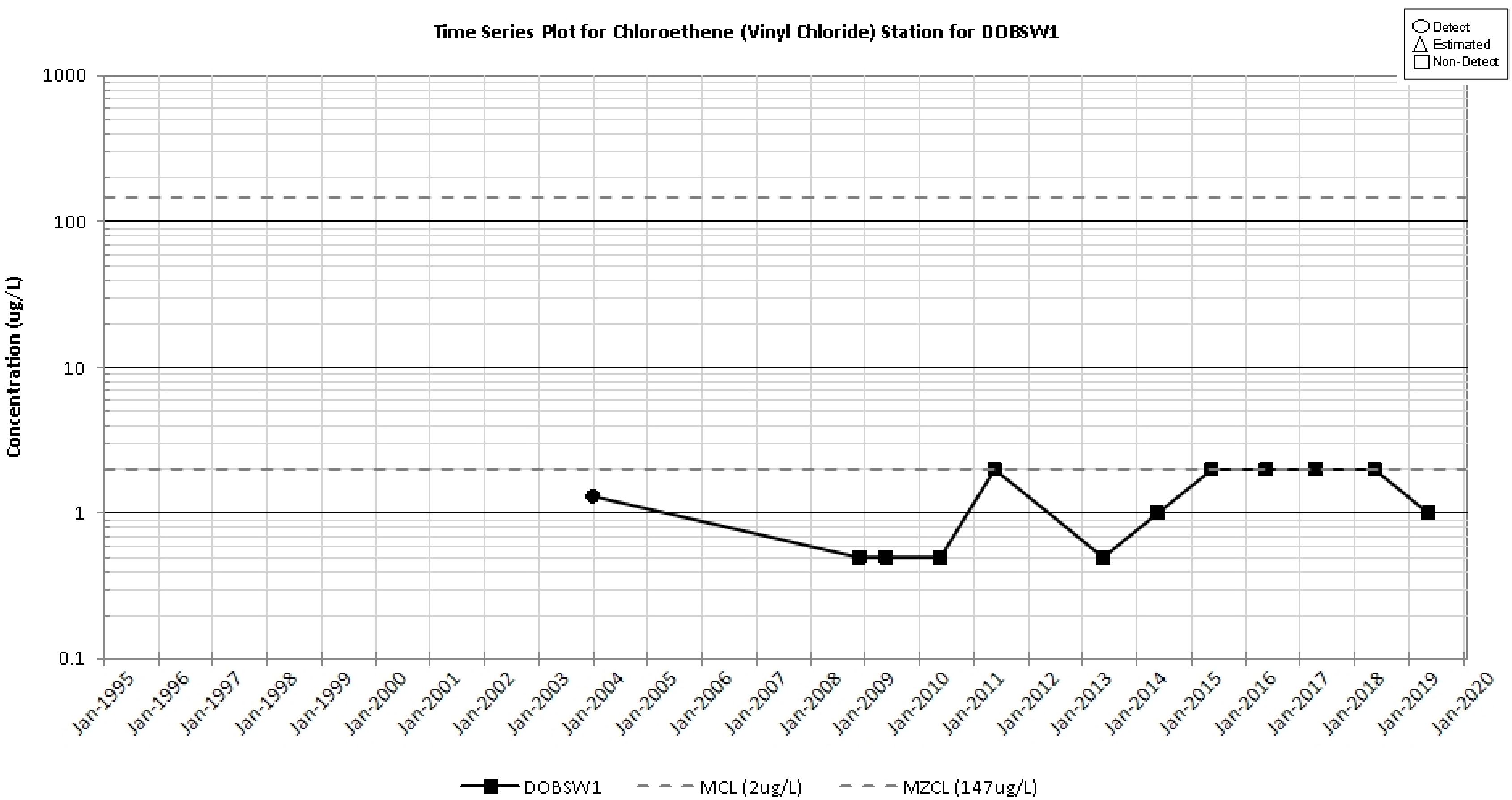


Figure D-44. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOB SW1

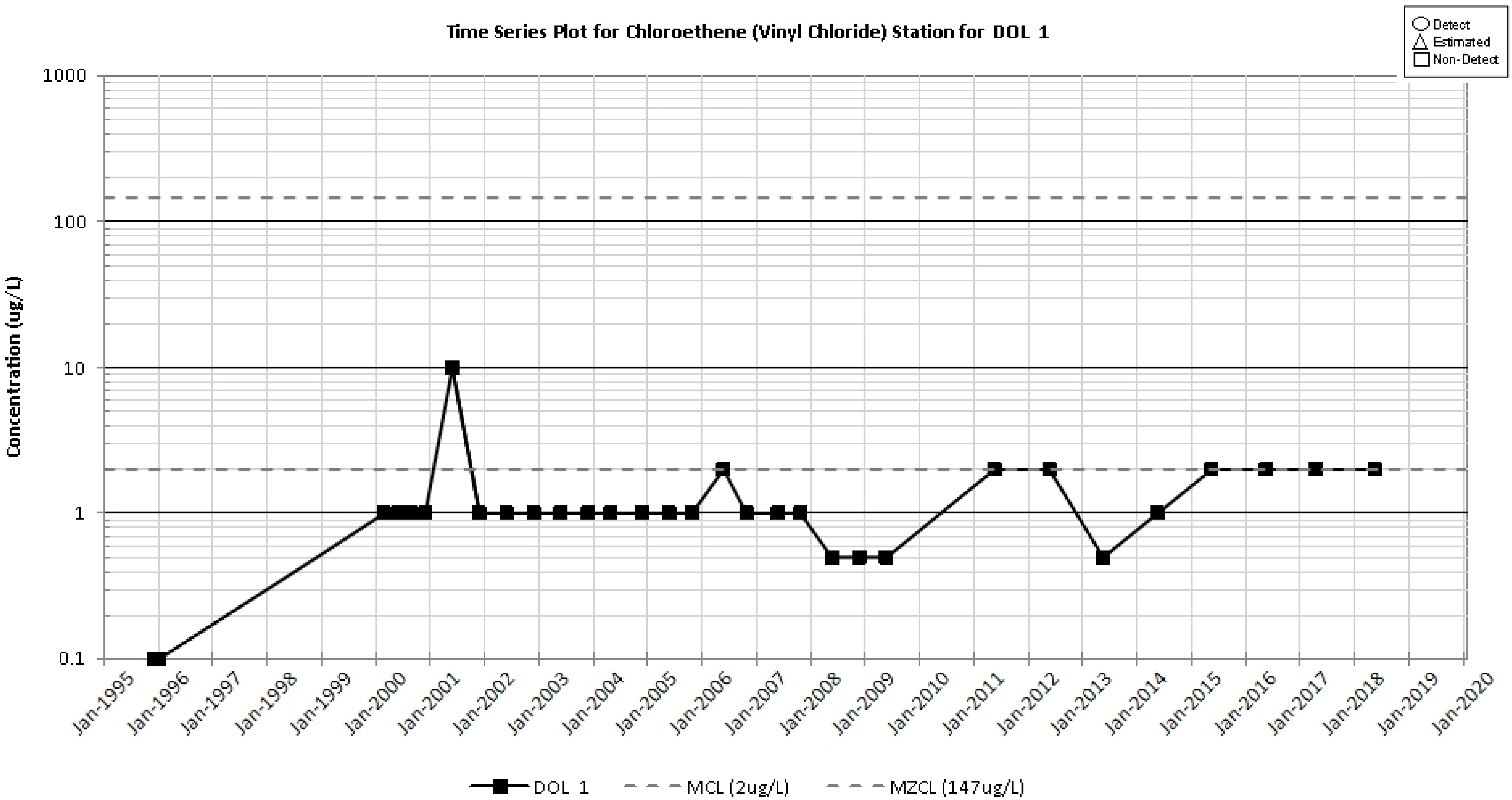


Figure D-45. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOL 1

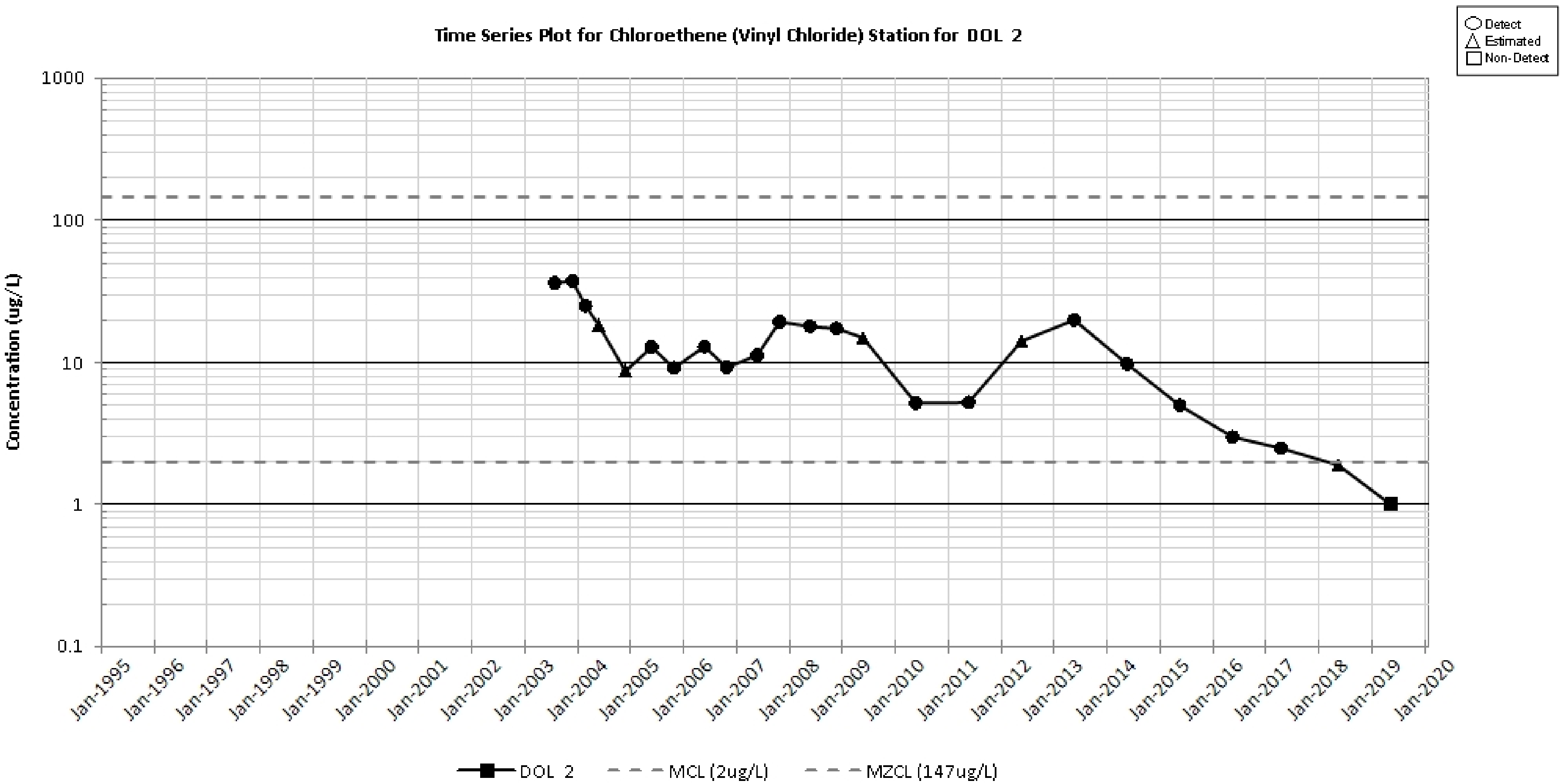


Figure D-46. Time Series Plot for Chloroethene (Vinyl Chloride) Station for DOL 2

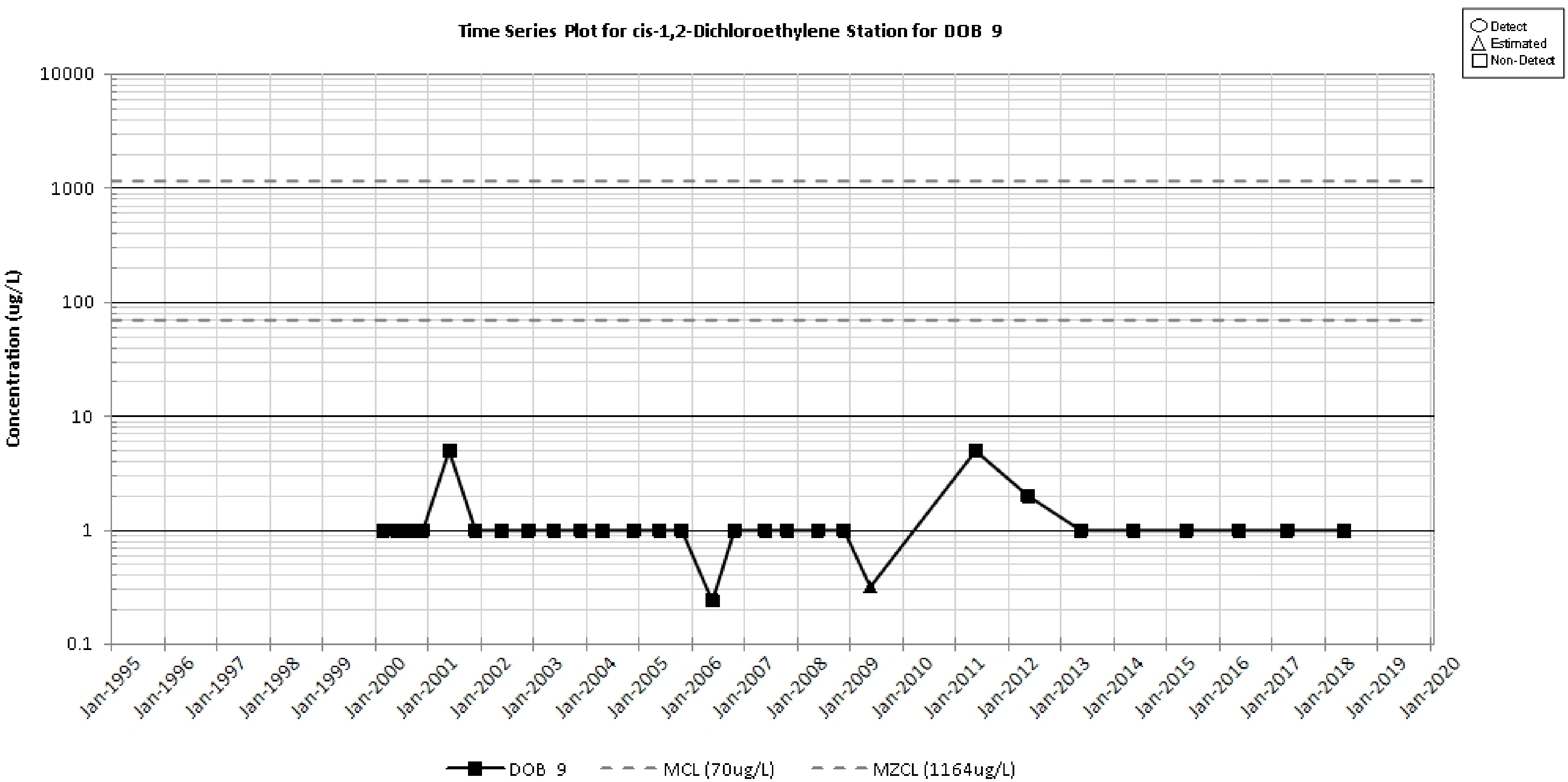


Figure D-47. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 9

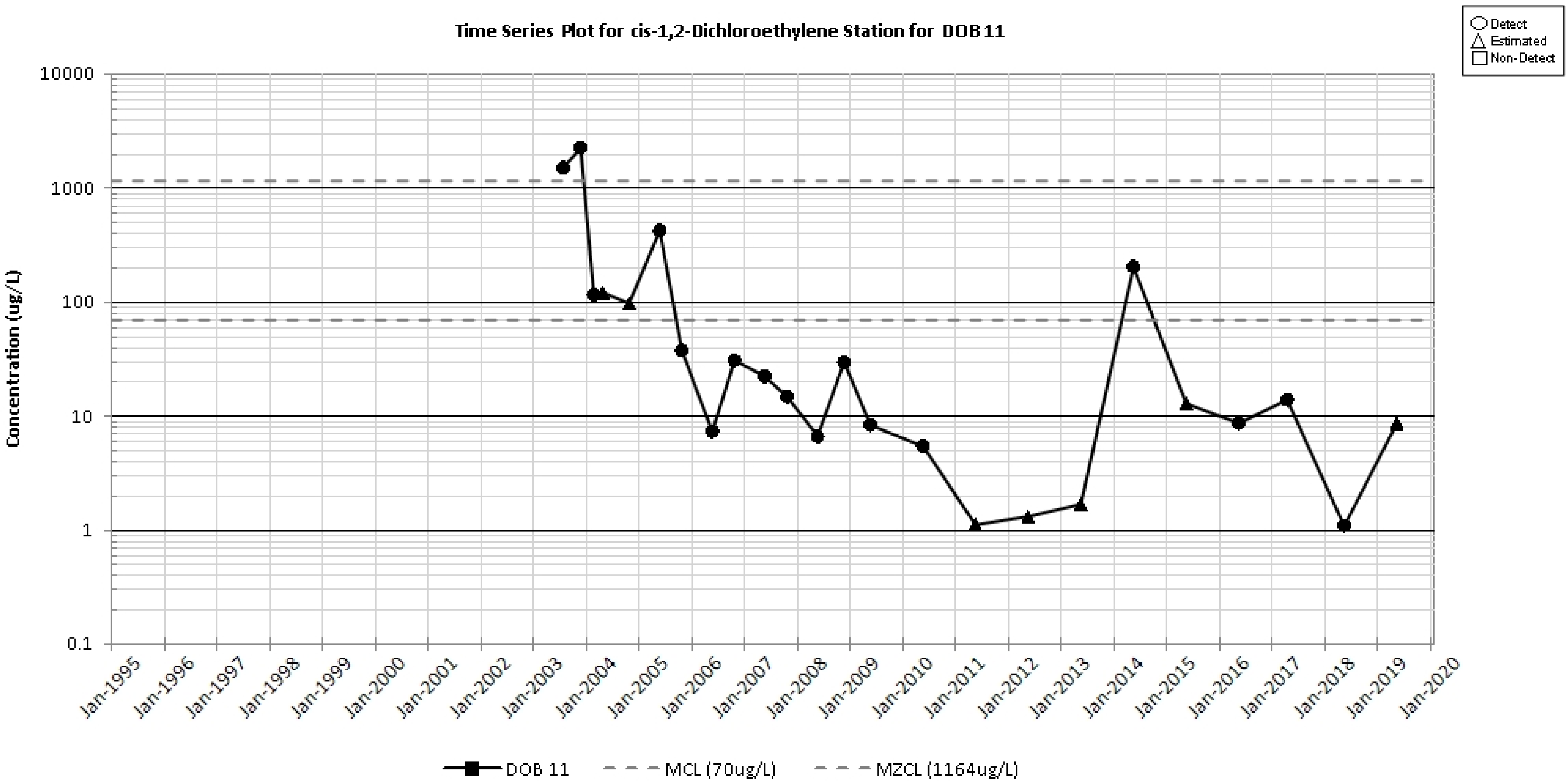


Figure D-48. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 11

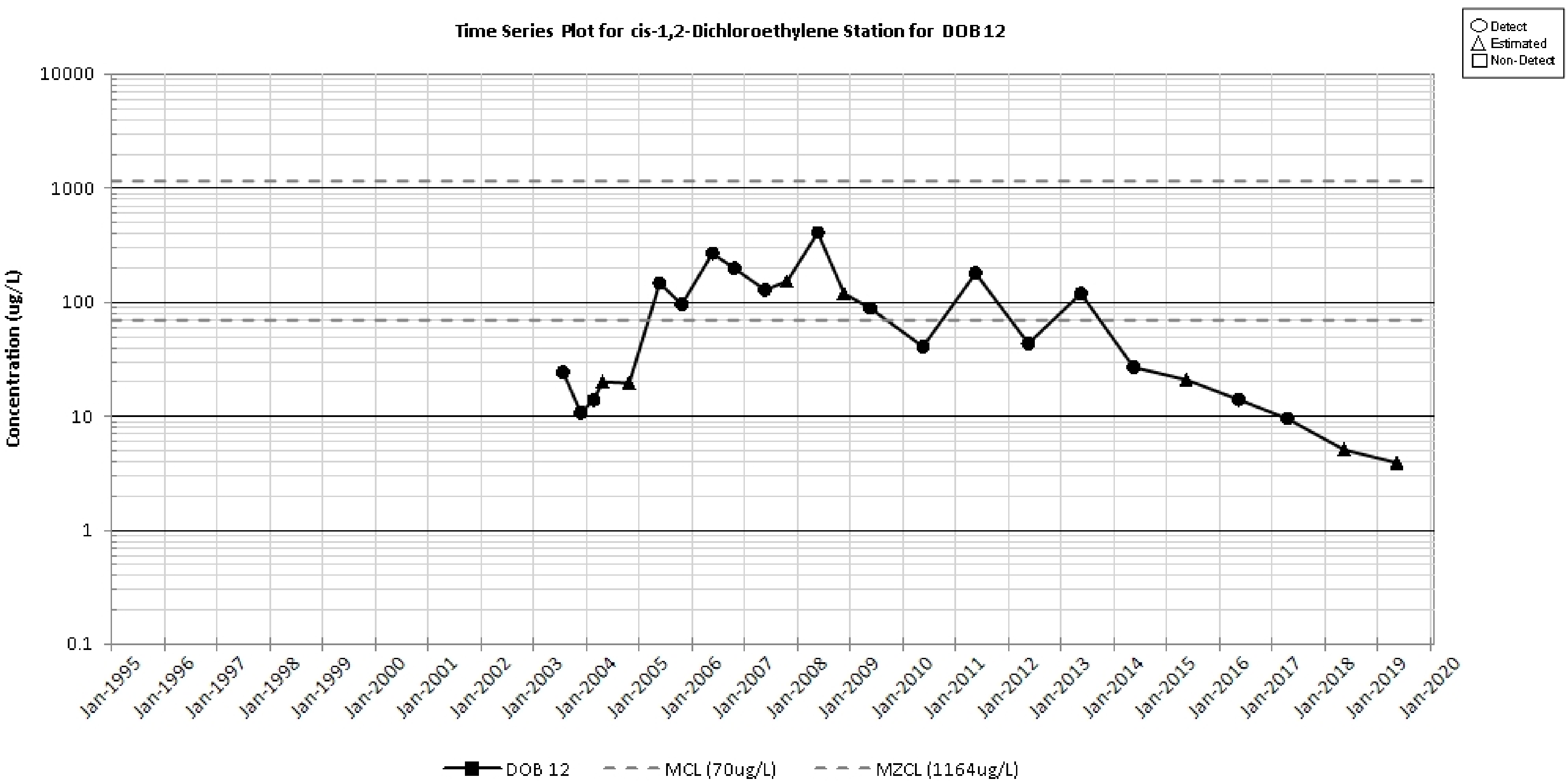


Figure D-49. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 12

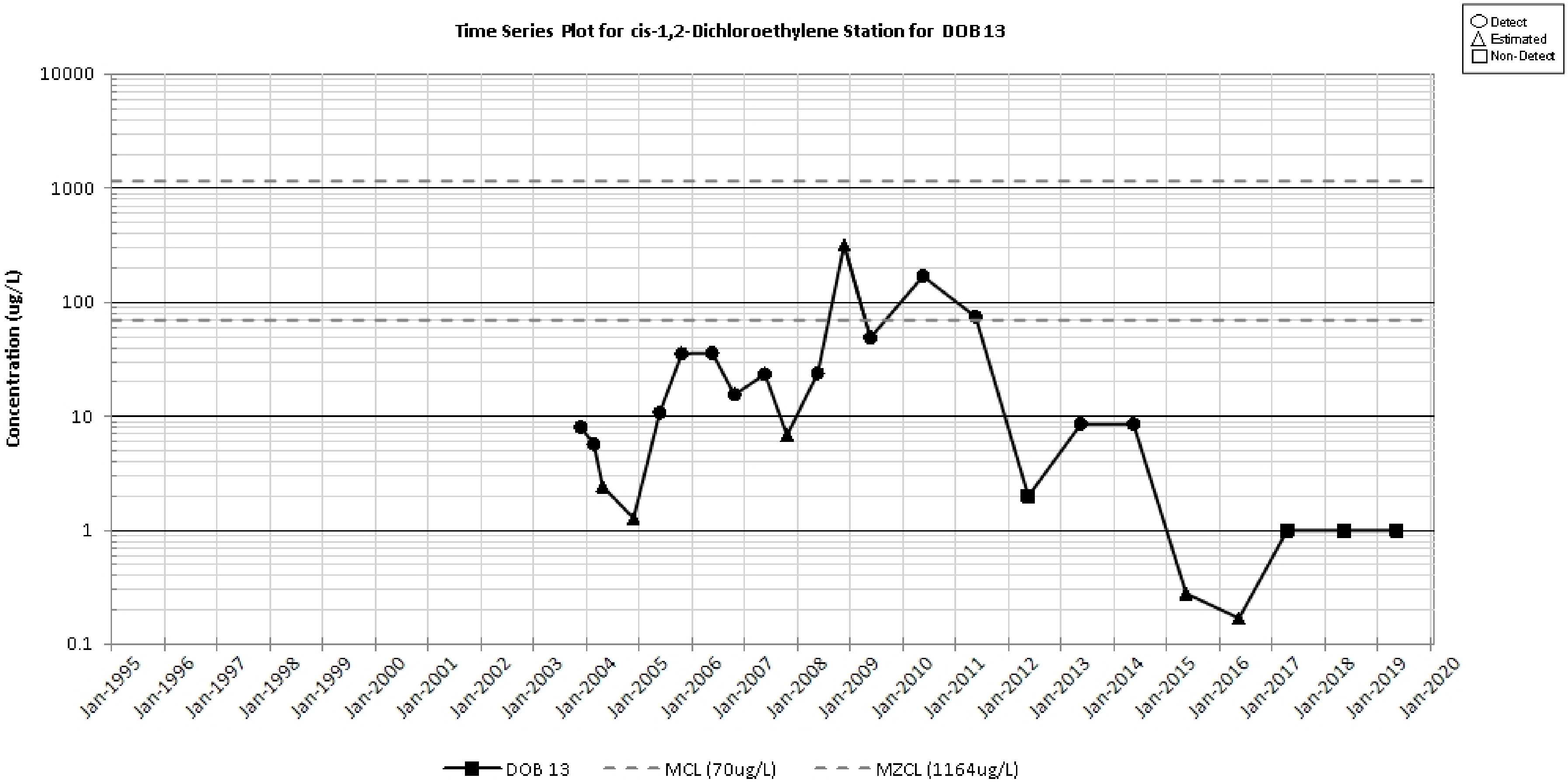


Figure D-50. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 13

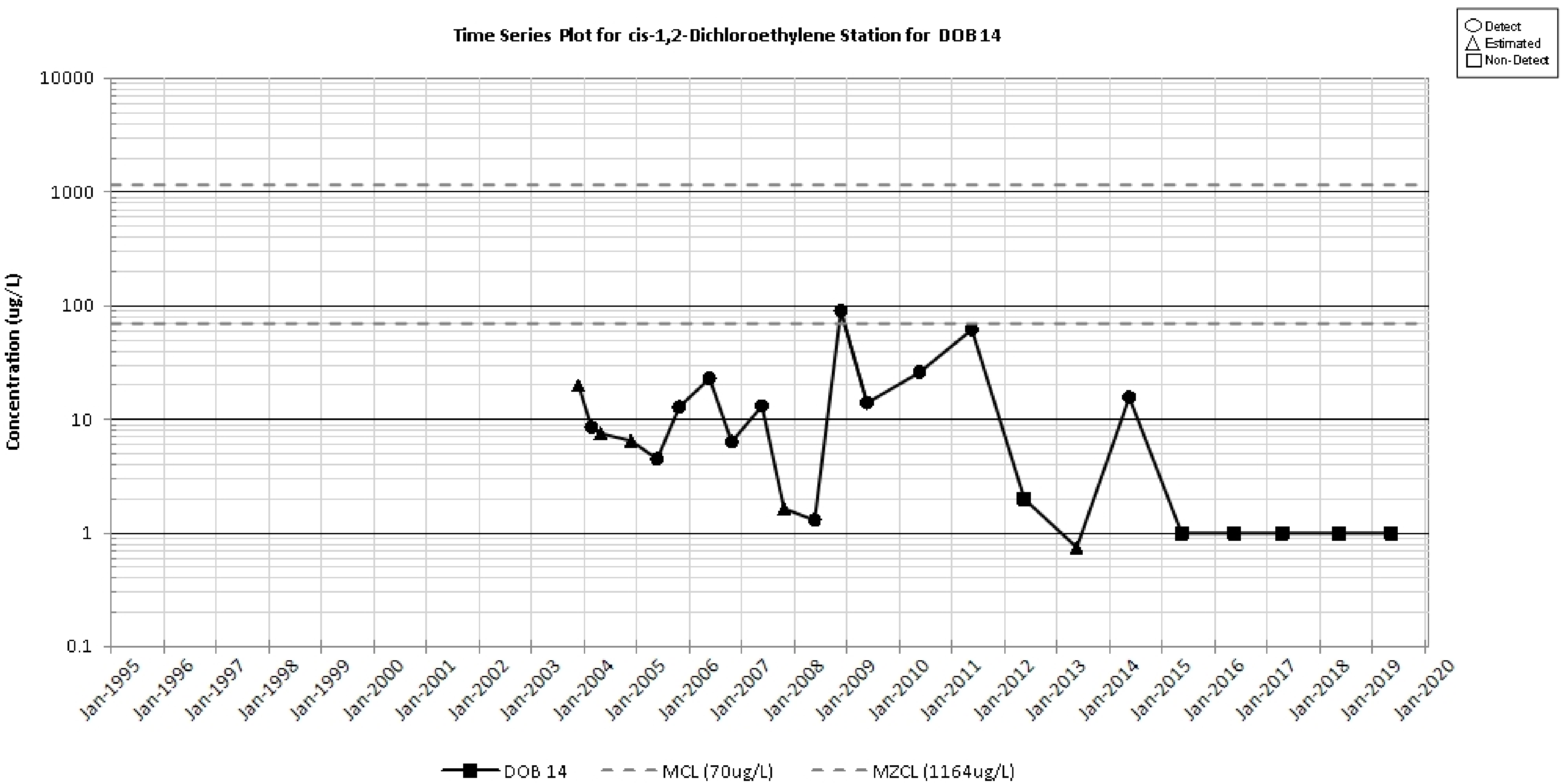


Figure D-51. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 14

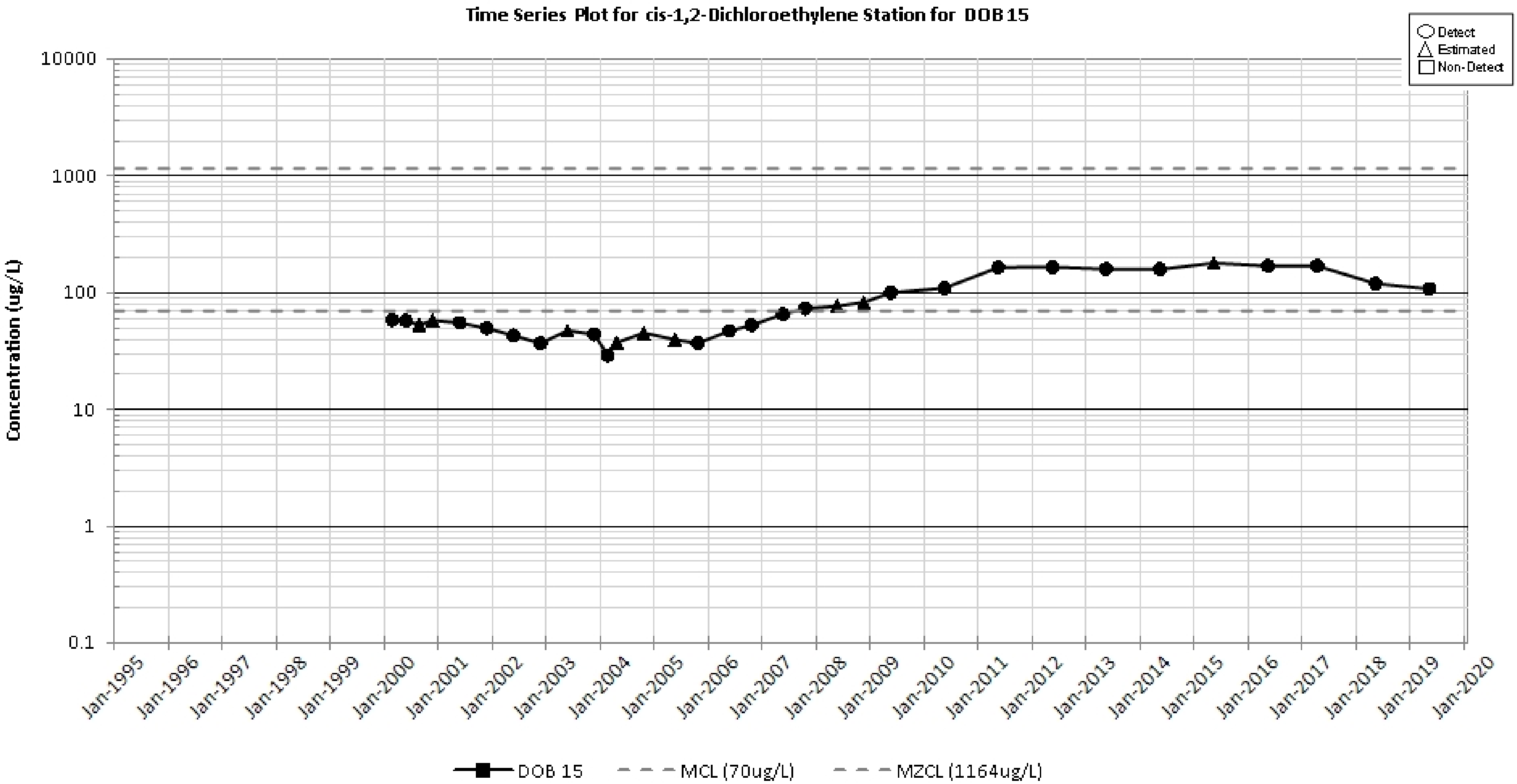


Figure D-52. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 15

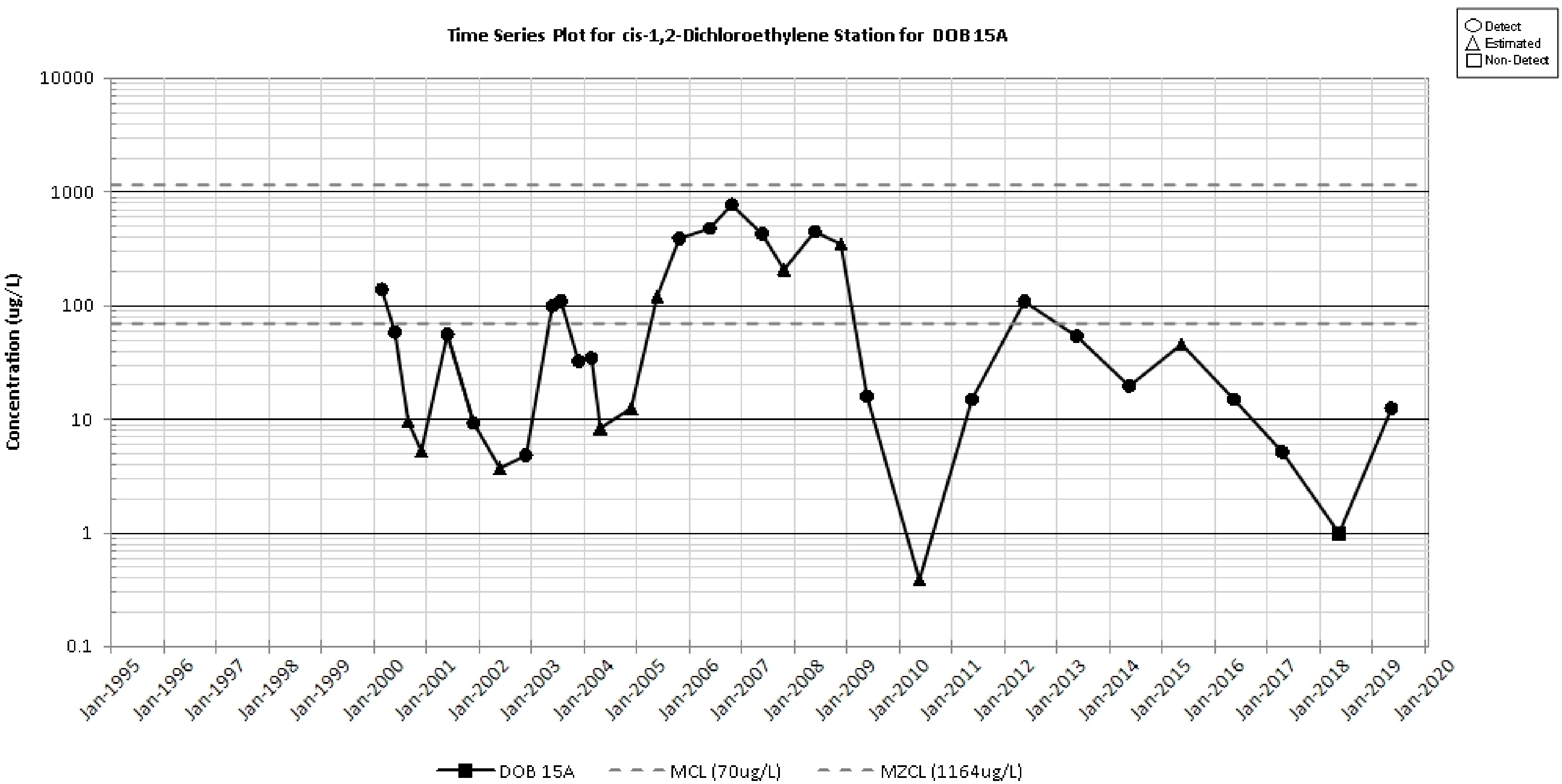


Figure D-53. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 15A

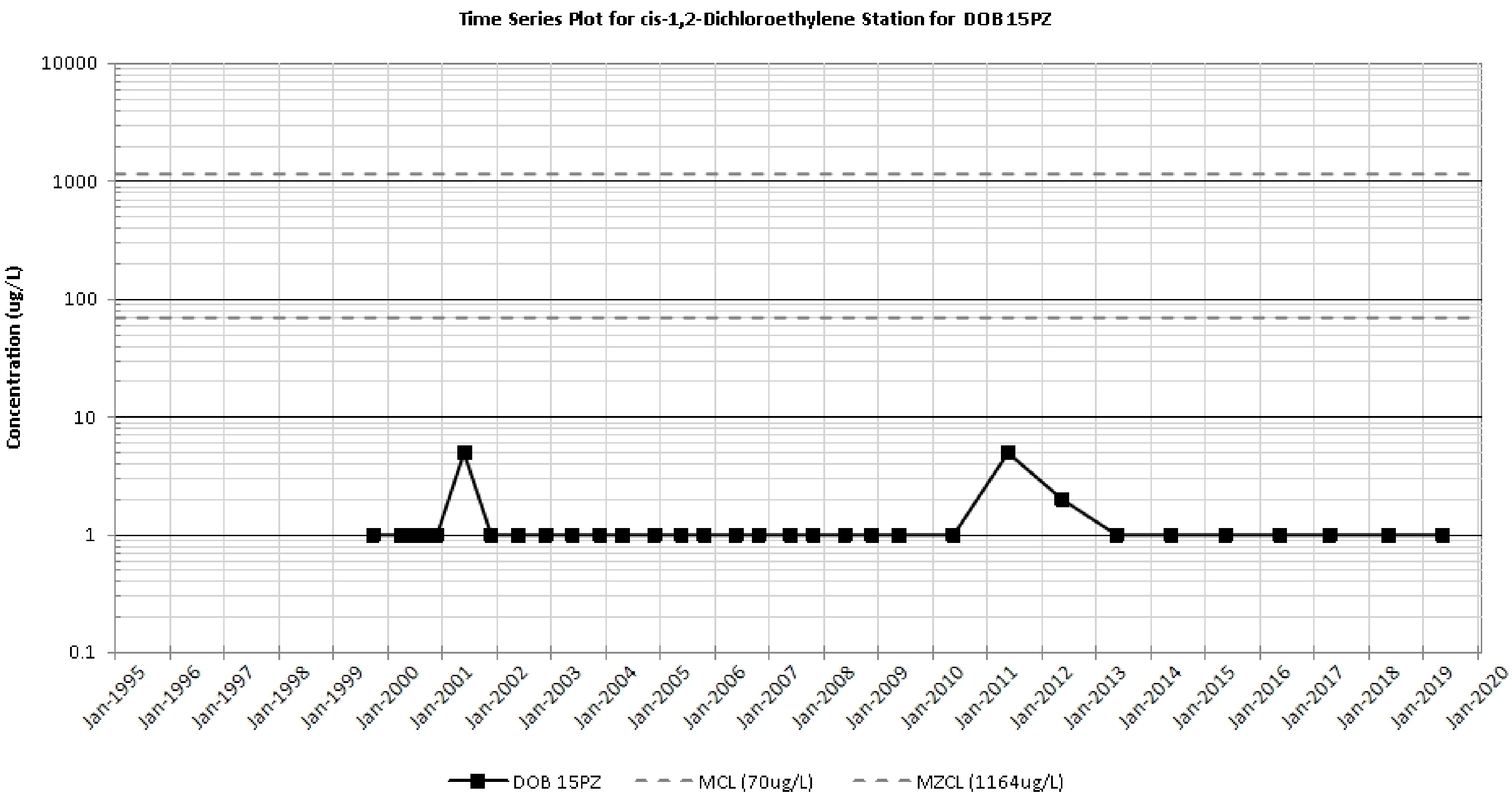
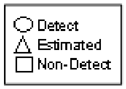


Figure D-54. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 15PZ



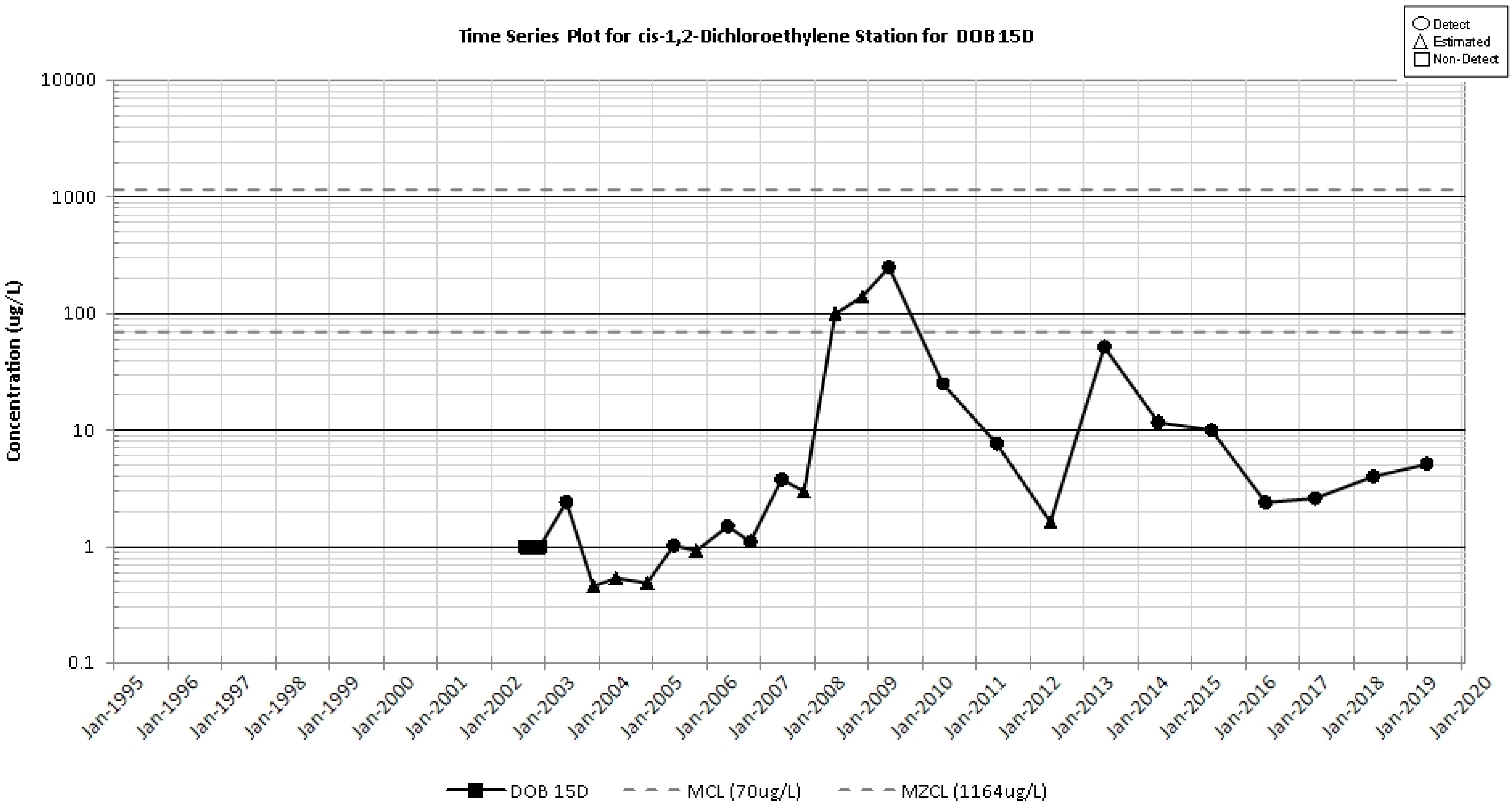


Figure D-55. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 15D

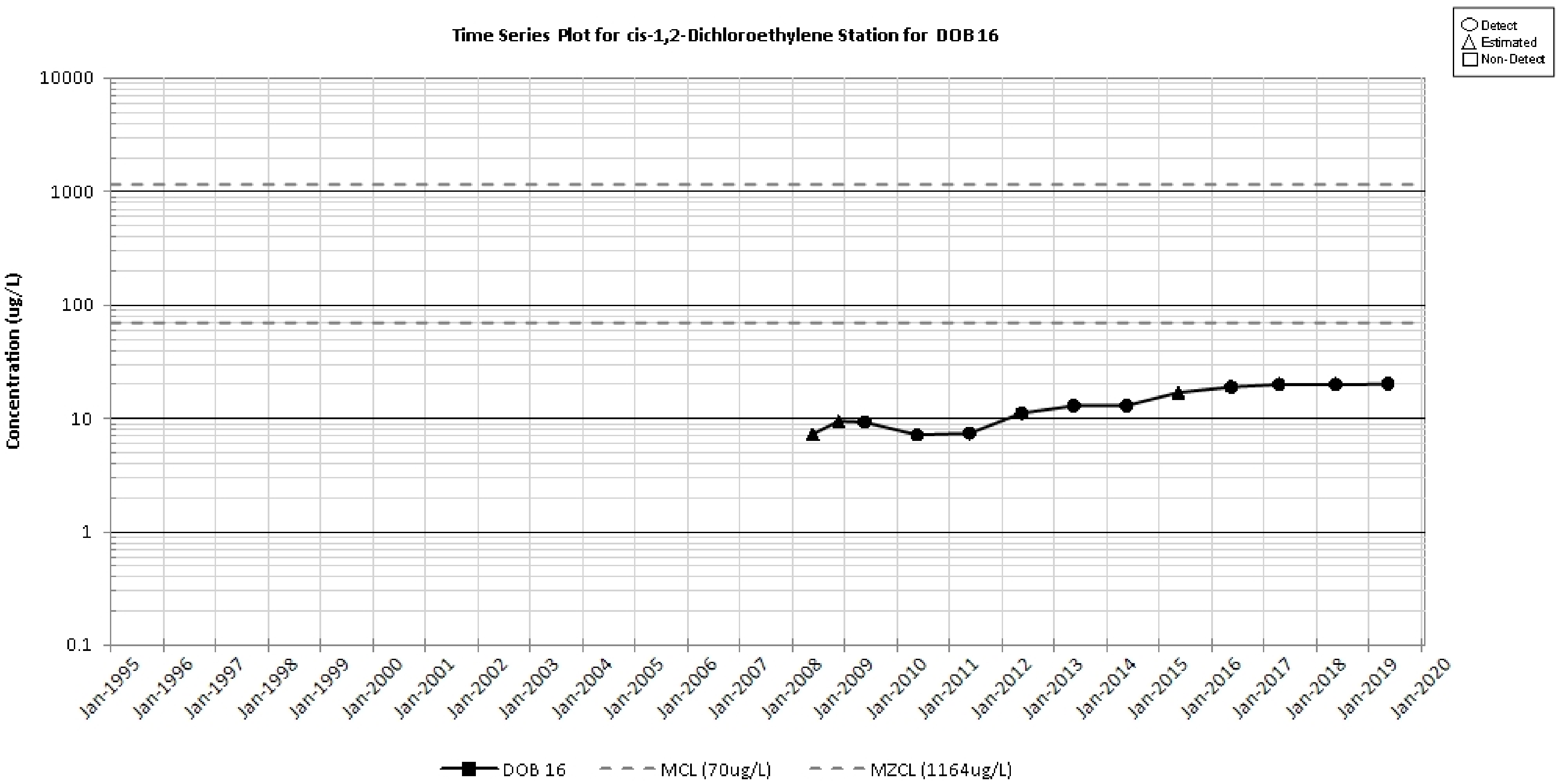


Figure D-56. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 16

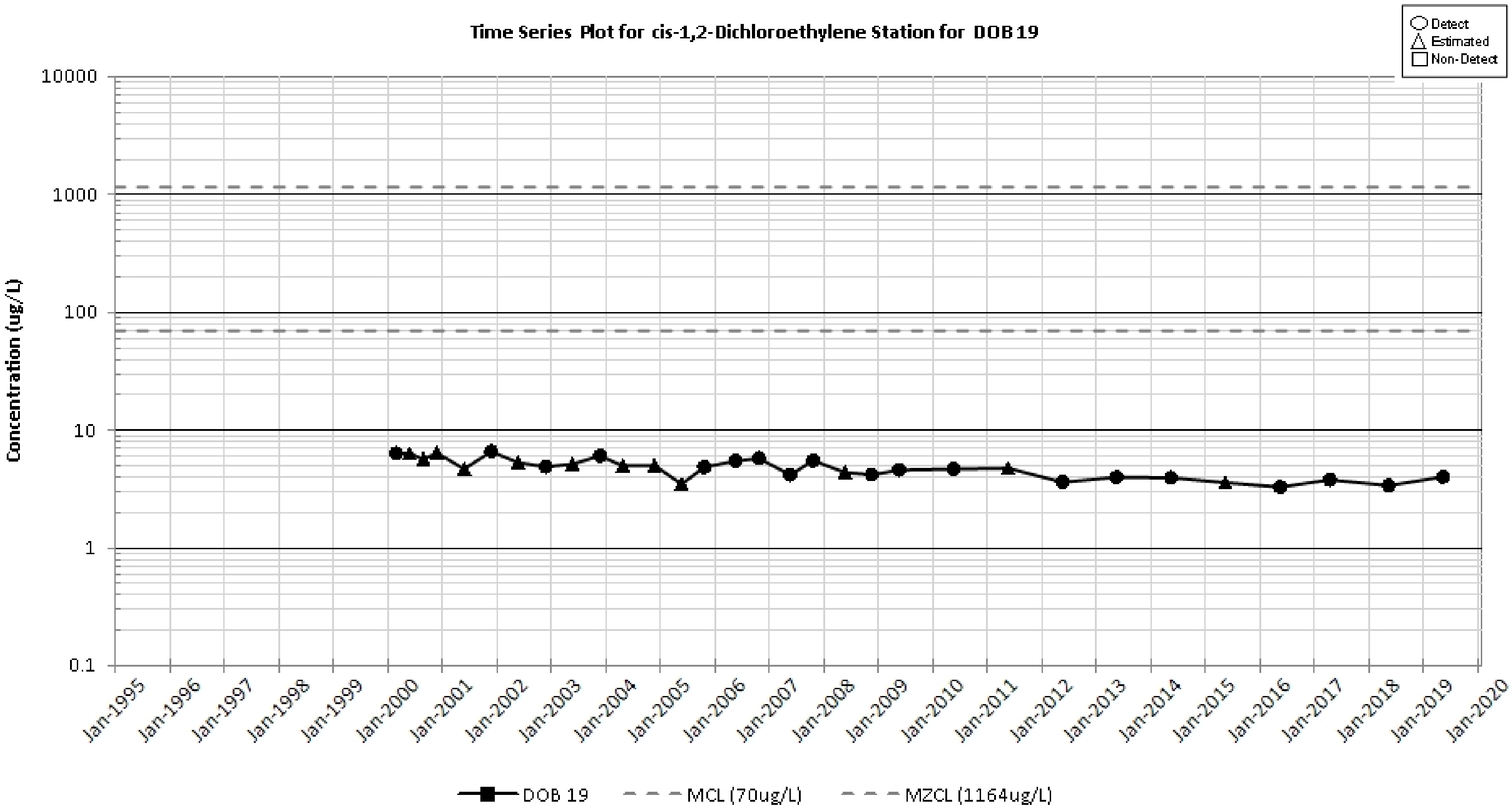


Figure D-57. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 19

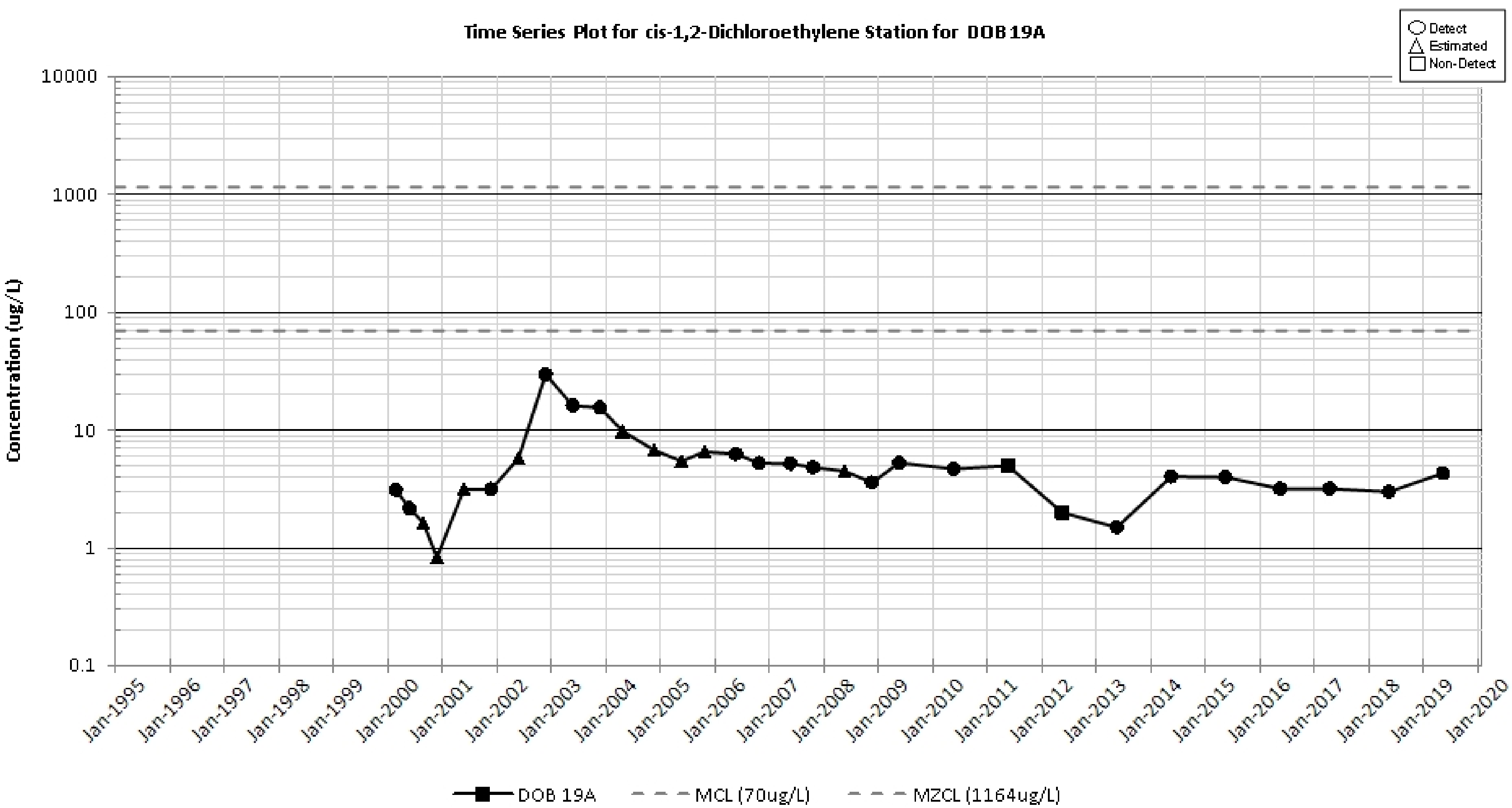


Figure D-58. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 19A

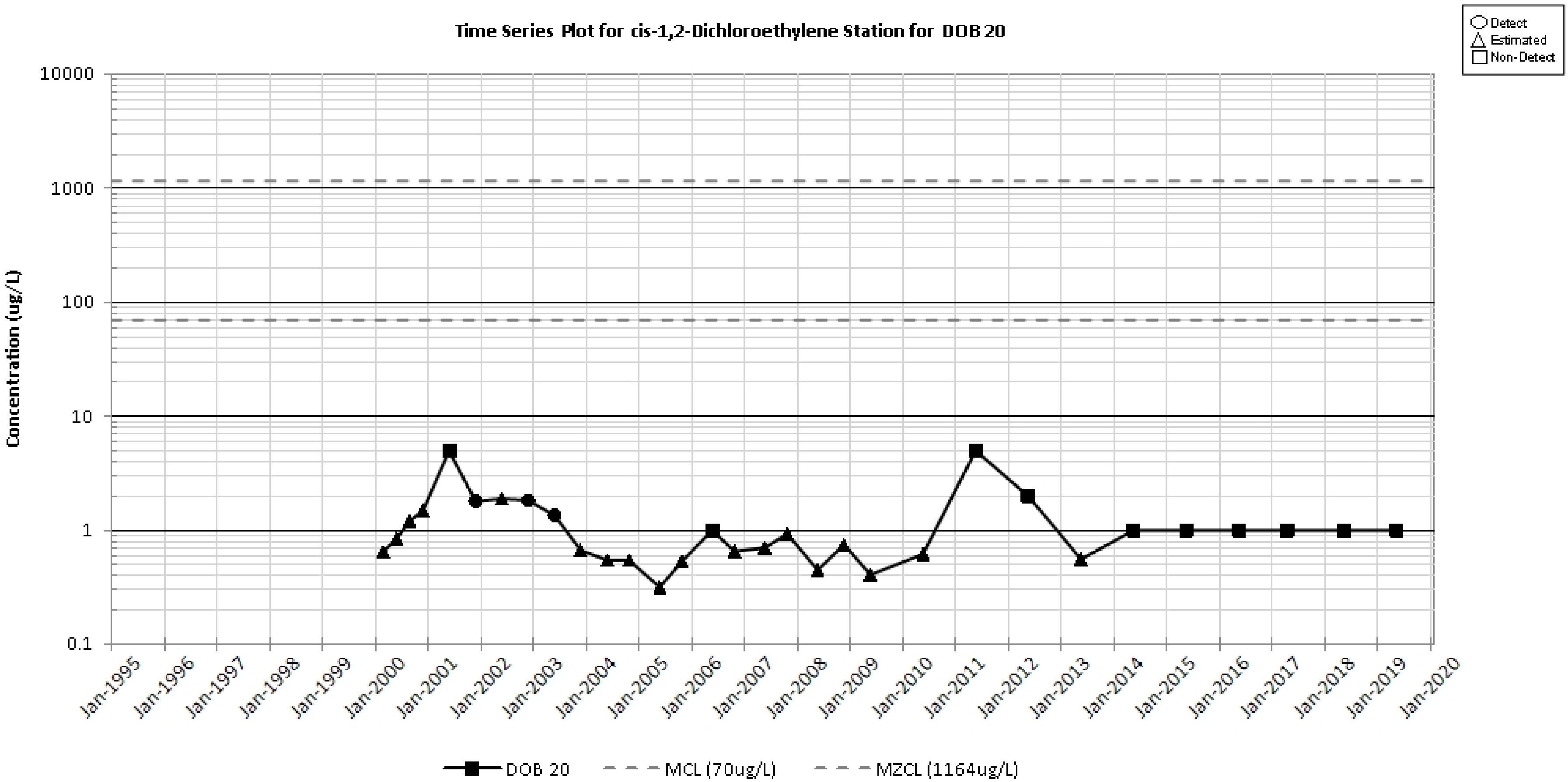


Figure D-59. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 20

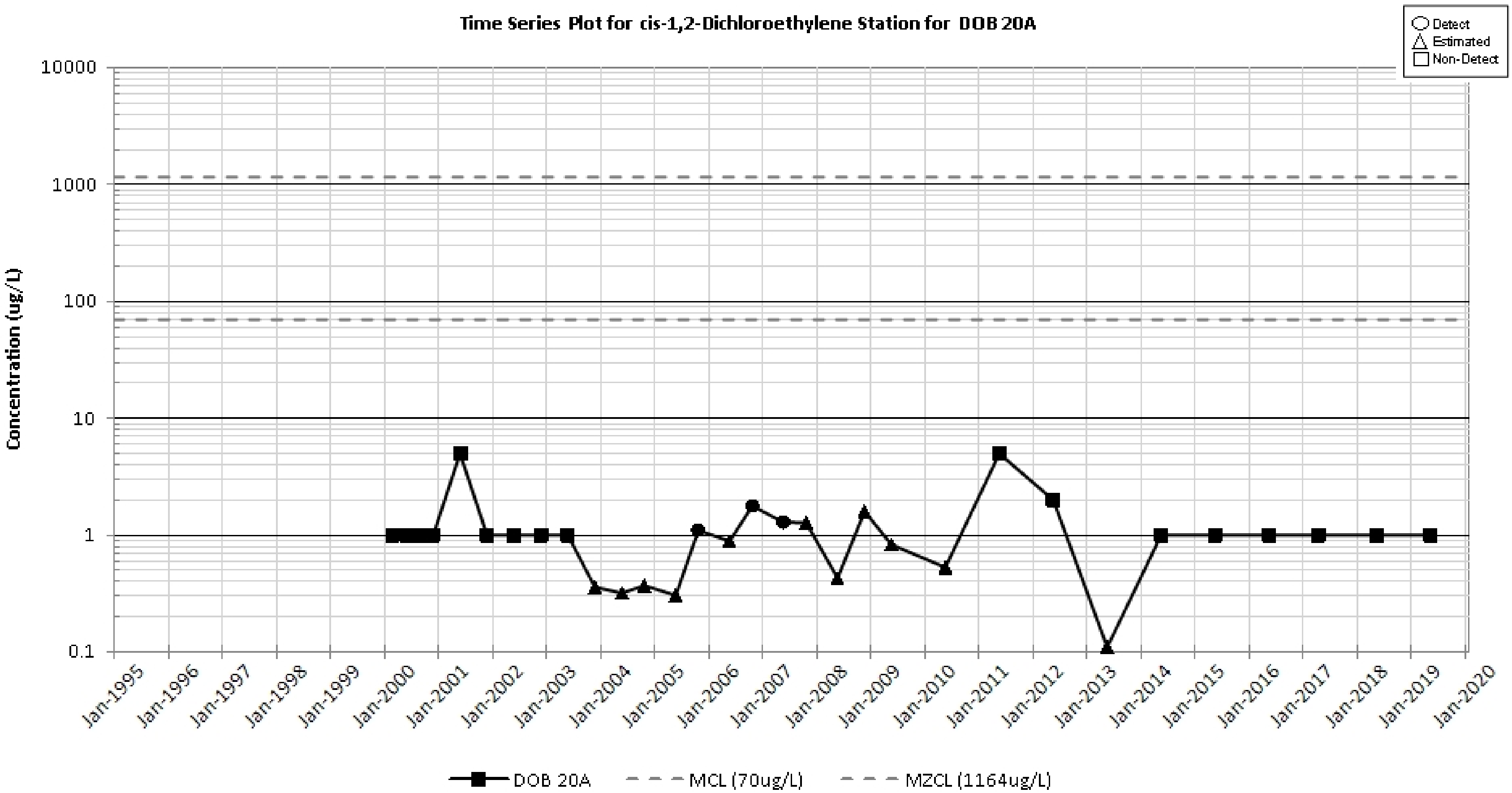


Figure D-60 Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 20A

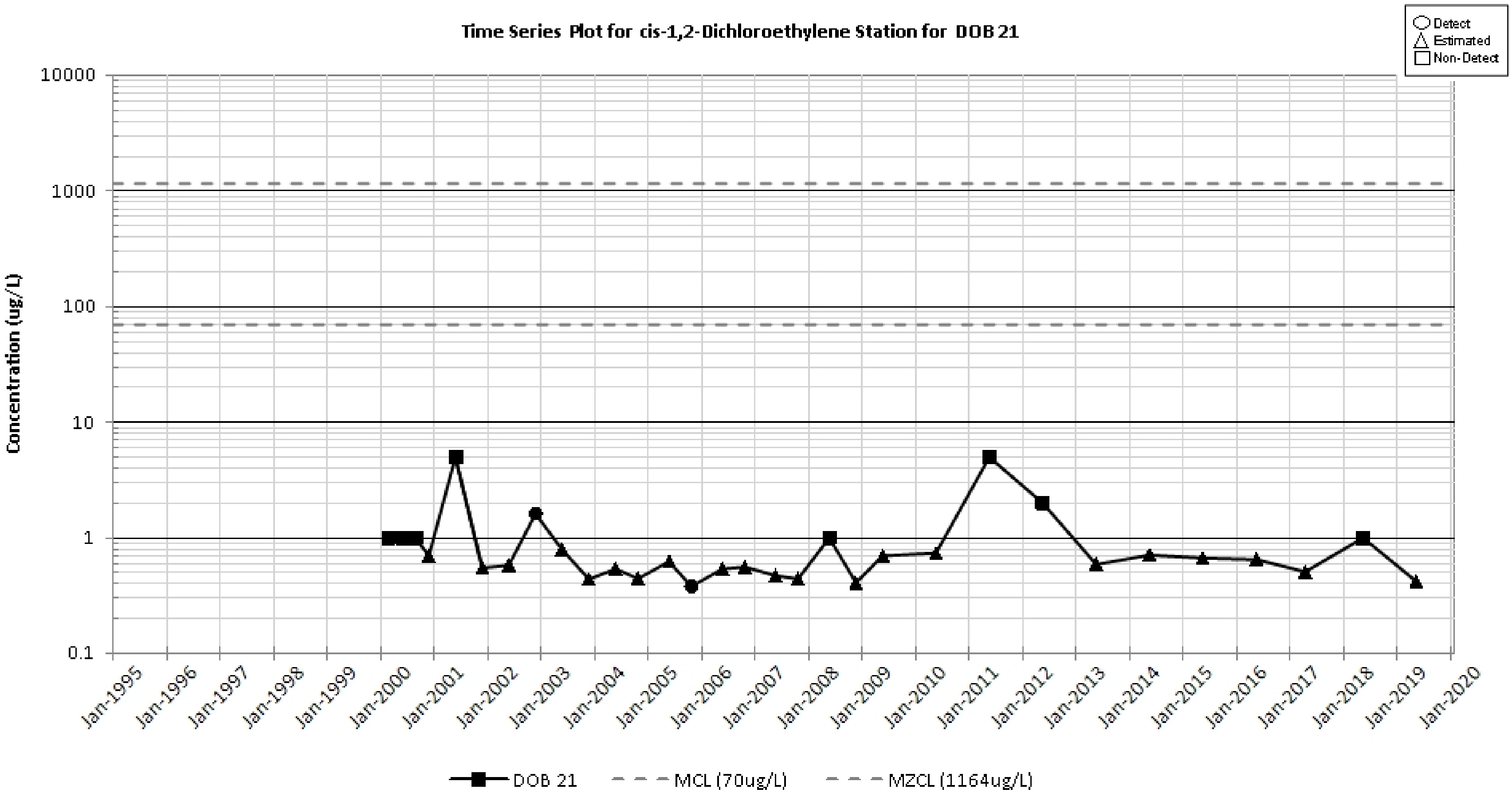


Figure D-61. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 21

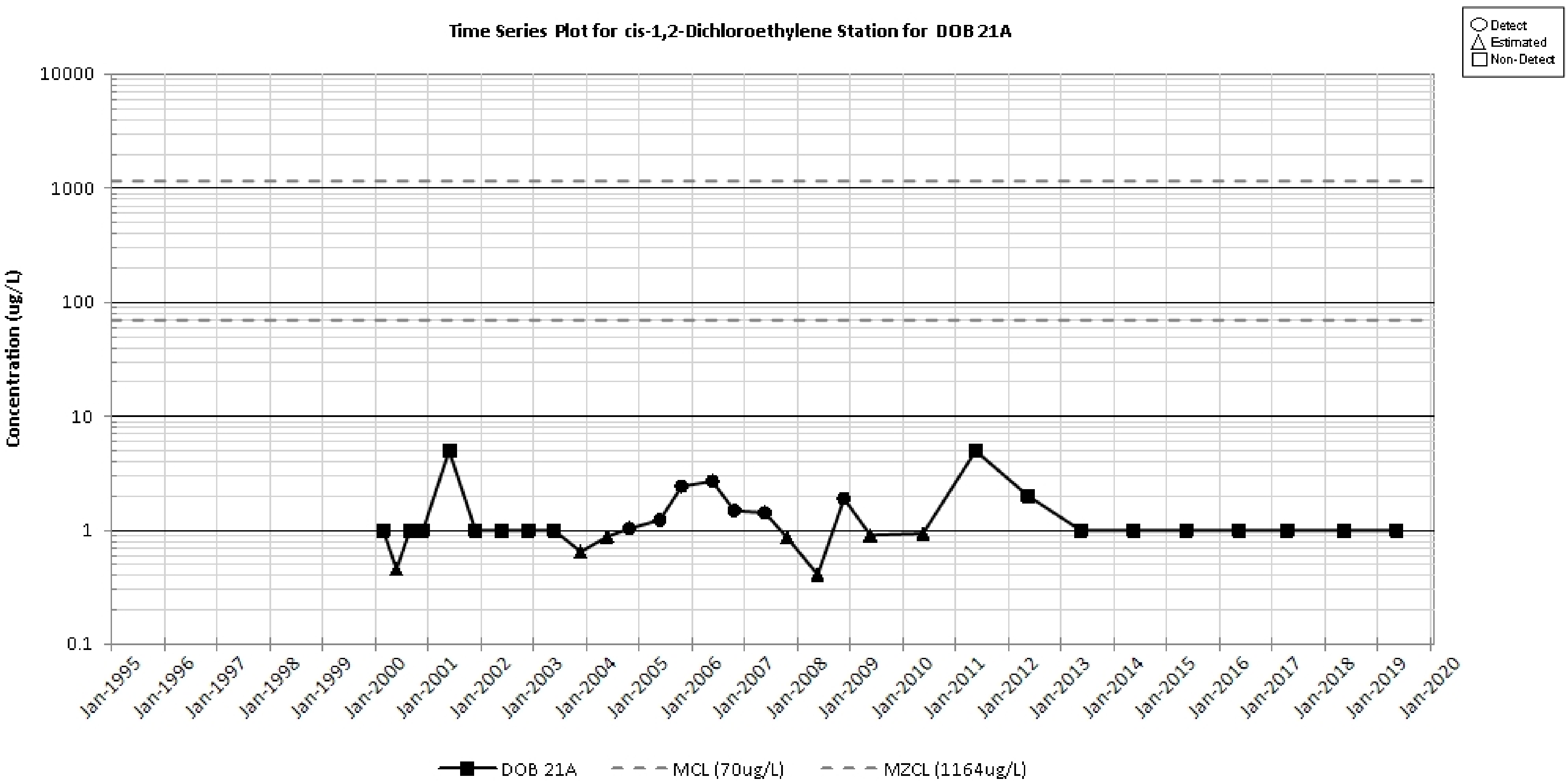


Figure D-62. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 21A

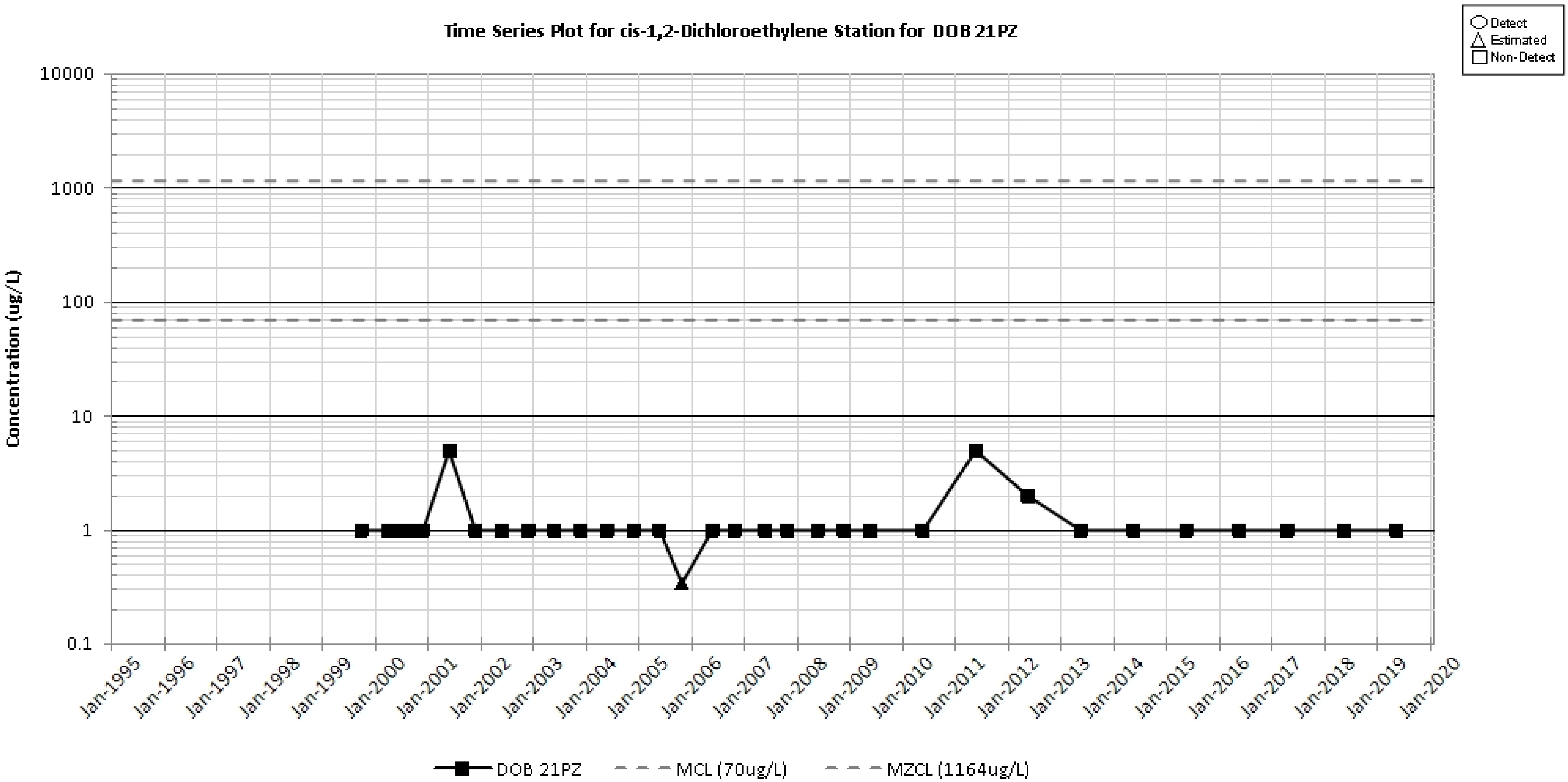


Figure D-63. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 21PZ

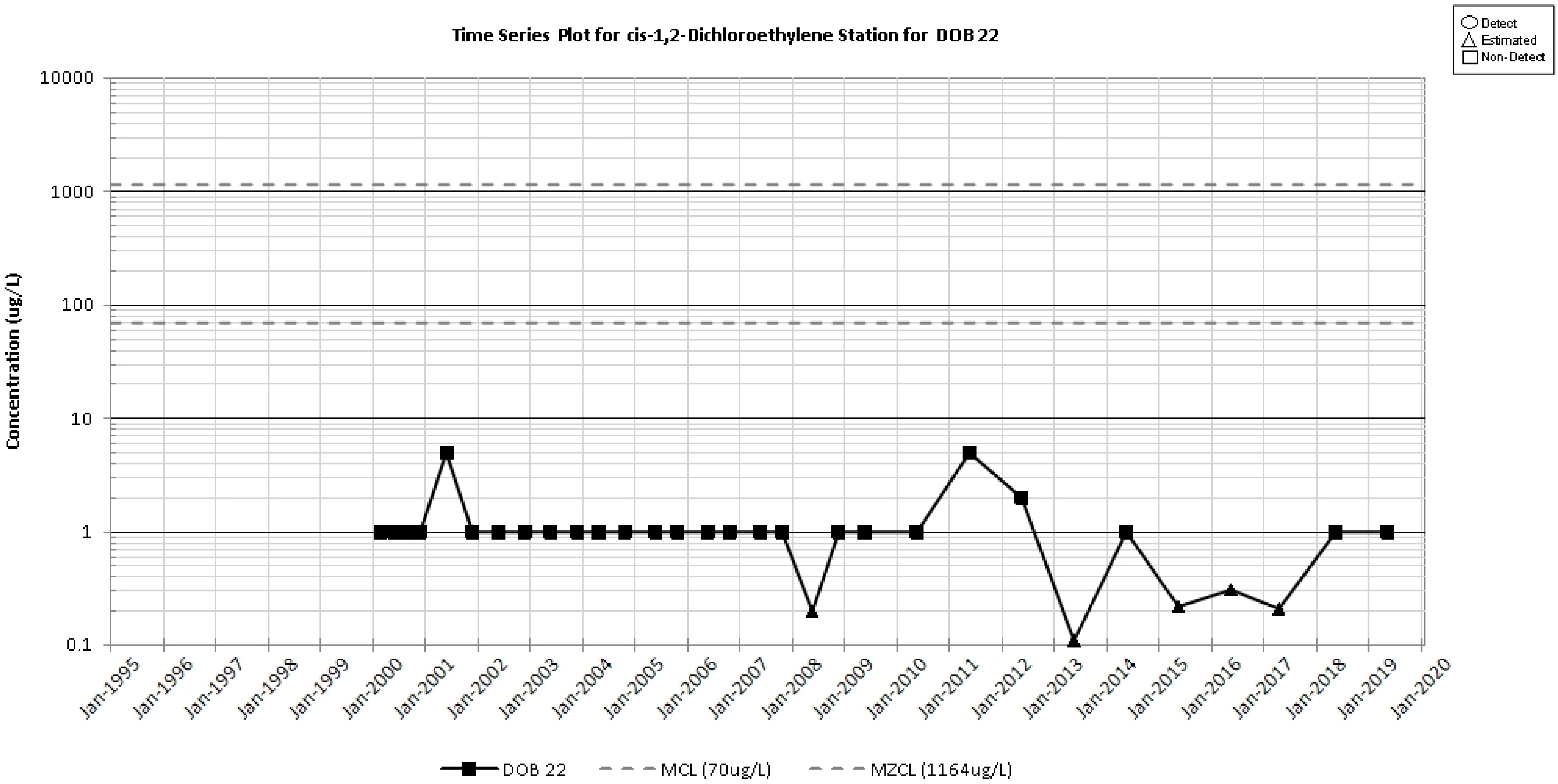


Figure D-64. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 22

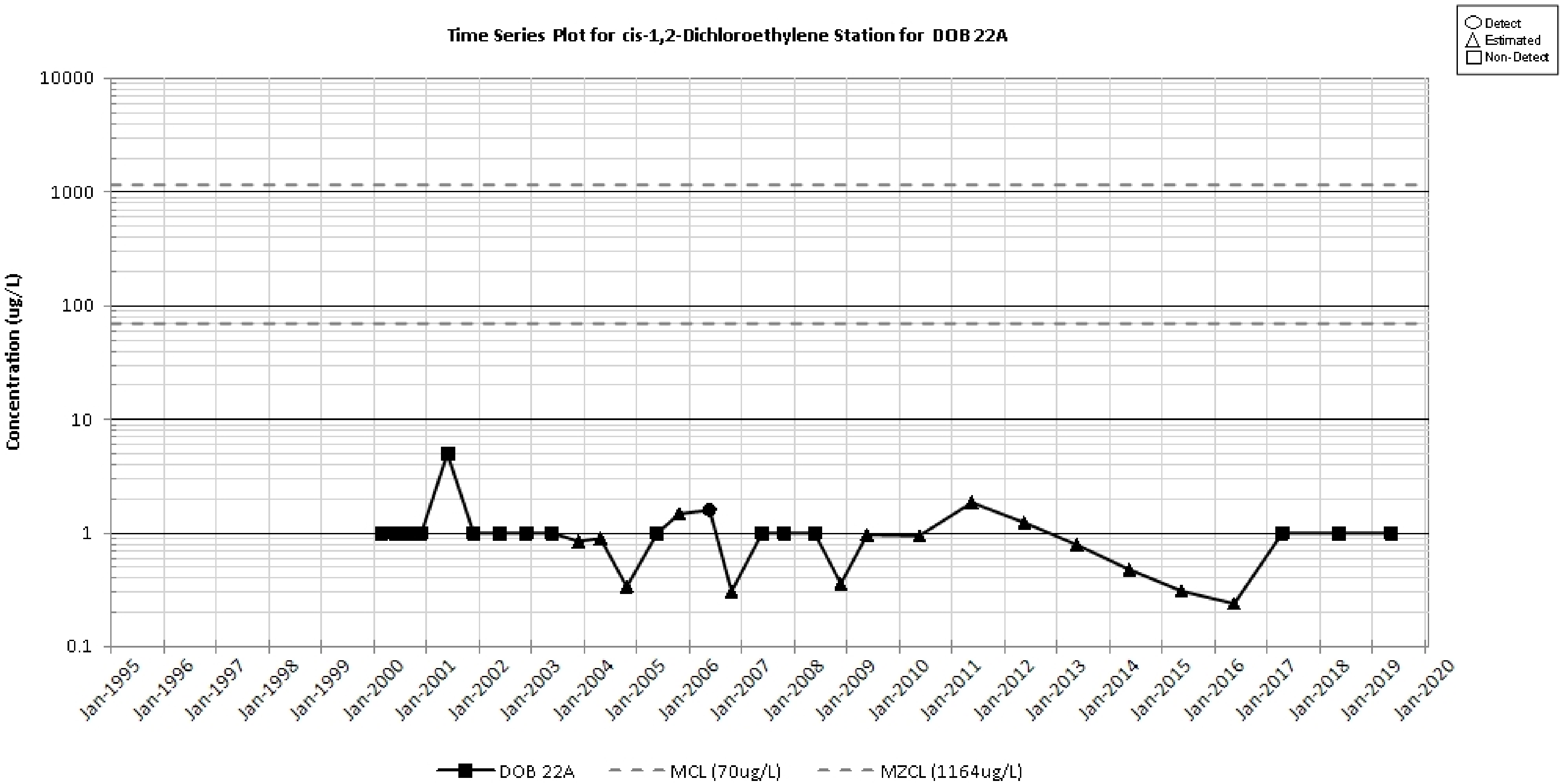


Figure D-65. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 22A

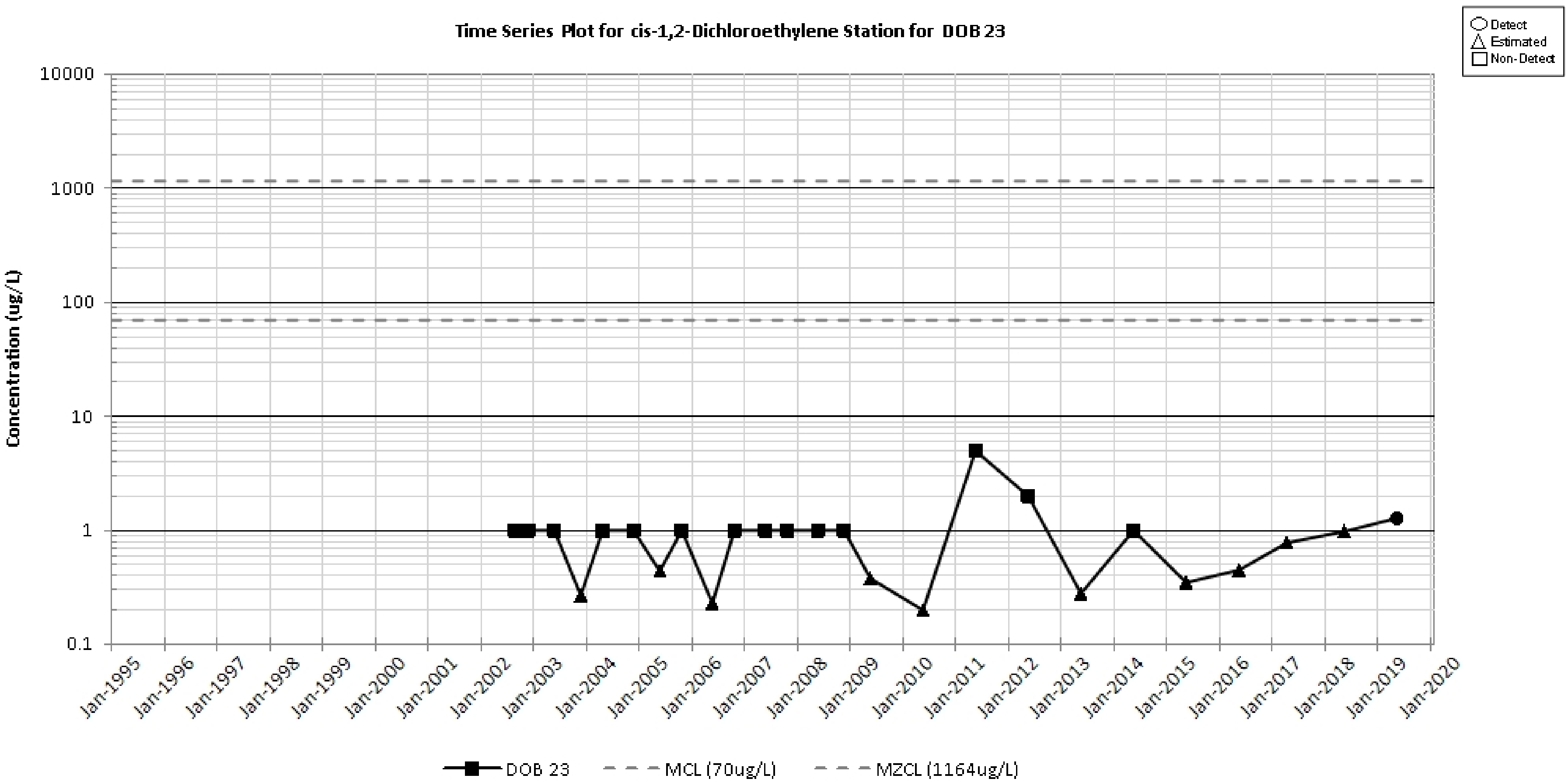


Figure D-66. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB 23

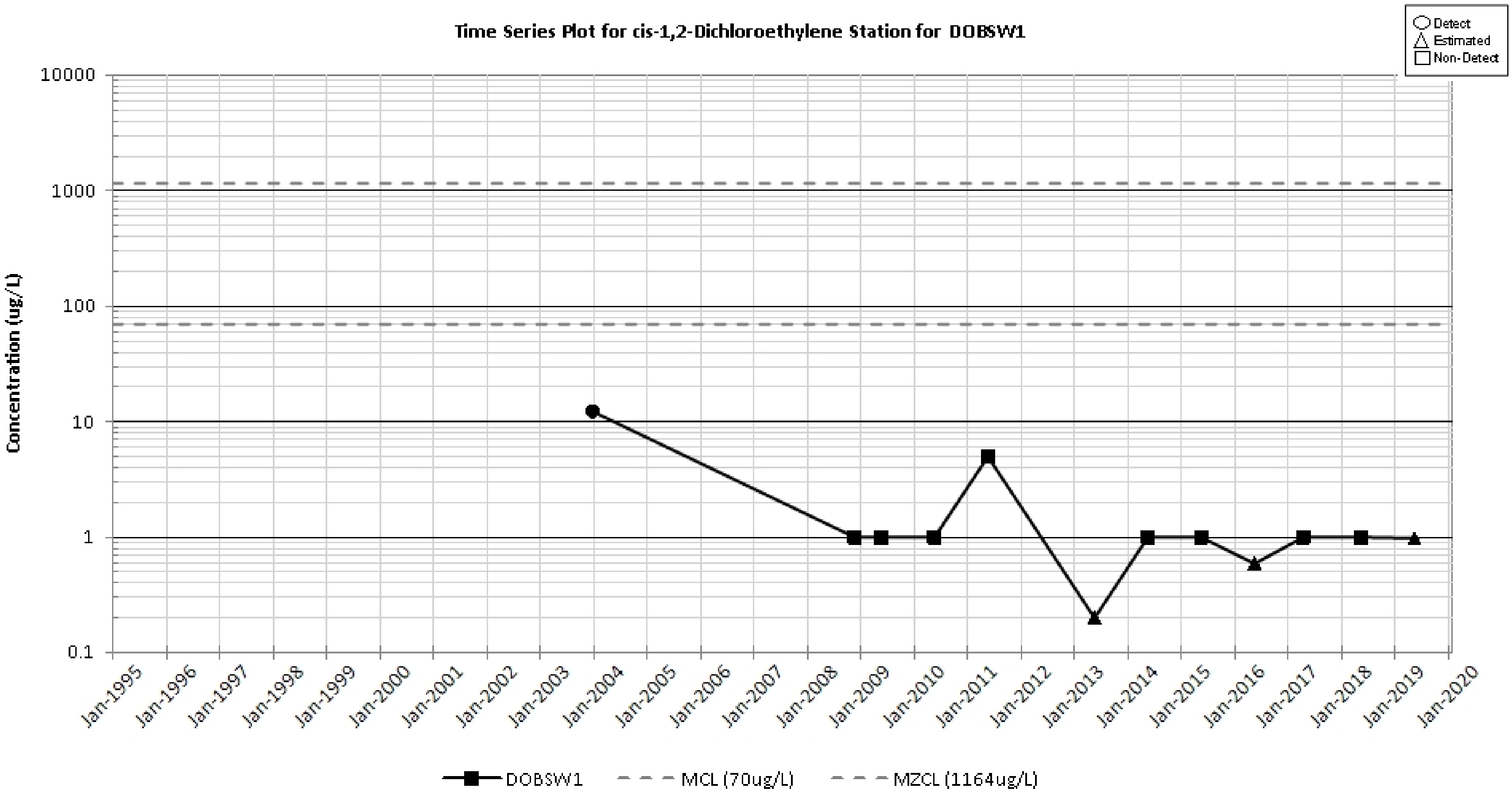


Figure D-67. Time Series Plot for cis-1,2-Dichloroethylene Station for DOB SW1

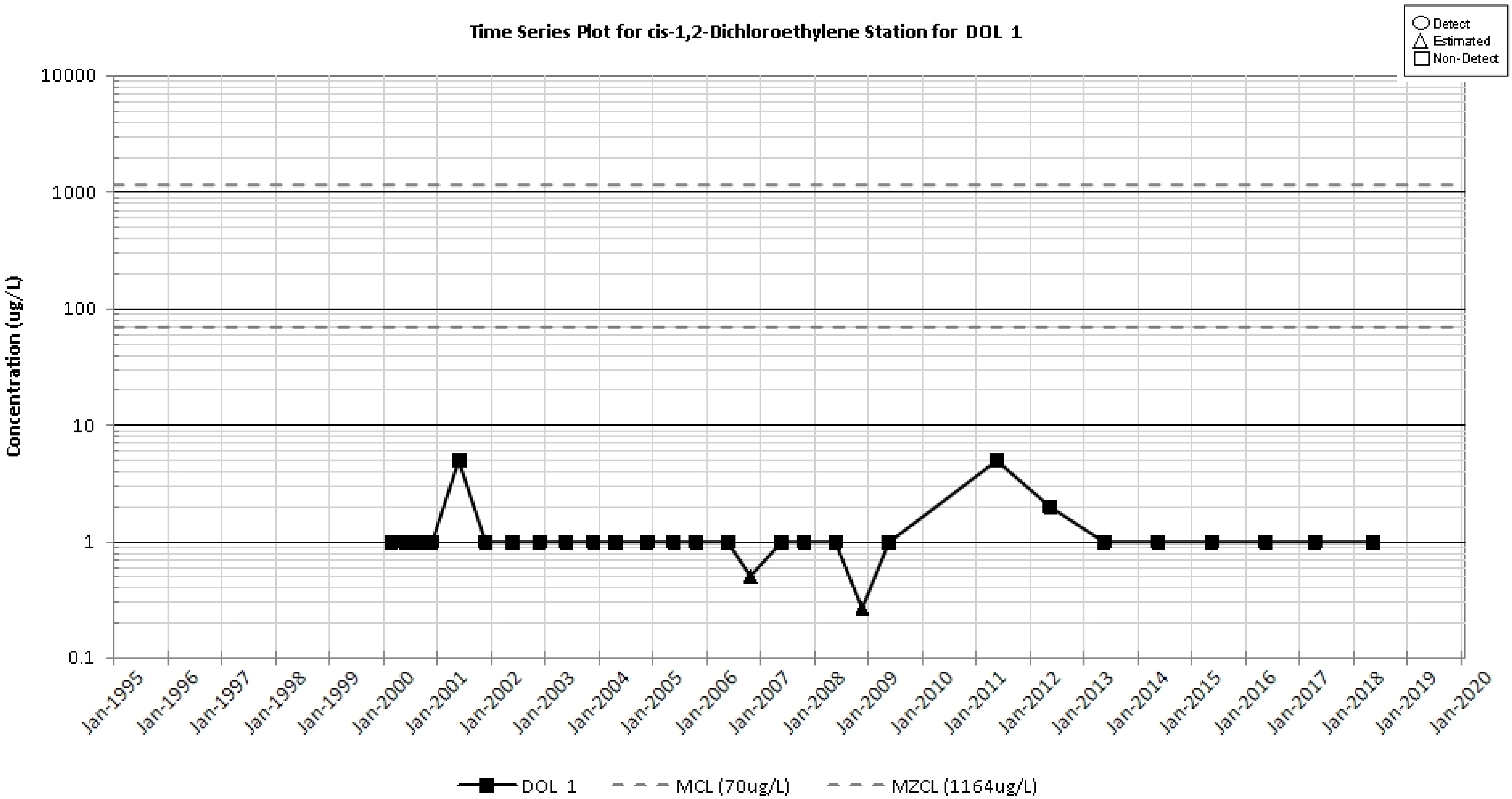


Figure D-68. Time Series Plot for cis-1,2-Dichloroethylene Station for DOL 1

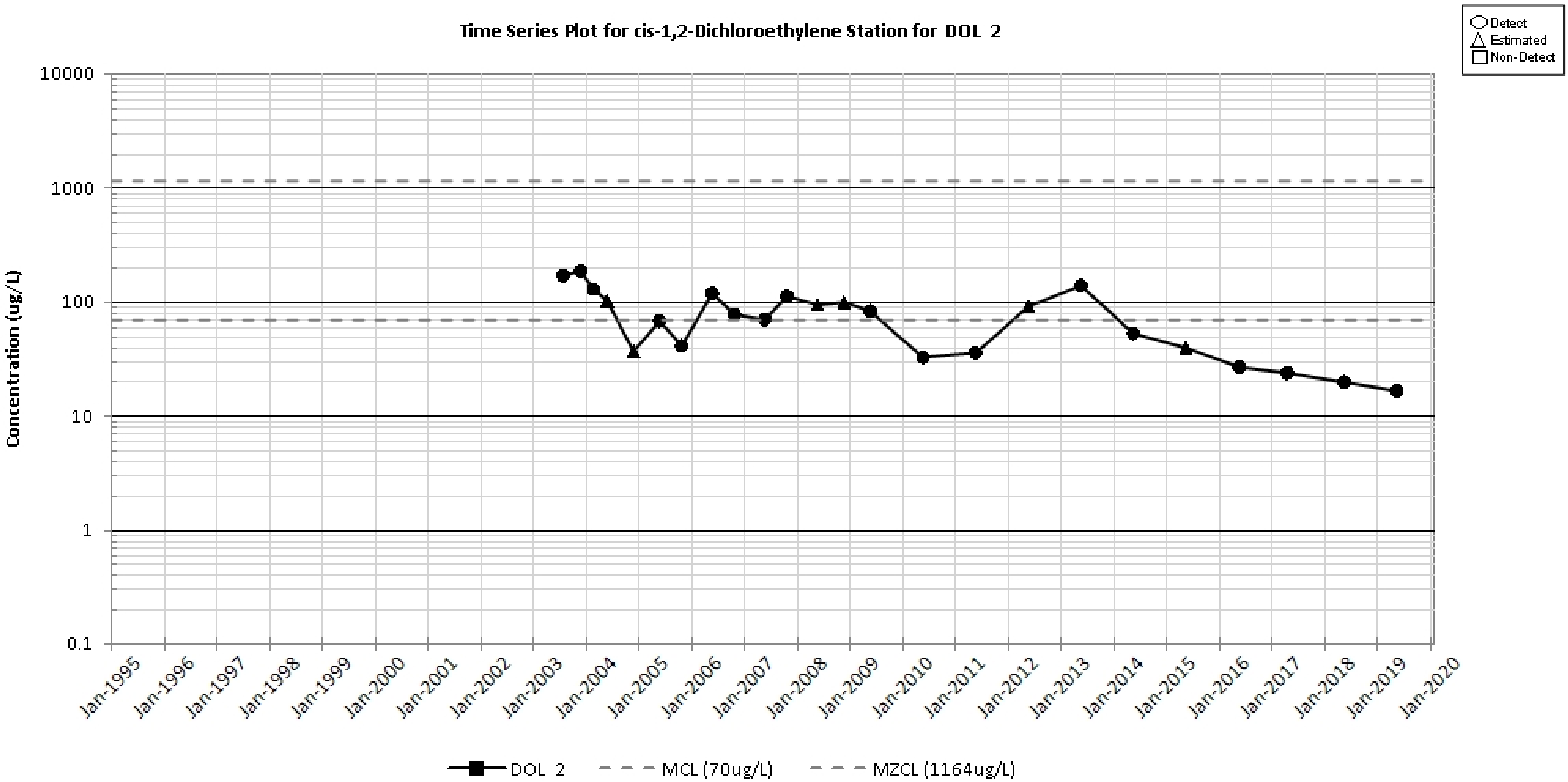


Figure D-69. Time Series Plot for cis-1,2-Dichloroethylene Station for DOL 2

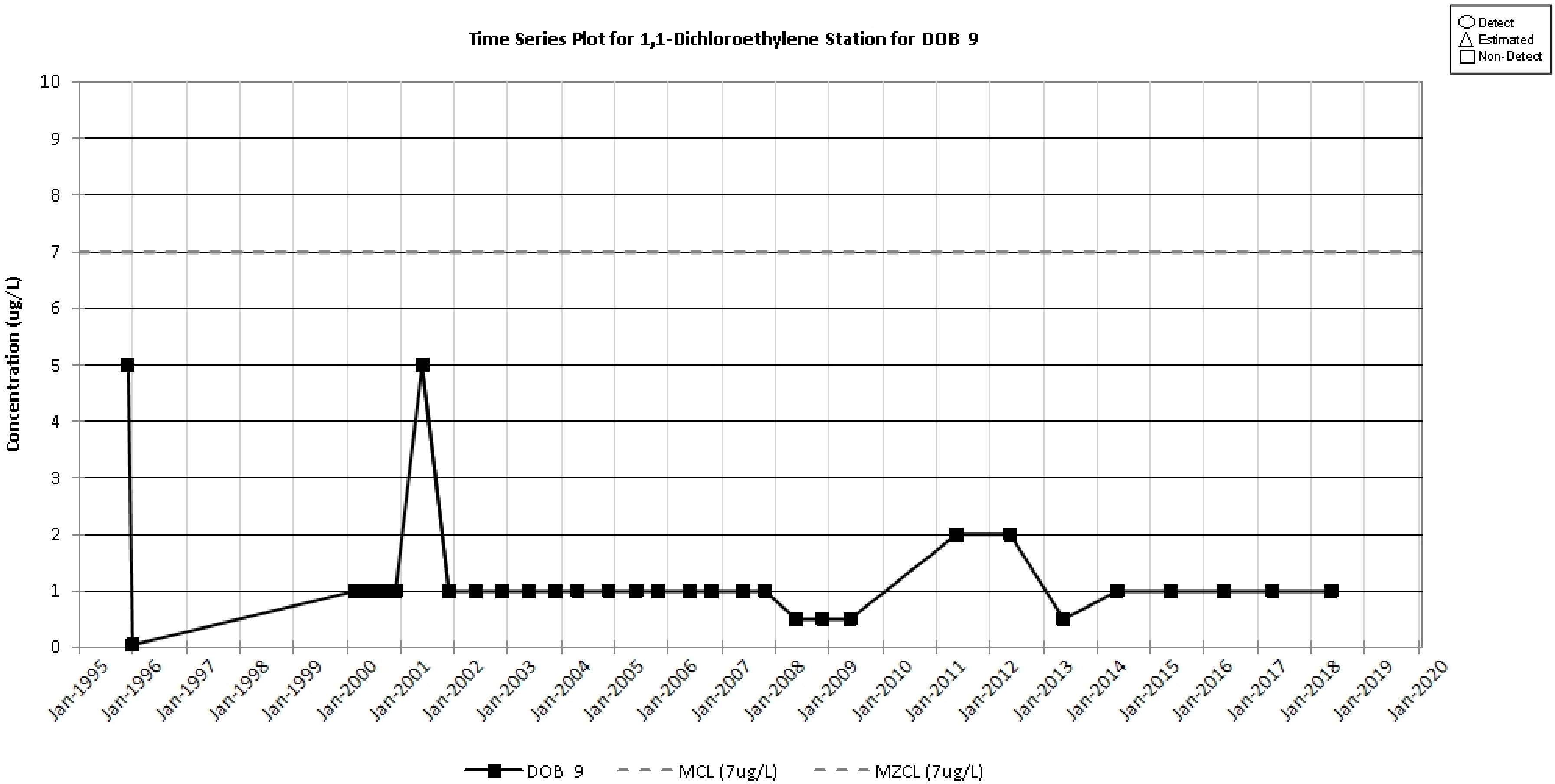


Figure D-70. Time Series Plot for 1,1-Dichloroethylene Station for DOB 9

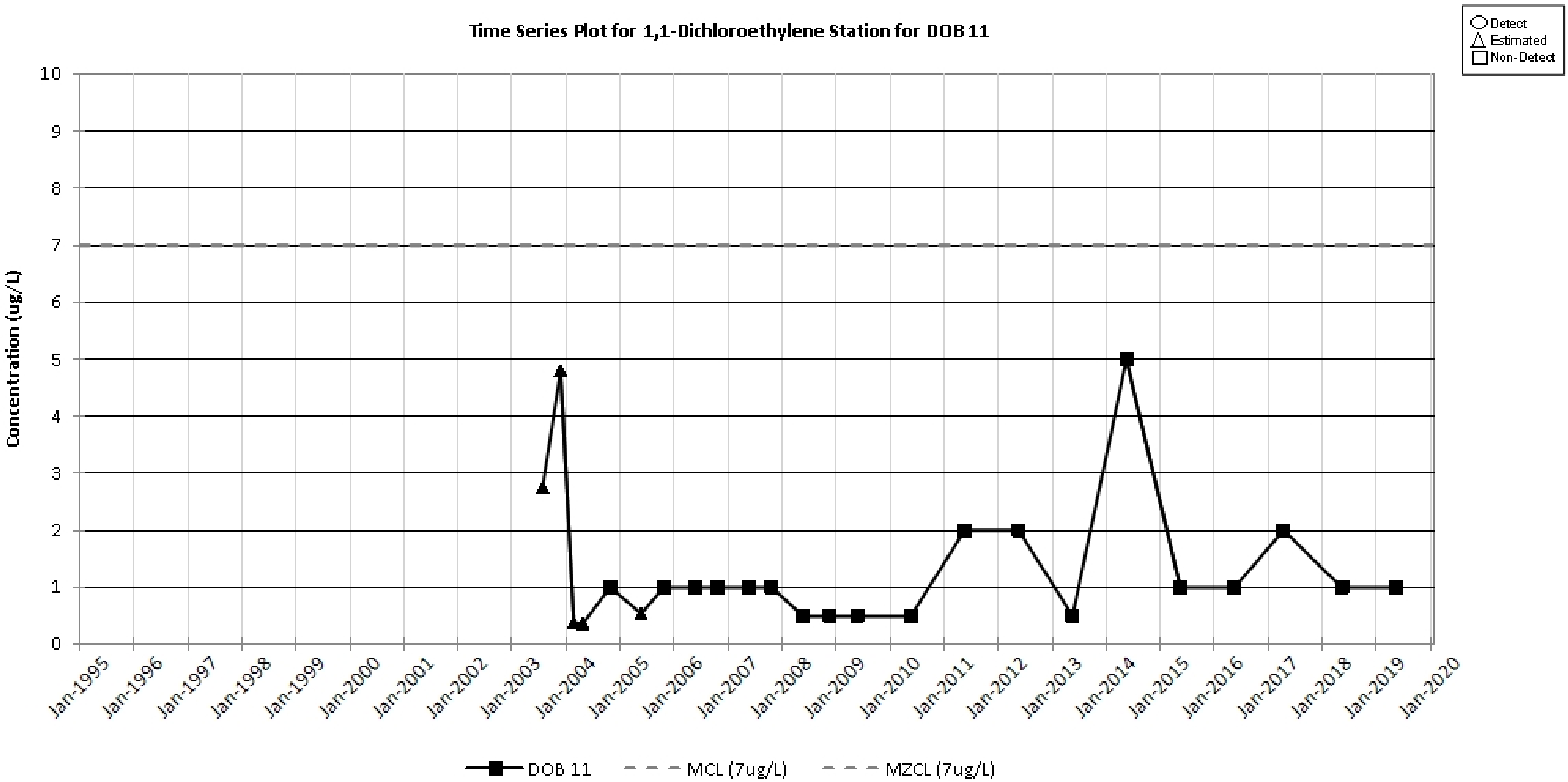


Figure D-71. Time Series Plot for 1,1-Dichloroethylene Station for DOB 11

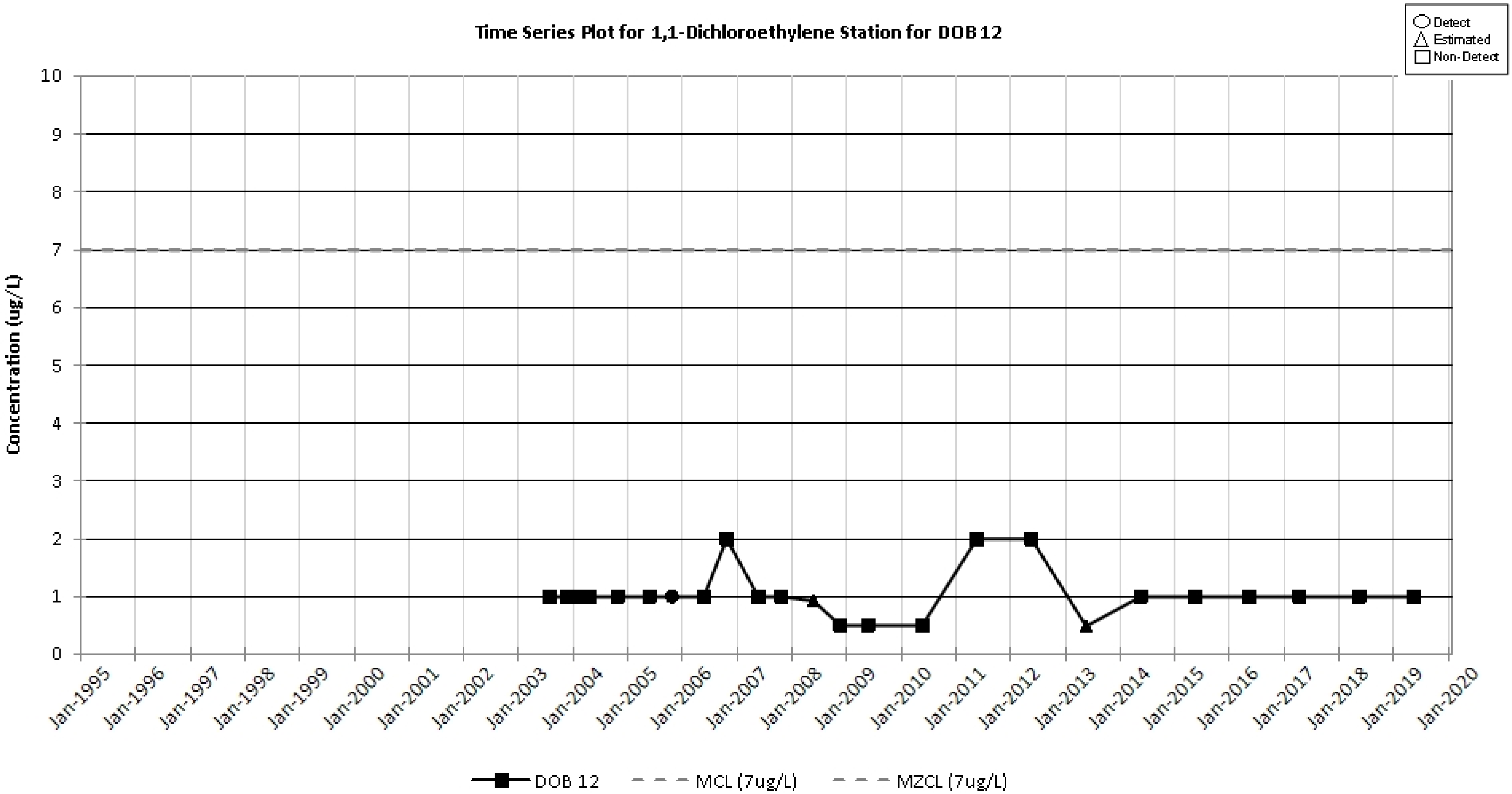


Figure D-72. Time Series Plot for 1,1-Dichloroethylene Station for DOB 12

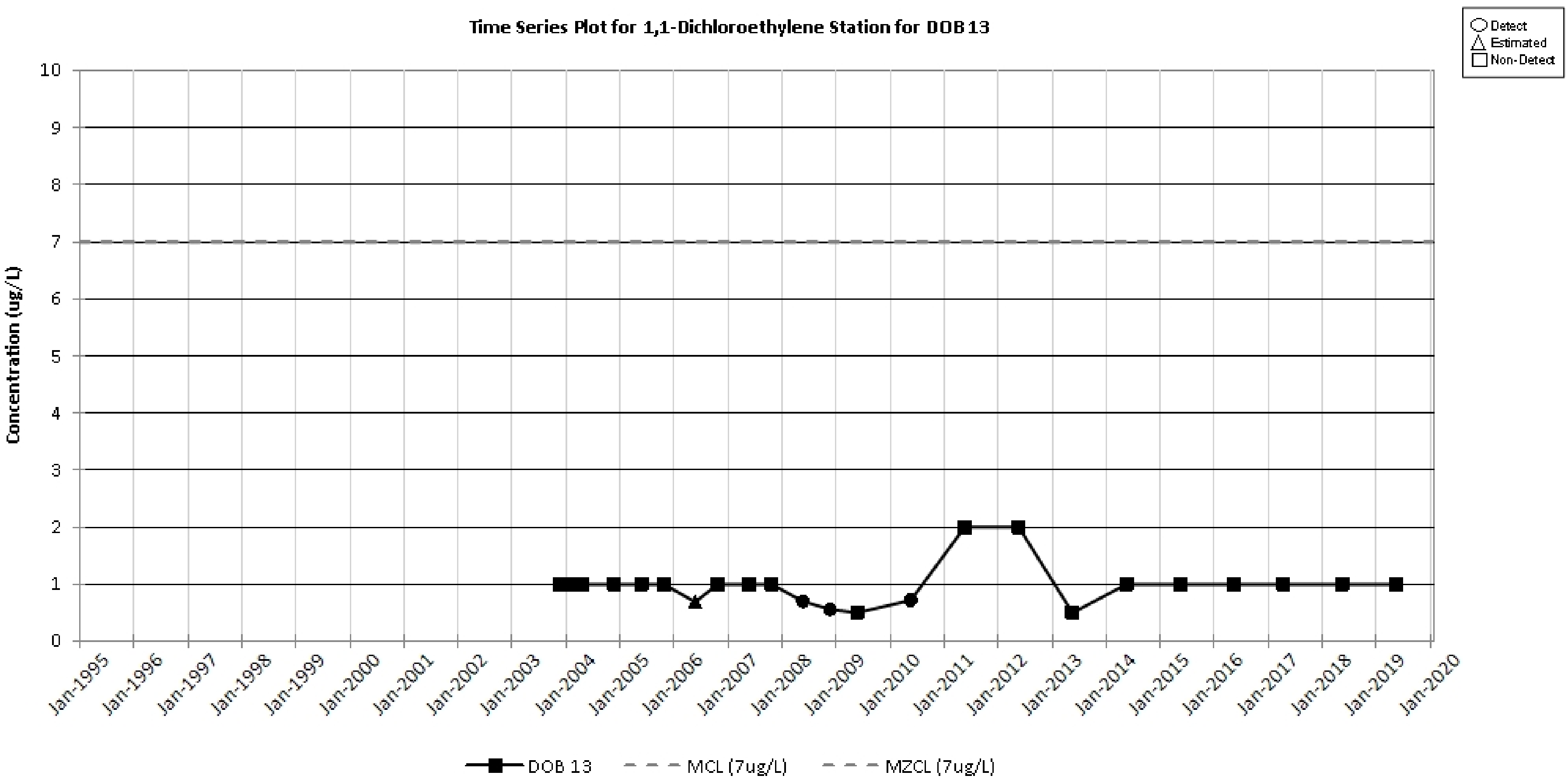


Figure D-73. Time Series Plot for 1,1-Dichloroethylene Station for DOB 13

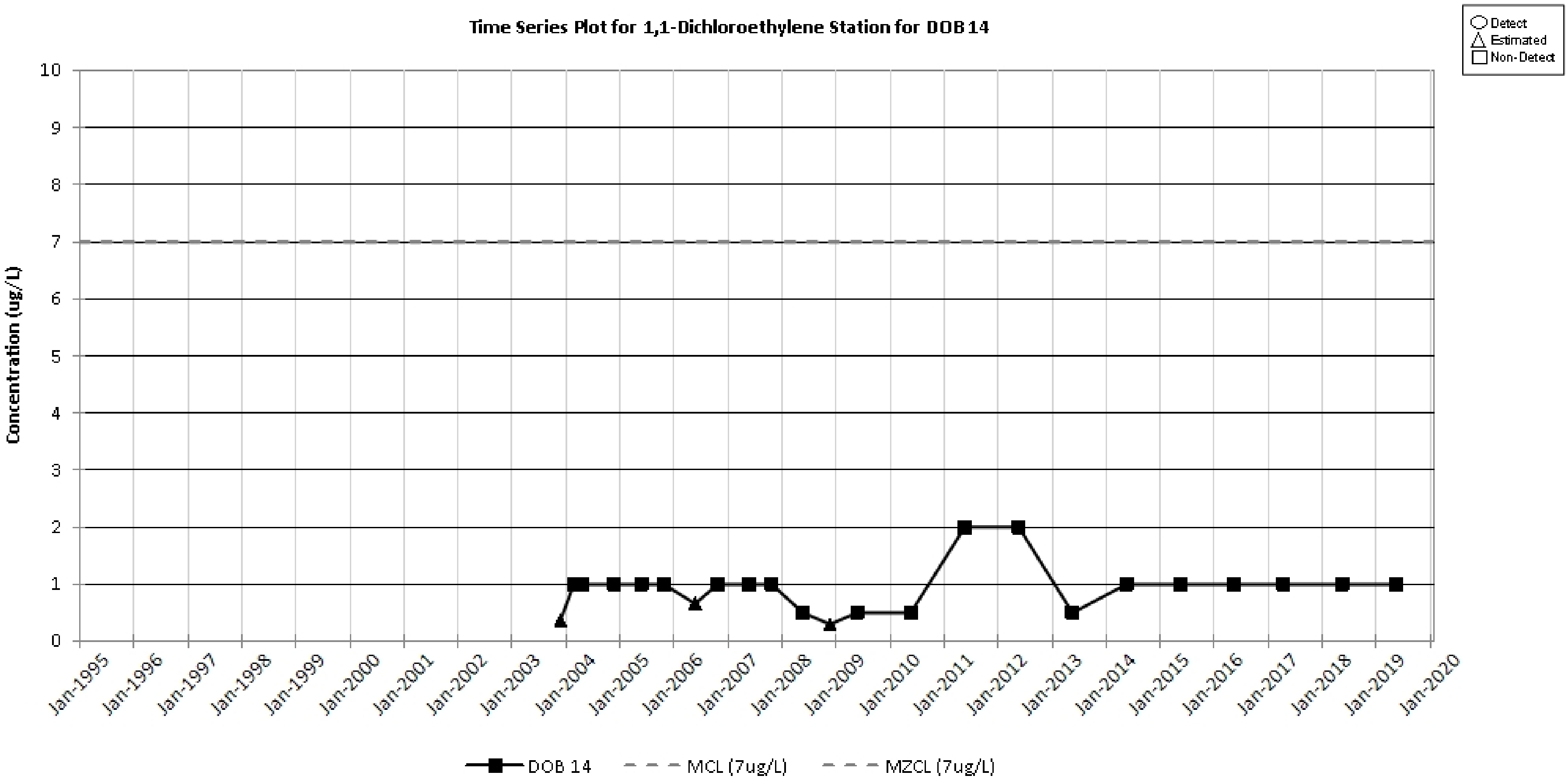


Figure D-74. Time Series Plot for 1,1-Dichloroethylene Station for DOB 14

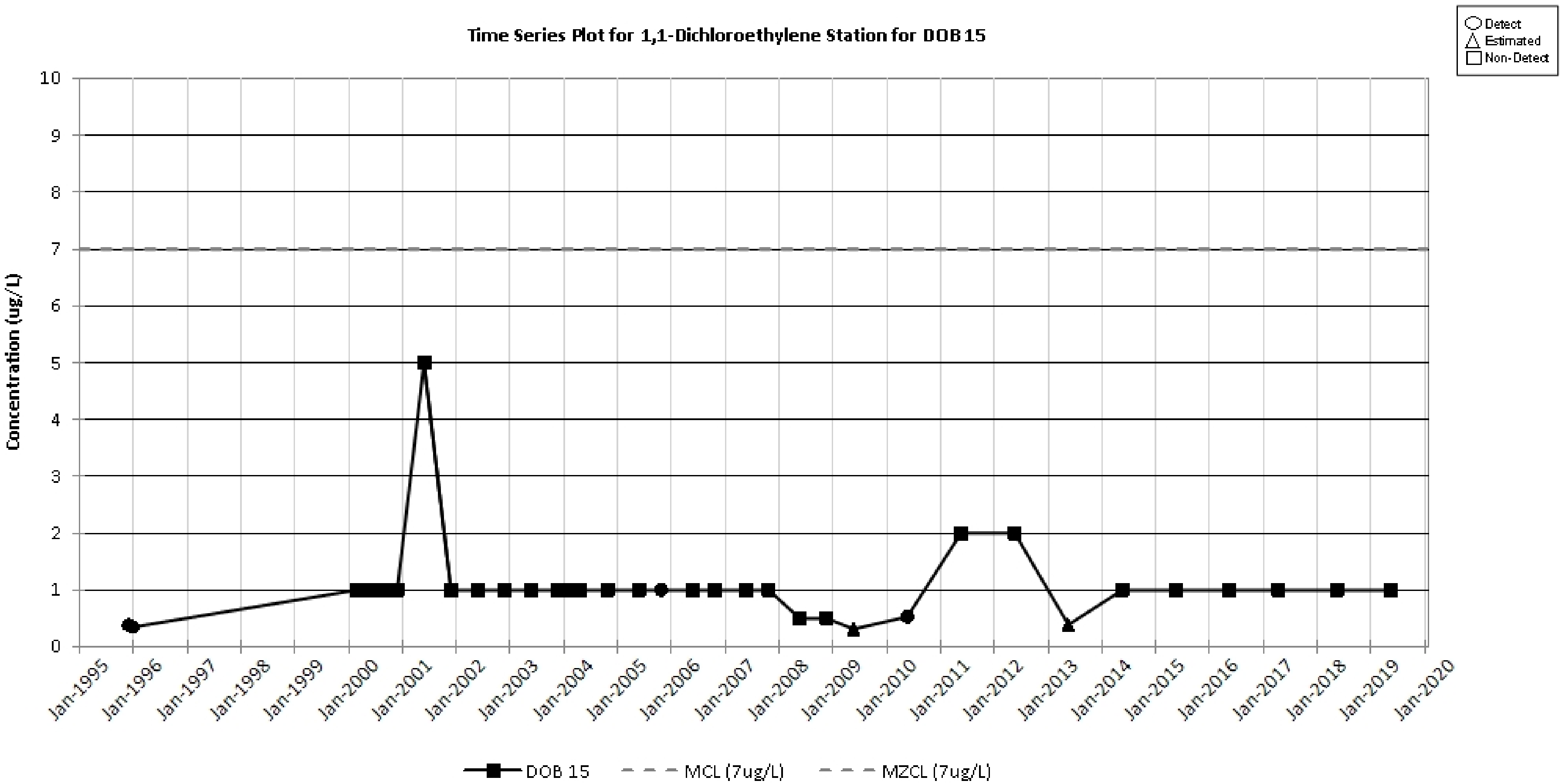


Figure D-75. Time Series Plot for 1,1-Dichloroethylene Station for DOB 15

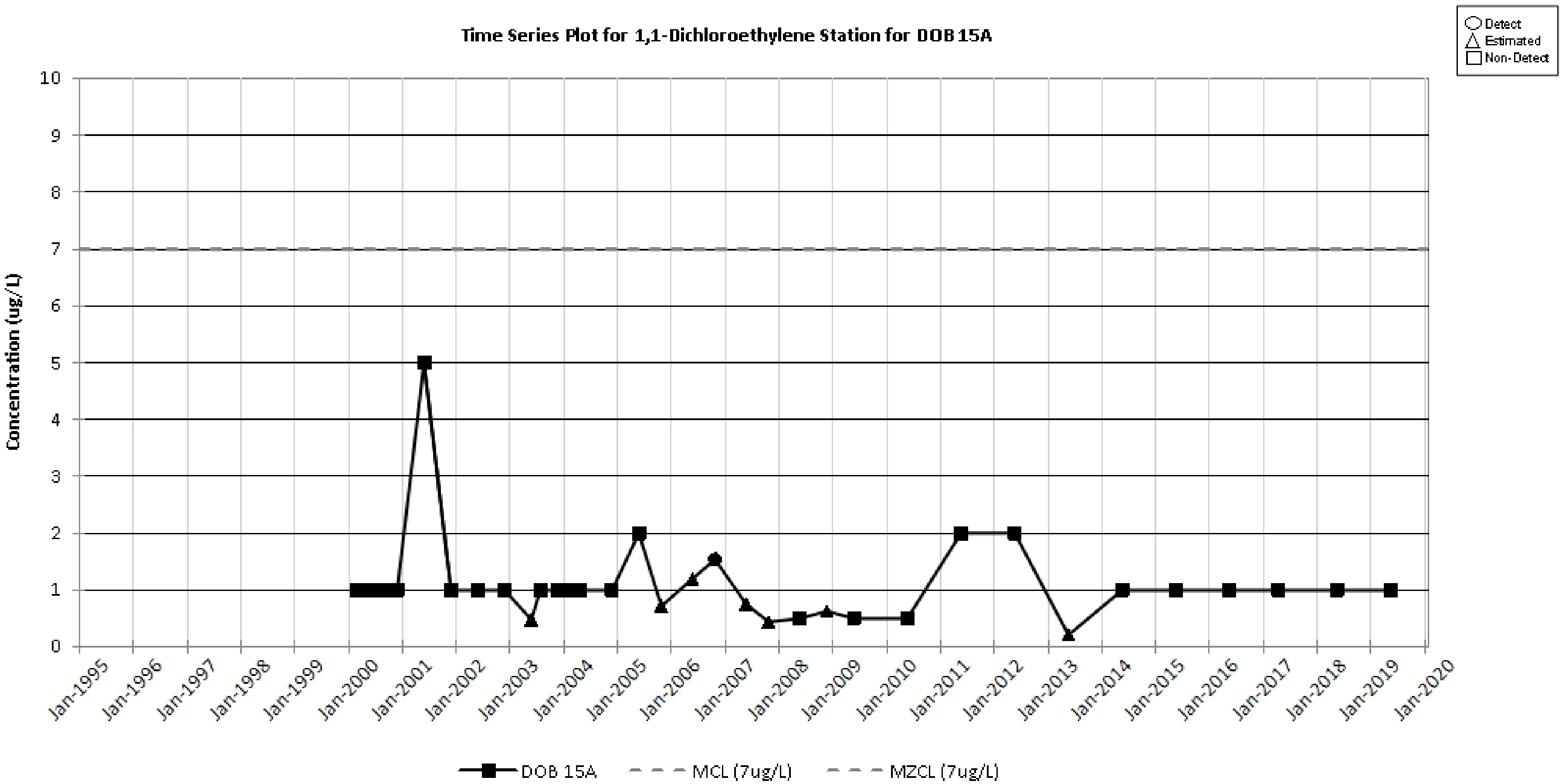


Figure D-76. Time Series Plot for 1,1-Dichloroethylene Station for DOB 15A

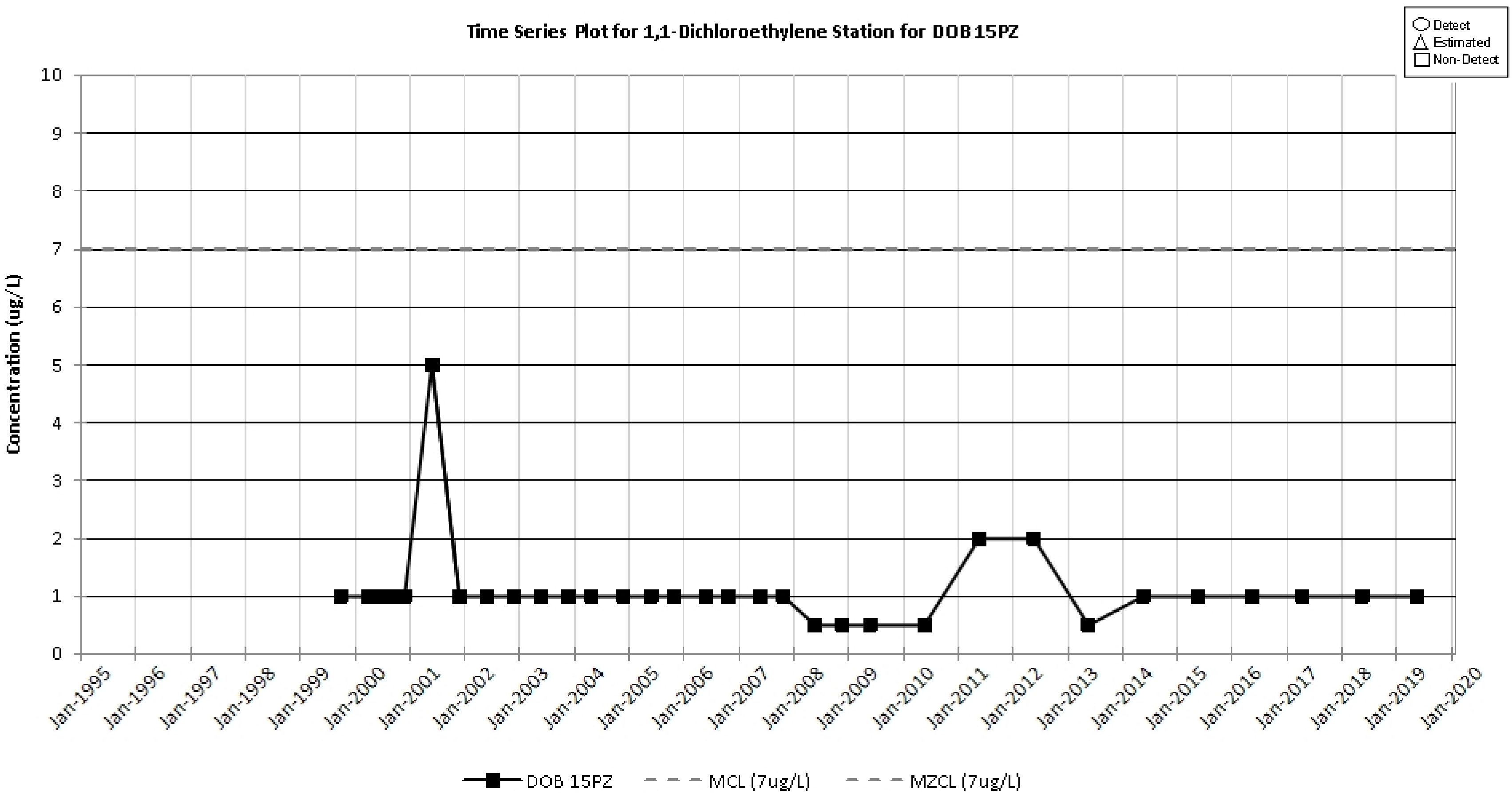


Figure D-77. Time Series Plot for 1,1-Dichloroethylene Station for DOB 15PZ

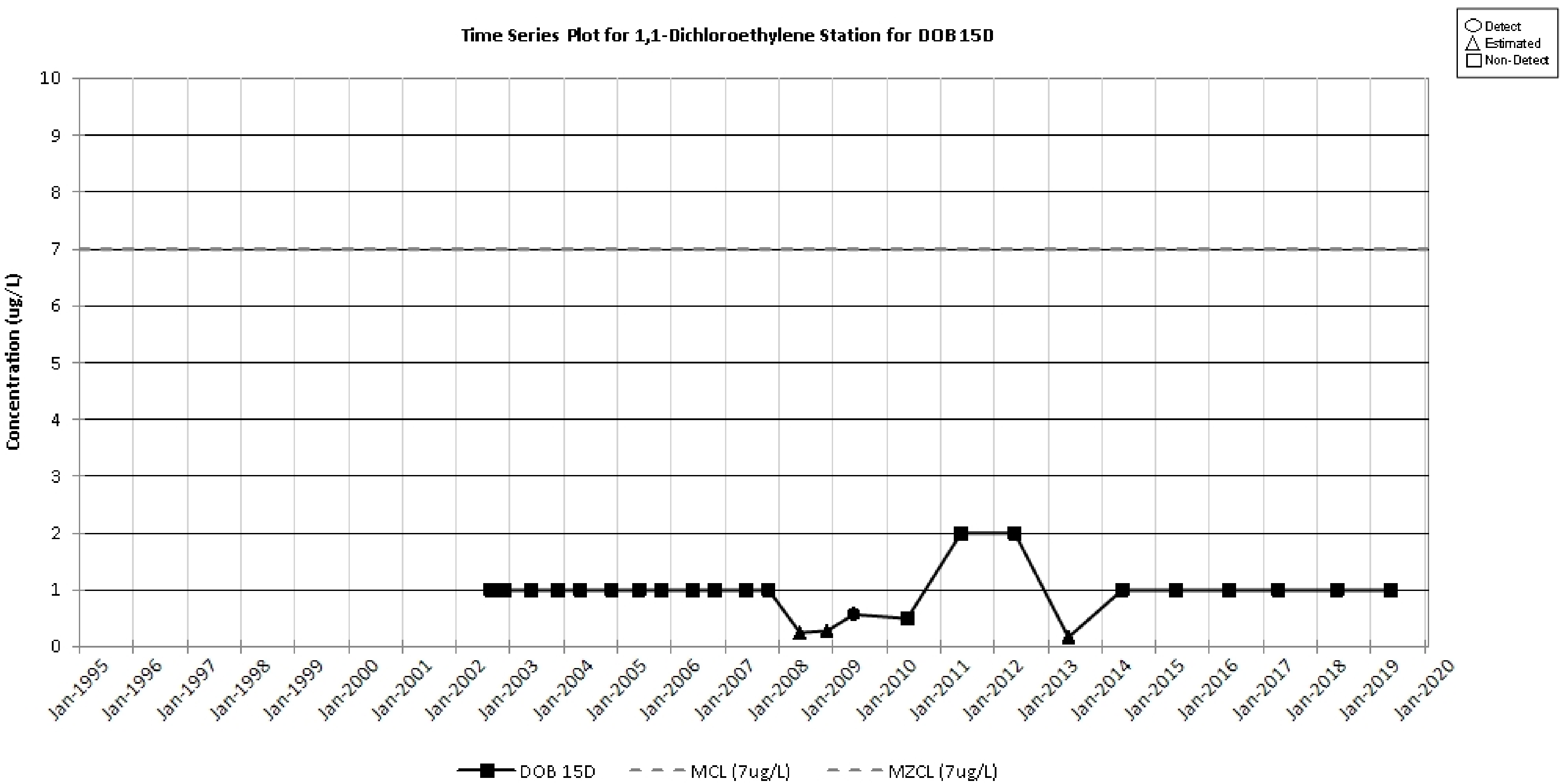


Figure D-78. Time Series Plot for 1,1-Dichloroethylene Station for DOB 15D

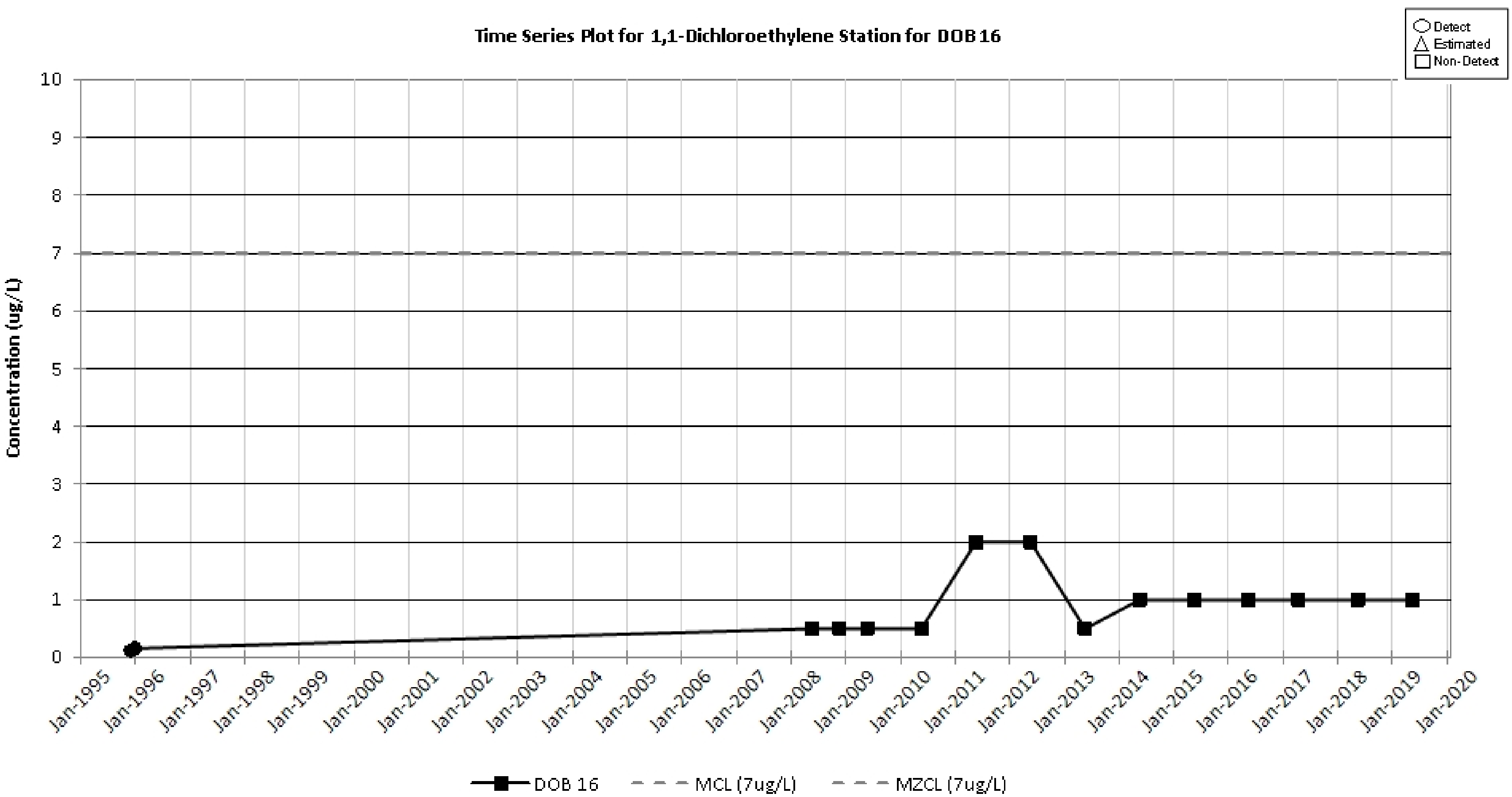


Figure D-79. Time Series Plot for 1,1-Dichloroethylene Station for DOB 16

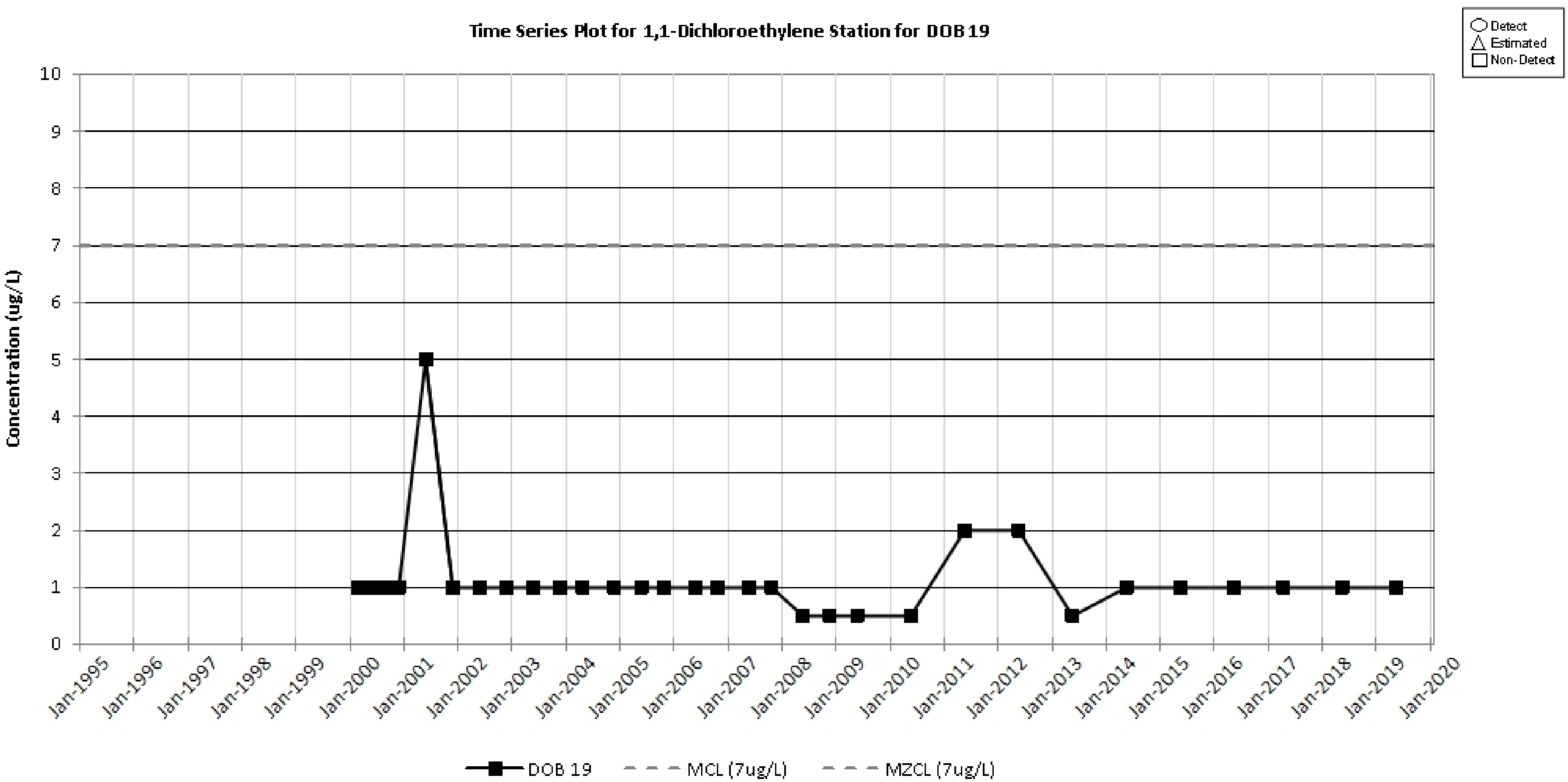


Figure D-80. Time Series Plot for 1,1-Dichloroethylene Station for DOB 19

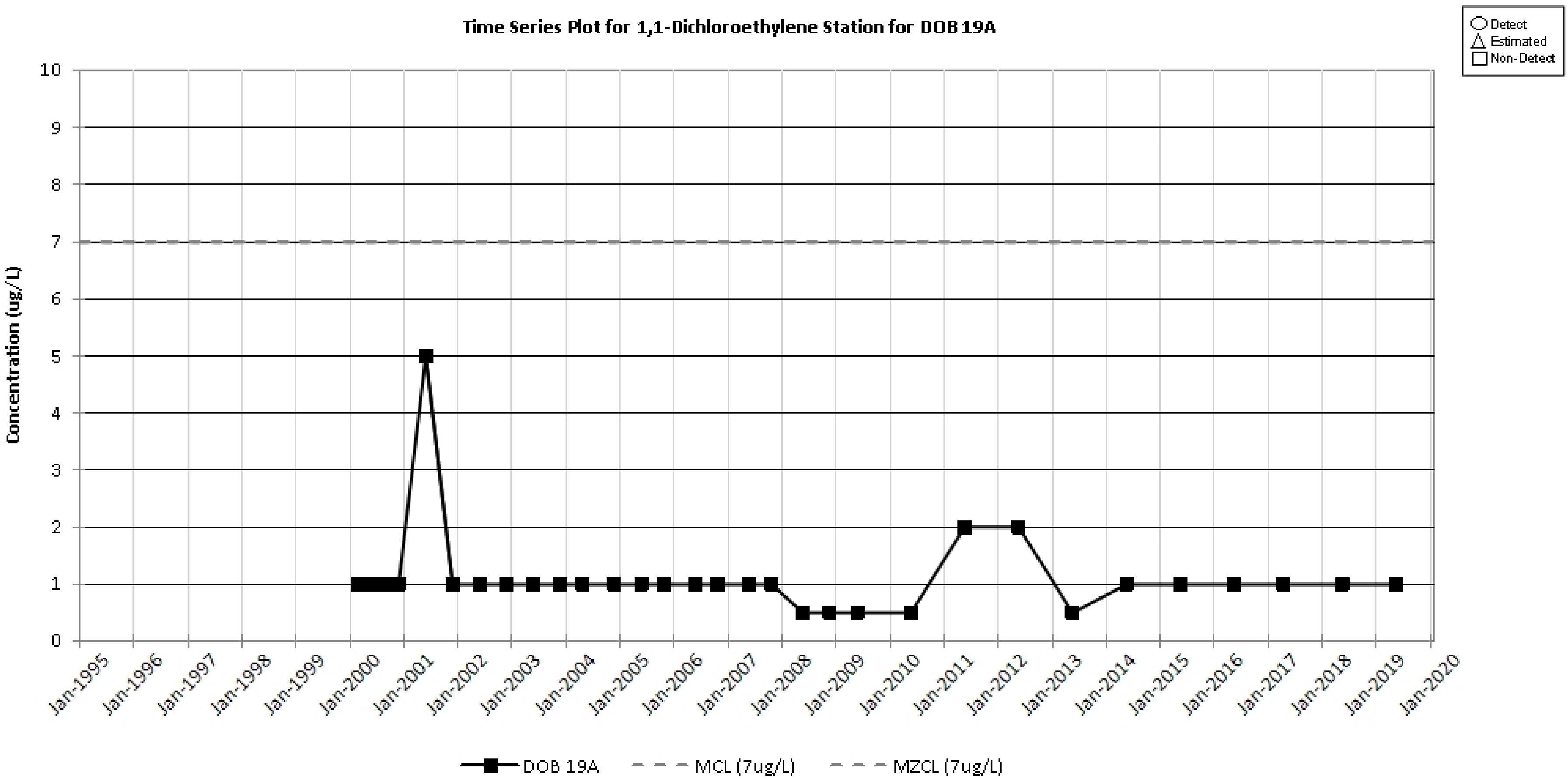


Figure D-81. Time Series Plot for 1,1-Dichloroethylene Station for DOB 19A

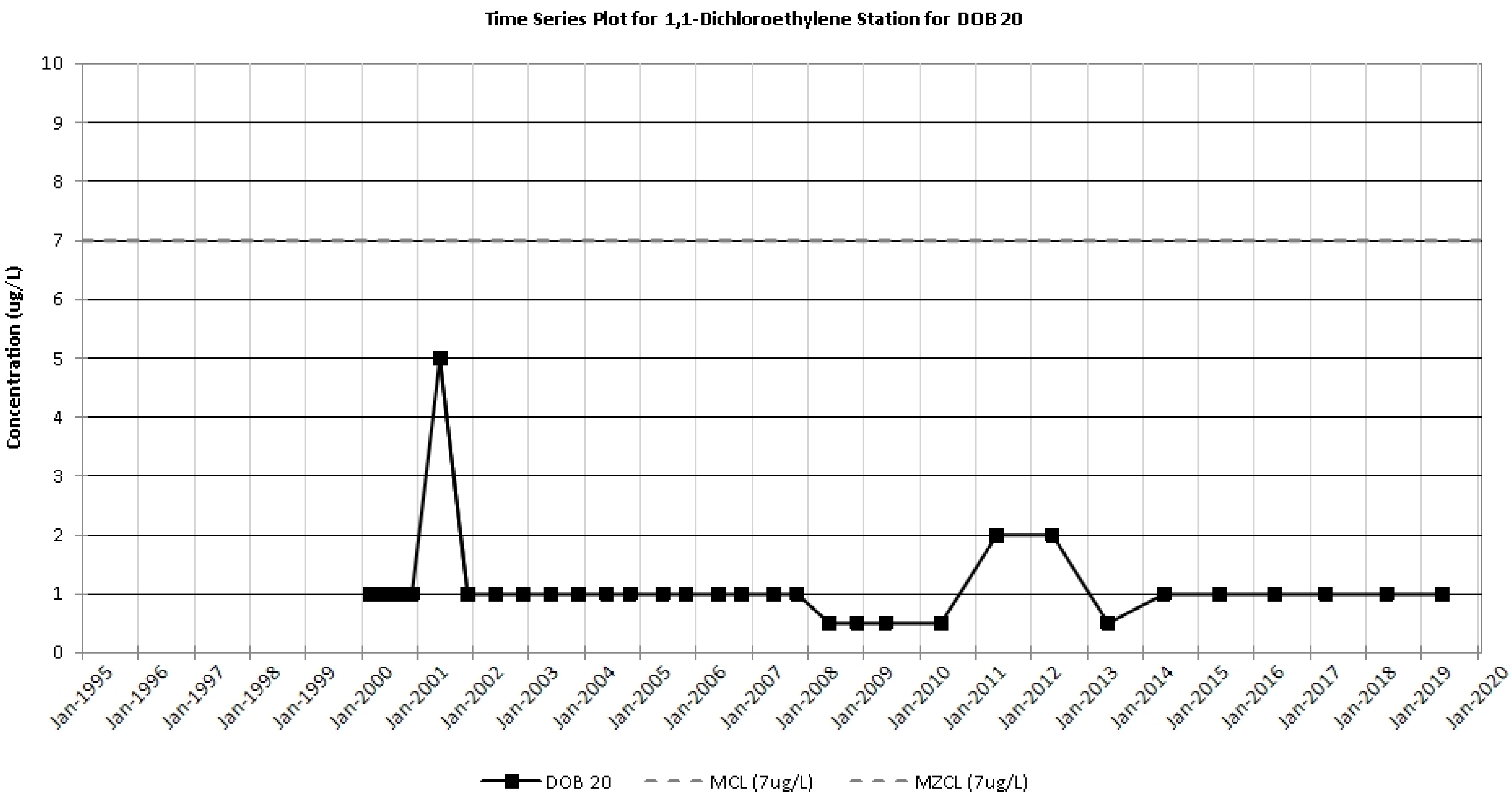
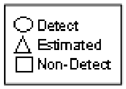


Figure D-82. Time Series Plot for 1,1-Dichloroethylene Station for DOB 20



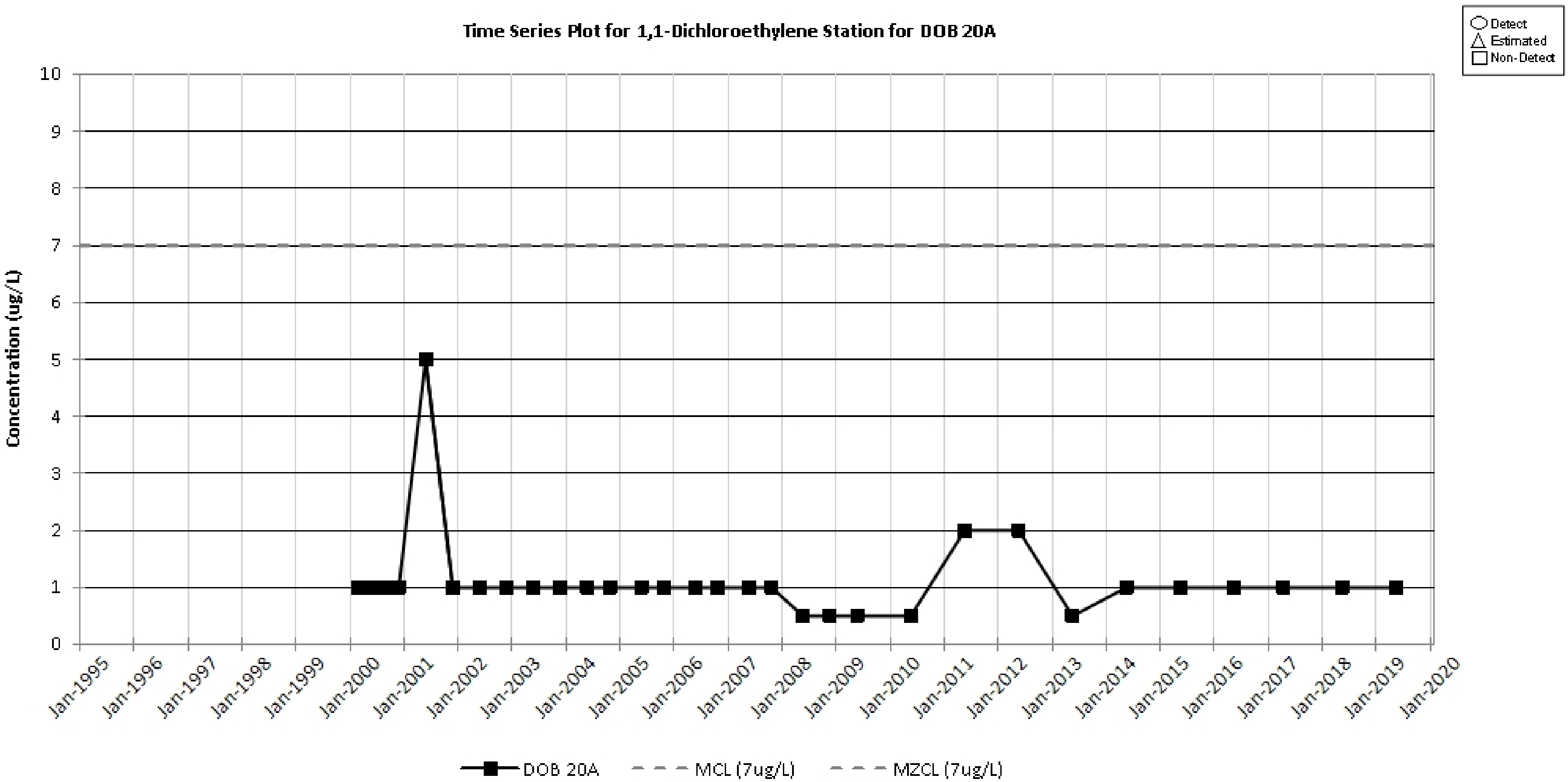


Figure D-83. Time Series Plot for 1,1-Dichloroethylene Station for DOB 20A

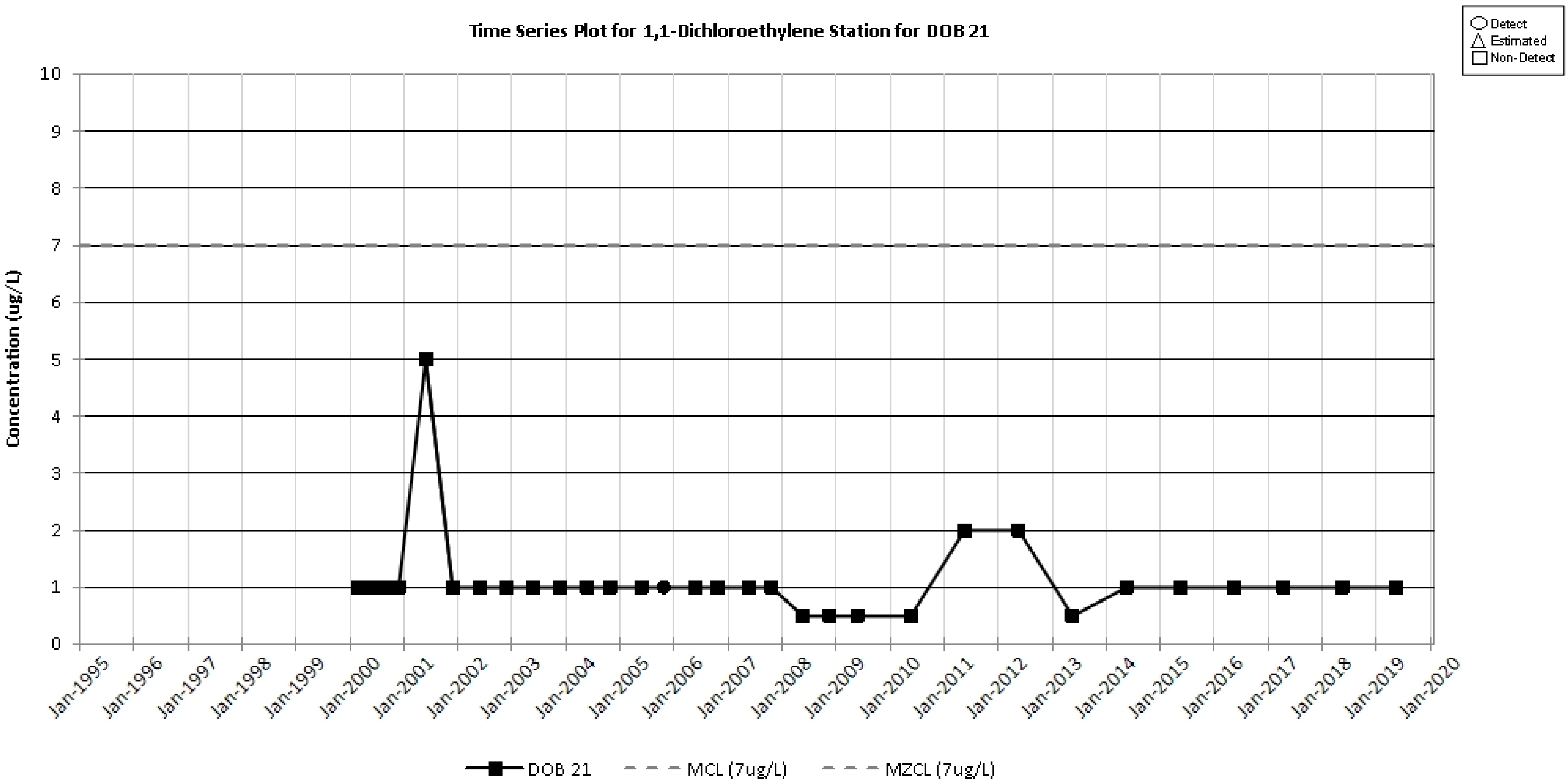


Figure D-84. Time Series Plot for 1,1-Dichloroethylene Station for DOB 21

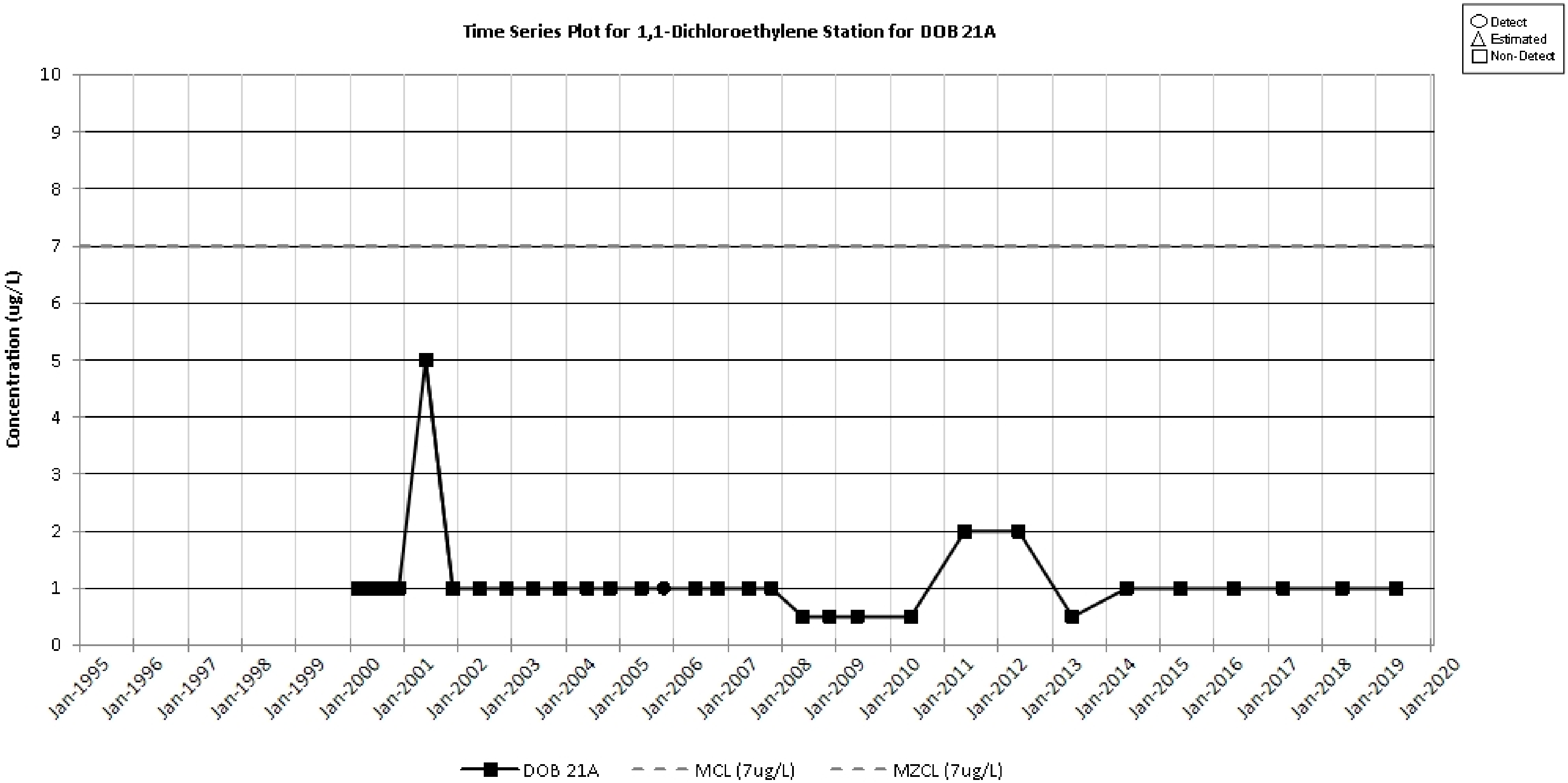


Figure D-85. Time Series Plot for 1,1-Dichloroethylene Station for DOB 21A

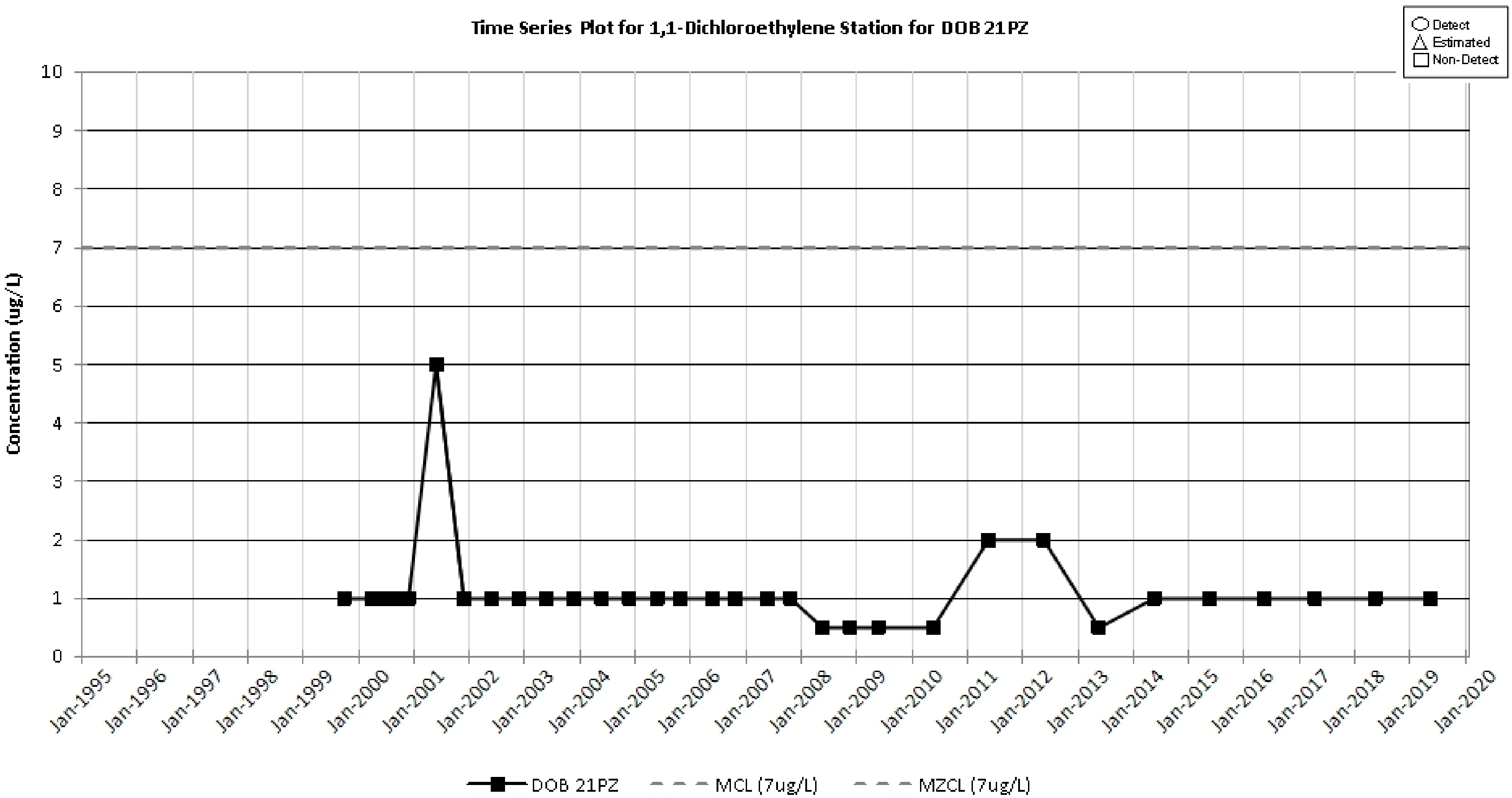


Figure D-86. Time Series Plot for 1,1-Dichloroethylene Station for DOB 21PZ

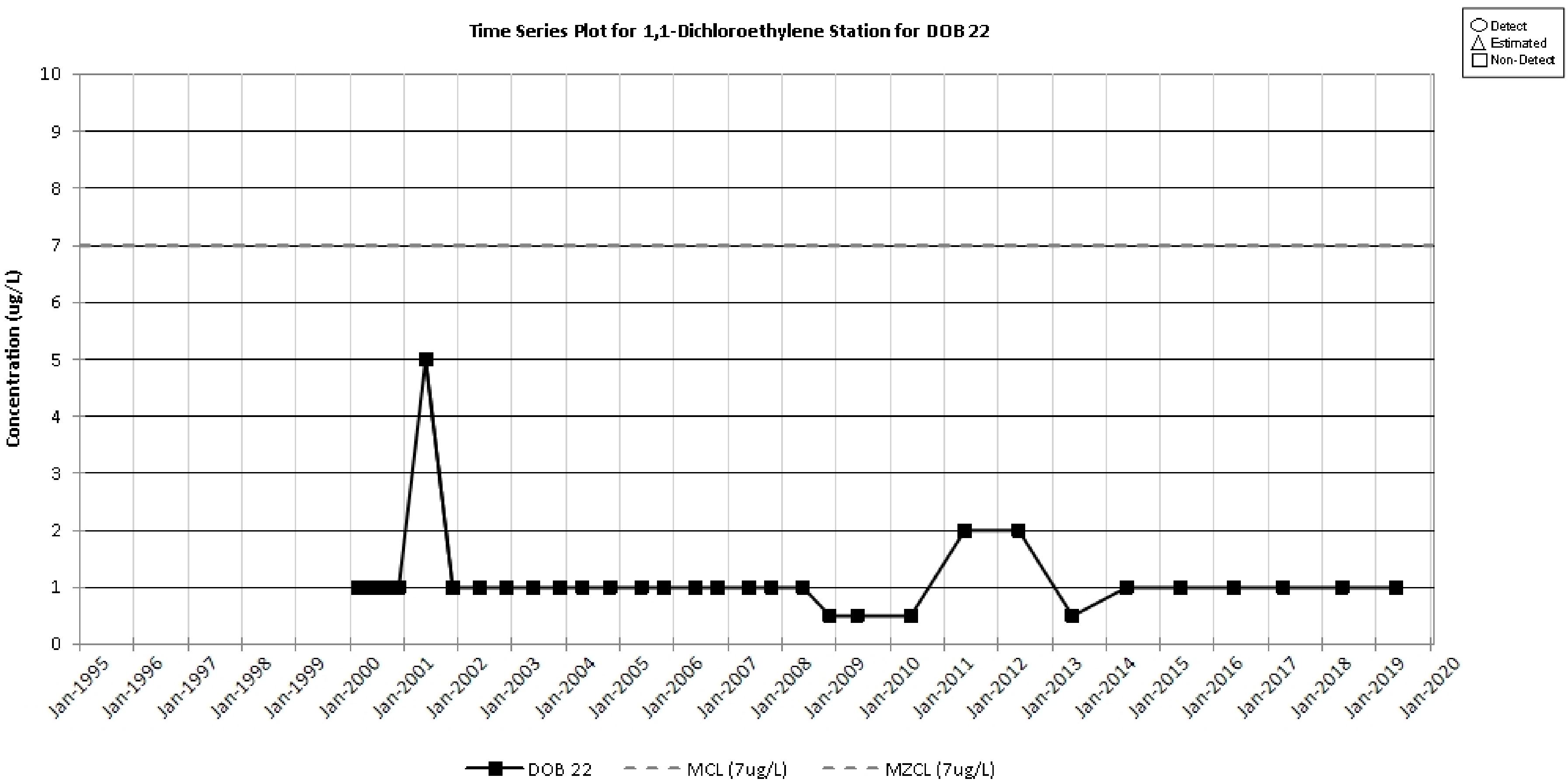


Figure D-87. Time Series Plot for 1,1-Dichloroethylene Station for DOB 22

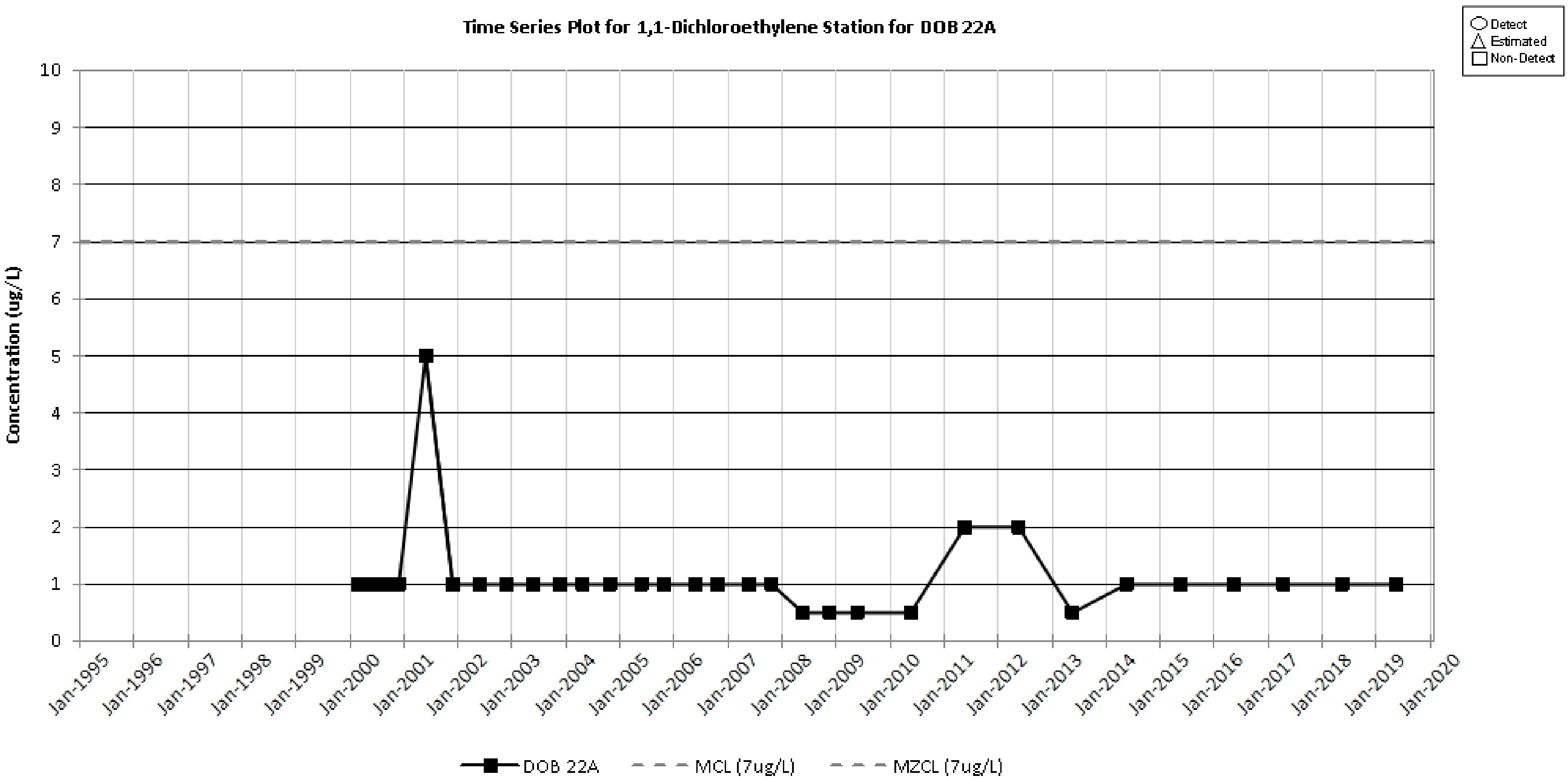


Figure D-88. Time Series Plot for 1,1-Dichloroethylene Station for DOB 22A

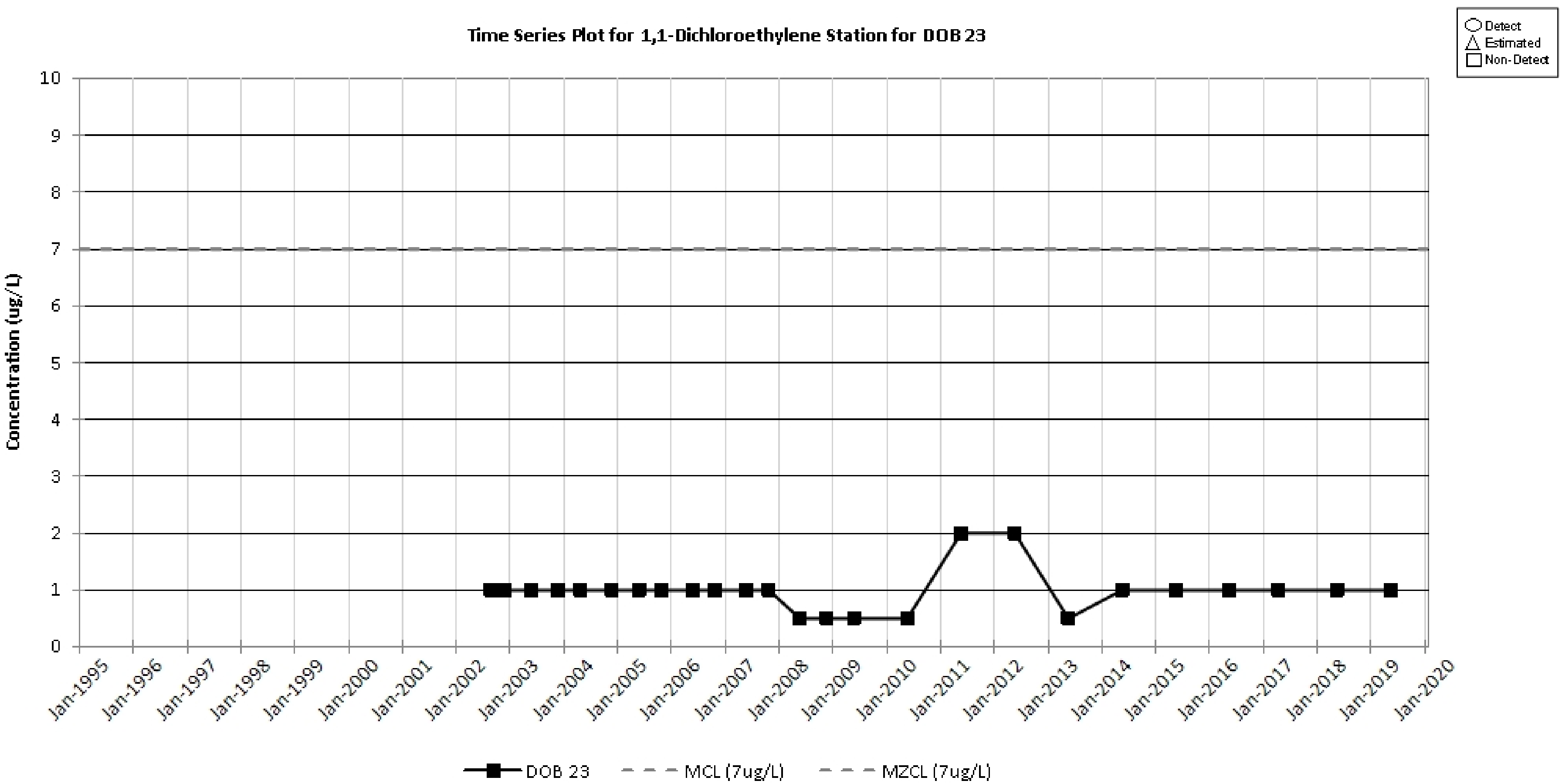


Figure D-89. Time Series Plot for 1,1-Dichloroethylene Station for DOB 23

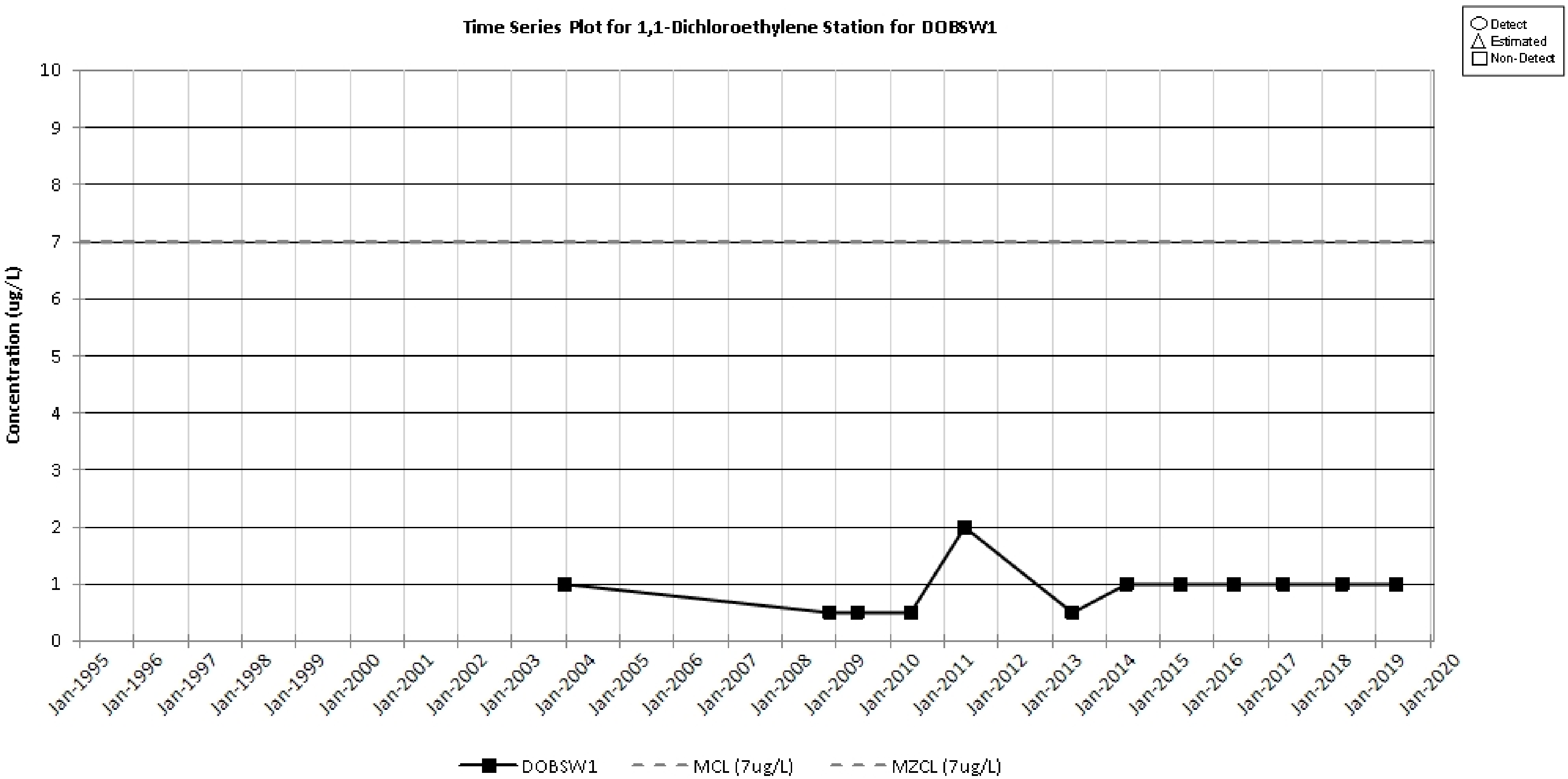


Figure D-90. Time Series Plot for 1,1-Dichloroethylene Station for DOB SW1

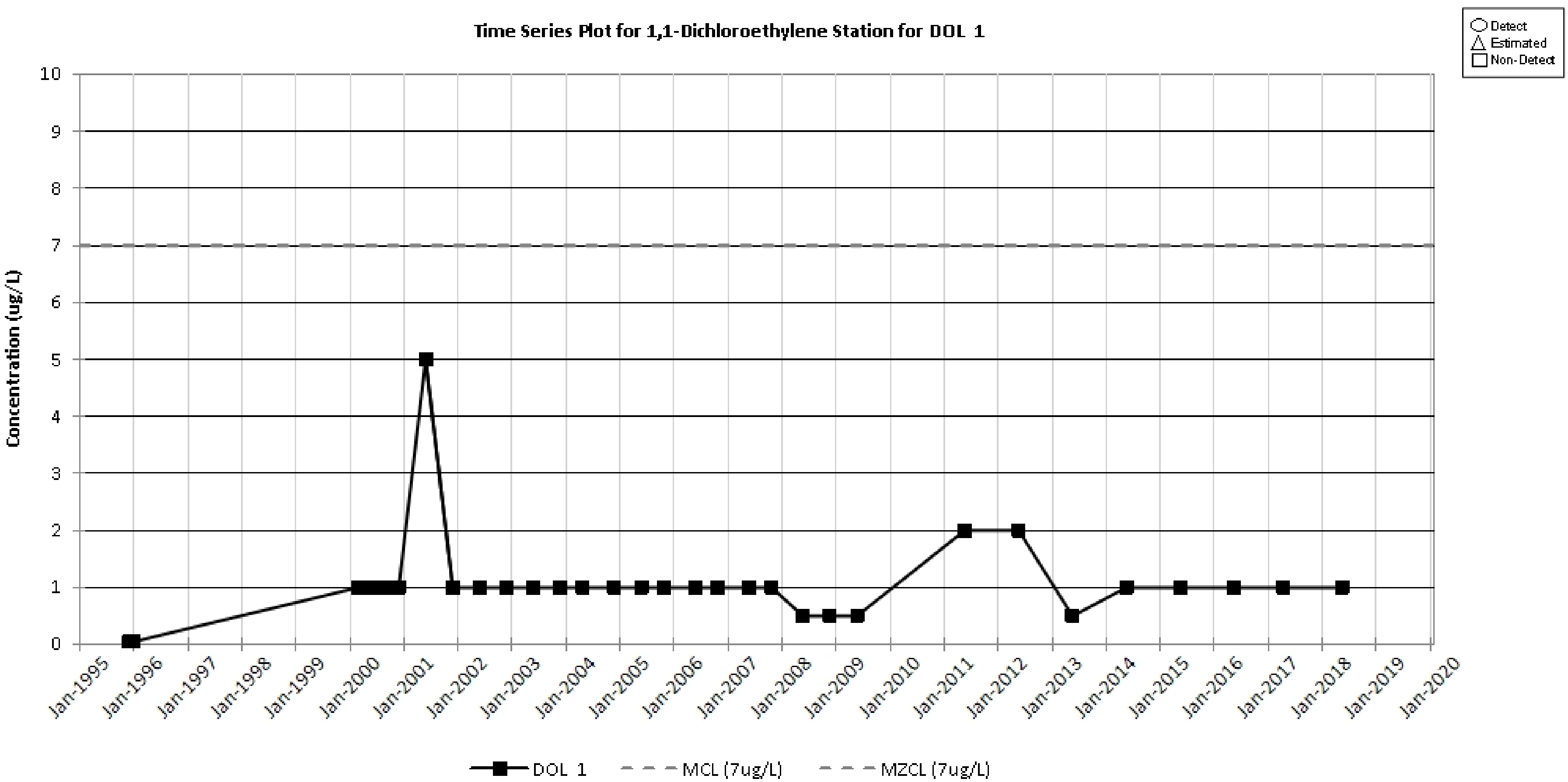


Figure D-91. Time Series Plot for 1,1-Dichloroethylene Station for DOL 1

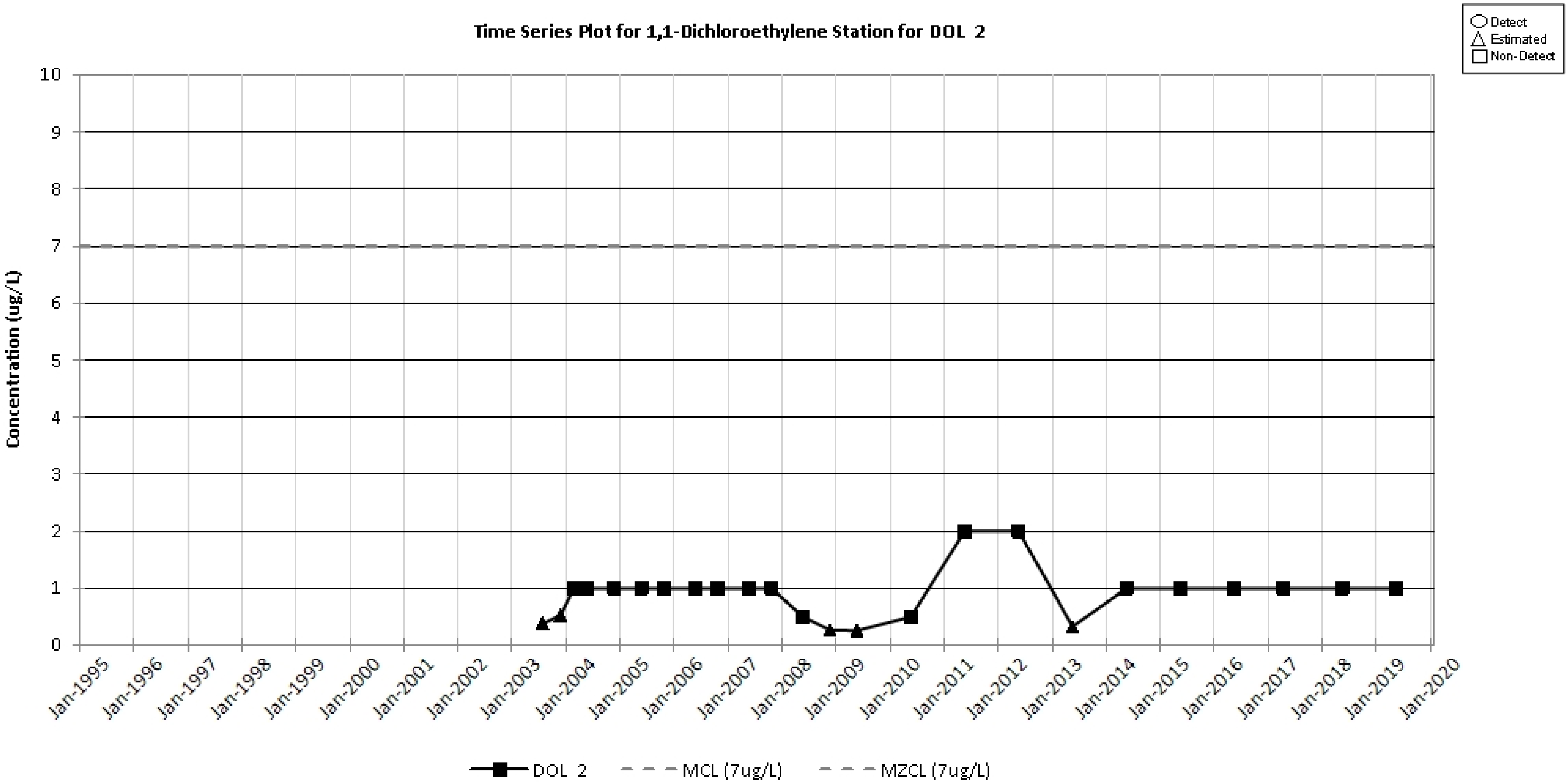


Figure D-92. Time Series Plot for 1,1-Dichloroethylene Station for DOL 2

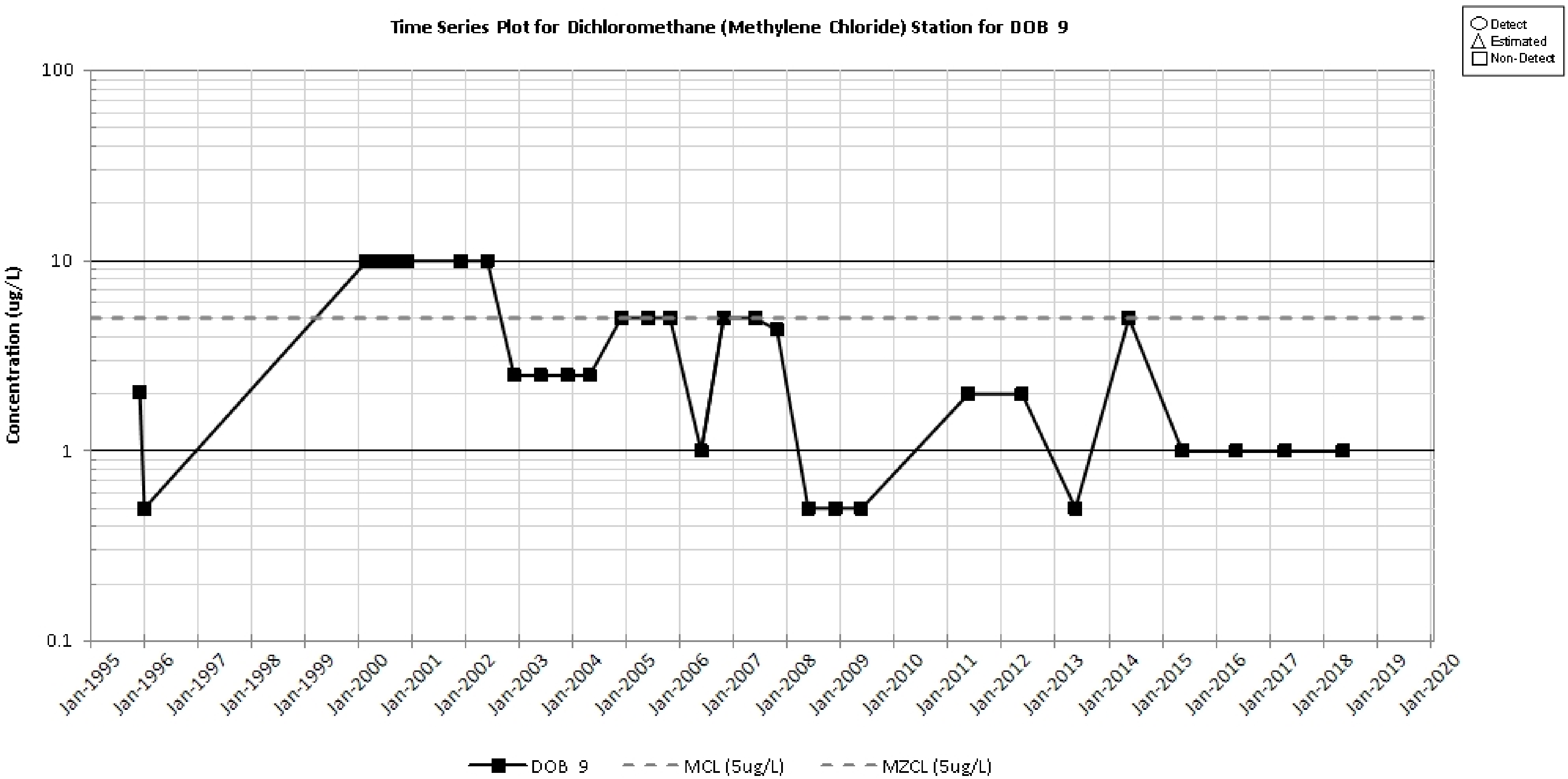


Figure D-93. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 9

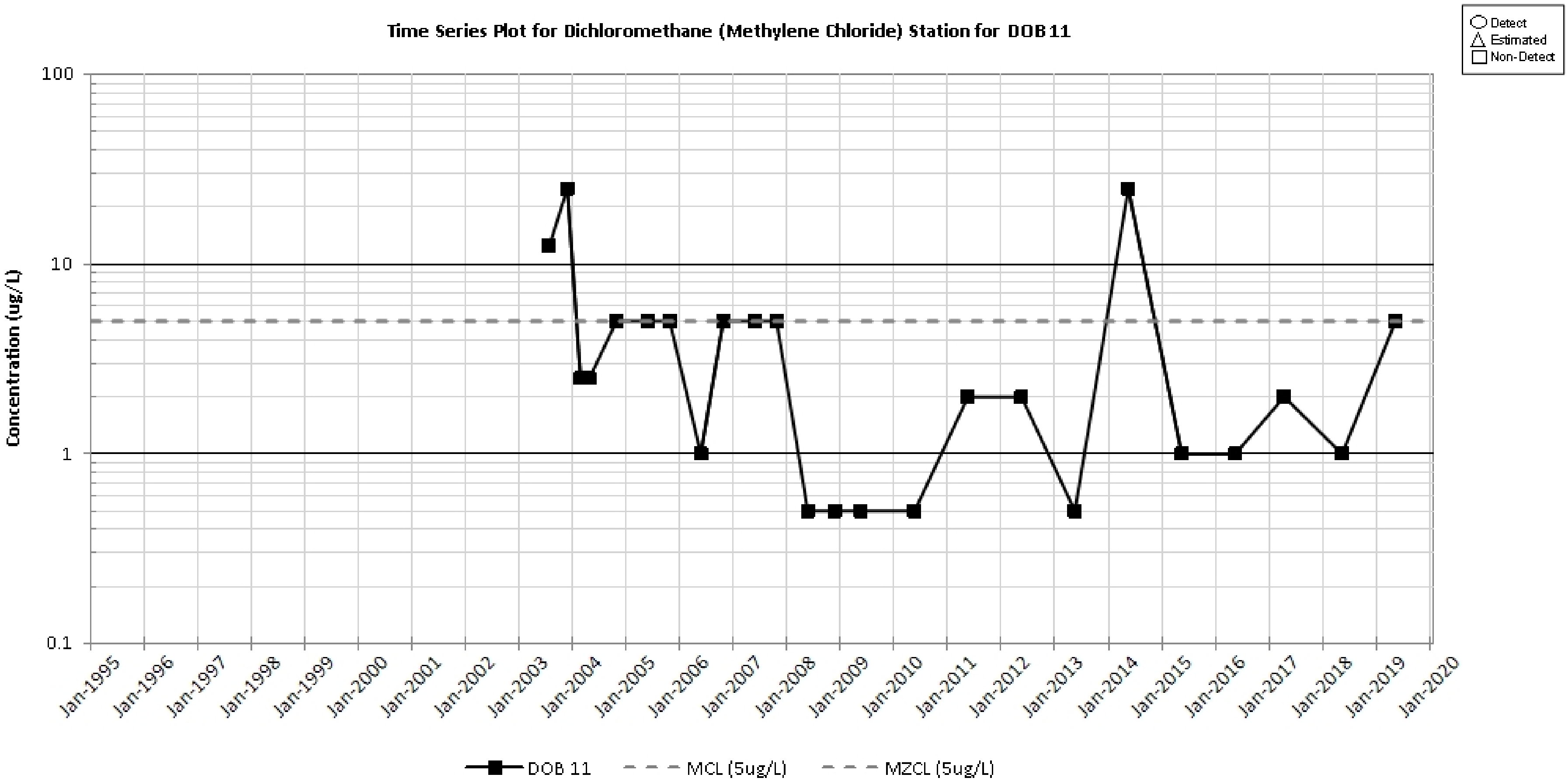


Figure D-94. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 11

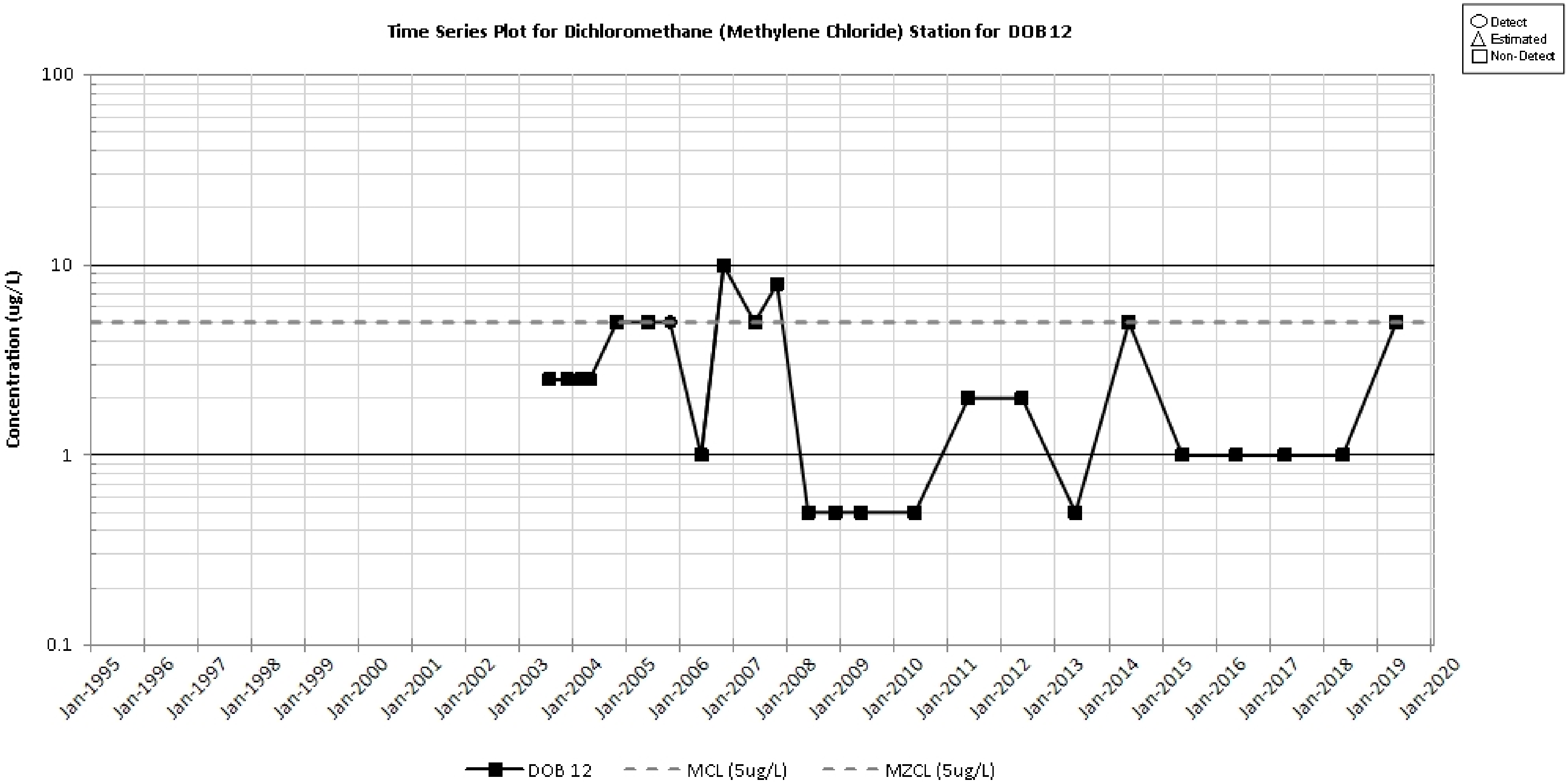


Figure D-95. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 12

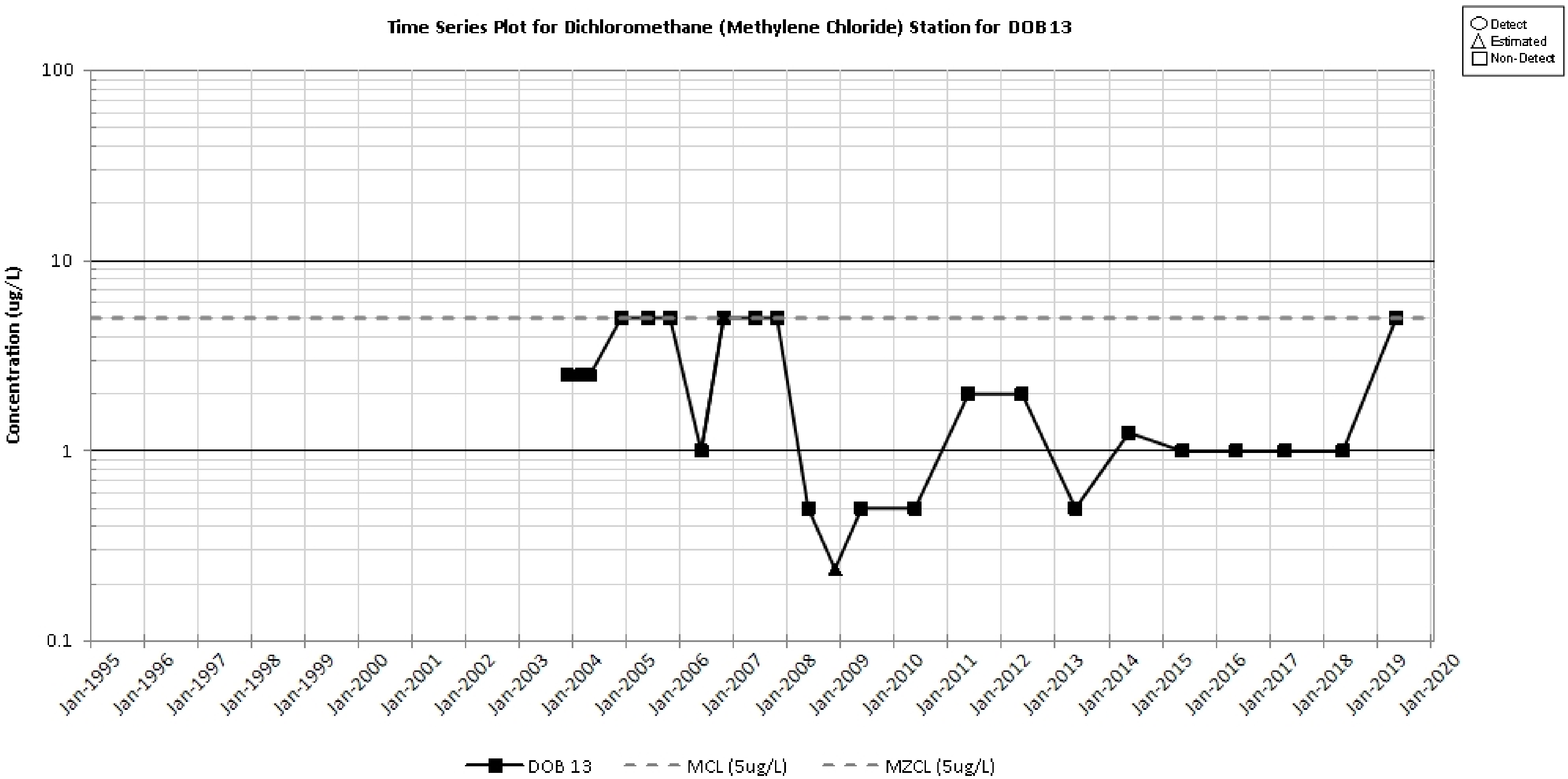


Figure D-96. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 13

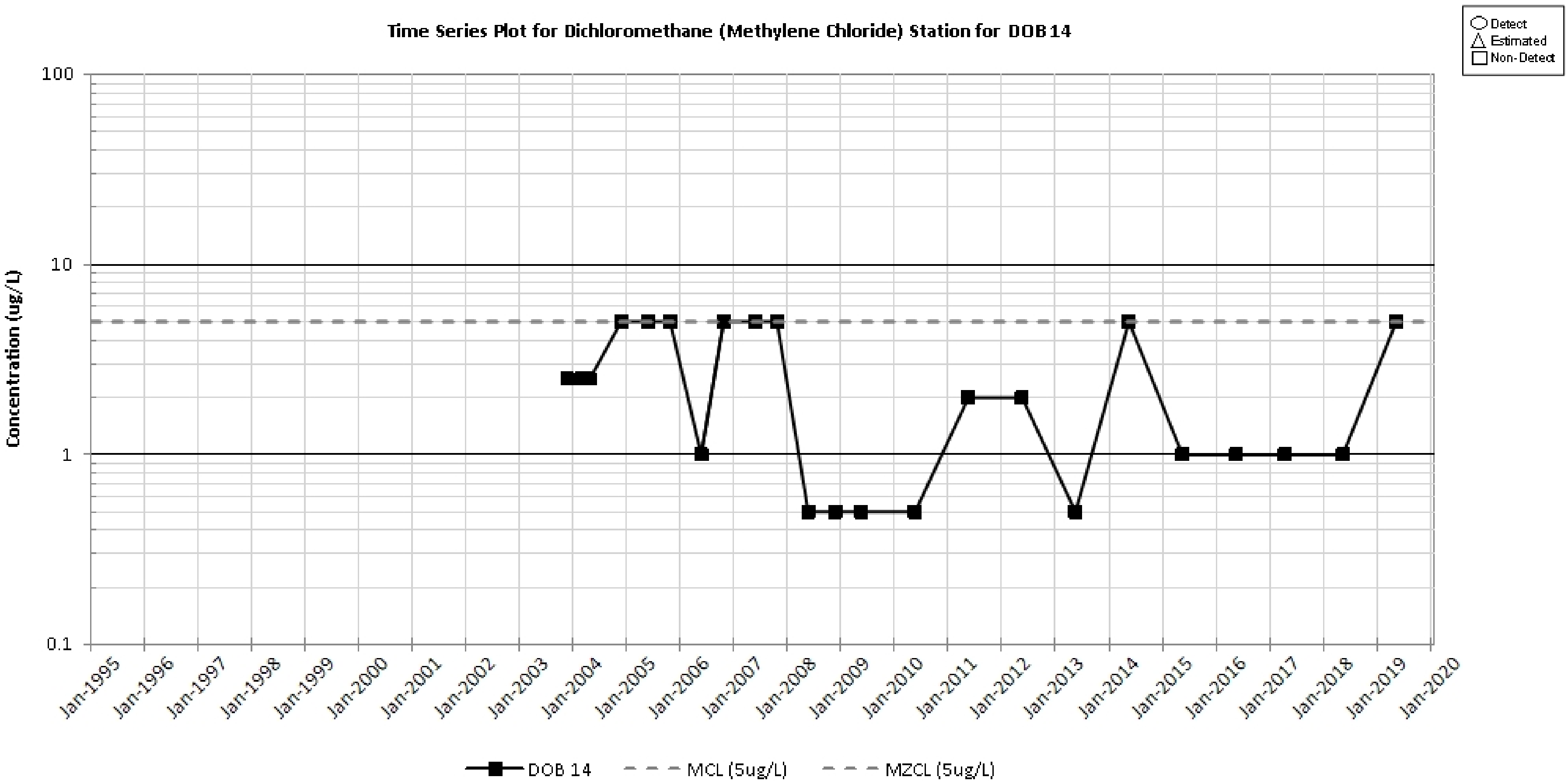


Figure D-97. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 14

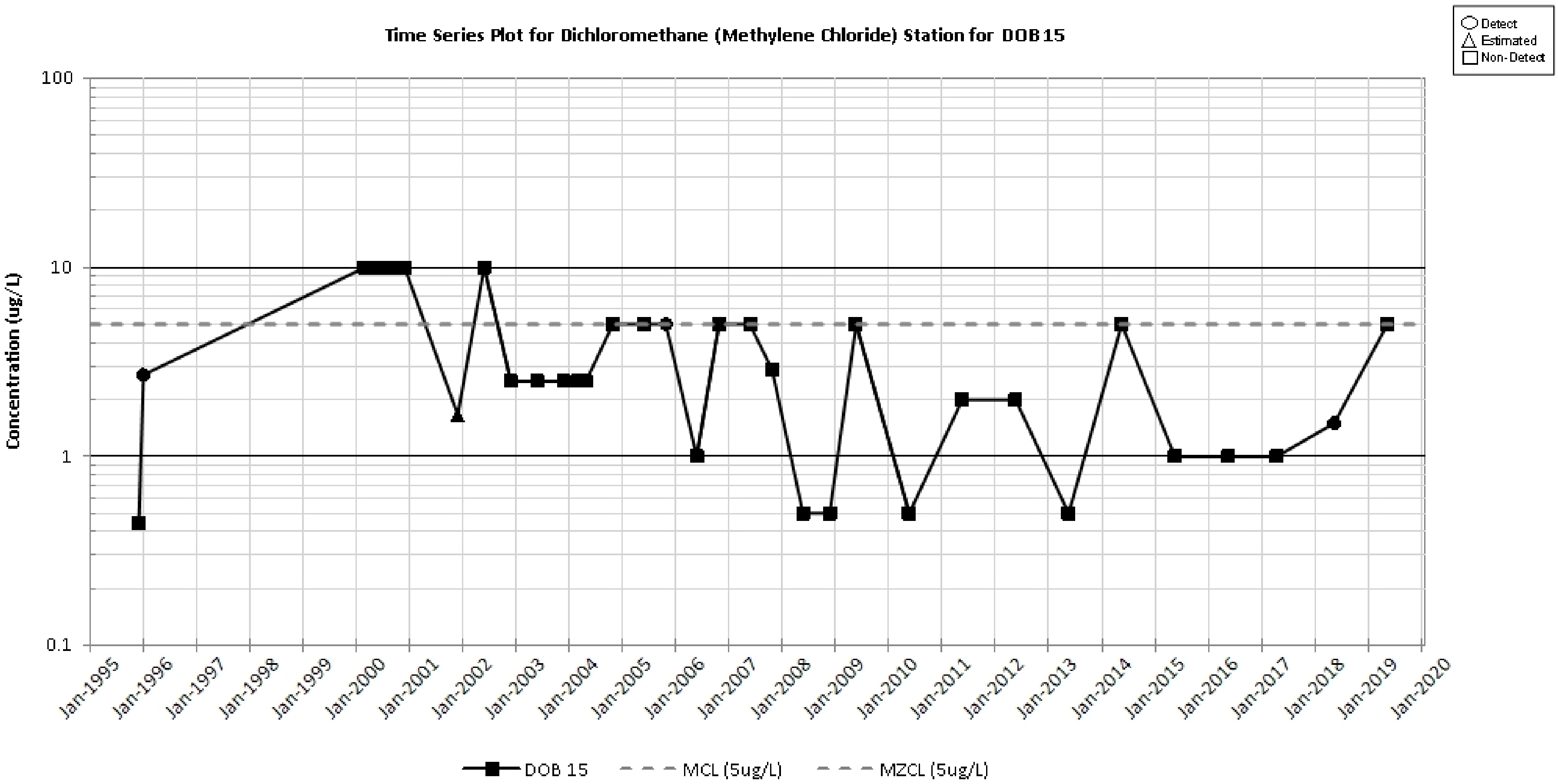


Figure D-98. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 15

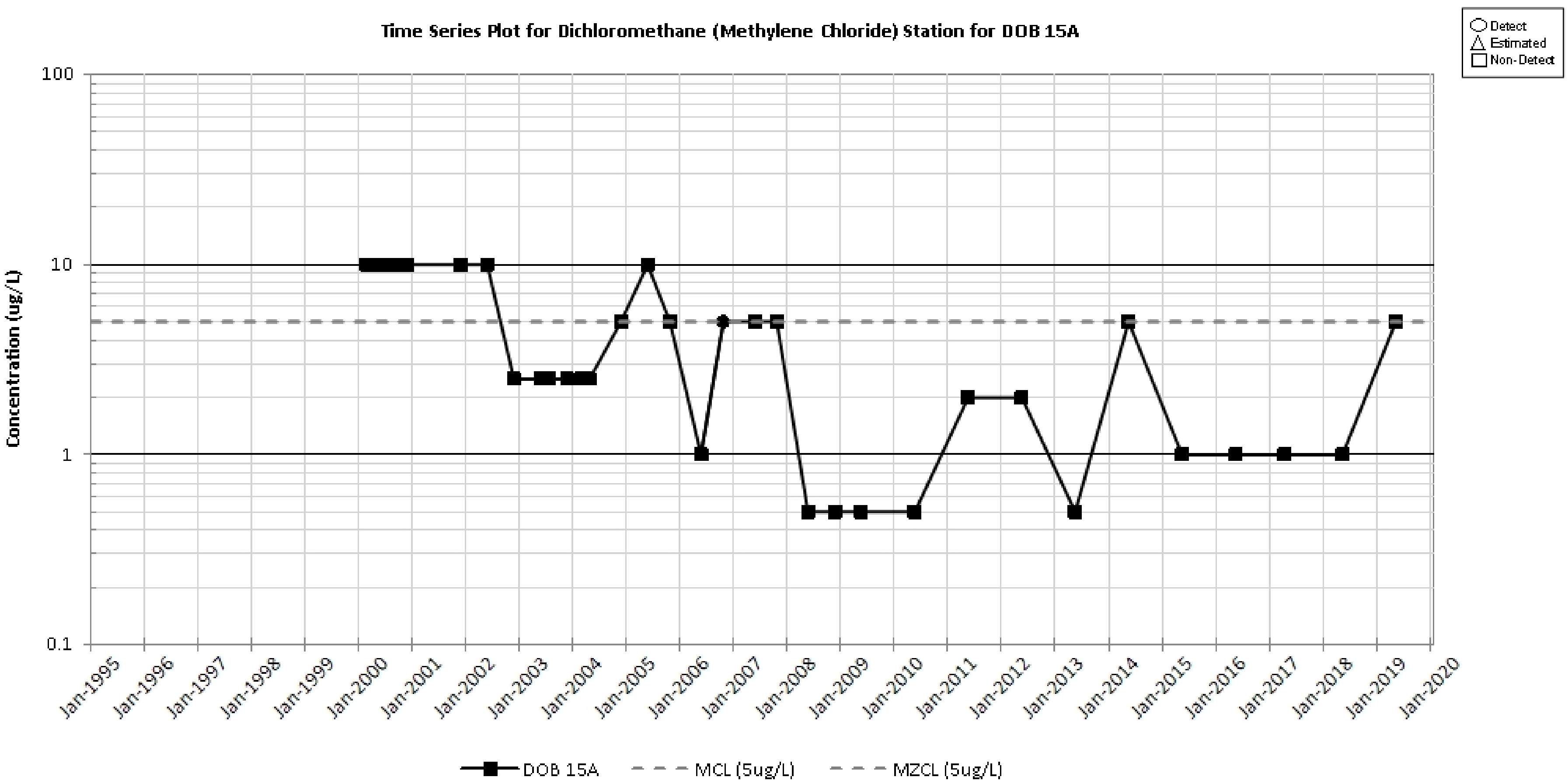


Figure D-99. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 15A

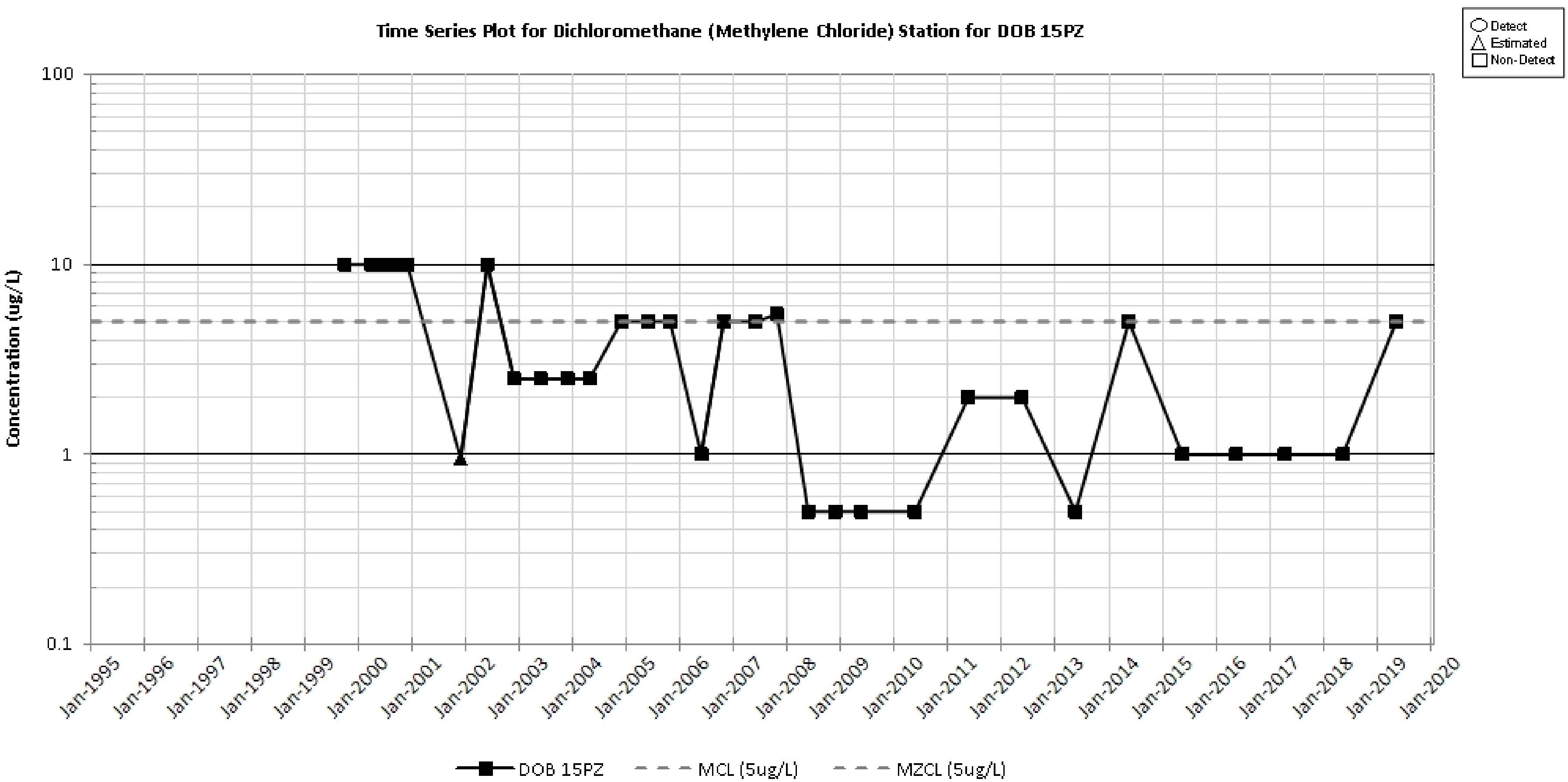


Figure D-100. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 15PZ

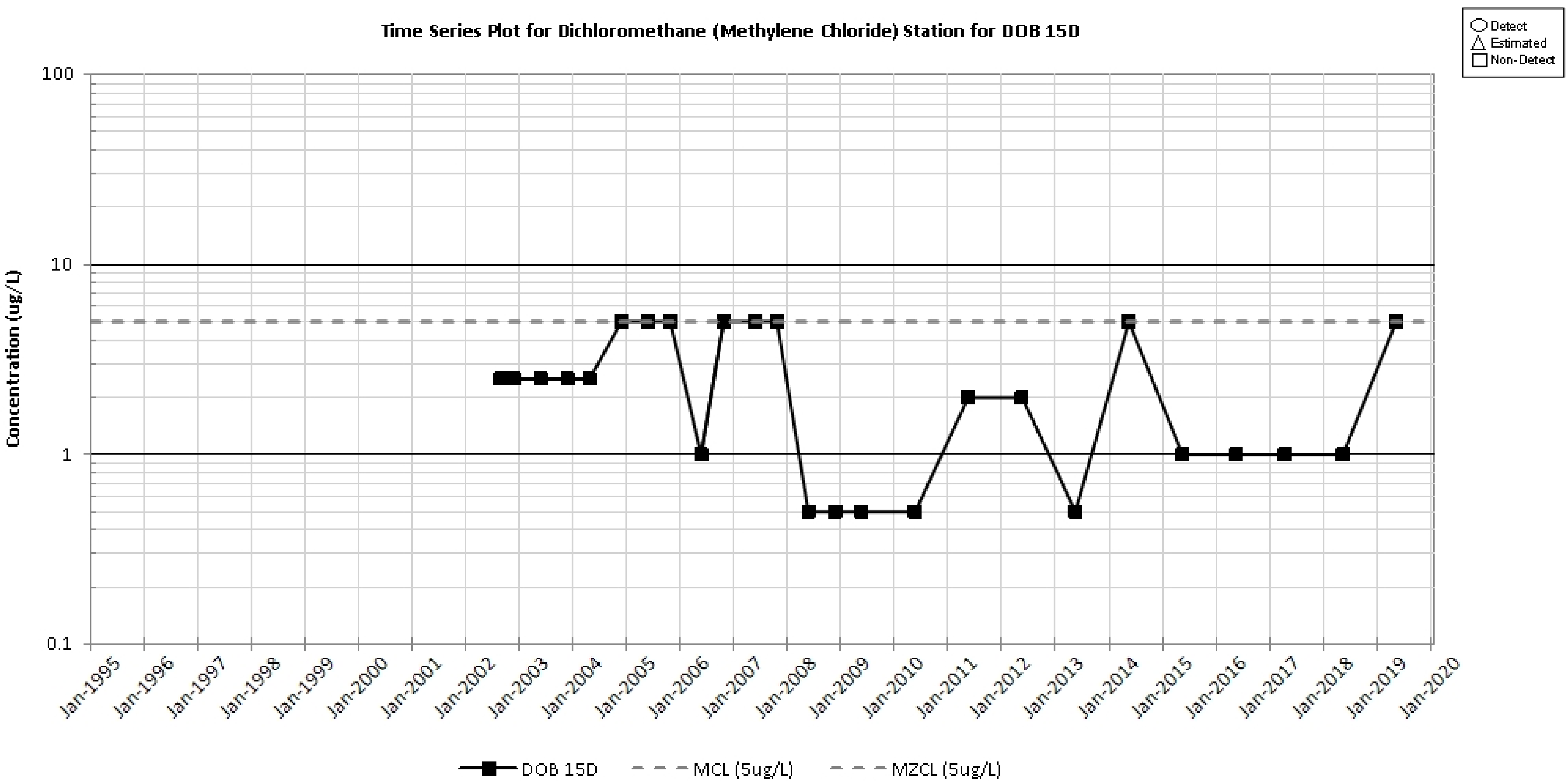


Figure D-101. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 15D

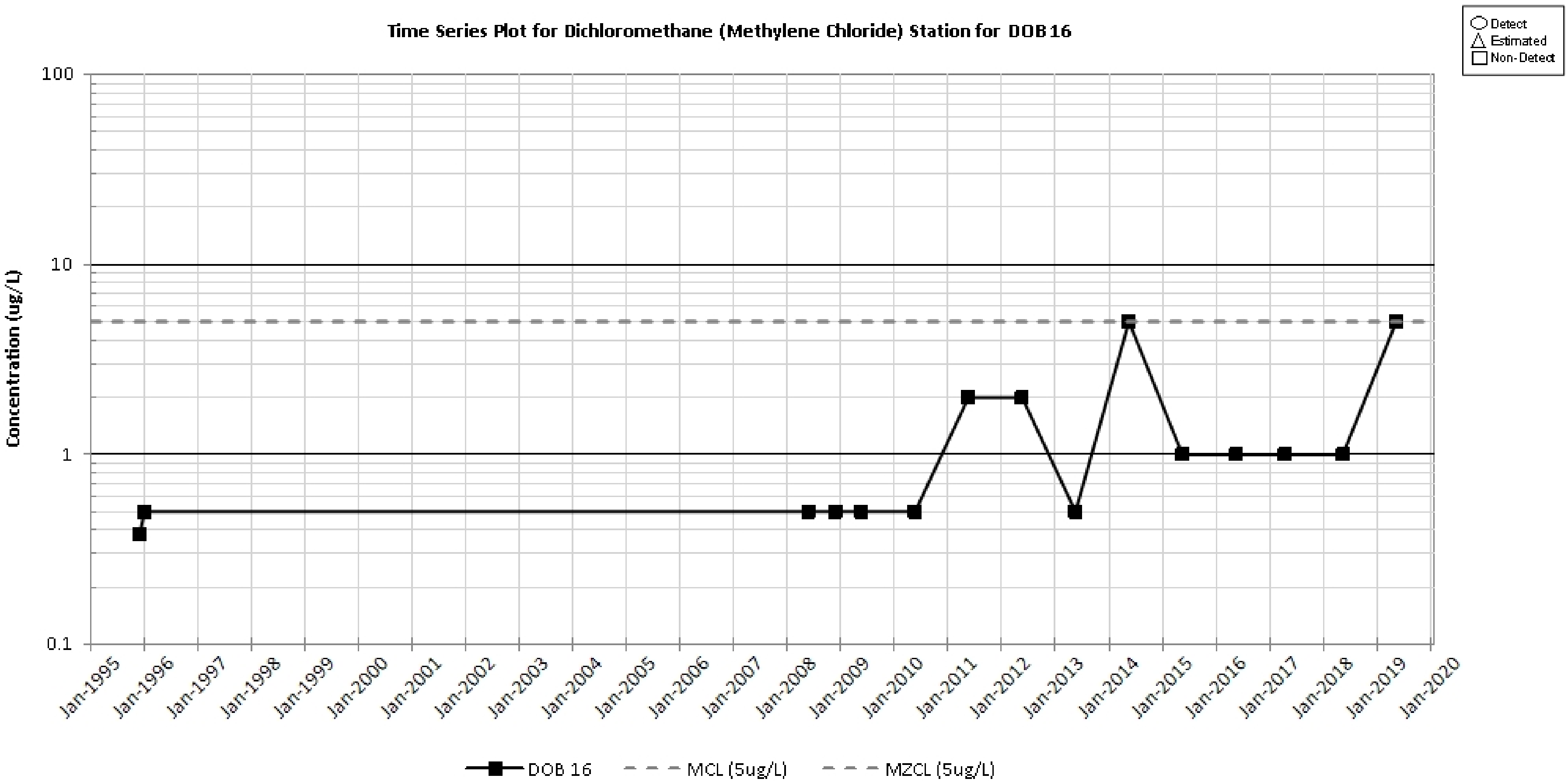


Figure D-102. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 16

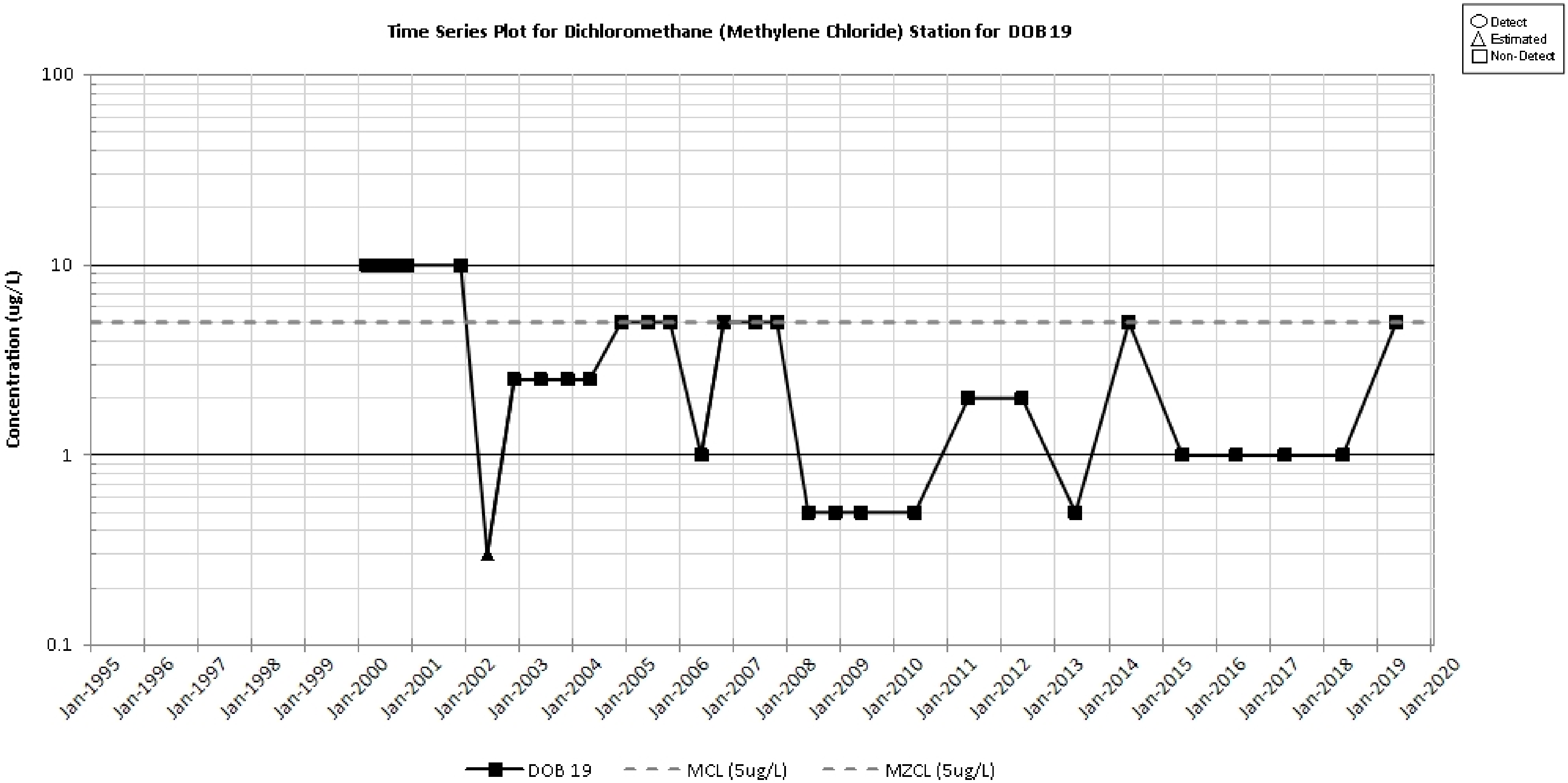


Figure D-103. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 19

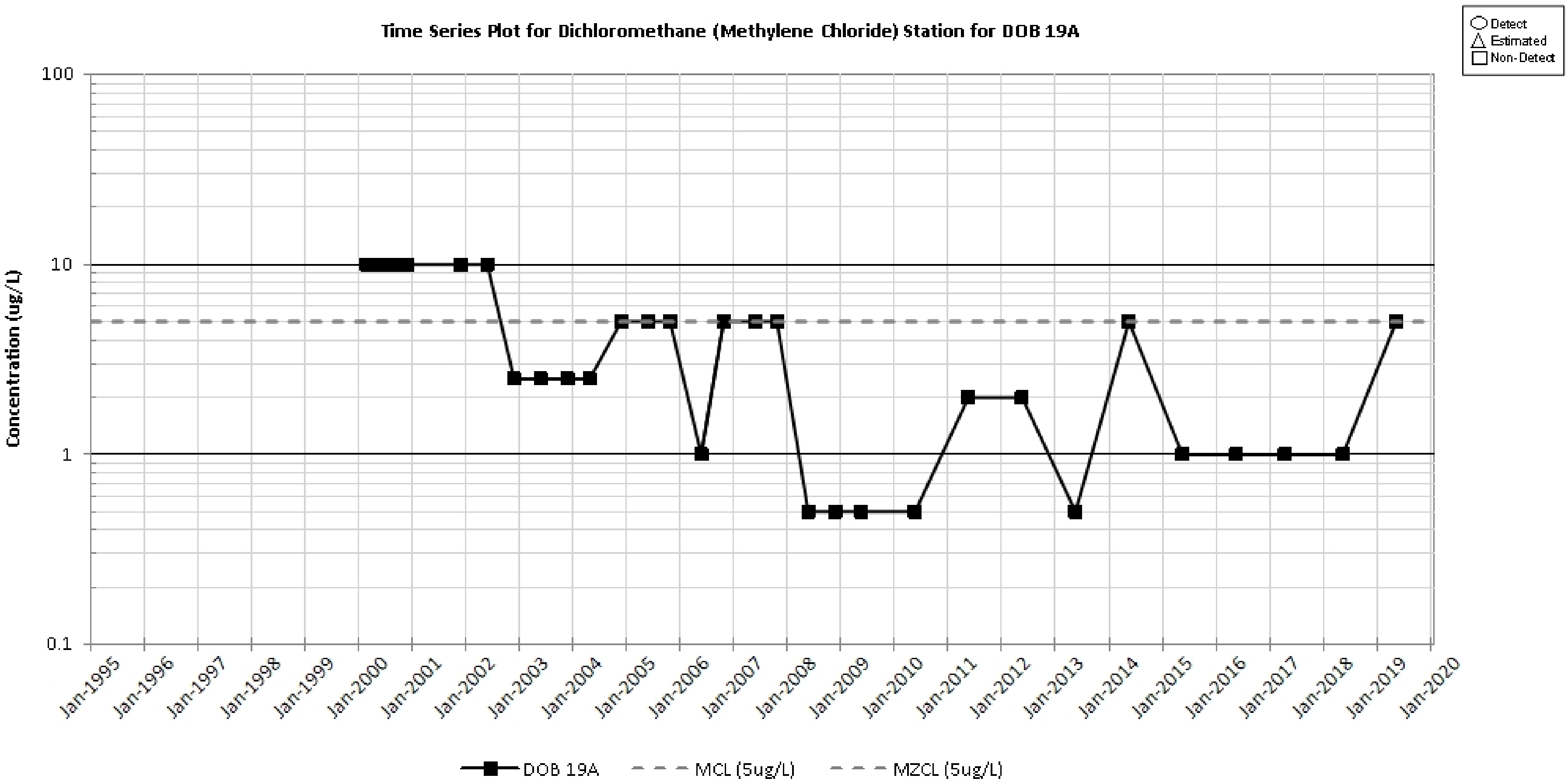


Figure D-104. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 19A

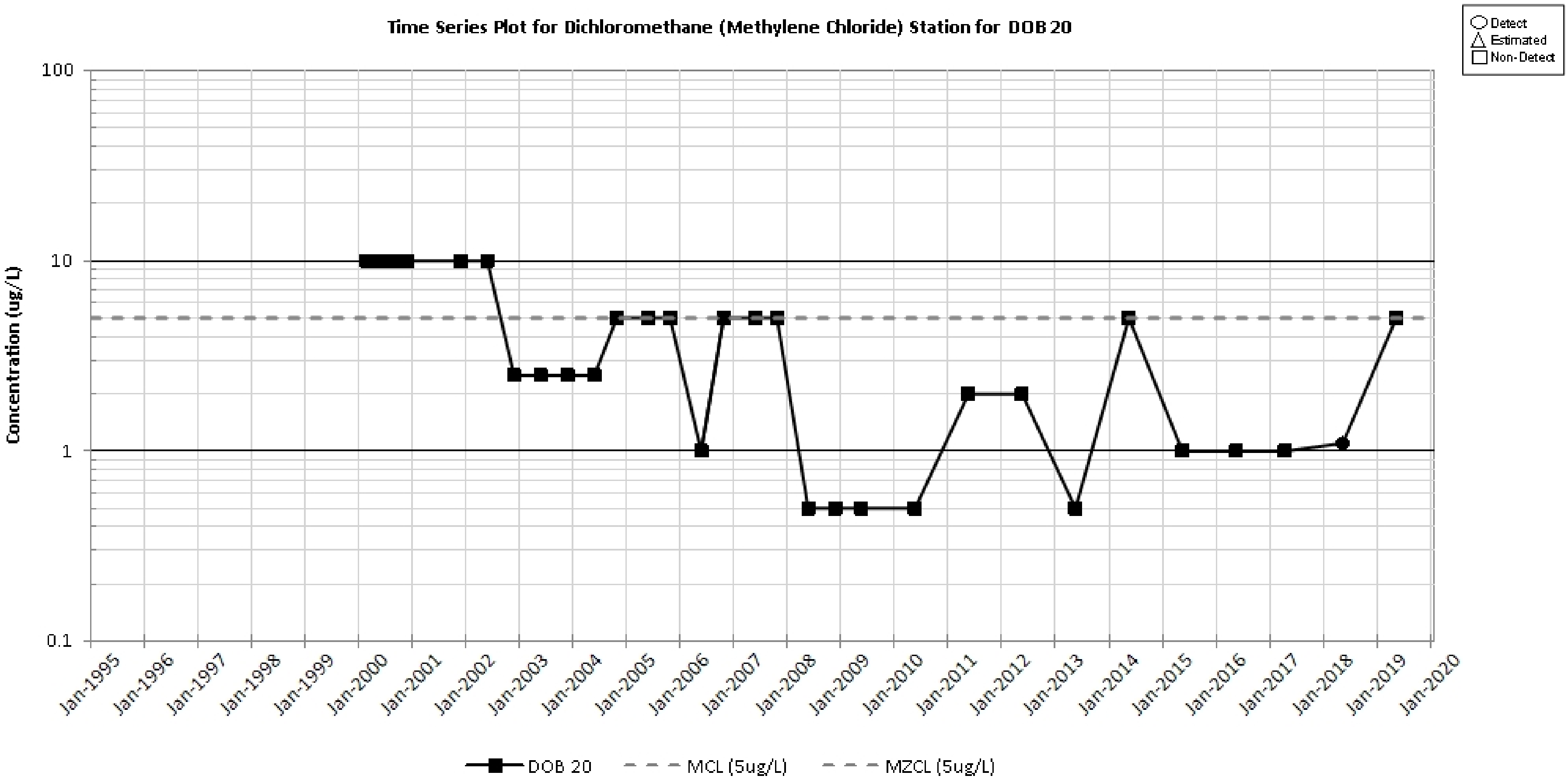


Figure D-105. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 20

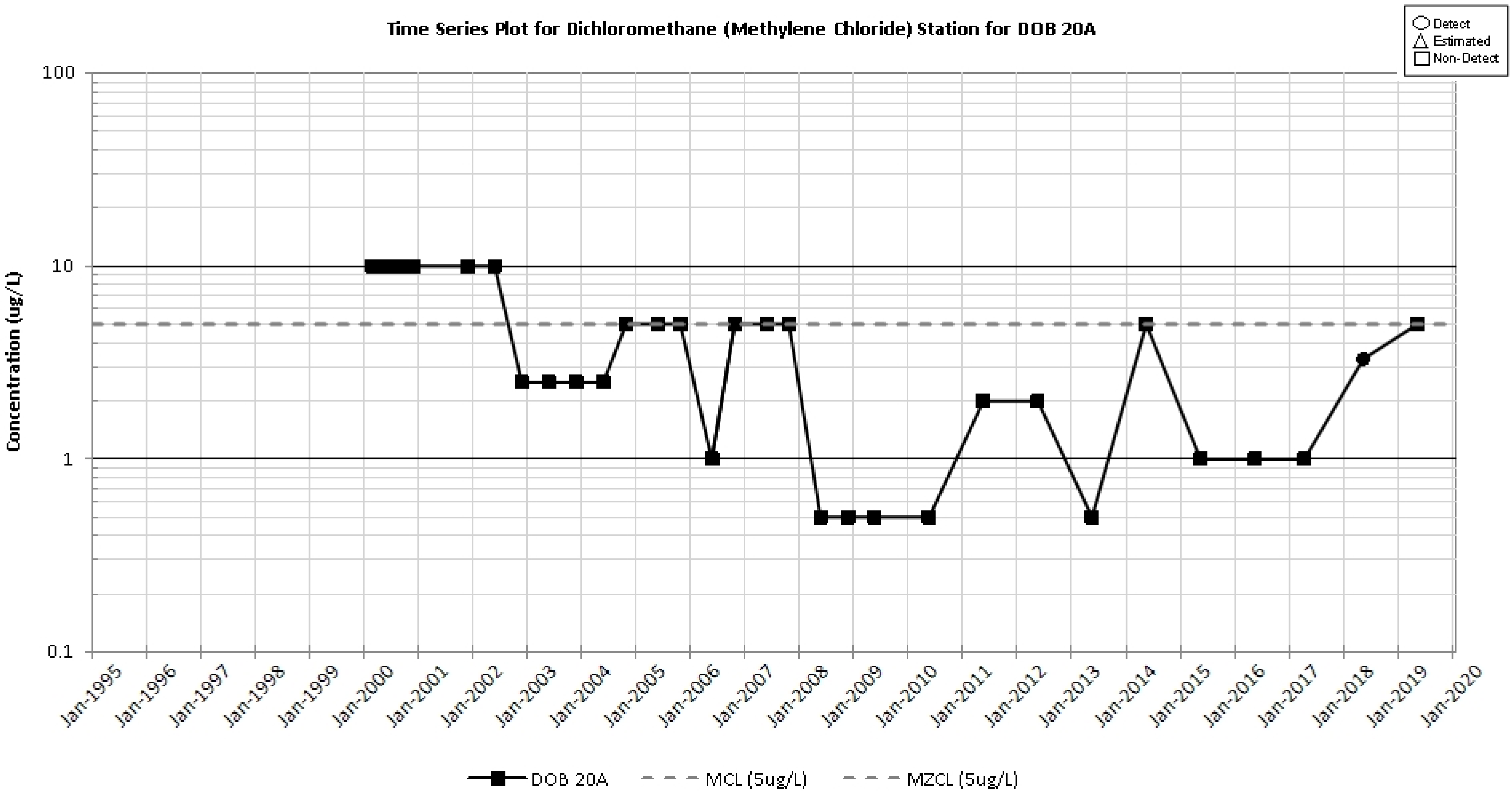


Figure D-106. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 20A

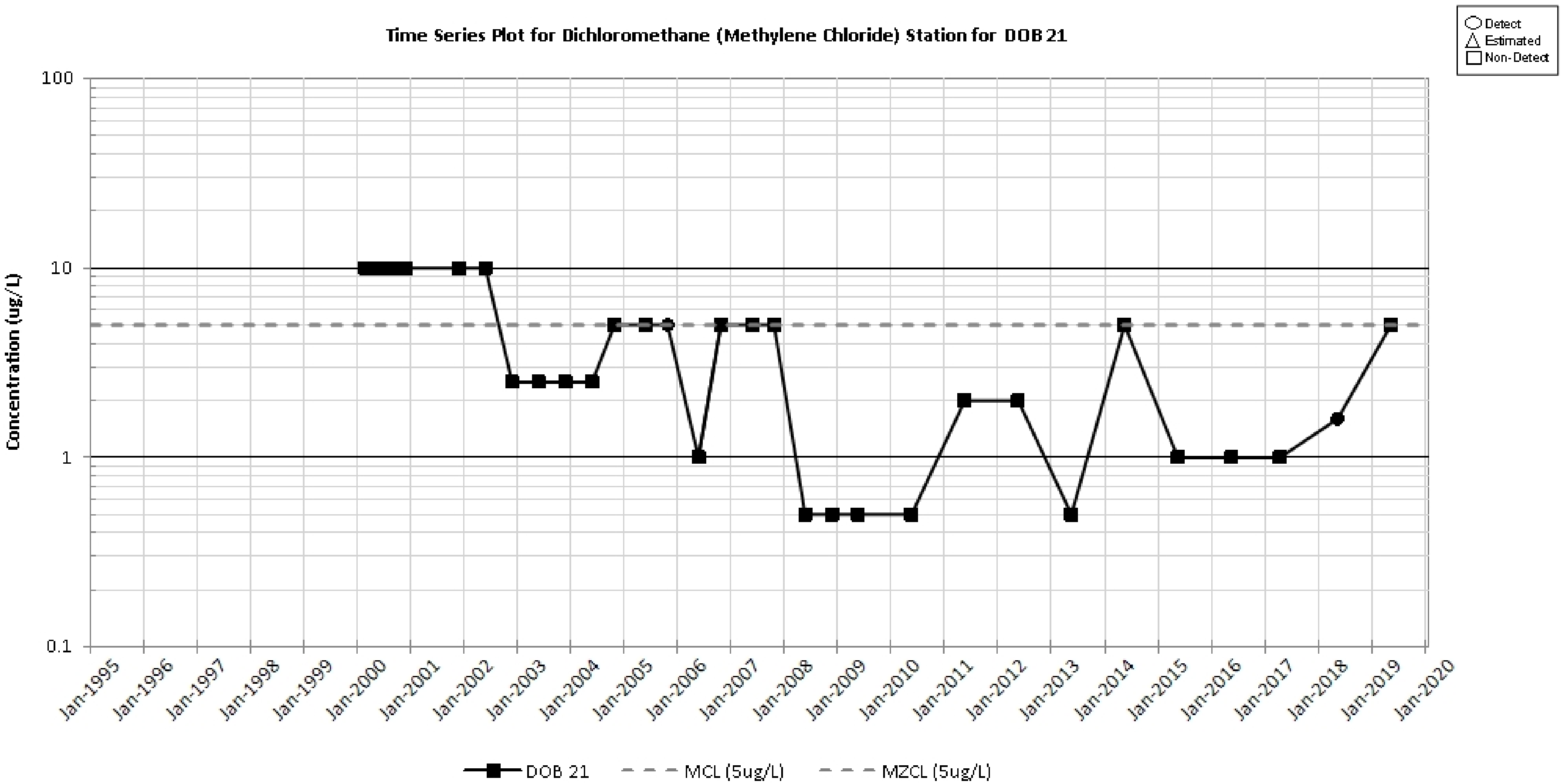


Figure D-107. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 21

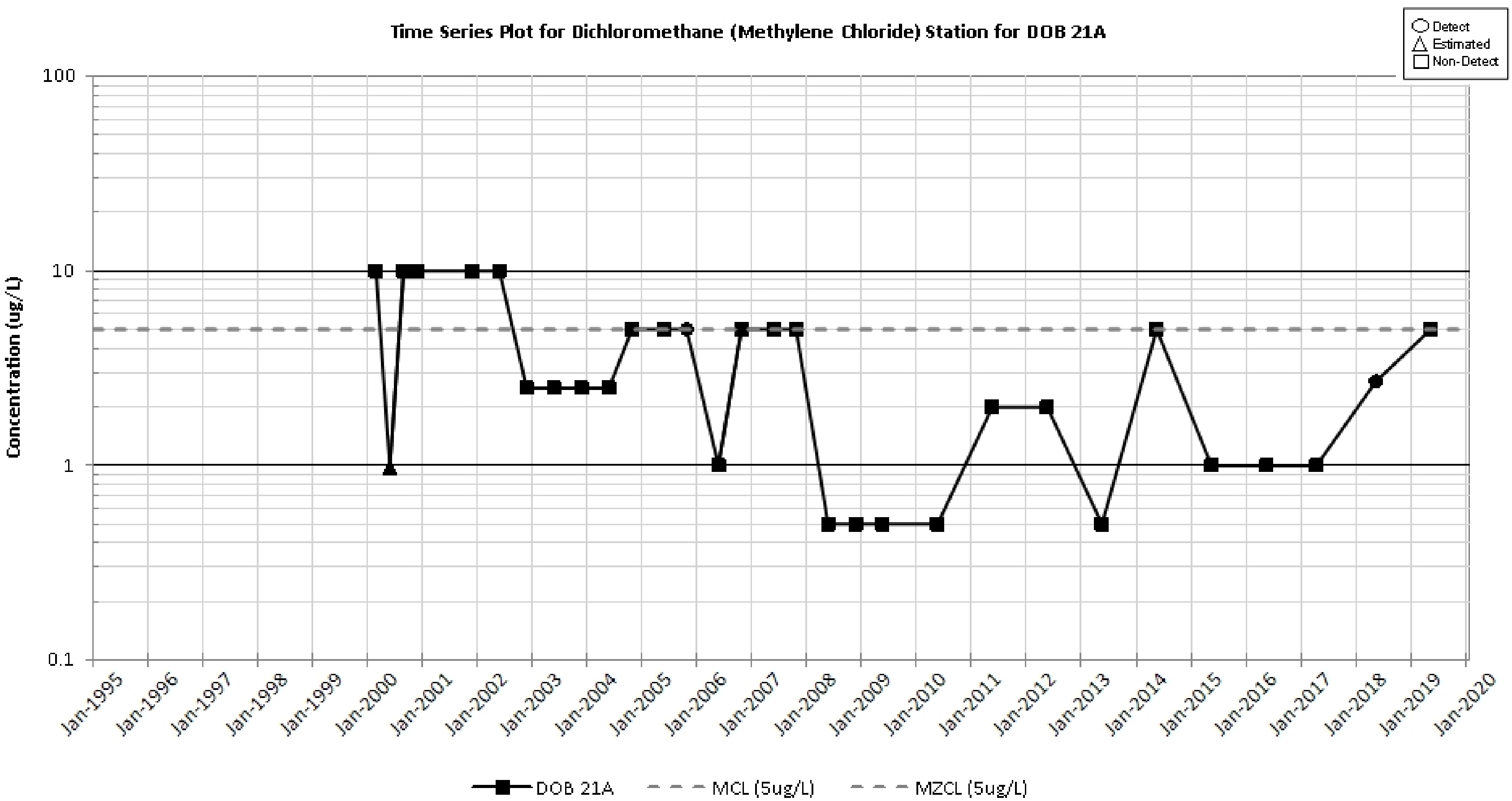


Figure D-108. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 21A

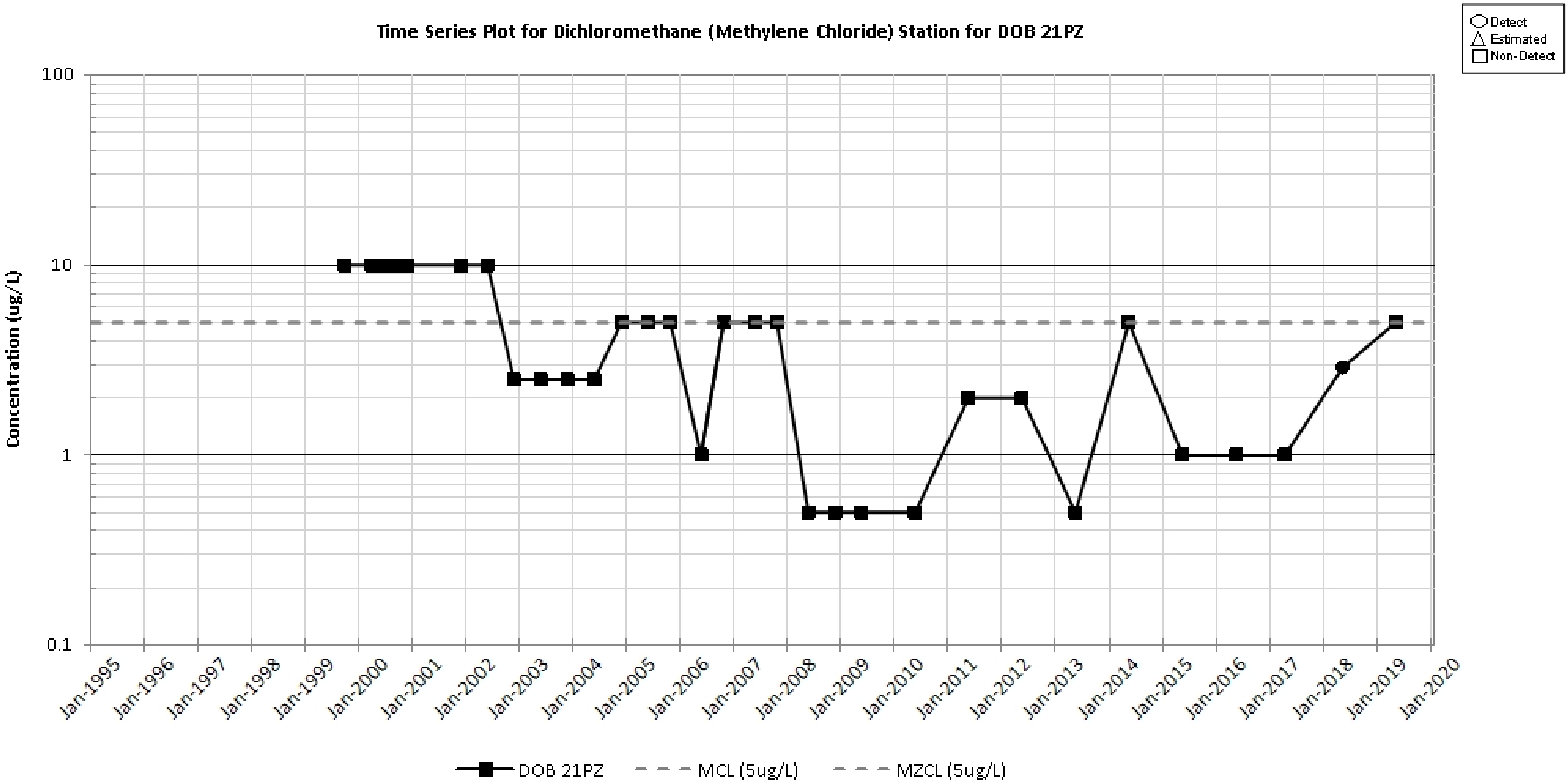


Figure D-109. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 21PZ

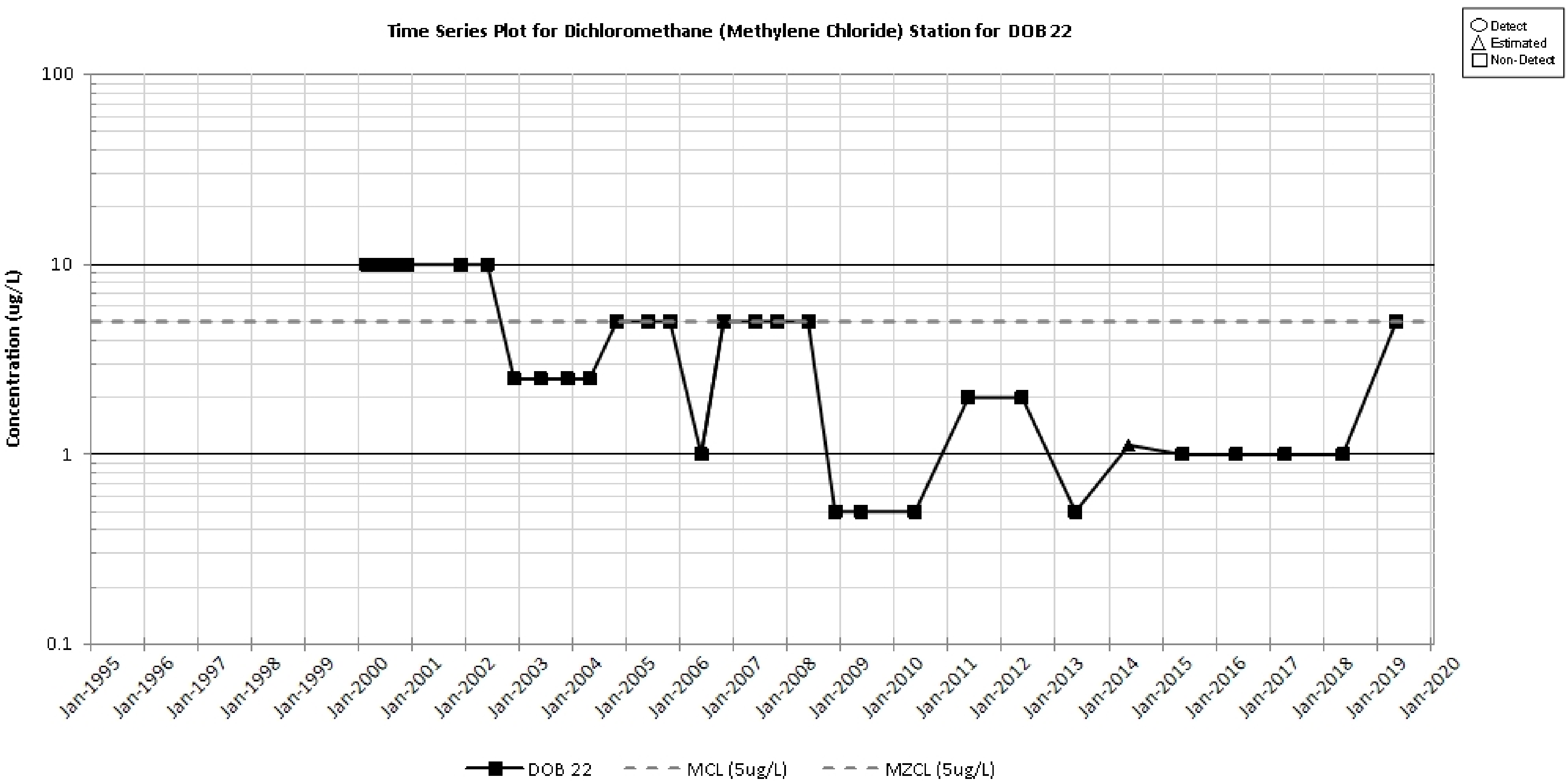


Figure D-110. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 22

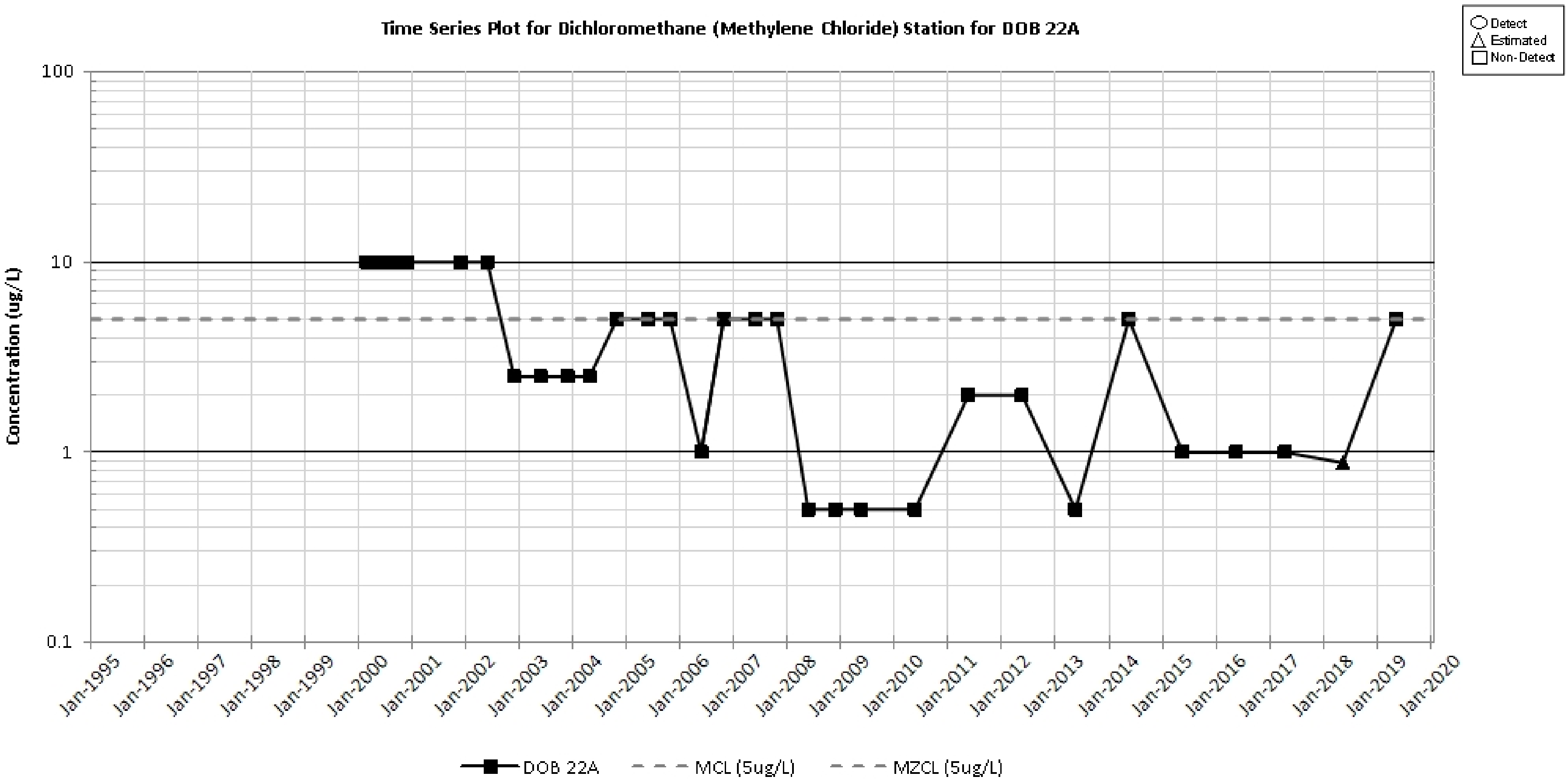


Figure D-111. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 22A

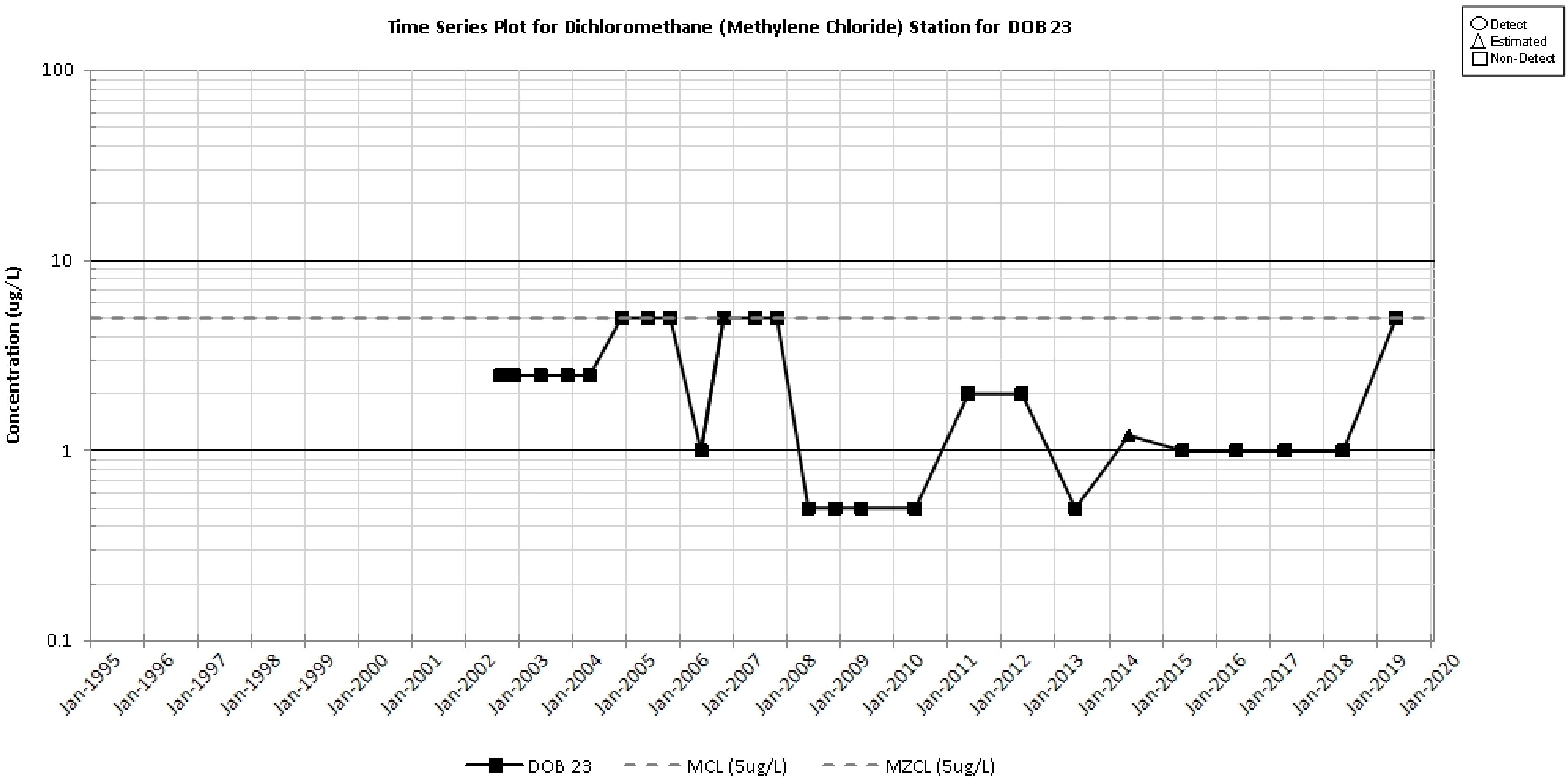


Figure D-112. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB 23

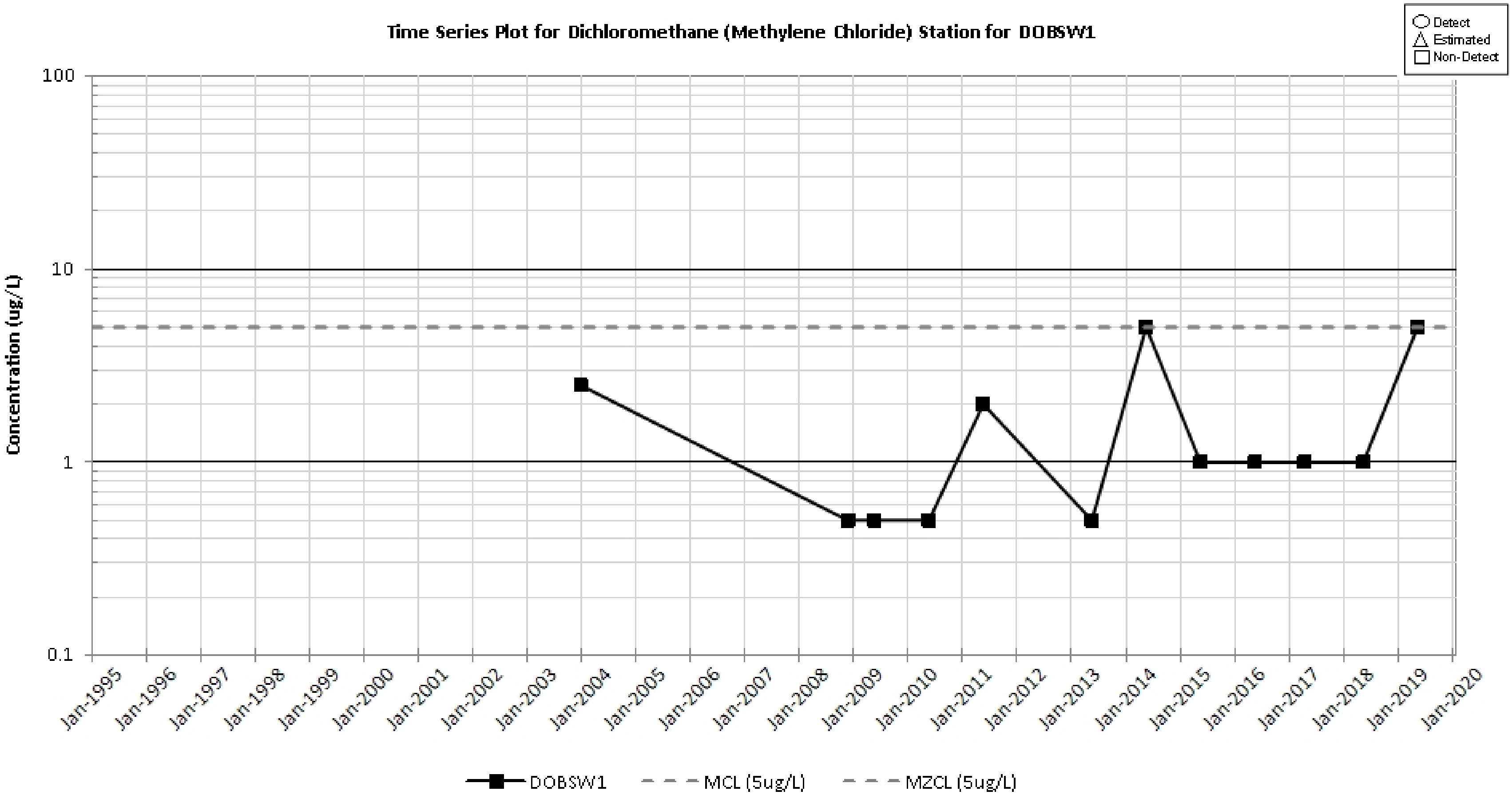


Figure D-113. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOB SW1

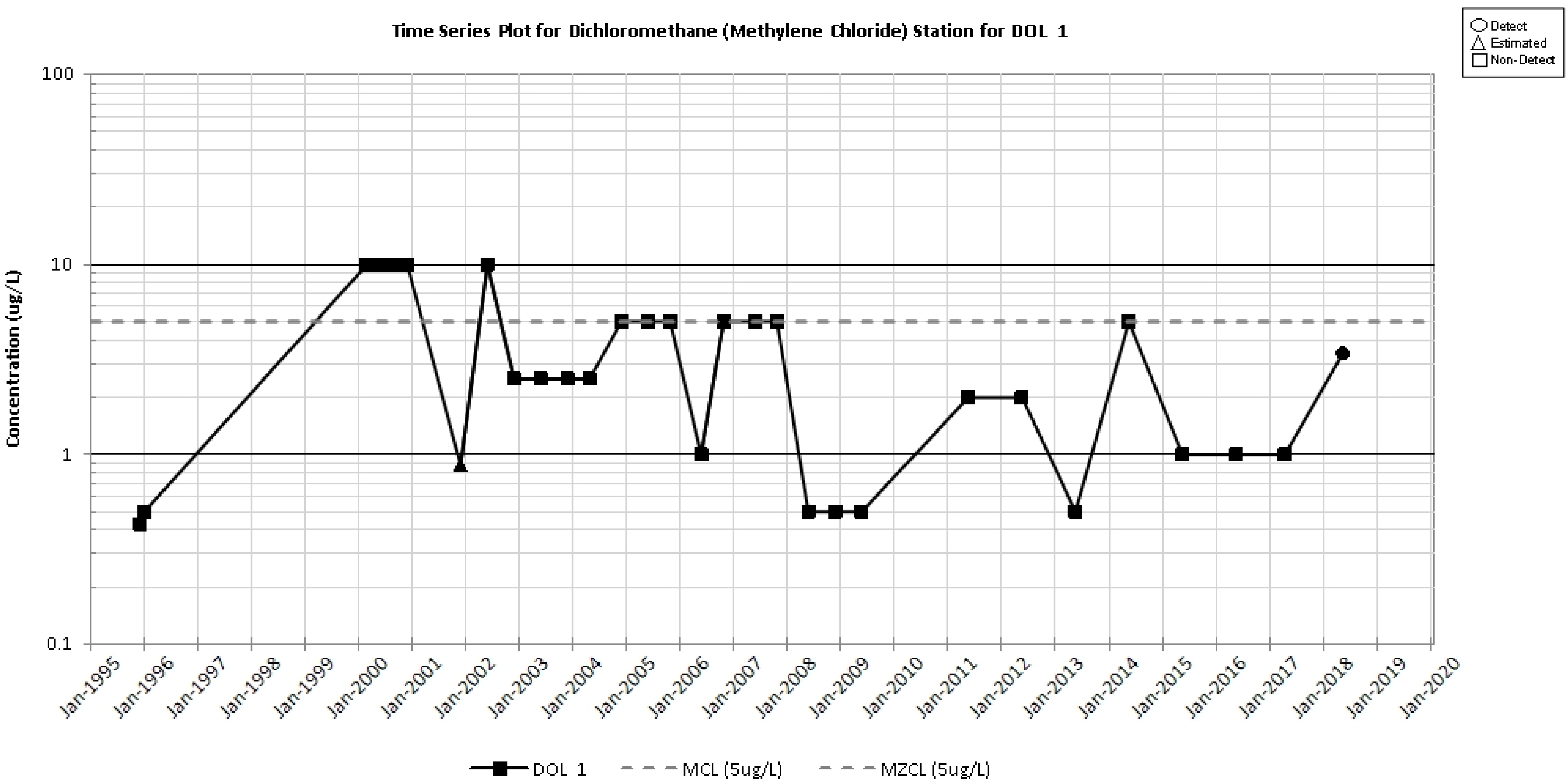


Figure D-114. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOL 1

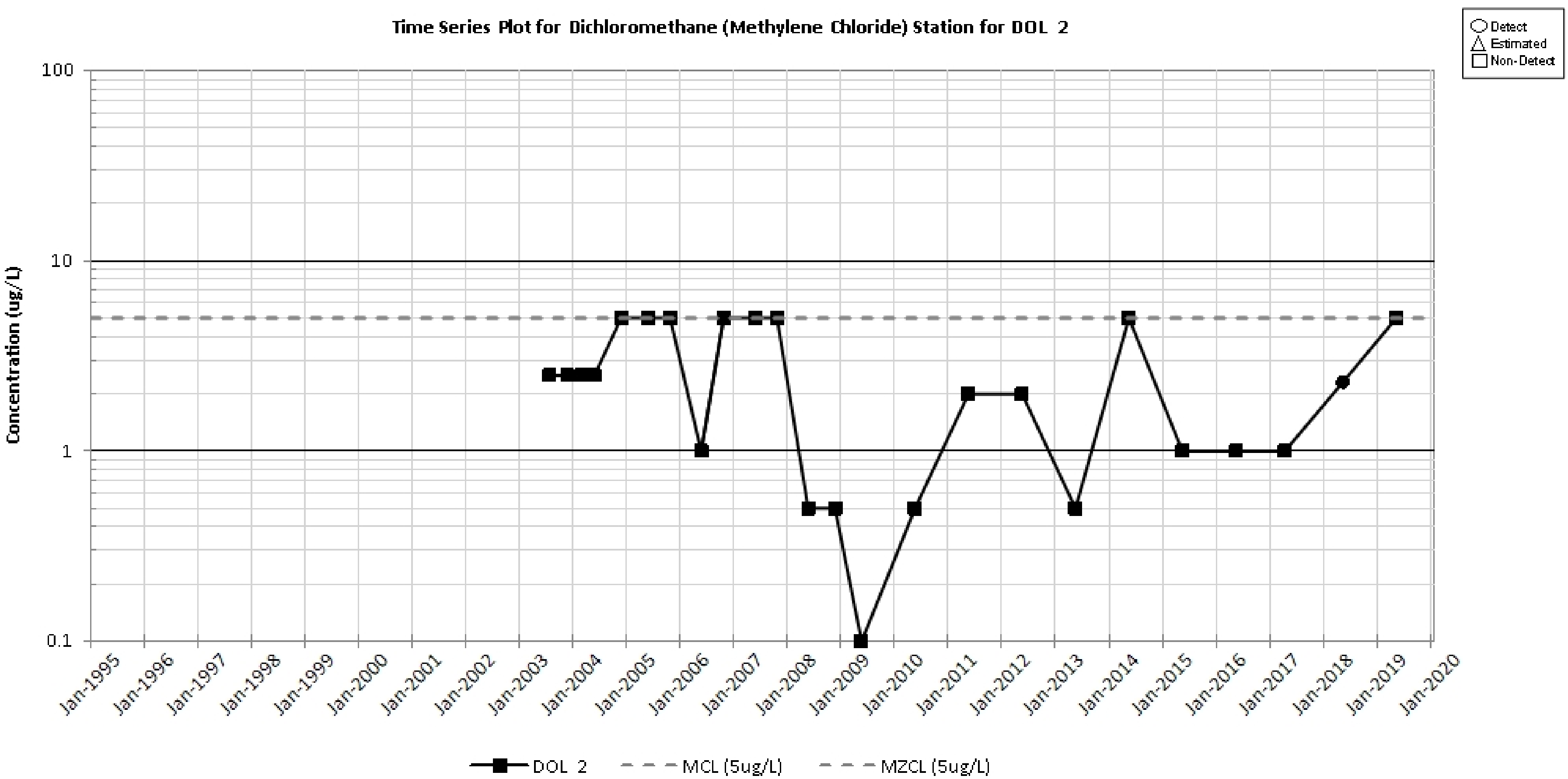


Figure D-115. Time Series Plot for Dichloromethane (Methylene Chloride) Station for DOL 2

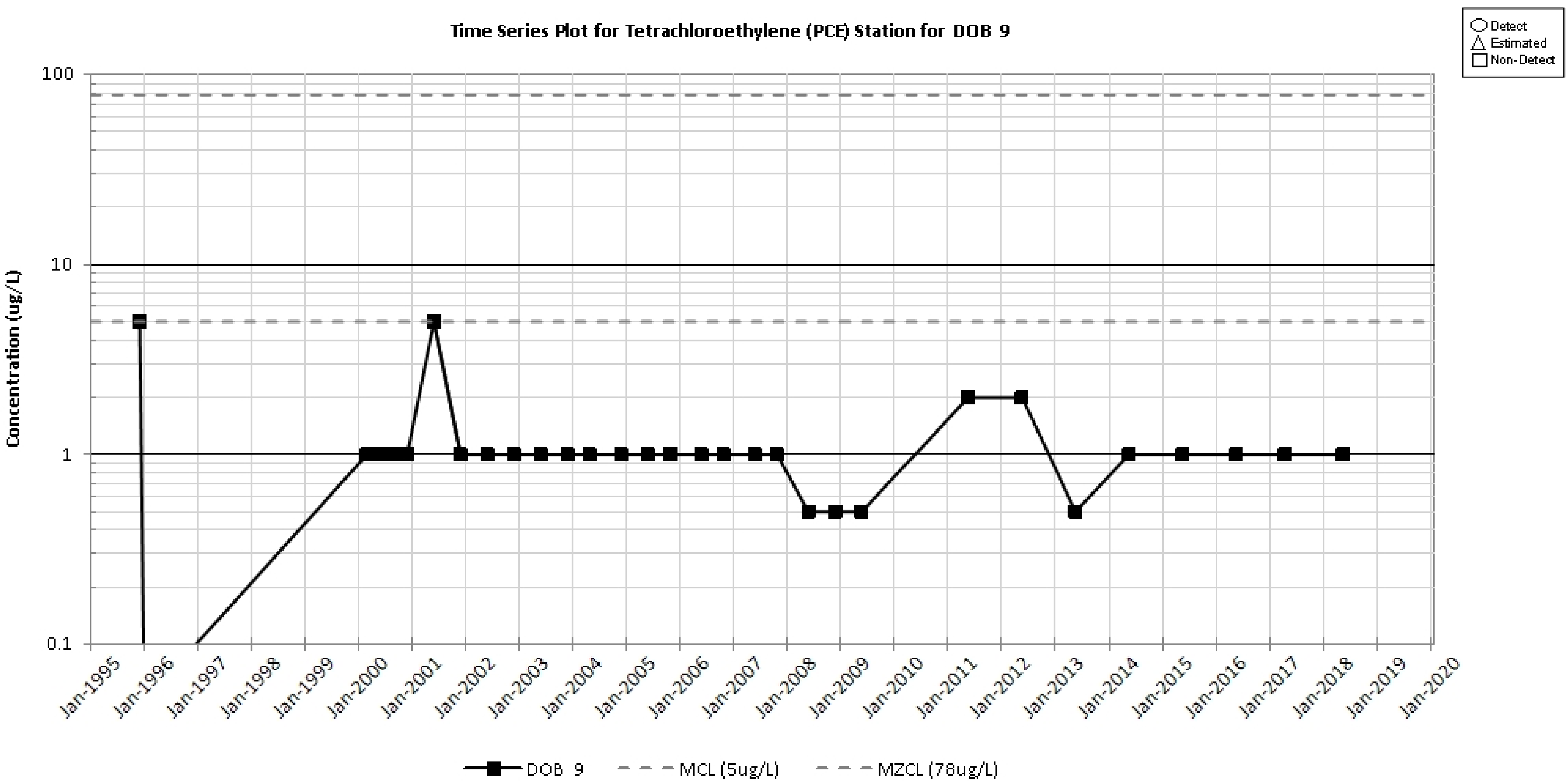


Figure D-116. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 9

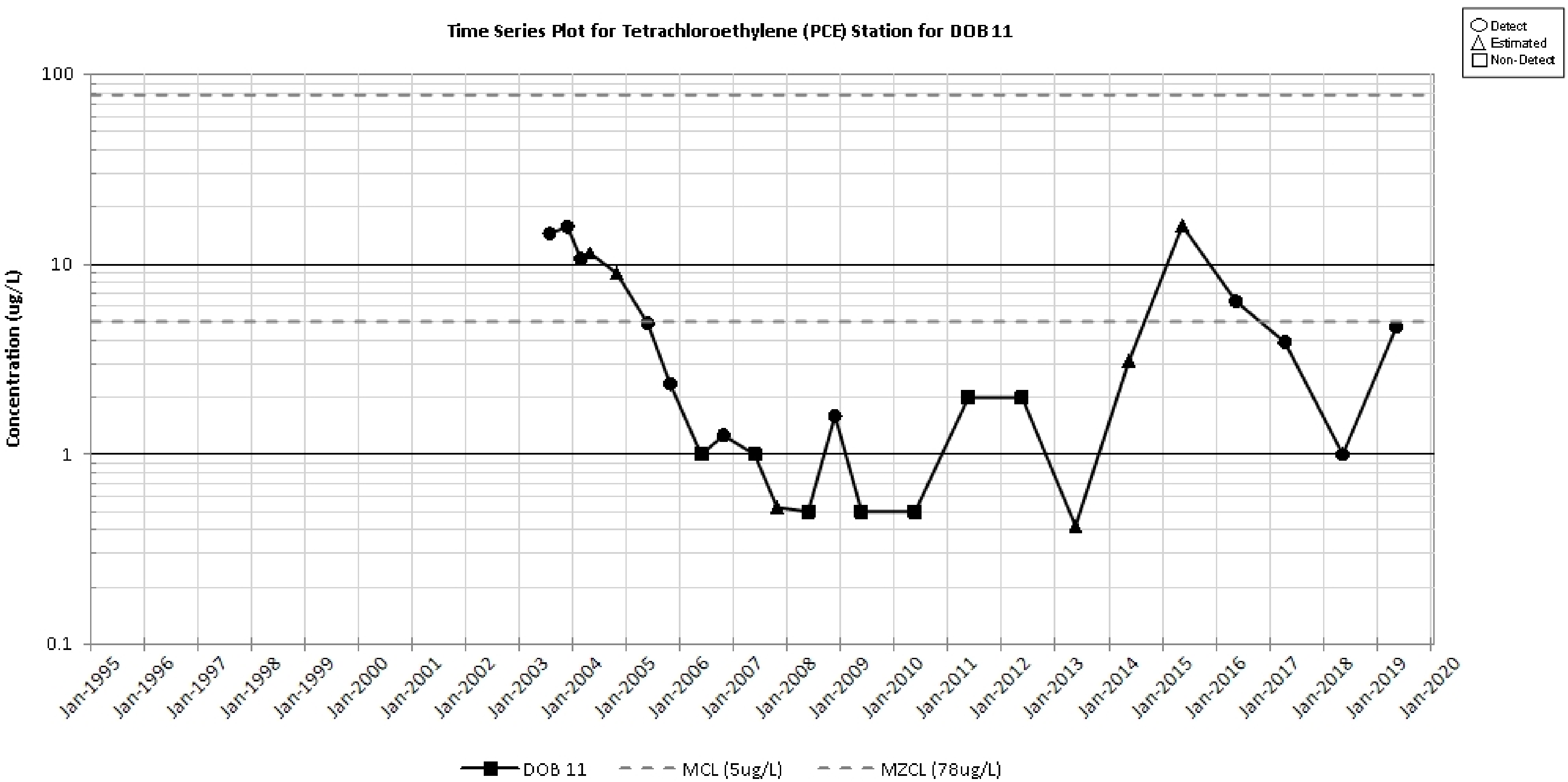


Figure D-117. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 11

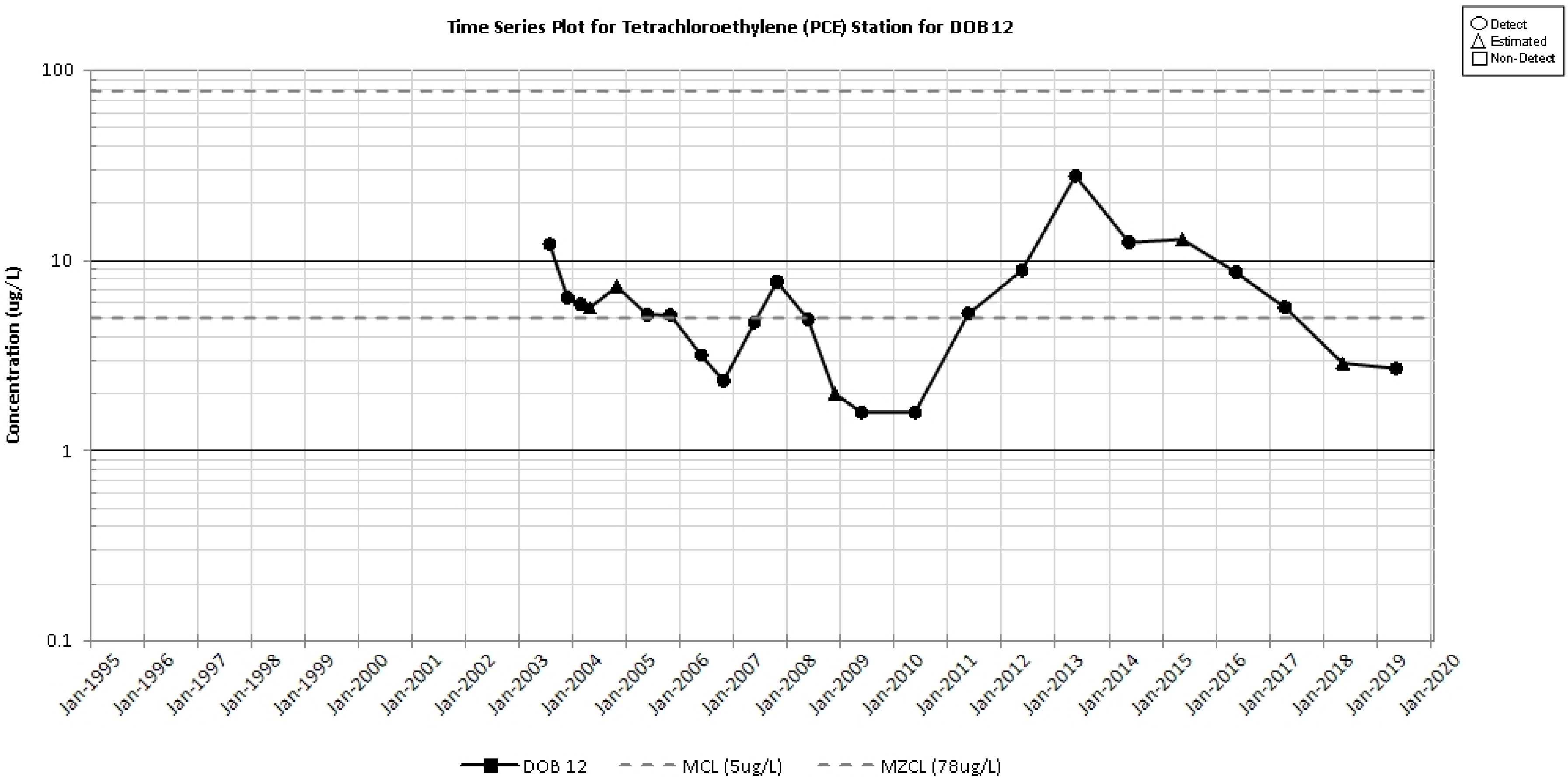


Figure D-118. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 12

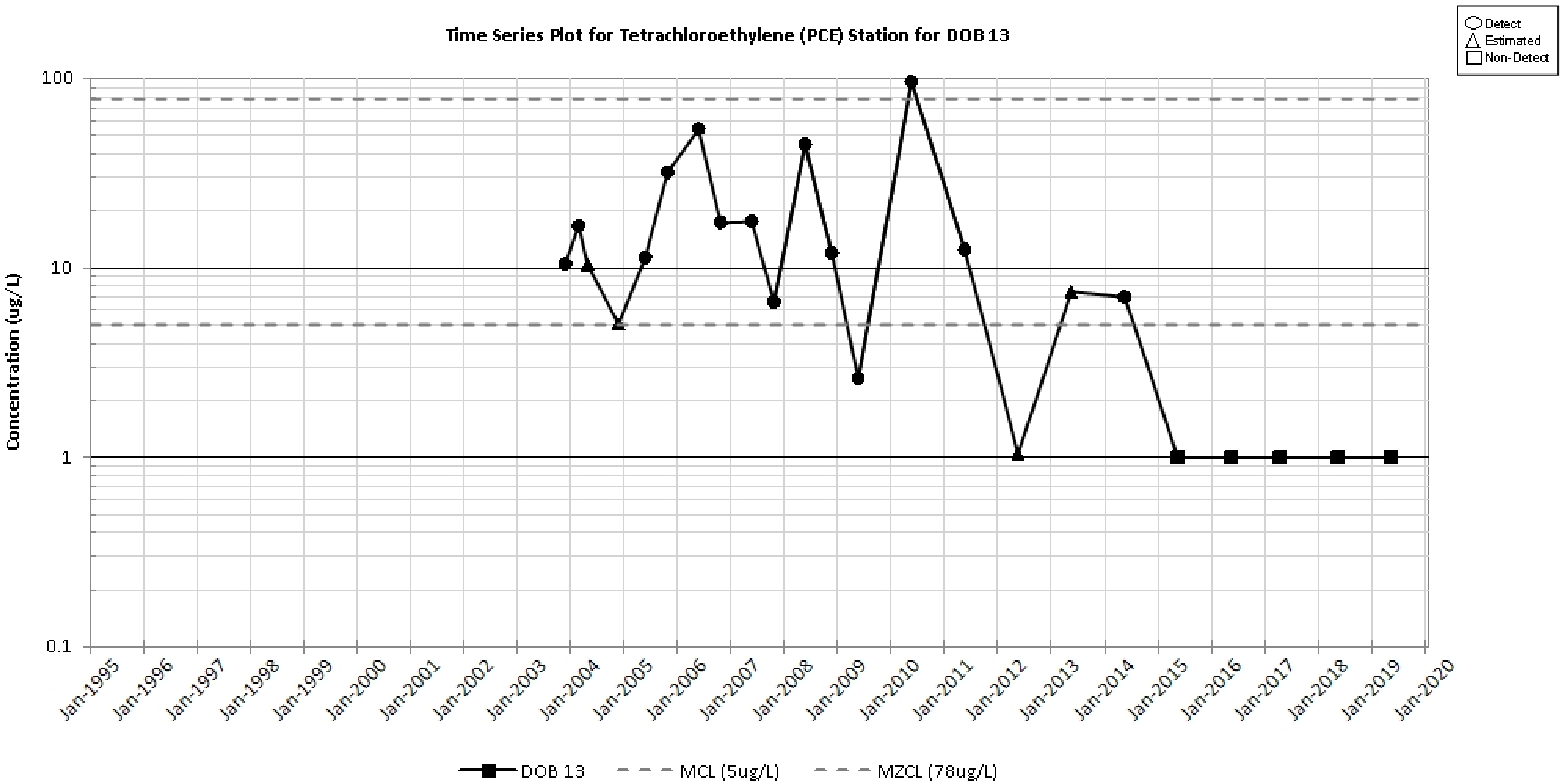


Figure D-119. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 13

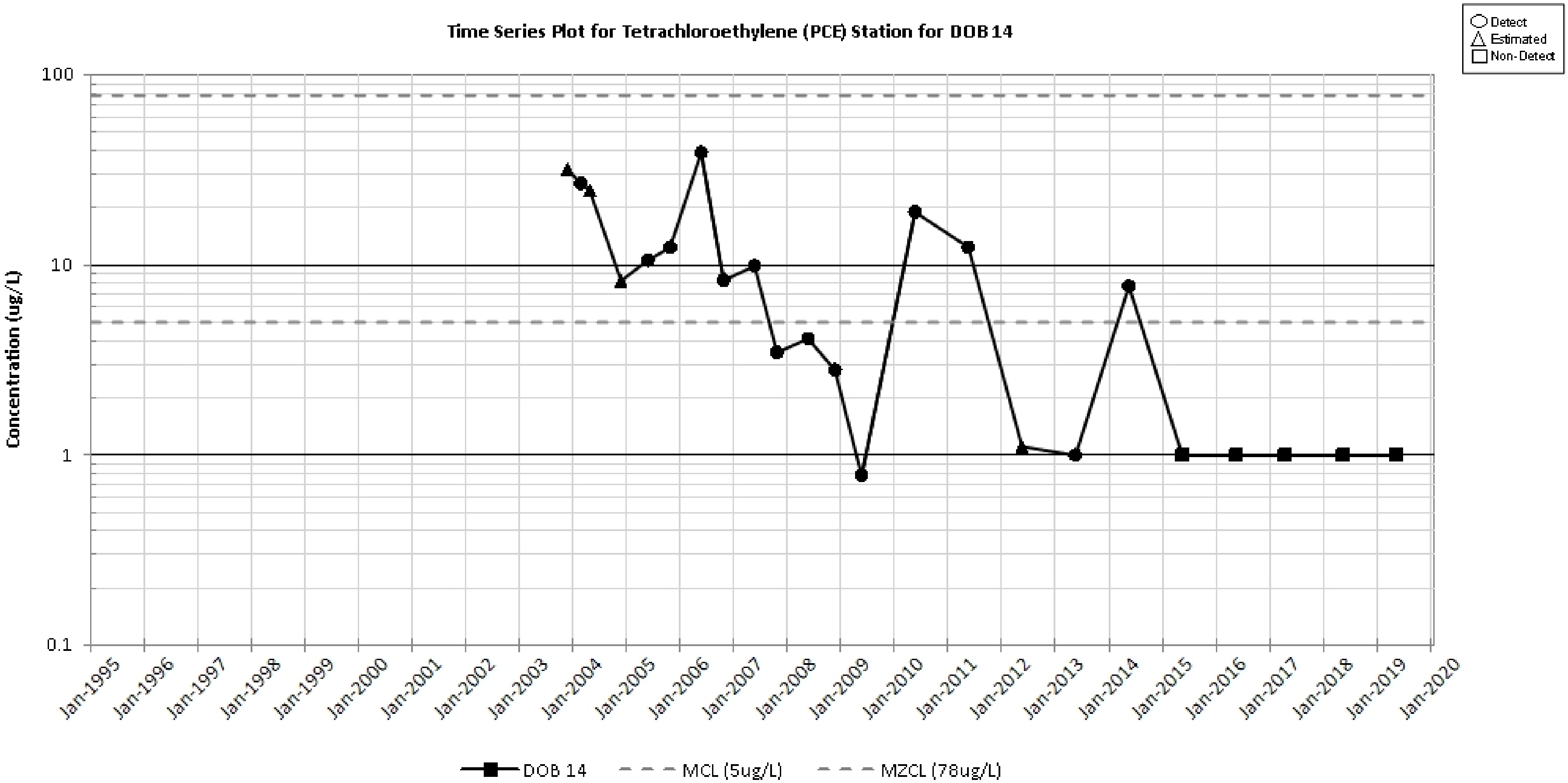


Figure D-120. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 14

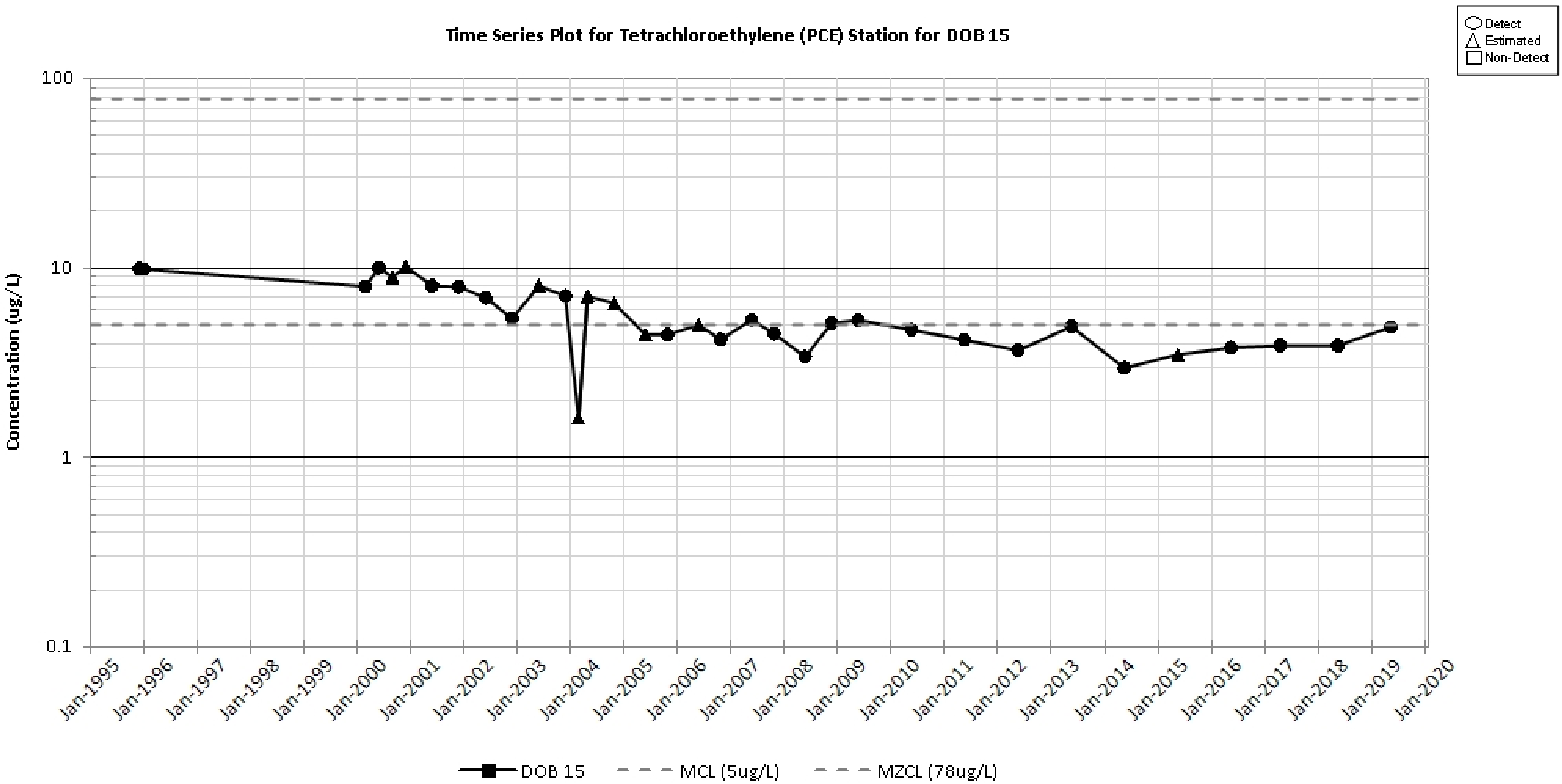


Figure D-121. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 15

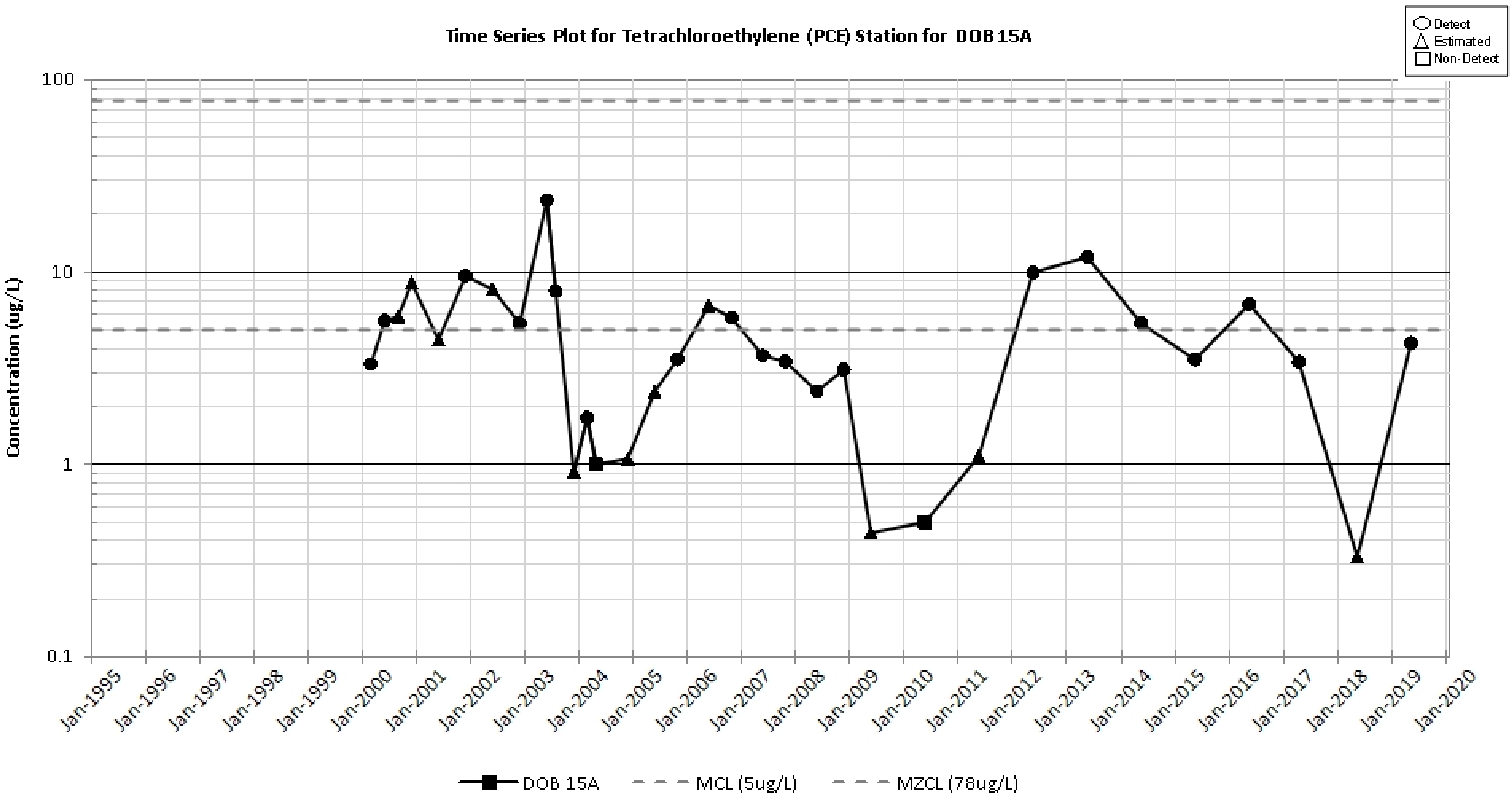


Figure D-122. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 15A

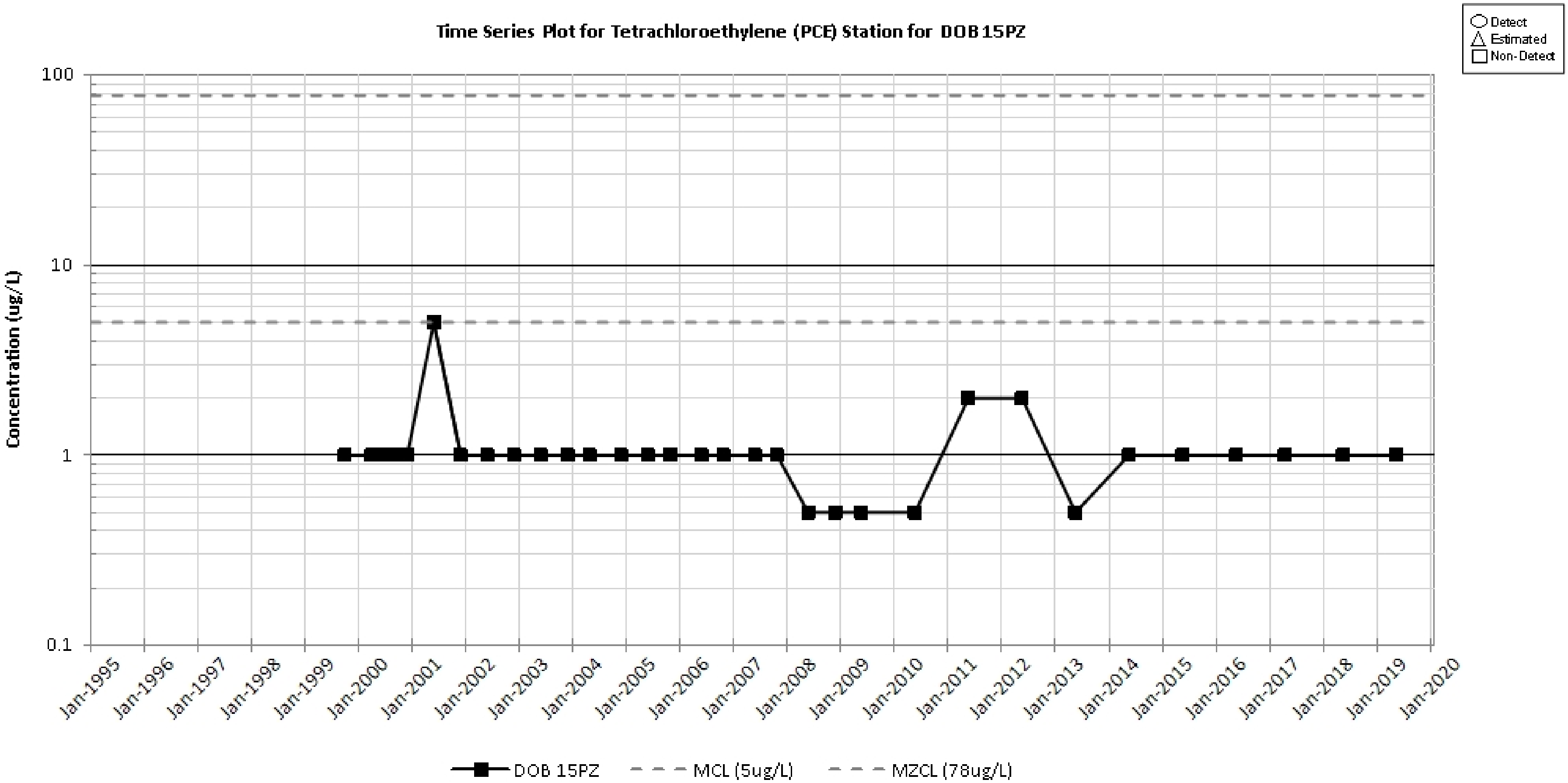


Figure D-123. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 15PZ

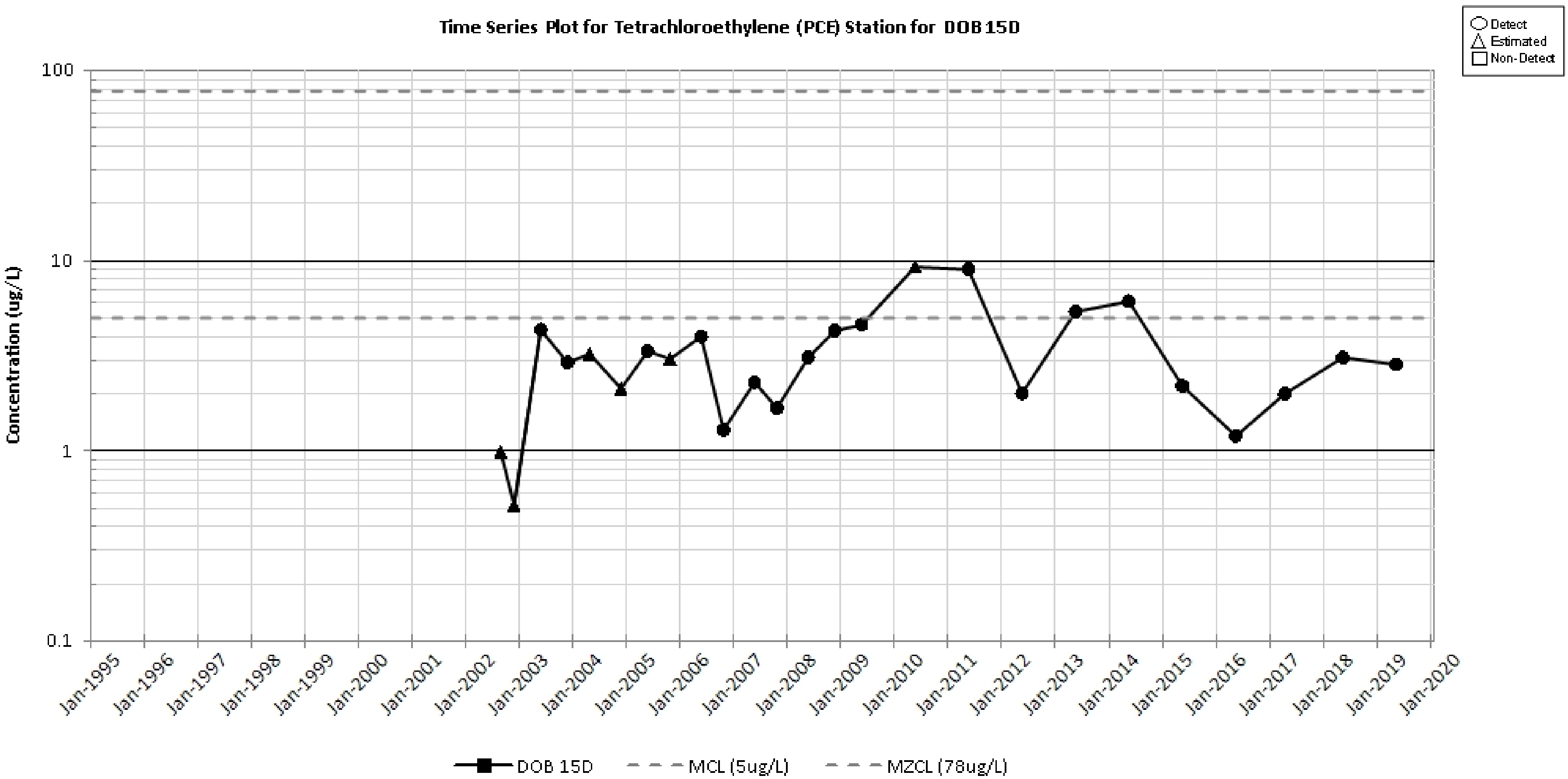


Figure D-124. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 15D

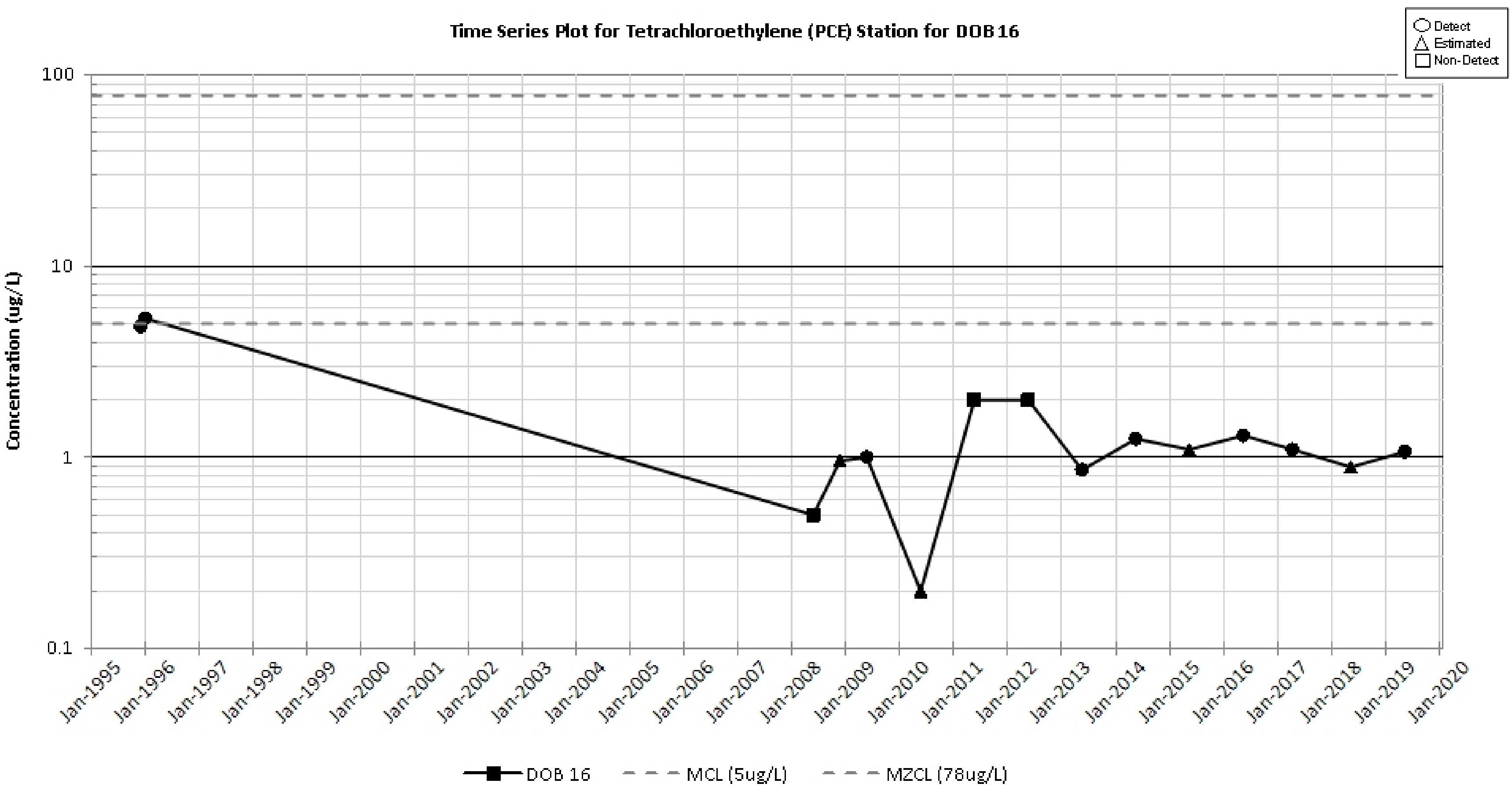


Figure D-125. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 16

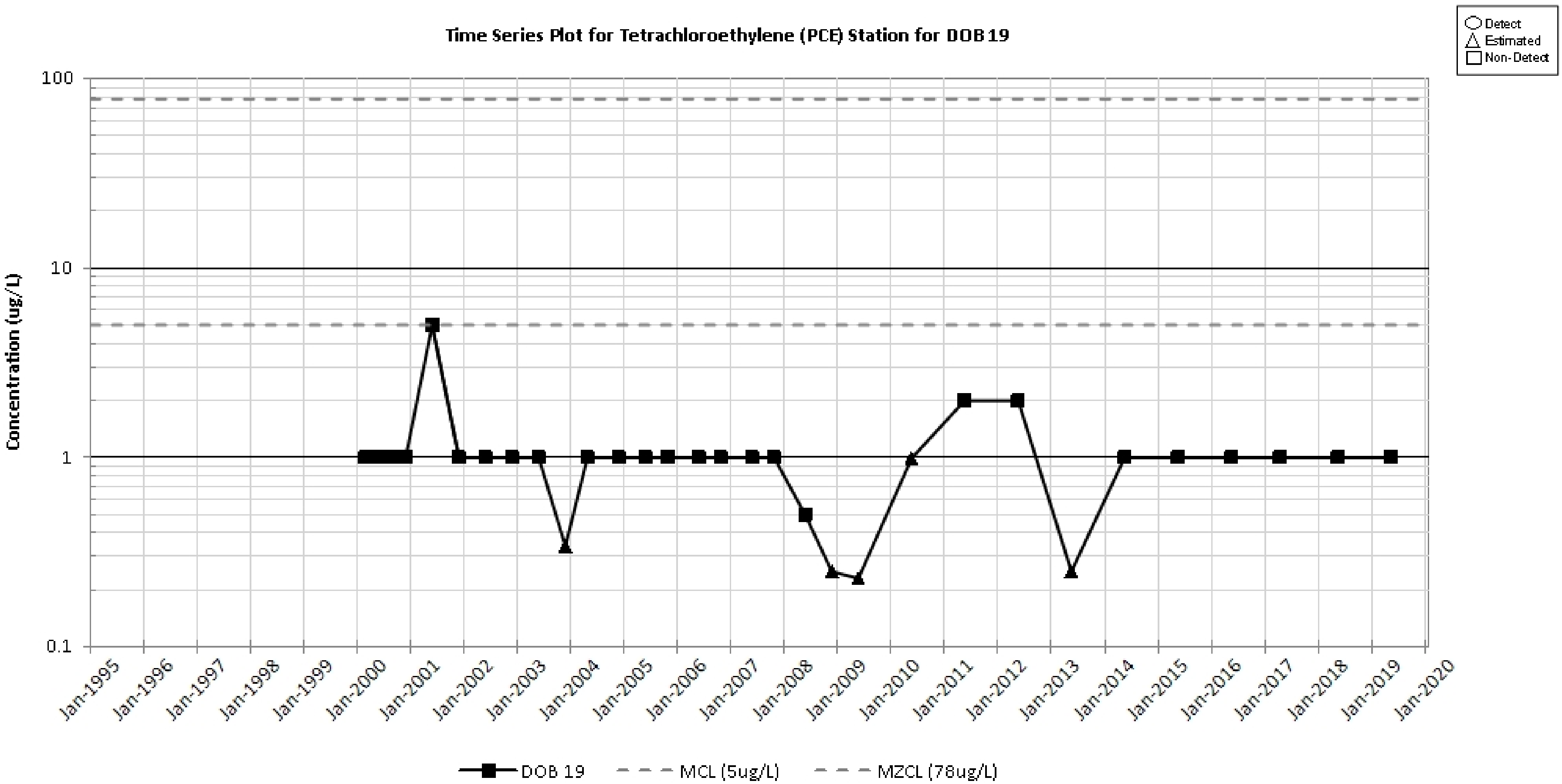


Figure D-126. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 19

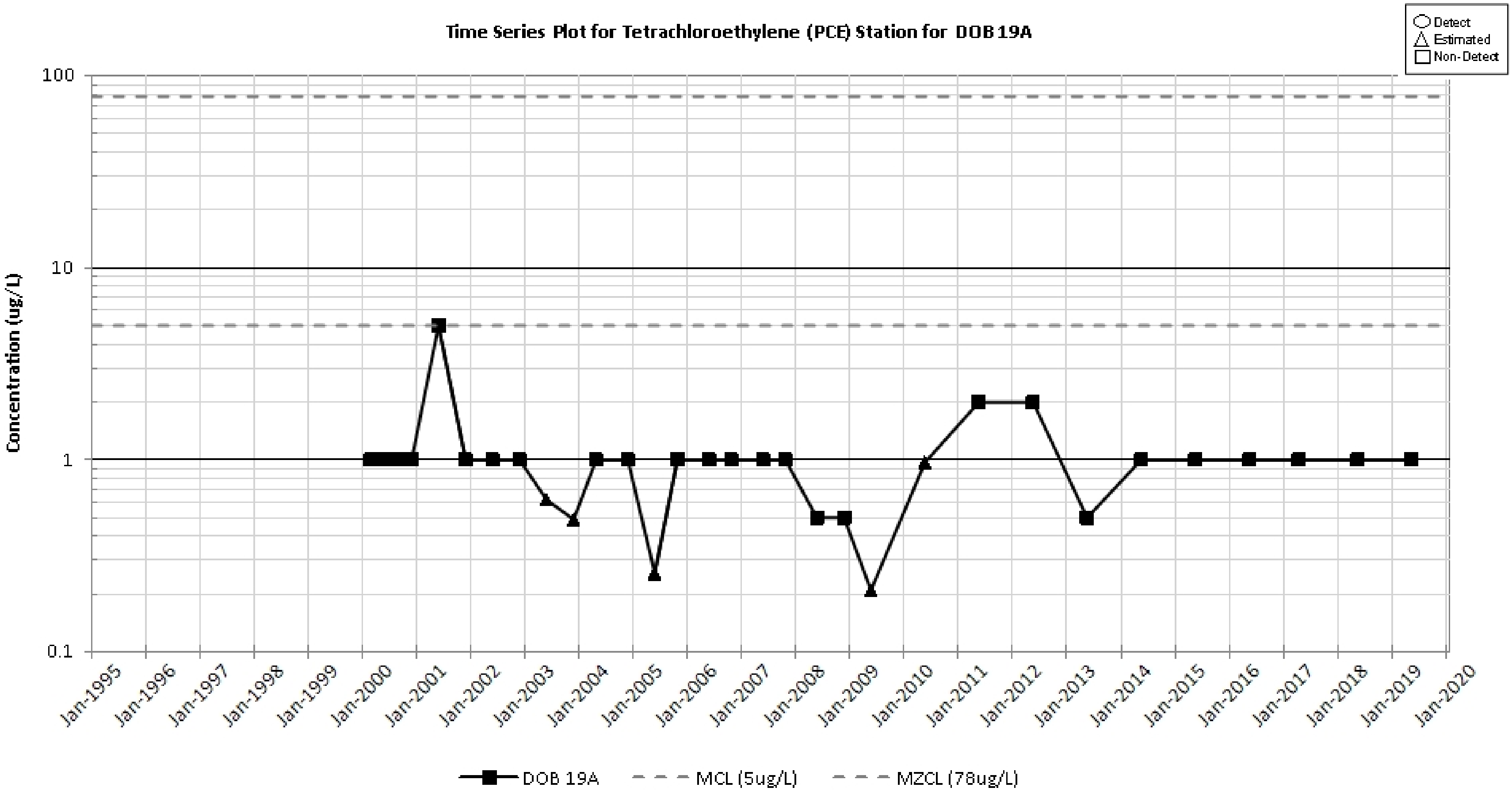


Figure D-127. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 19A

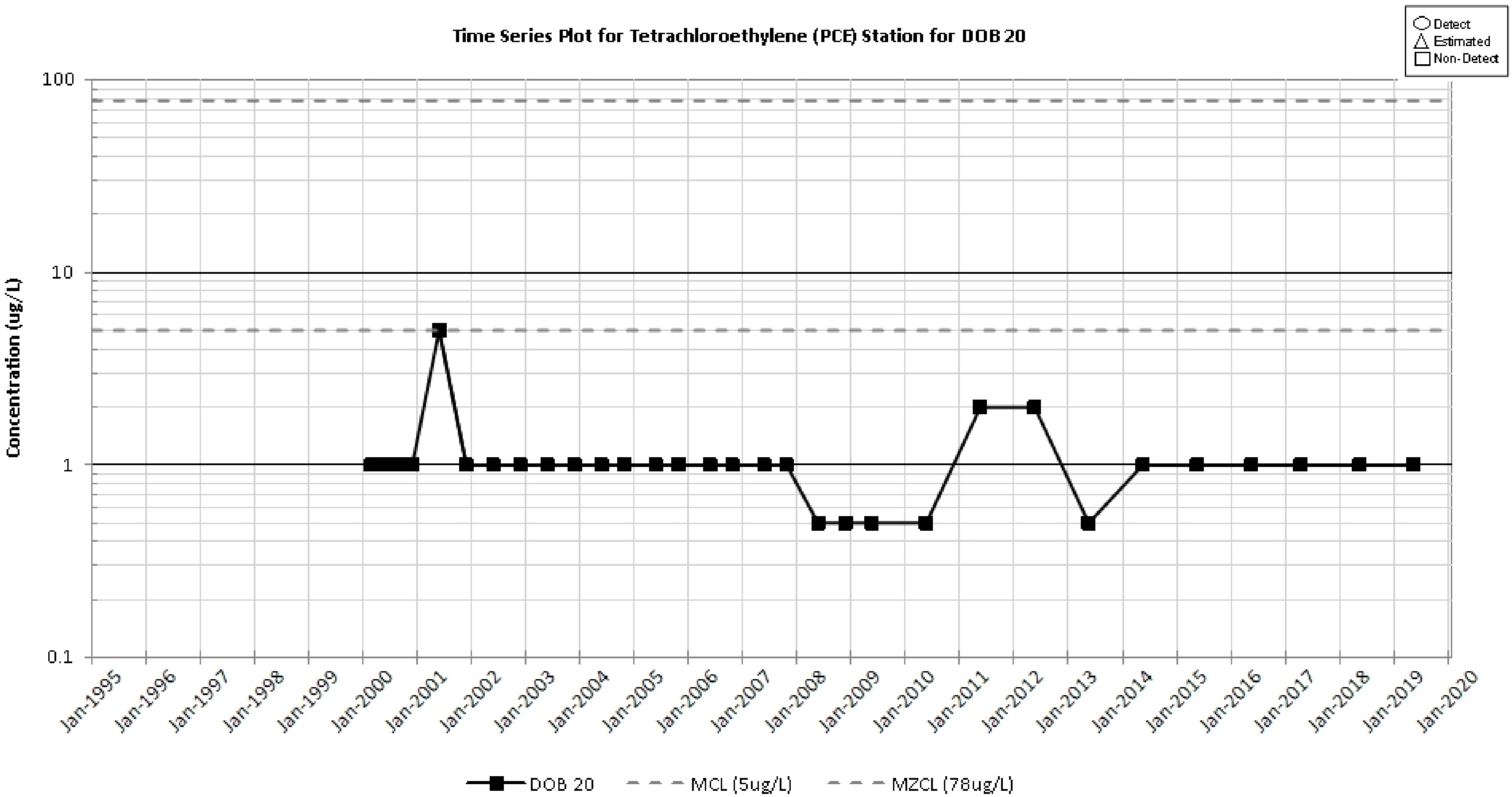


Figure D-128. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 20

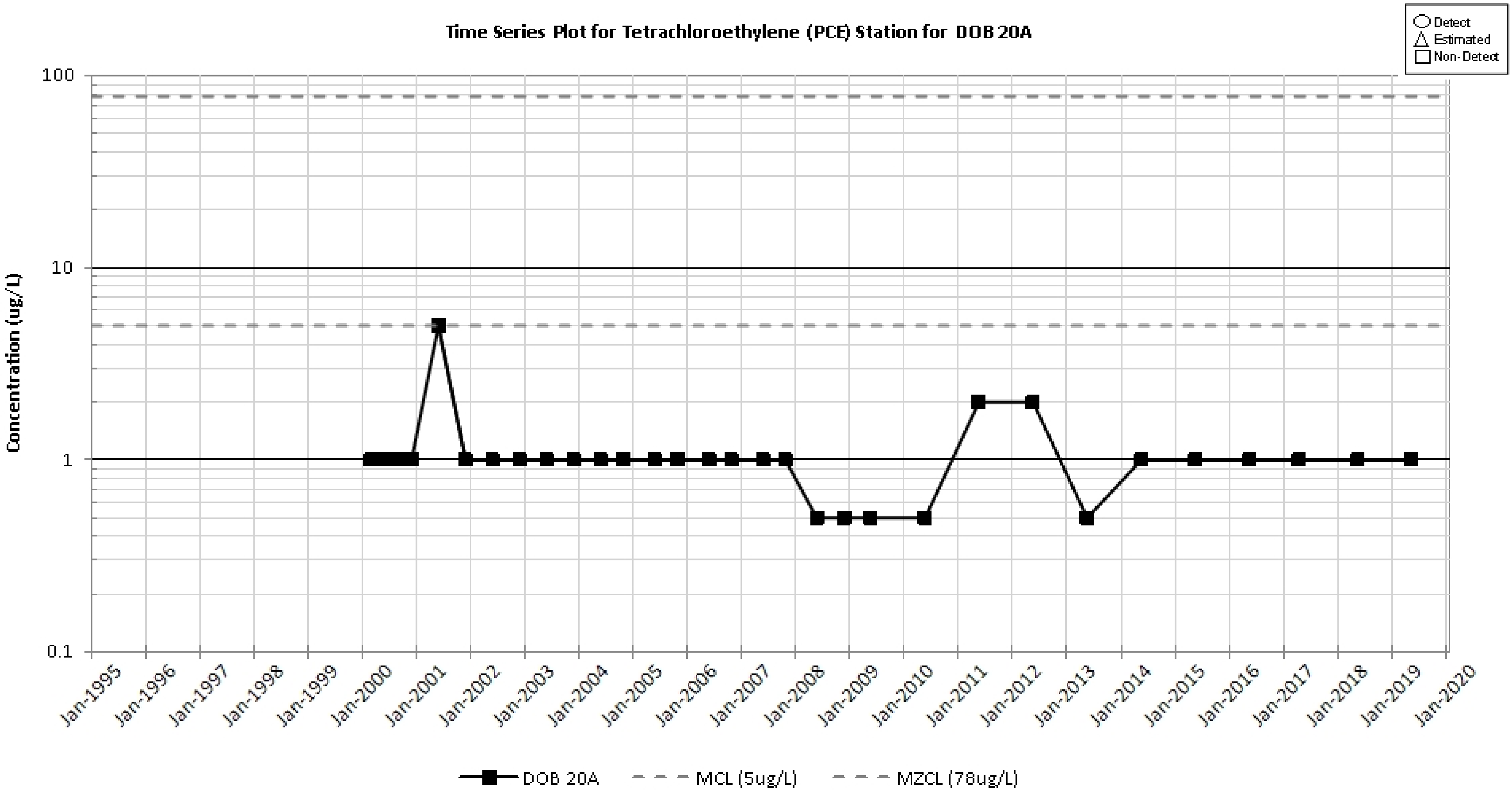


Figure D-129. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 20A

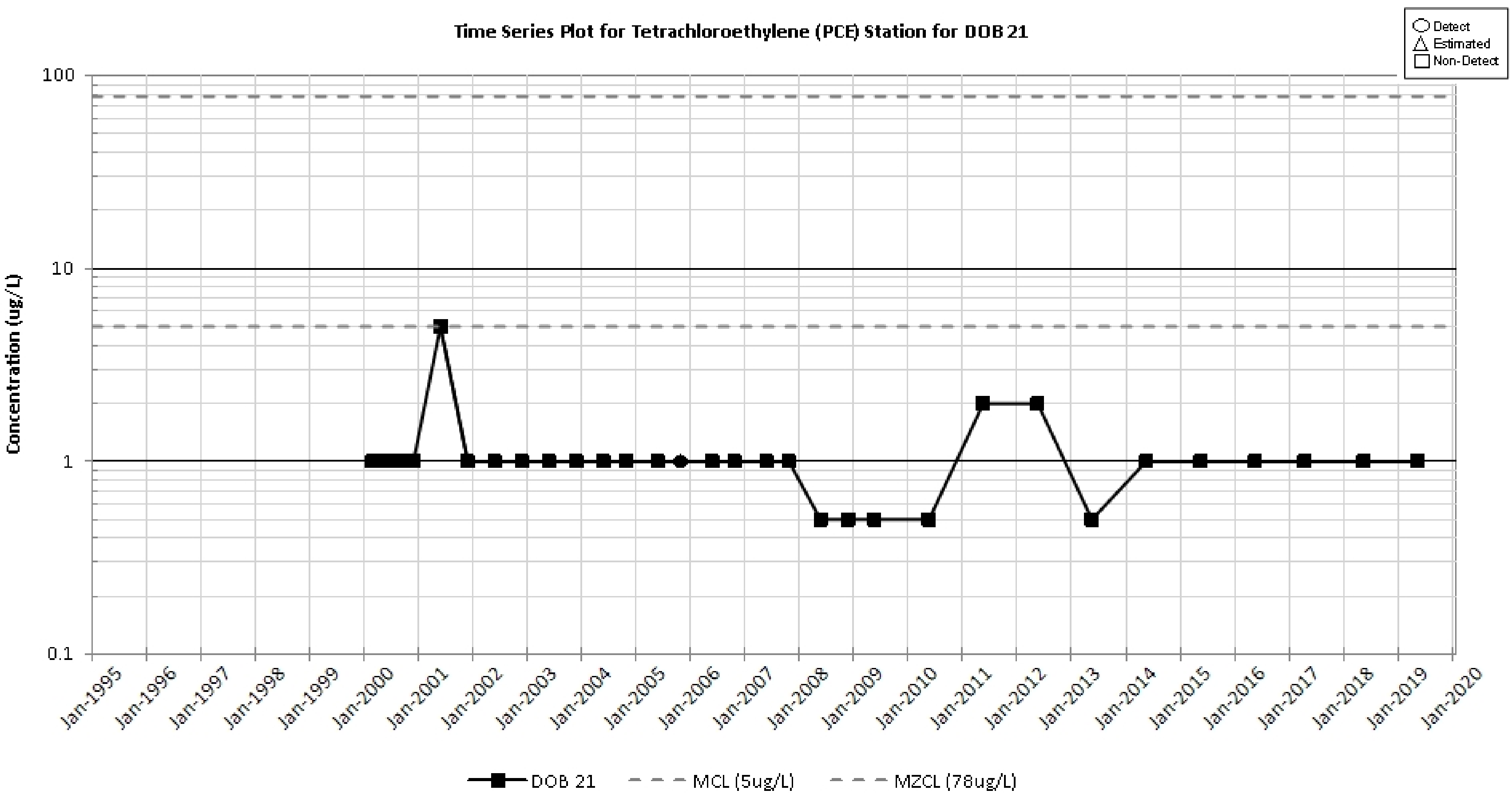


Figure D-130. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 21

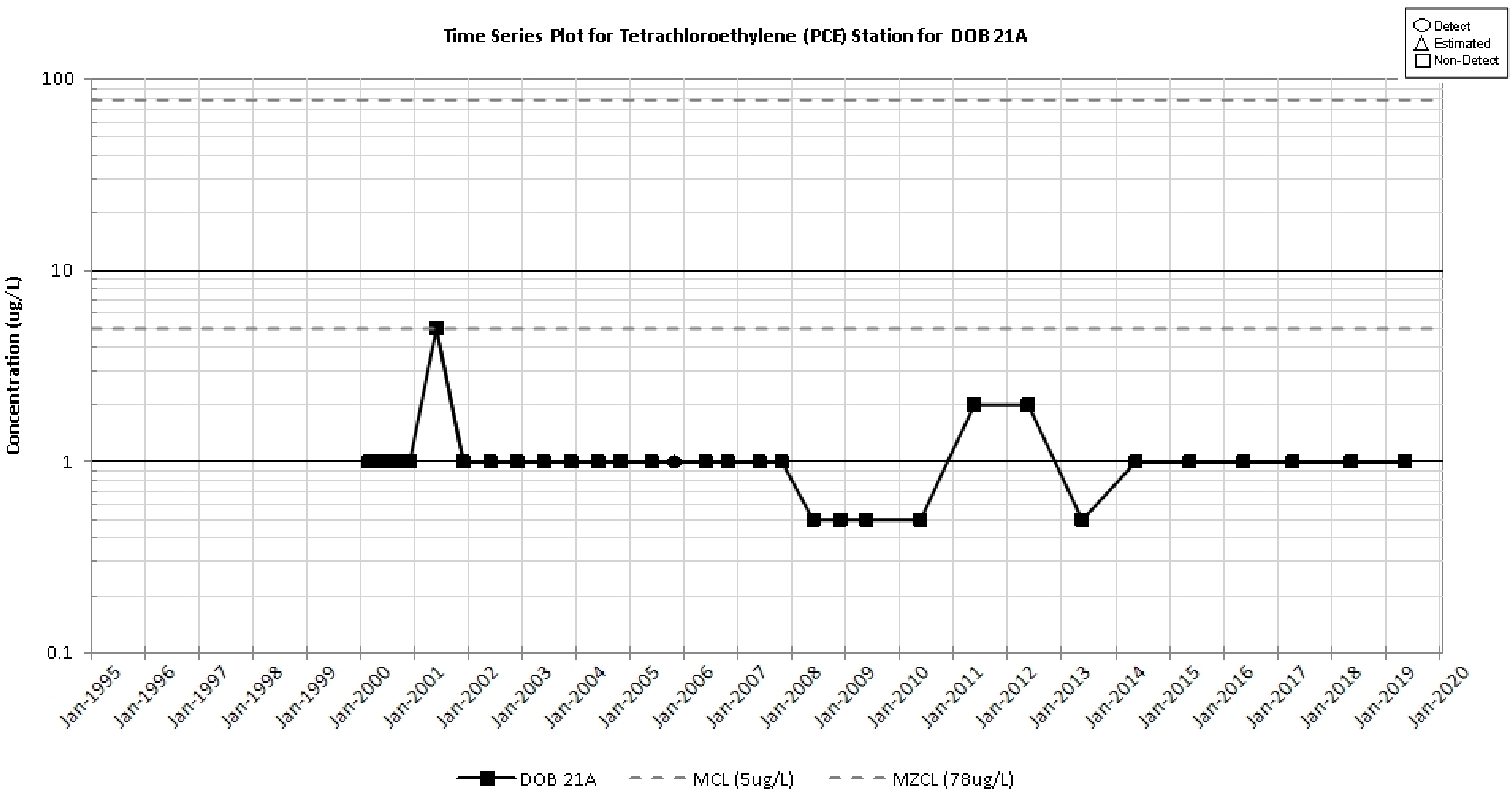


Figure D-131. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 21A

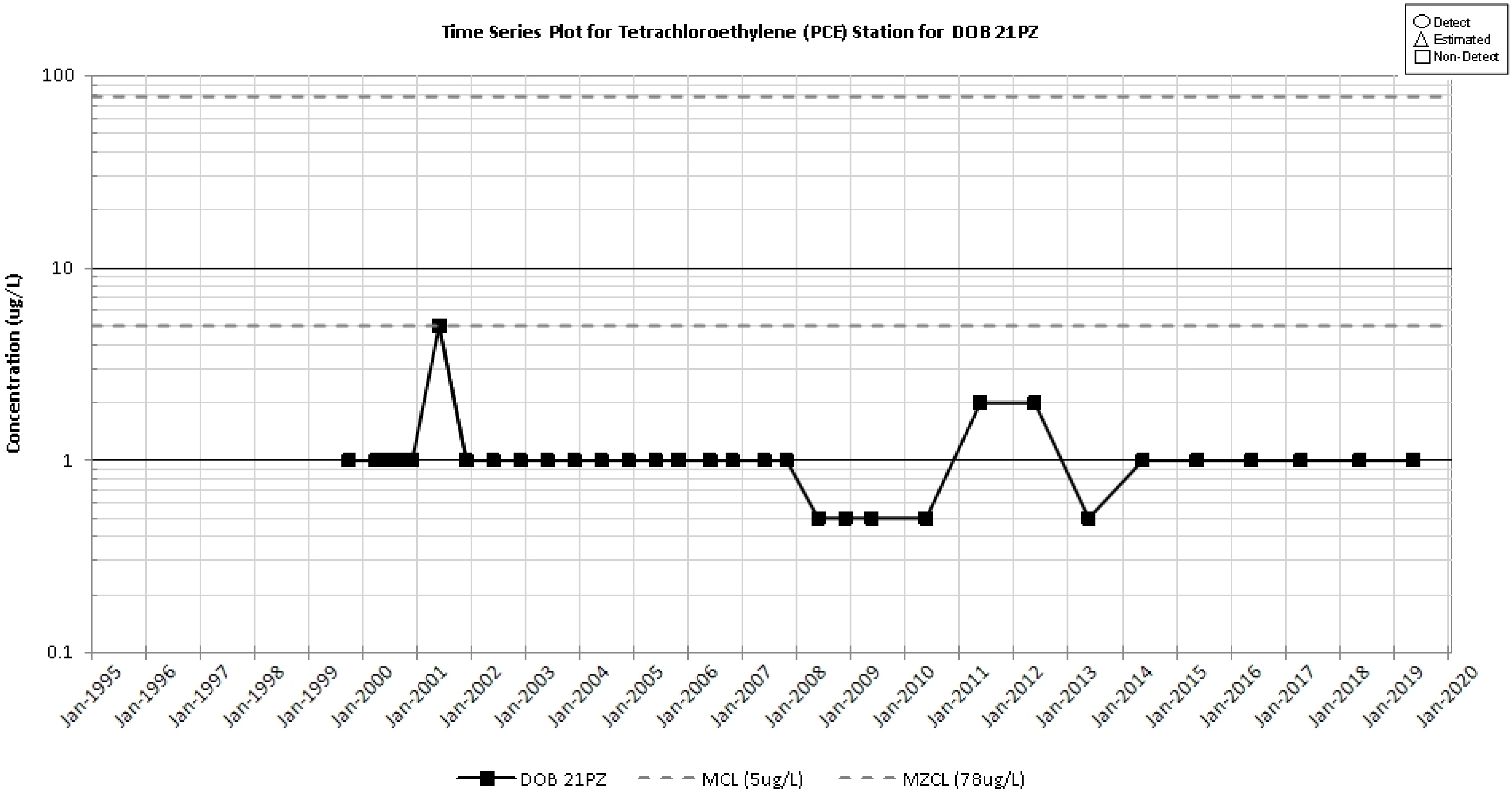


Figure D-132. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 21PZ

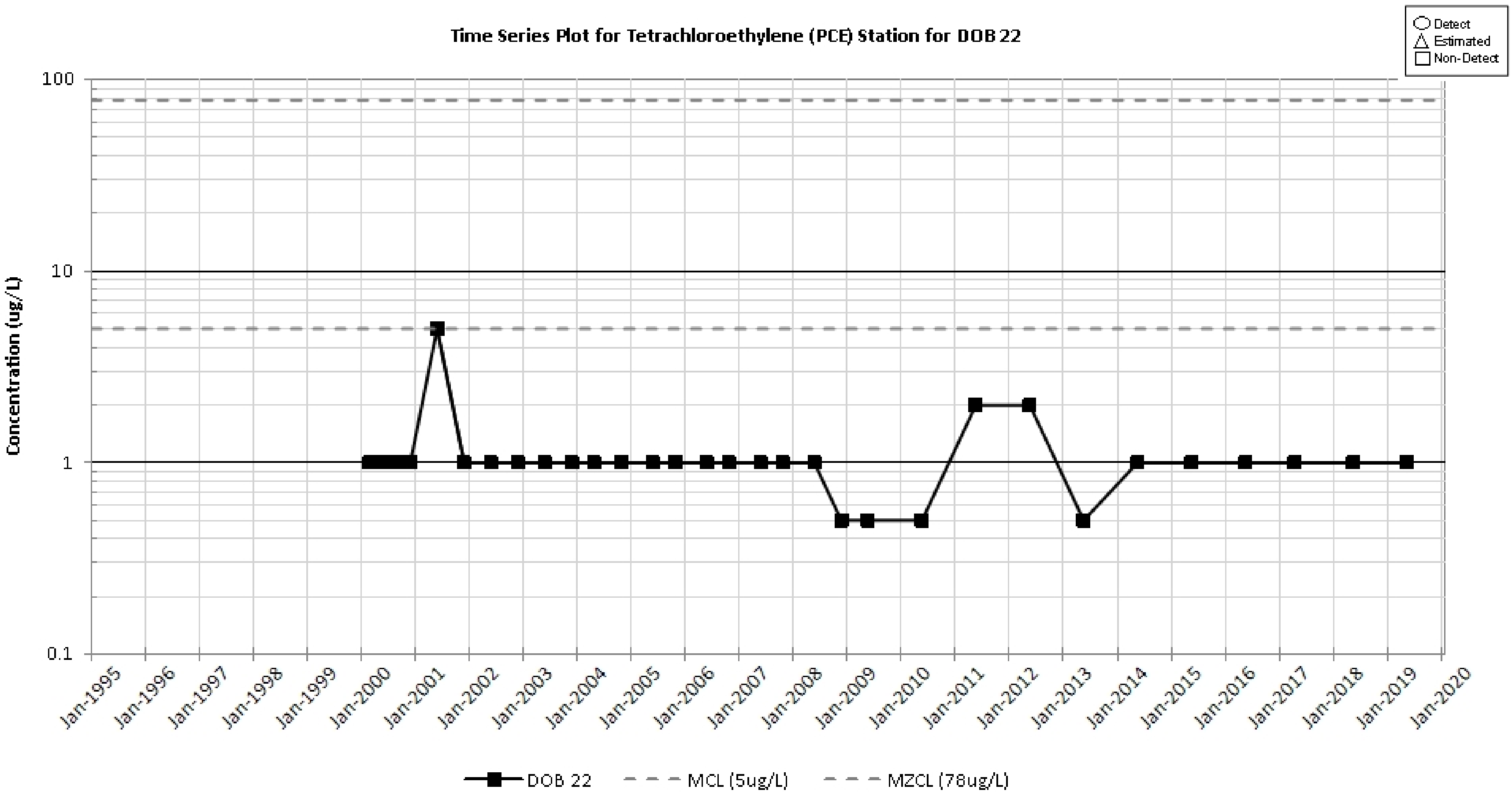


Figure D-133. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 22

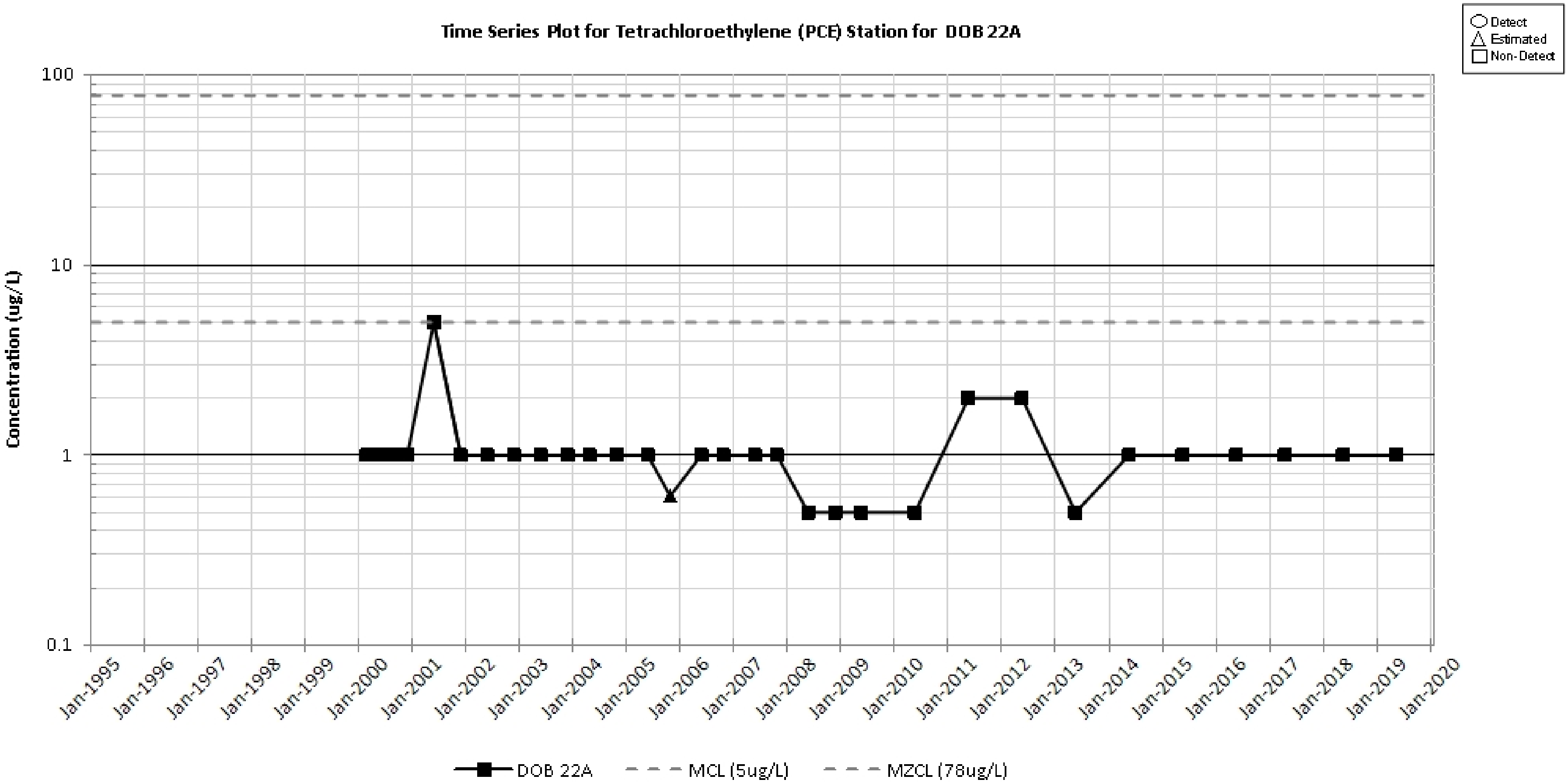


Figure D-134. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 22A

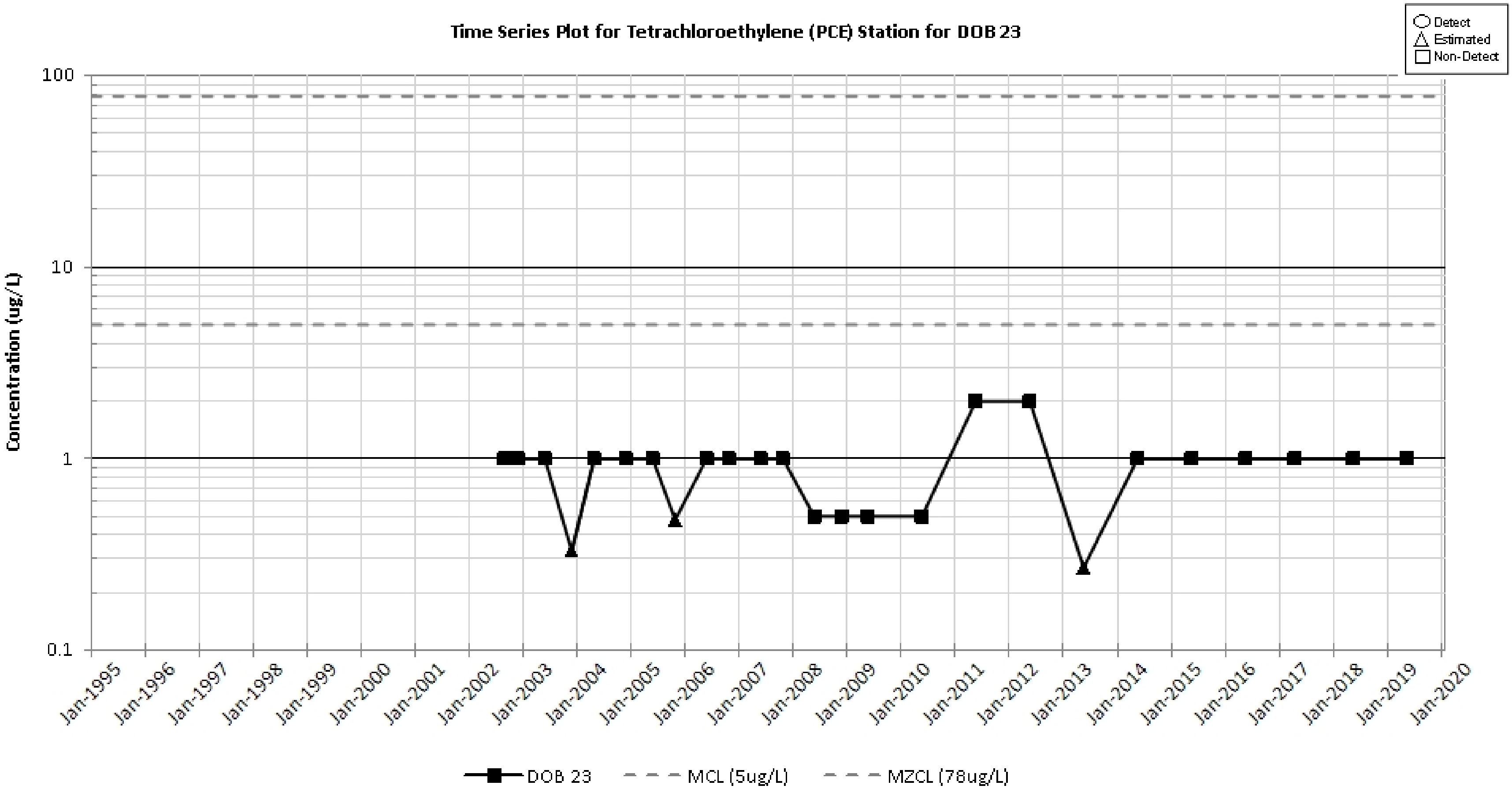


Figure D-135. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB 23

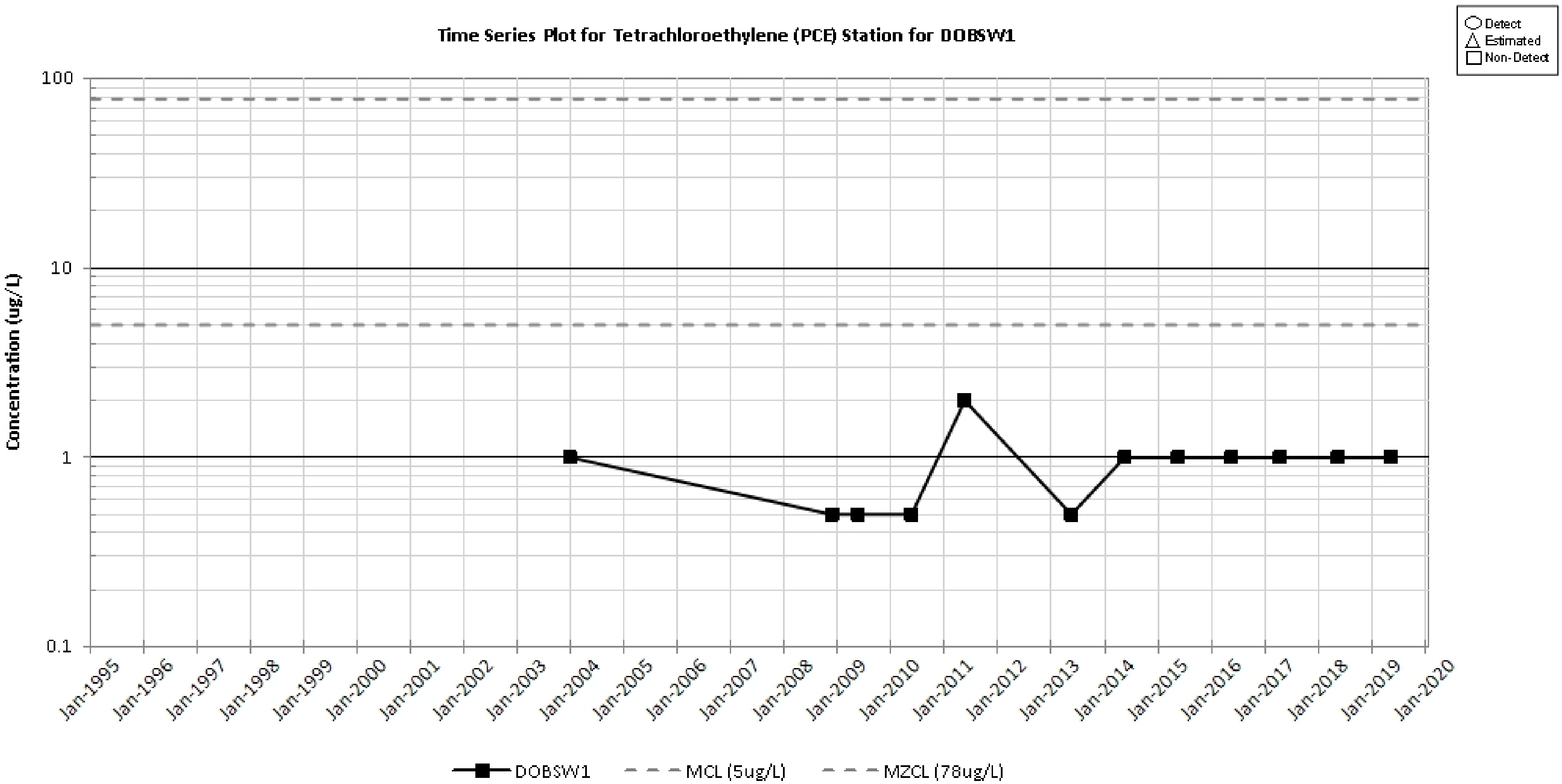


Figure D-136. Time Series Plot for Tetrachloroethylene (PCE) Station for DOB SW1

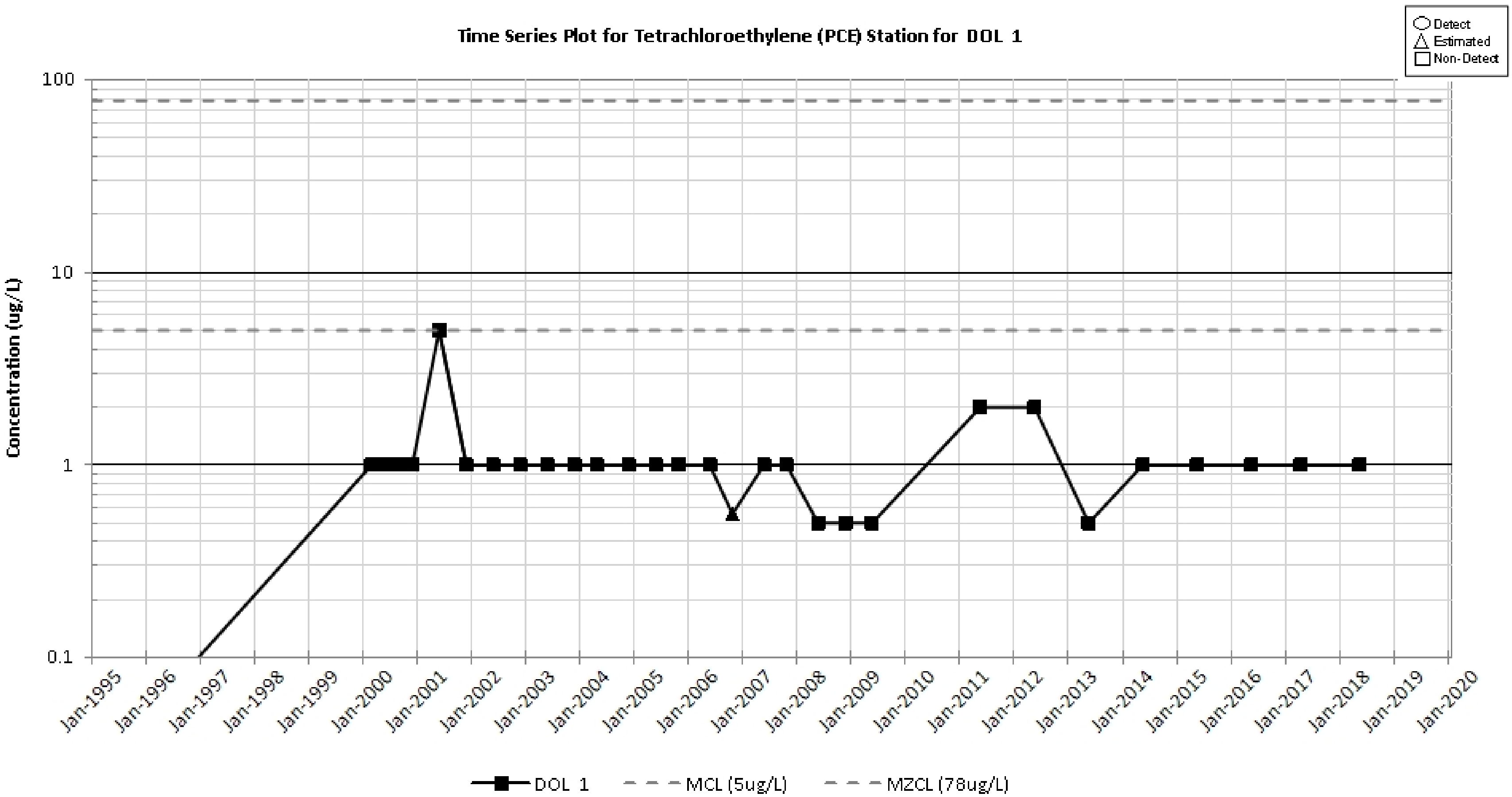


Figure D-137. Time Series Plot for Tetrachloroethylene (PCE) Station for DOL 1

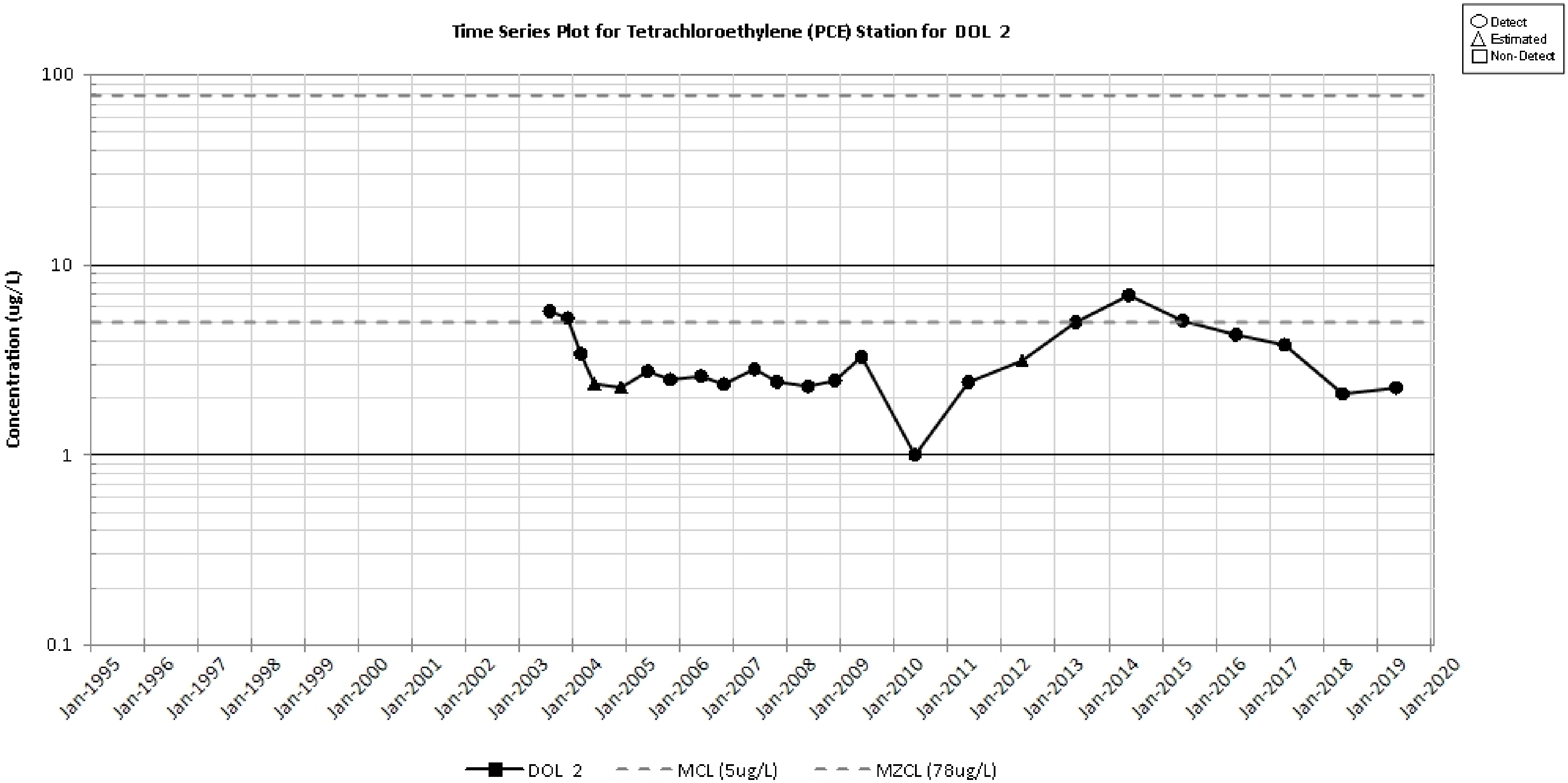


Figure D-138. Time Series Plot for Tetrachloroethylene (PCE) Station for DOL 2

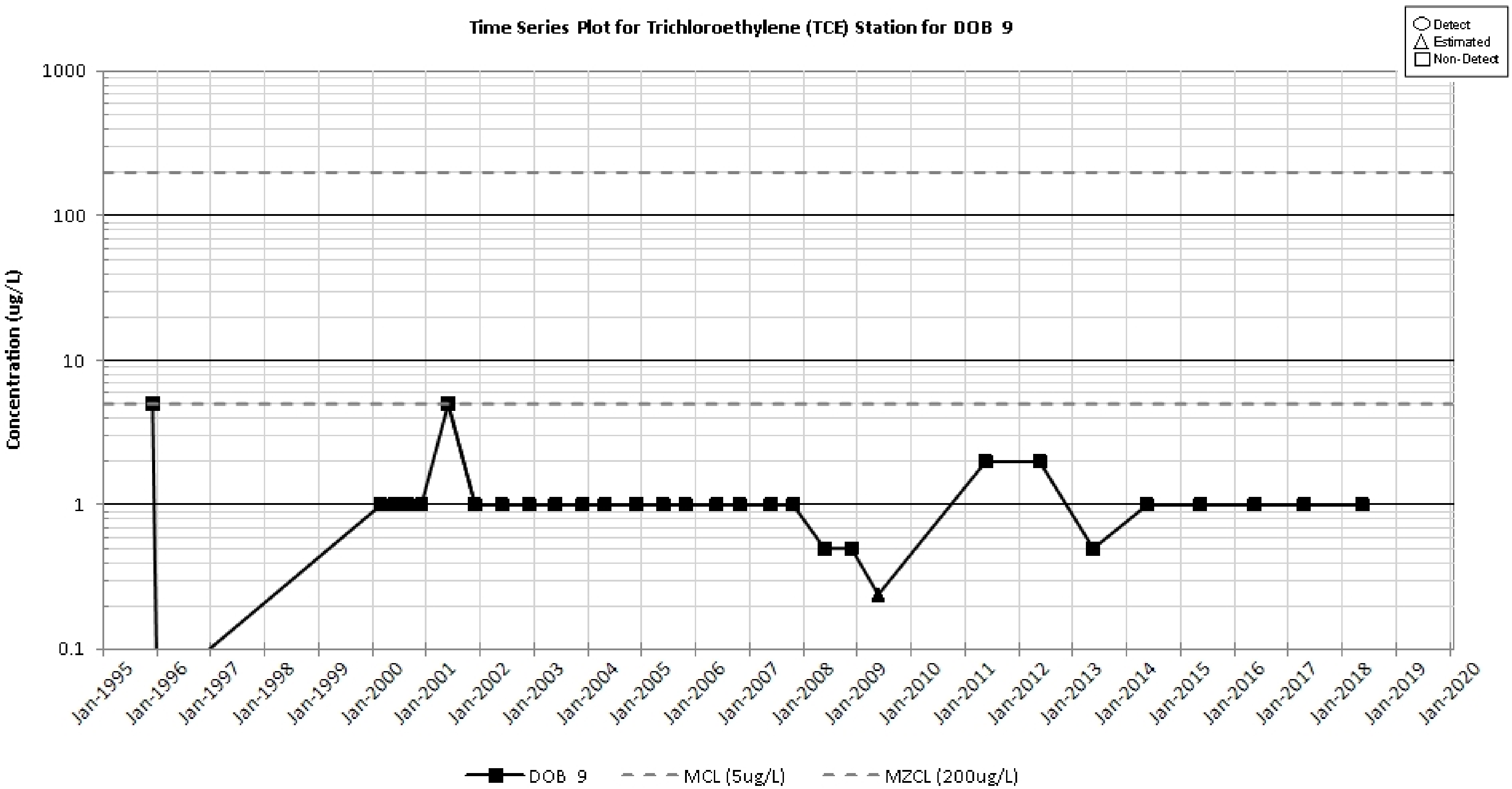


Figure D-139. Time Series Plot for Trichloroethylene (TCE) Station for DOB 9

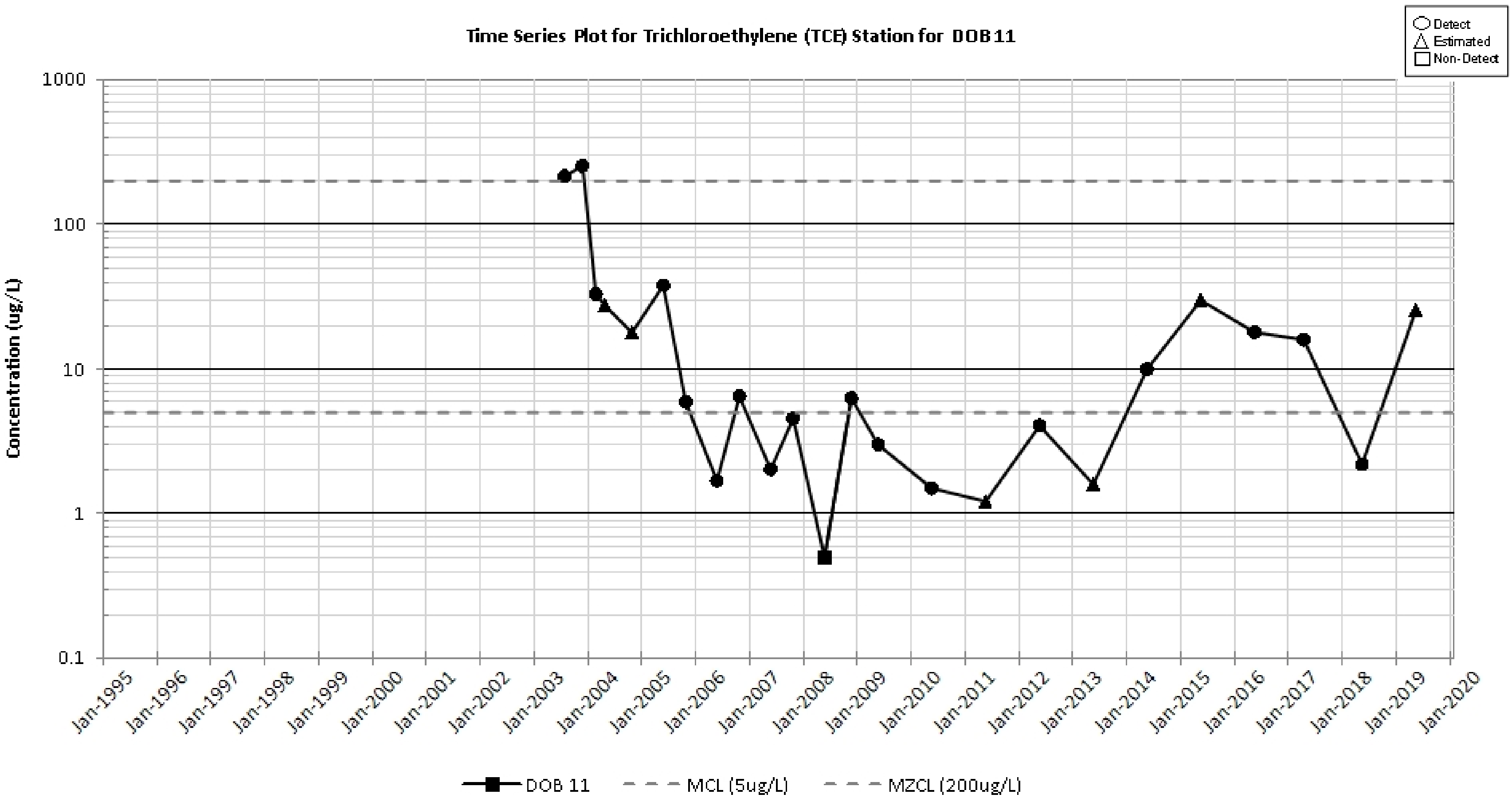


Figure D-140. Time Series Plot for Trichloroethylene (TCE) Station for DOB 11

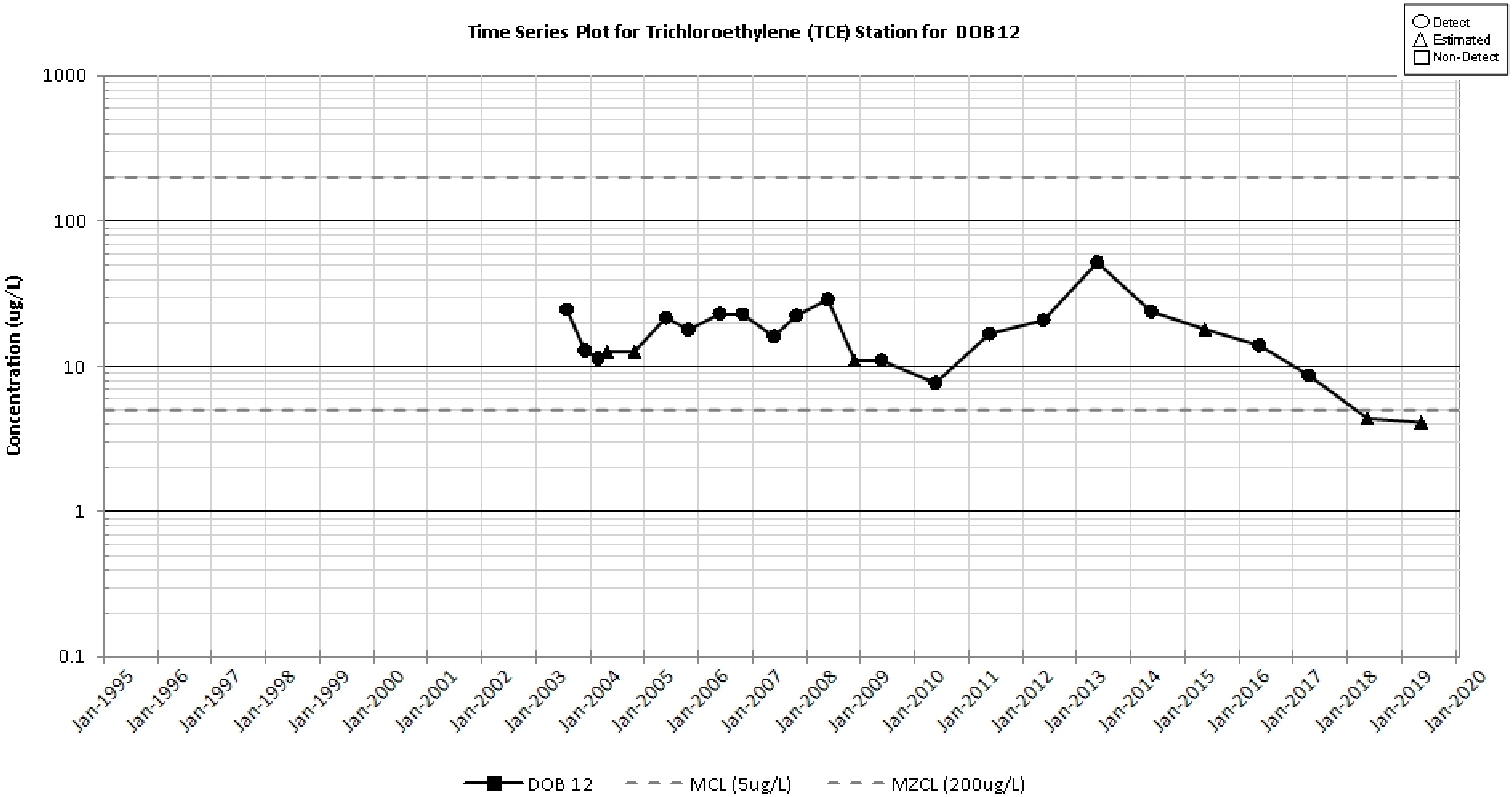


Figure D-141. Time Series Plot for Trichloroethylene (TCE) Station for DOB 12

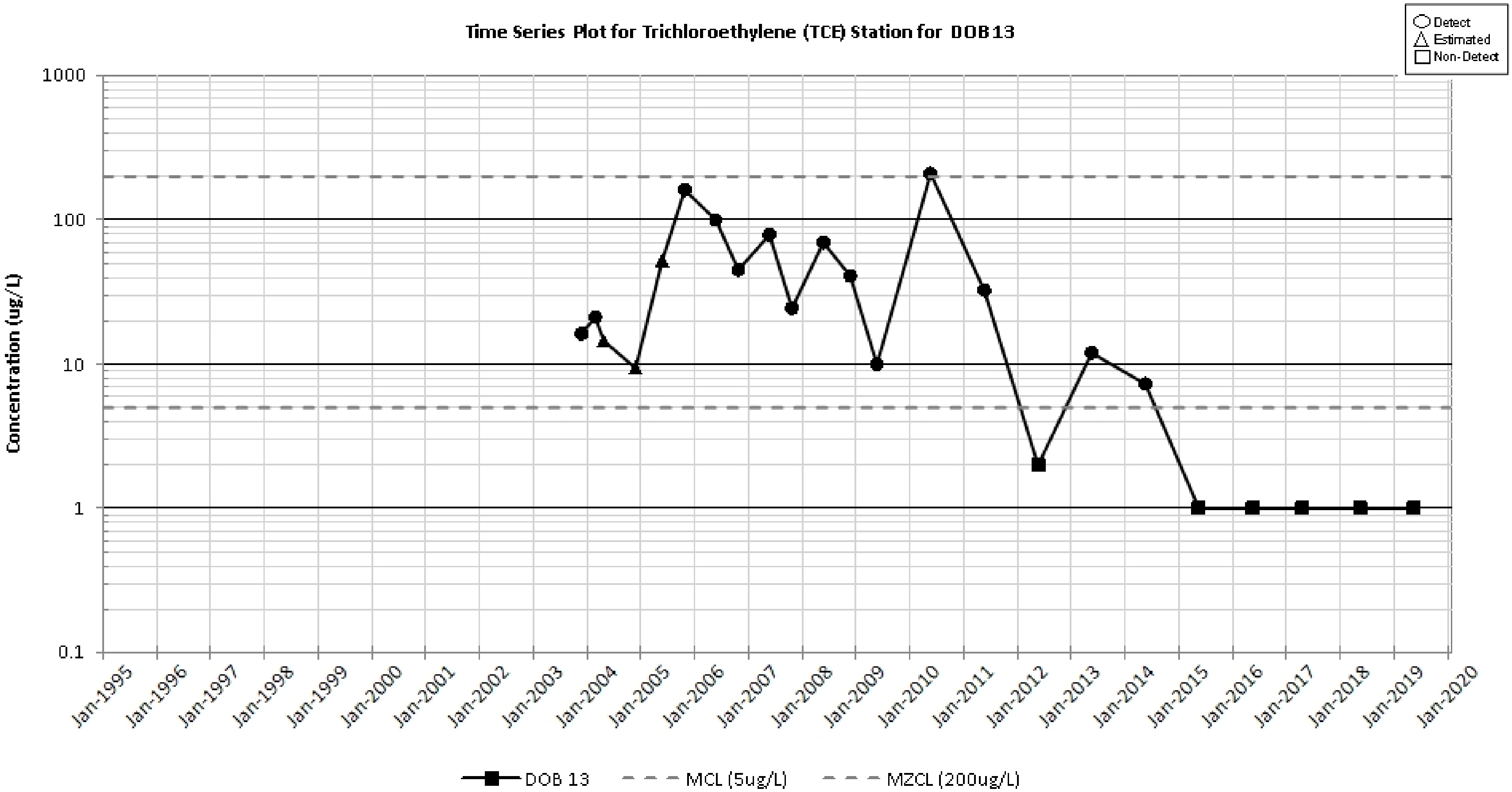


Figure D-142. Time Series Plot for Trichloroethylene (TCE) Station for DOB 13

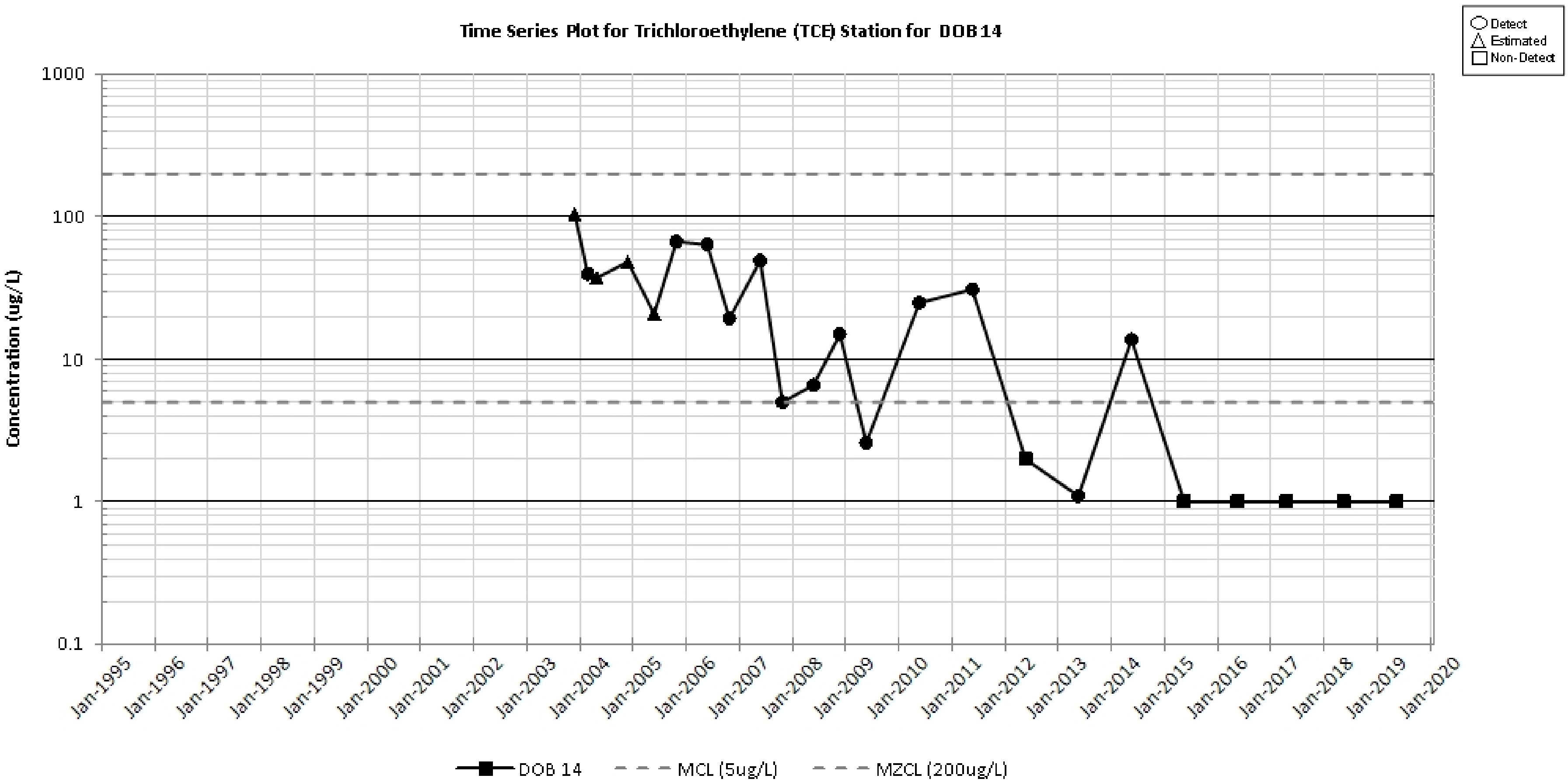


Figure D-143. Time Series Plot for Trichloroethylene (TCE) Station for DOB 14

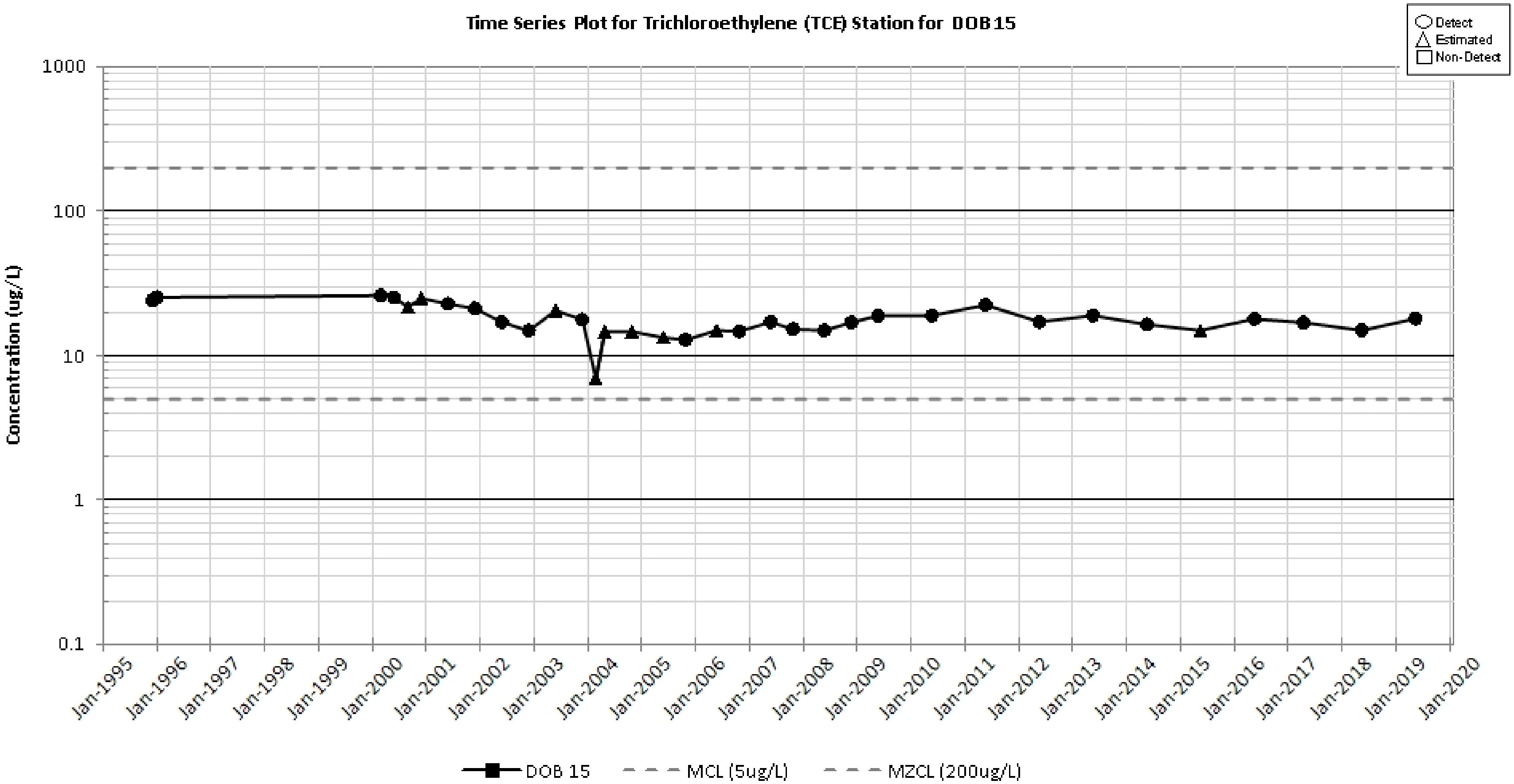


Figure D-144. Time Series Plot for Trichloroethylene (TCE) Station for DOB 15

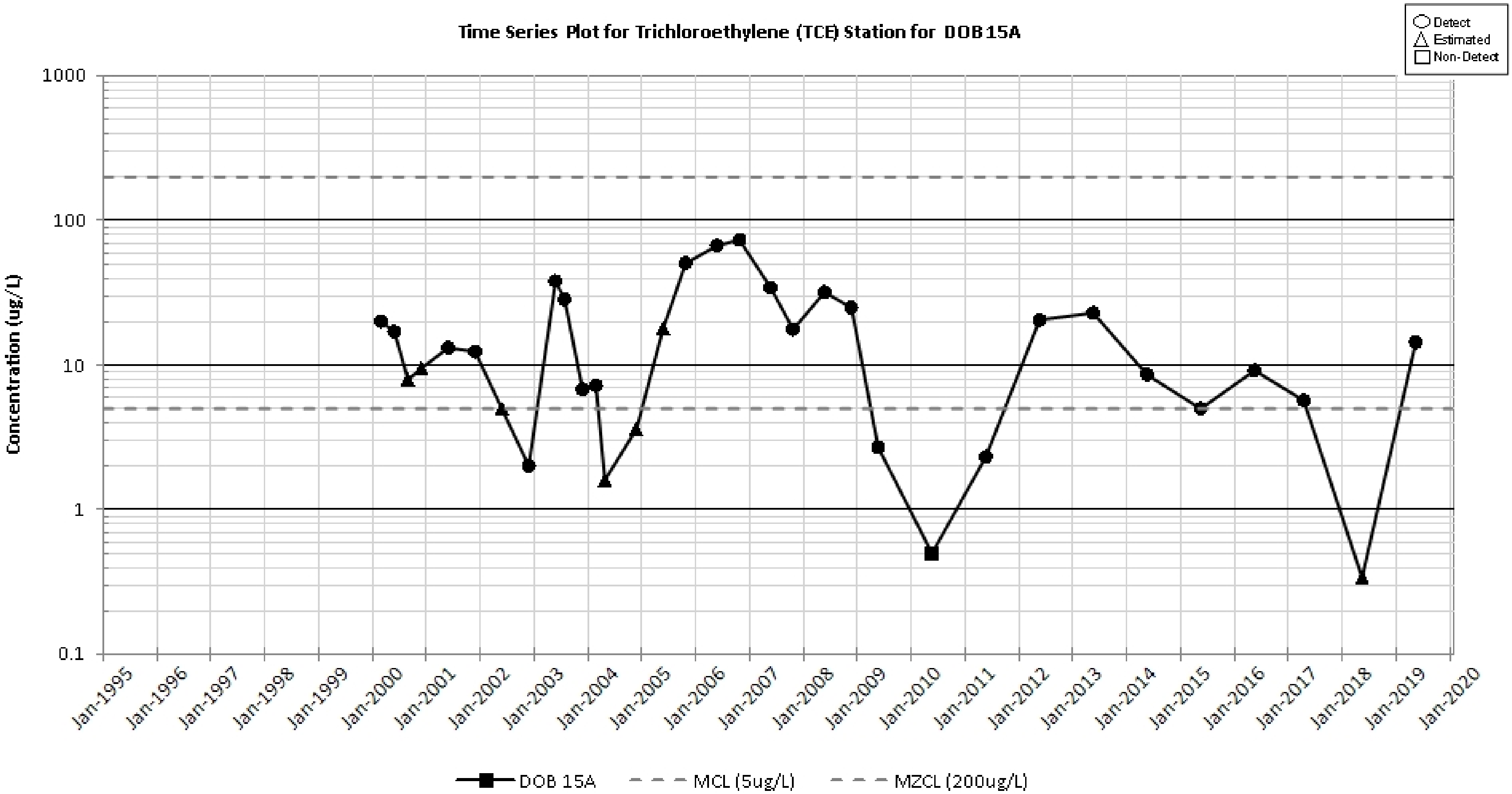


Figure D-145. Time Series Plot for Trichloroethylene (TCE) Station for DOB 15A

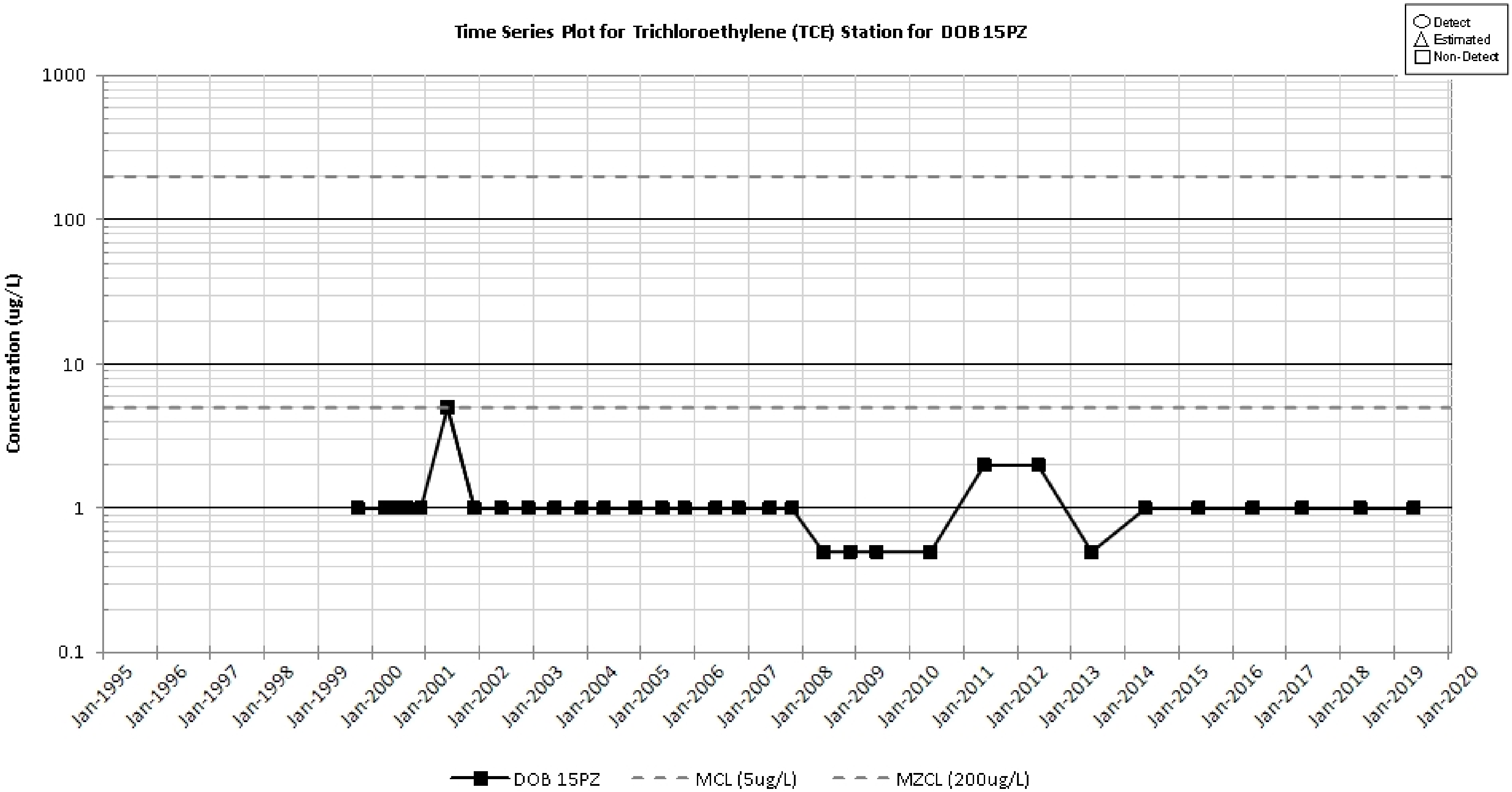


Figure D-146. Time Series Plot for Trichloroethylene (TCE) Station for DOB 15PZ

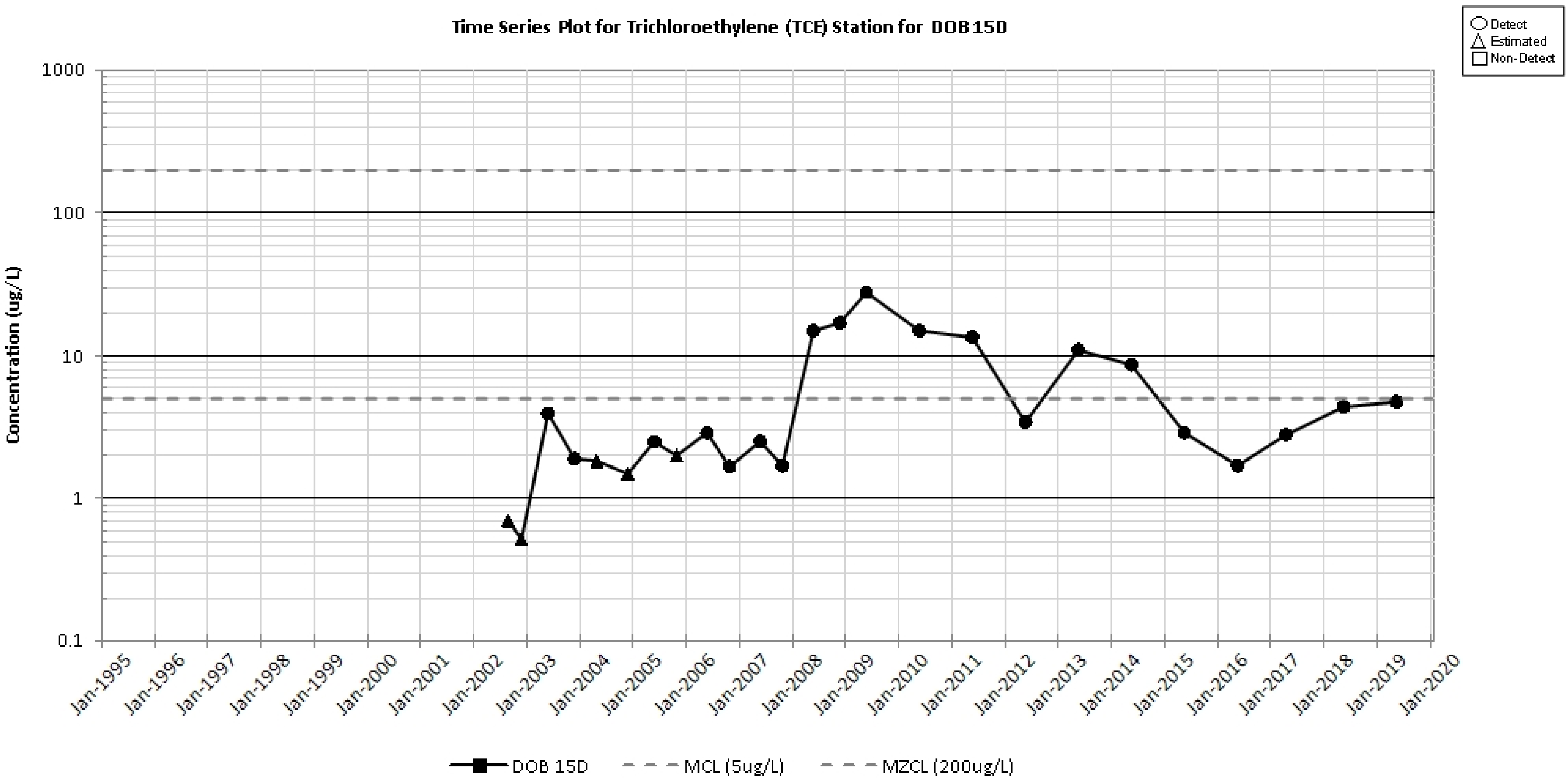


Figure D-147. Time Series Plot for Trichloroethylene (TCE) Station for DOB 15D

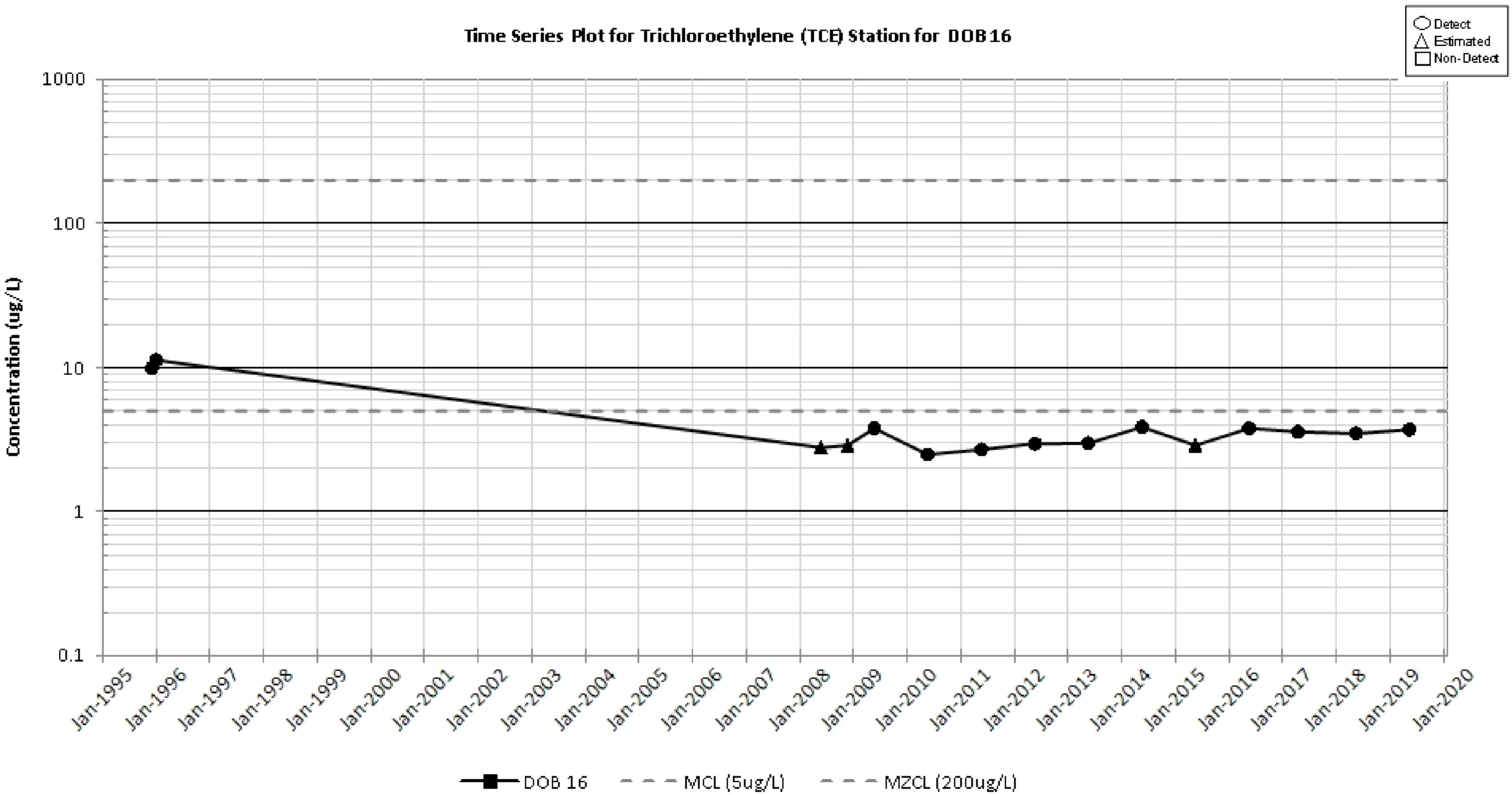


Figure D-148. Time Series Plot for Trichloroethylene (TCE) Station for DOB 16

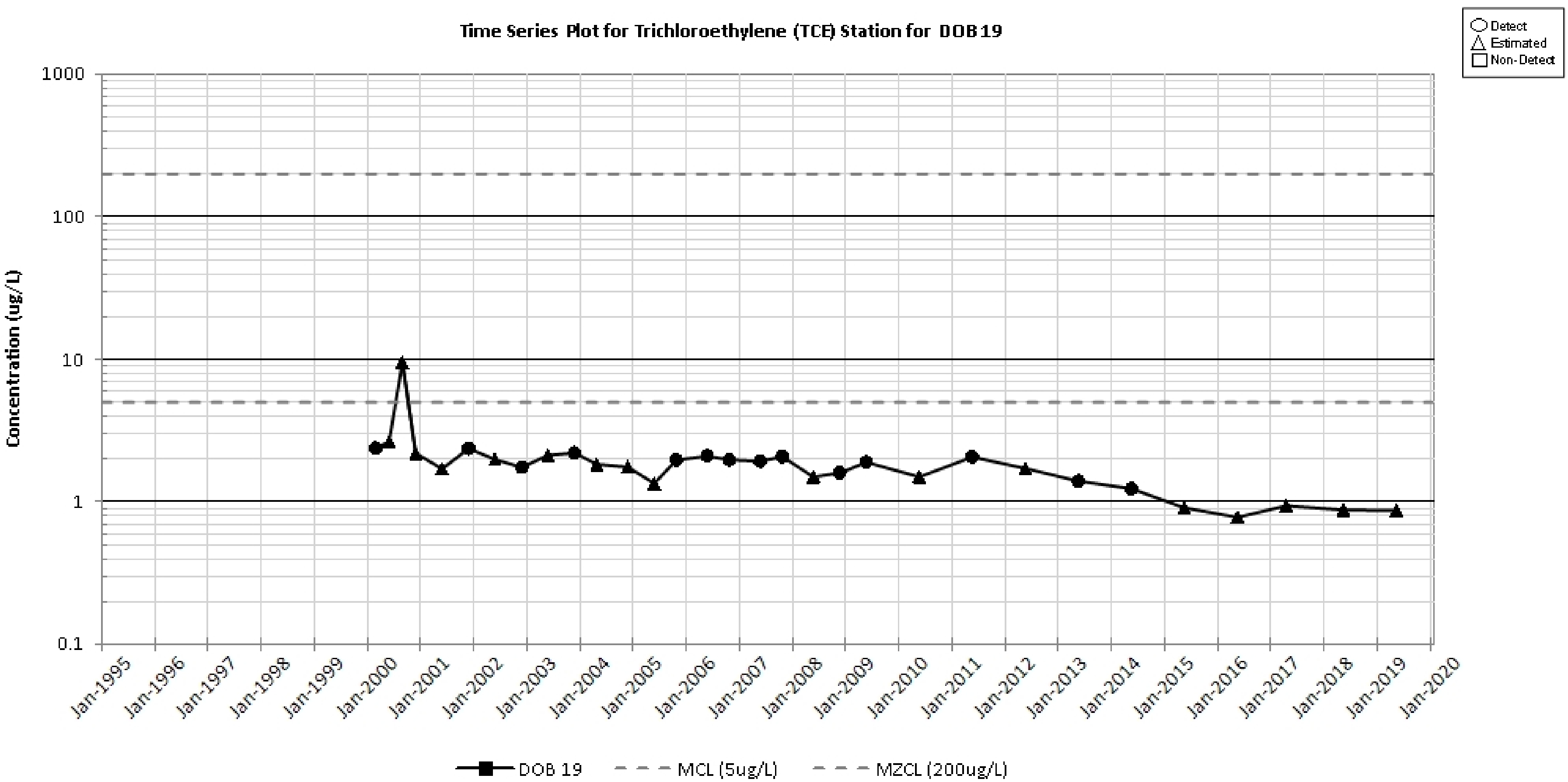


Figure D-149. Time Series Plot for Trichloroethylene (TCE) Station for DOB 19

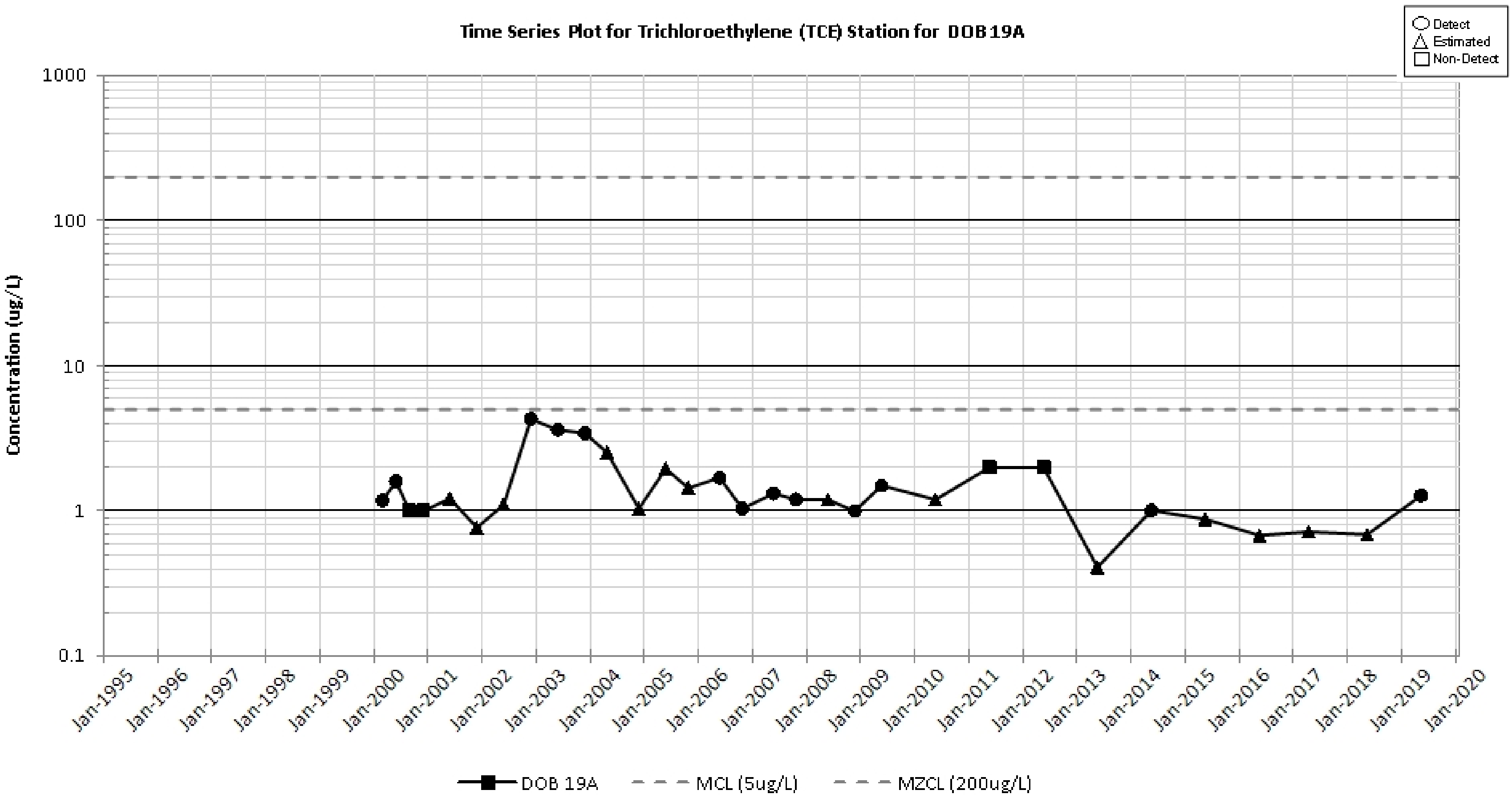


Figure D-150. Time Series Plot for Trichloroethylene (TCE) Station for DOB 19A

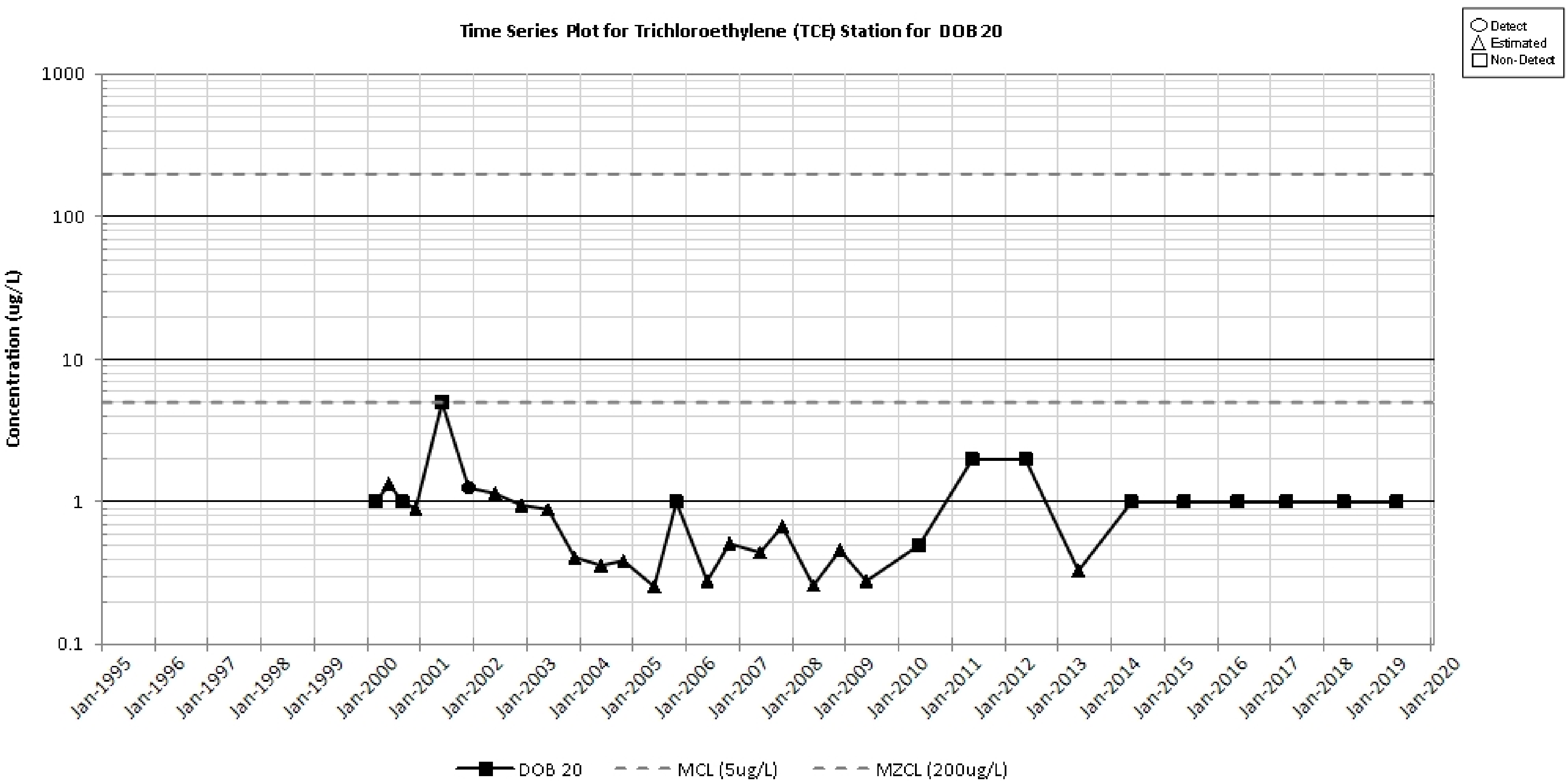


Figure D-151. Time Series Plot for Trichloroethylene (TCE) Station for DOB 20

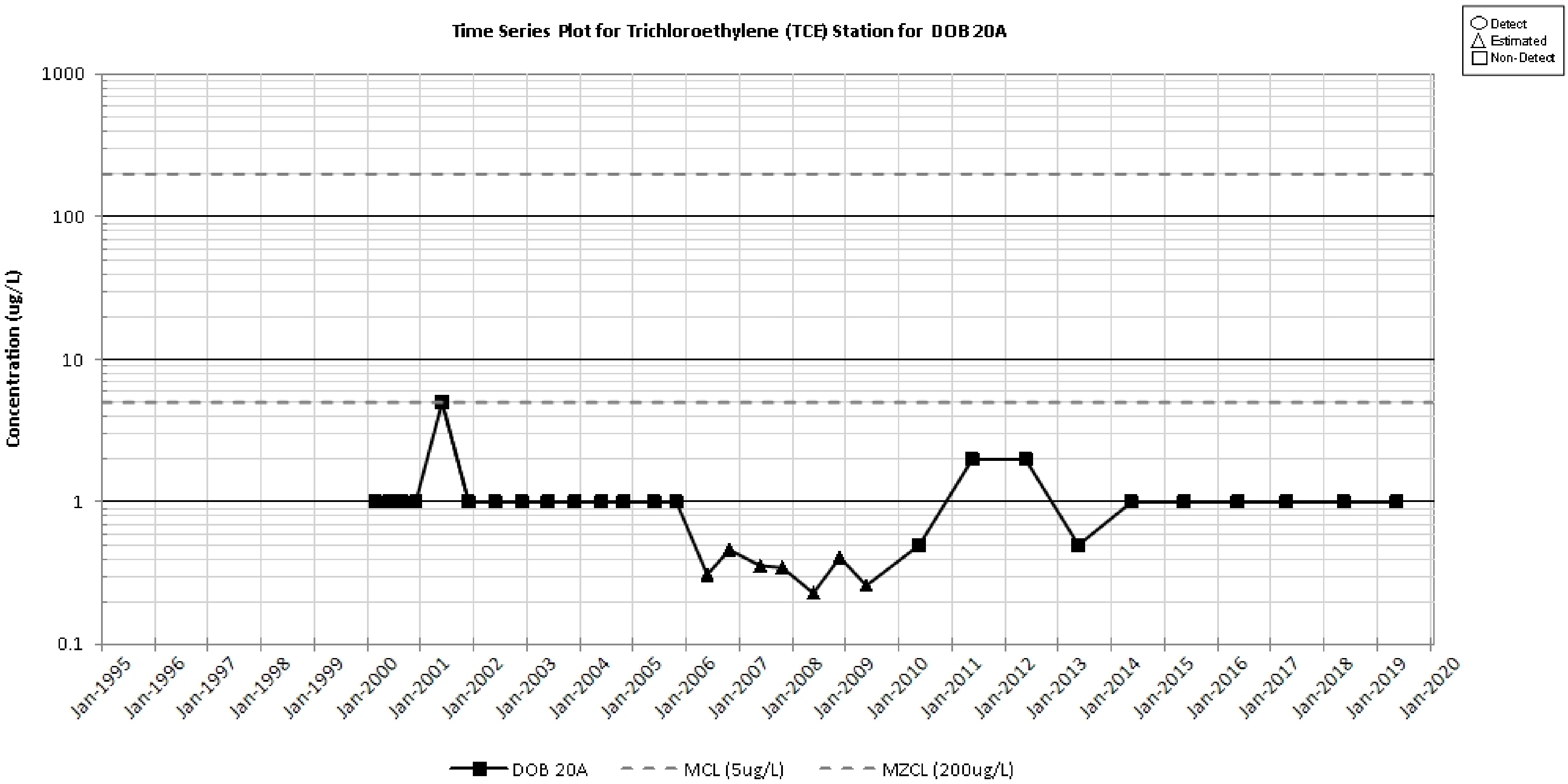


Figure D-152. Time Series Plot for Trichloroethylene (TCE) Station for DOB 20A

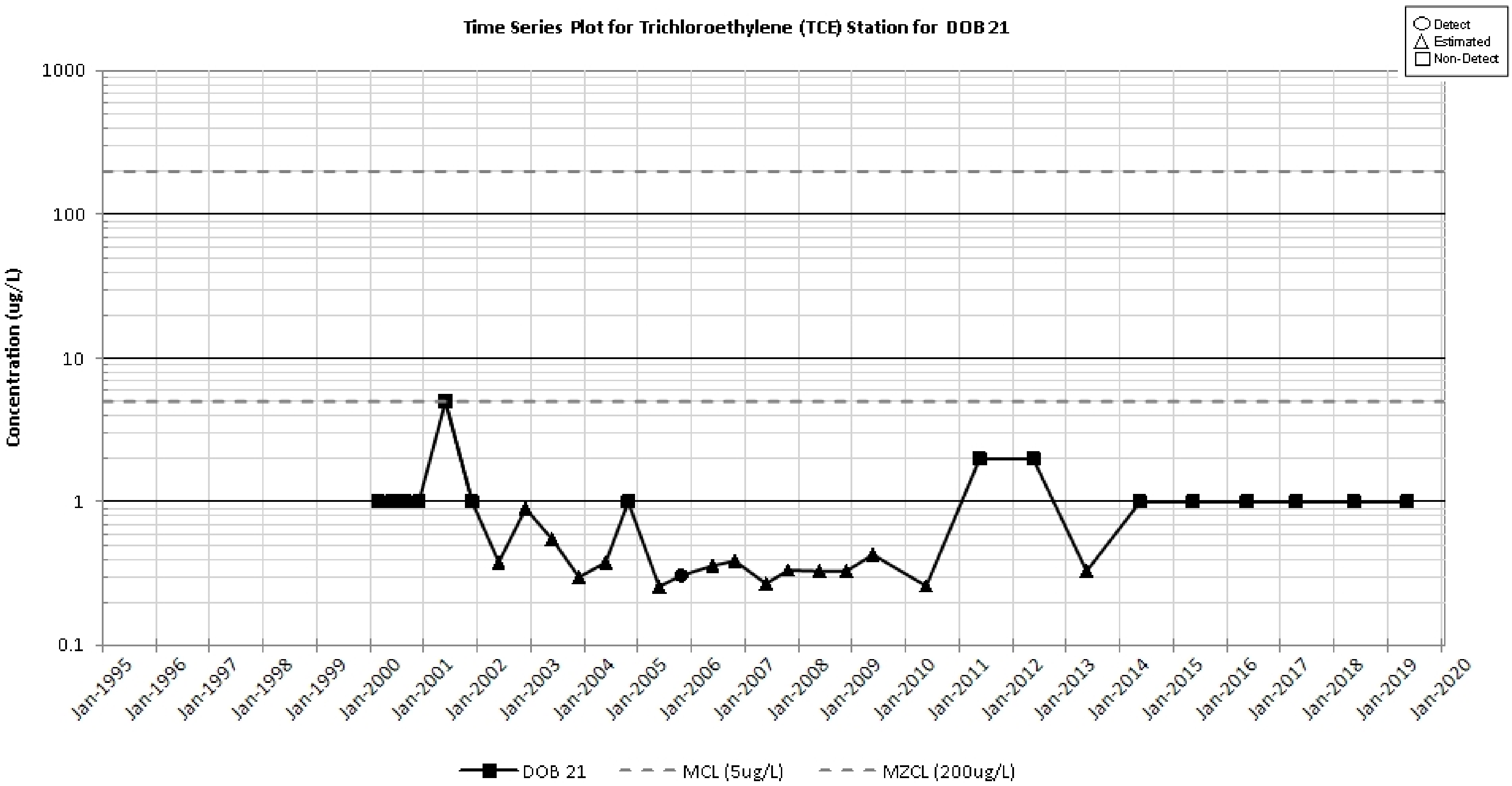


Figure D-153. Time Series Plot for Trichloroethylene (TCE) Station for DOB 21

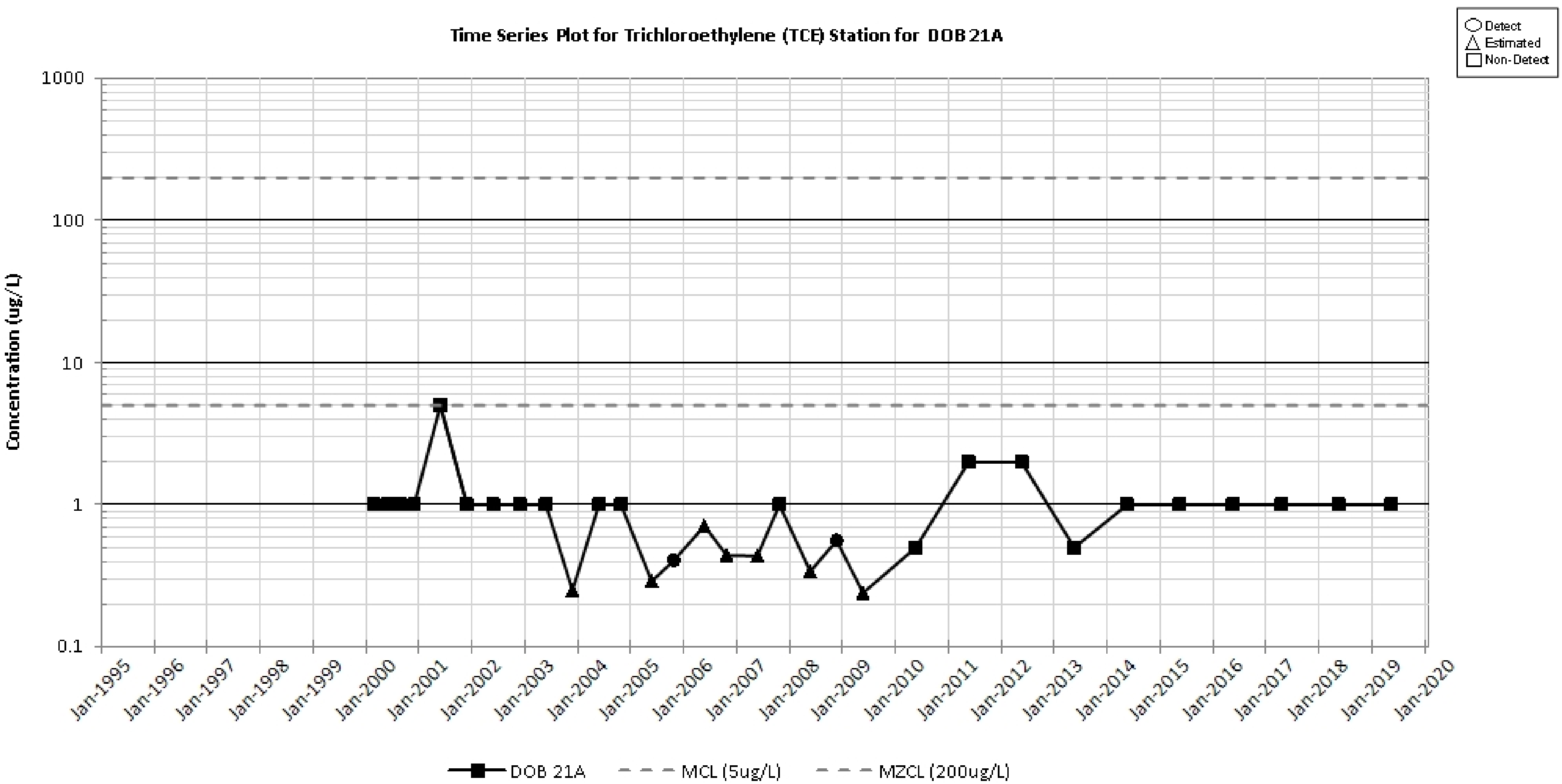


Figure D-154. Time Series Plot for Trichloroethylene (TCE) Station for DOB 21A

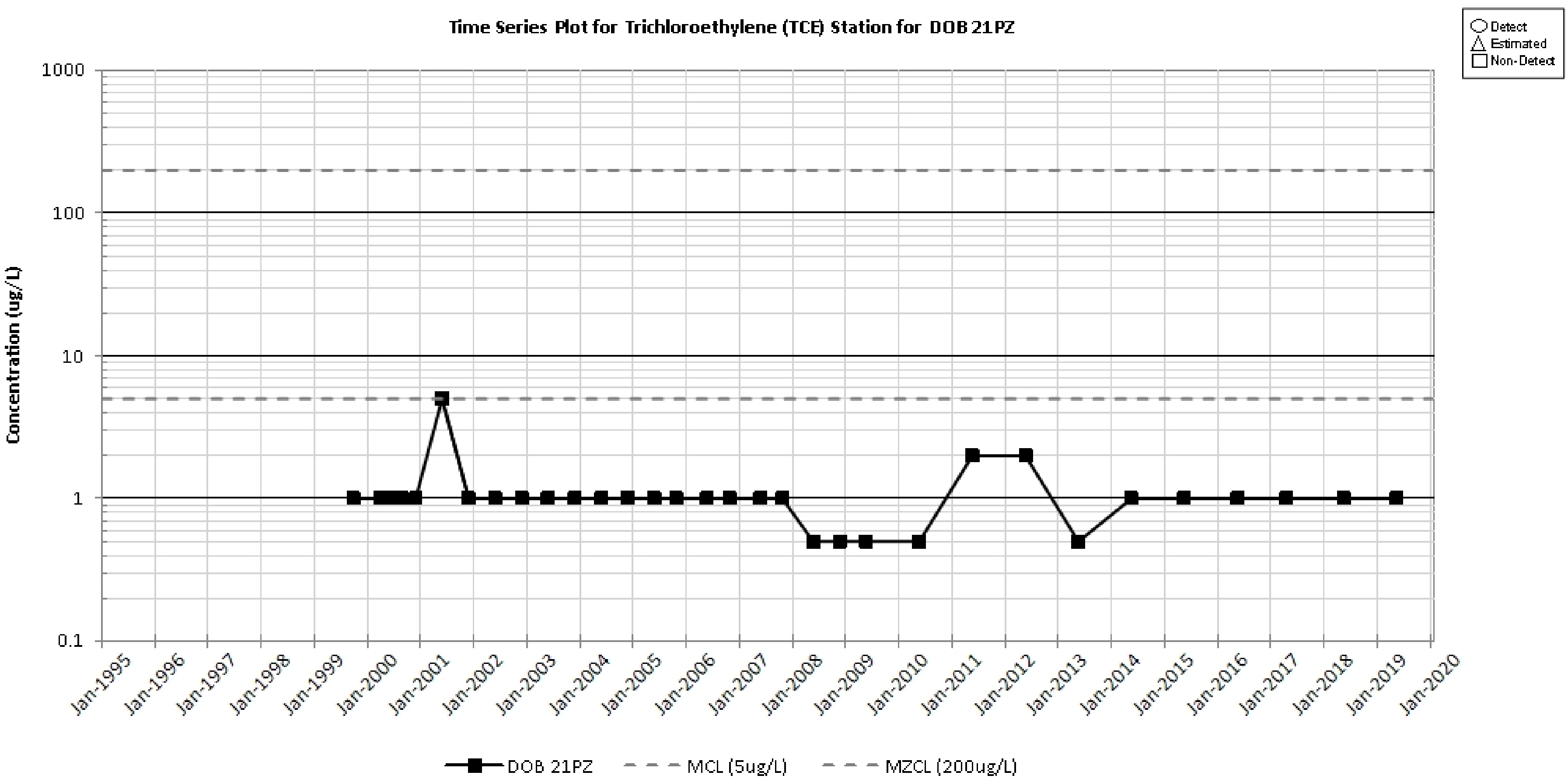


Figure D-155. Time Series Plot for Trichloroethylene (TCE) Station for DOB 21PZ

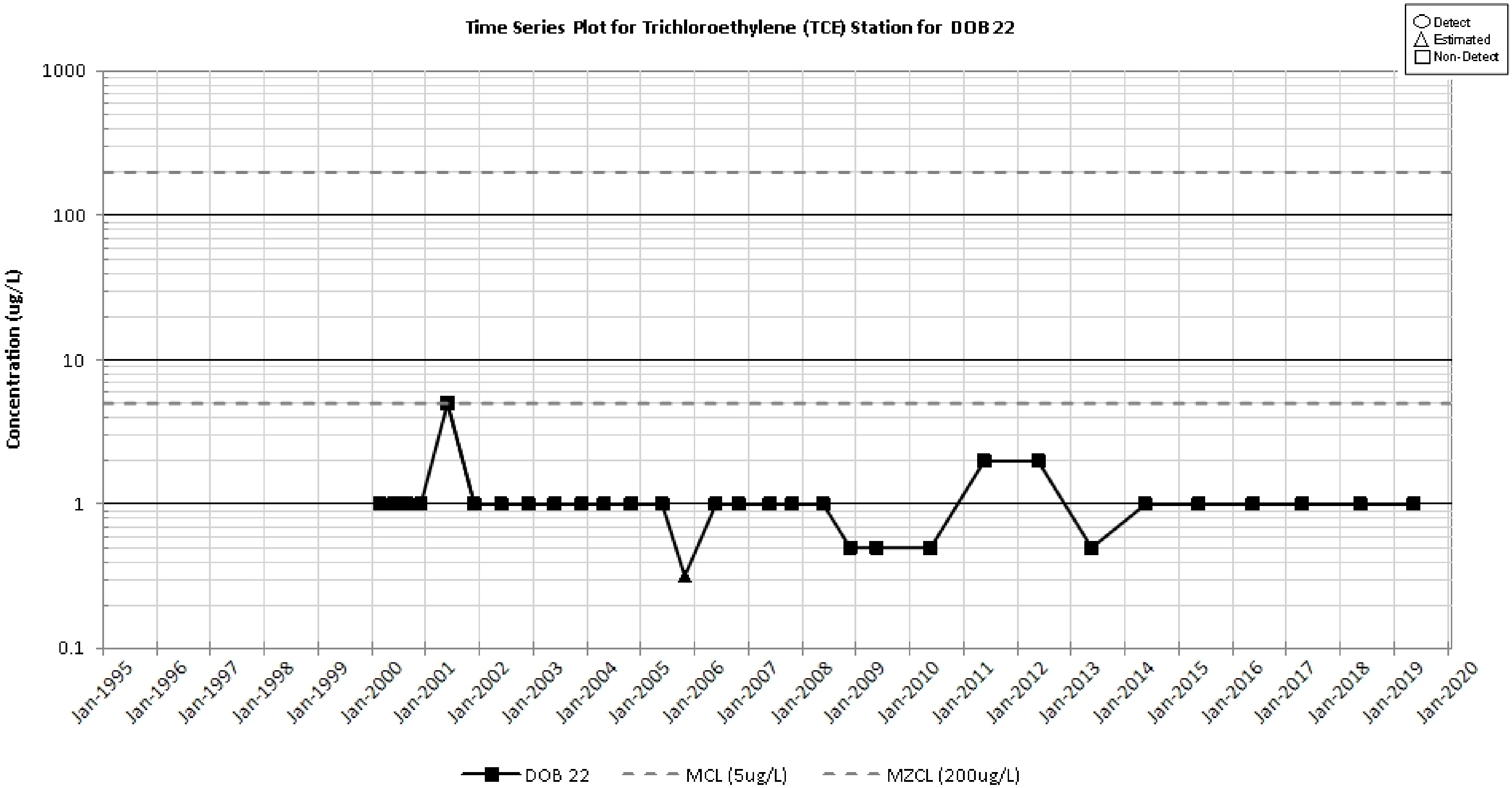


Figure D-156. Time Series Plot for Trichloroethylene (TCE) Station for DOB 22

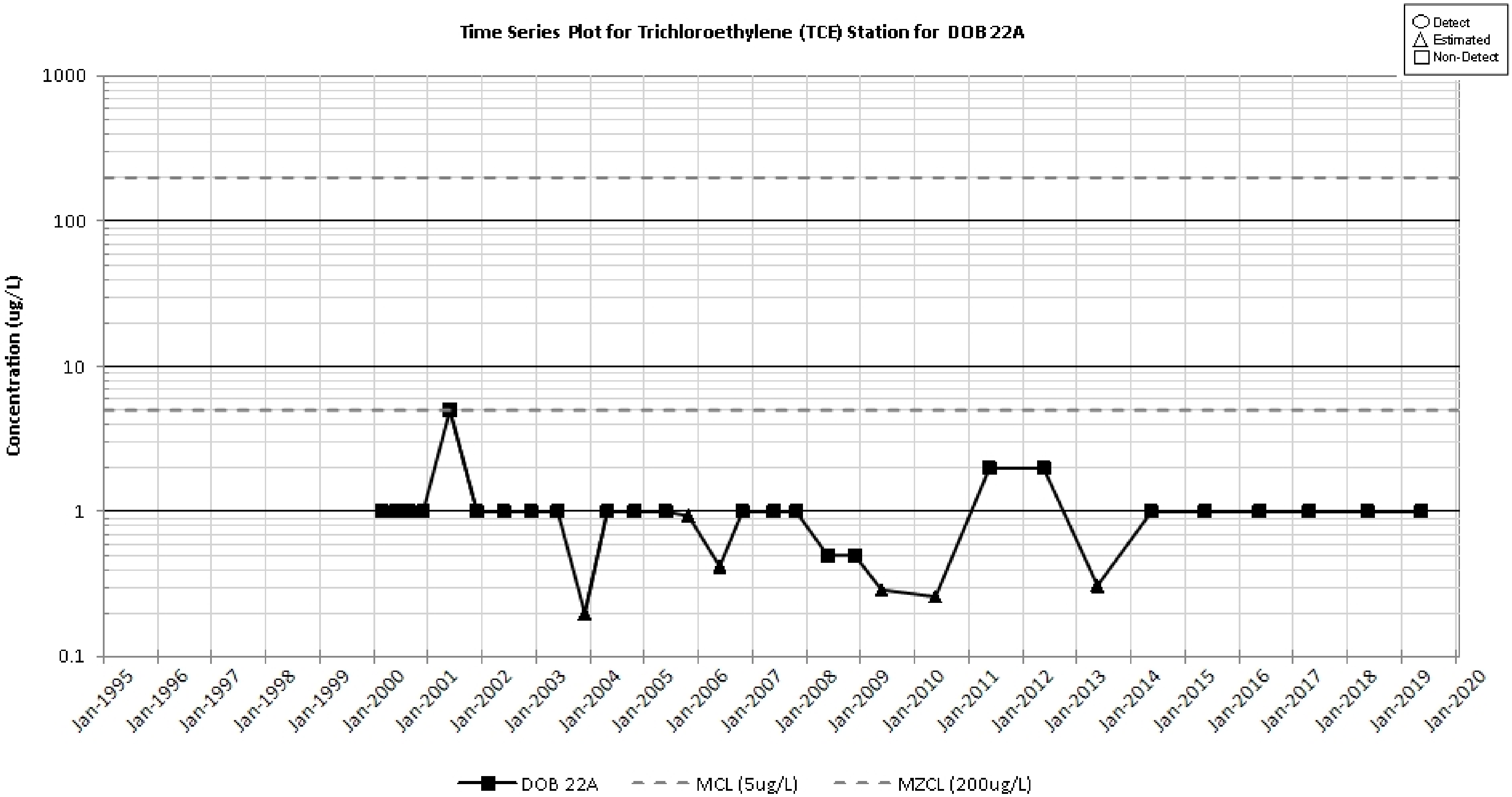


Figure D-157. Time Series Plot for Trichloroethylene (TCE) Station for DOB 22A

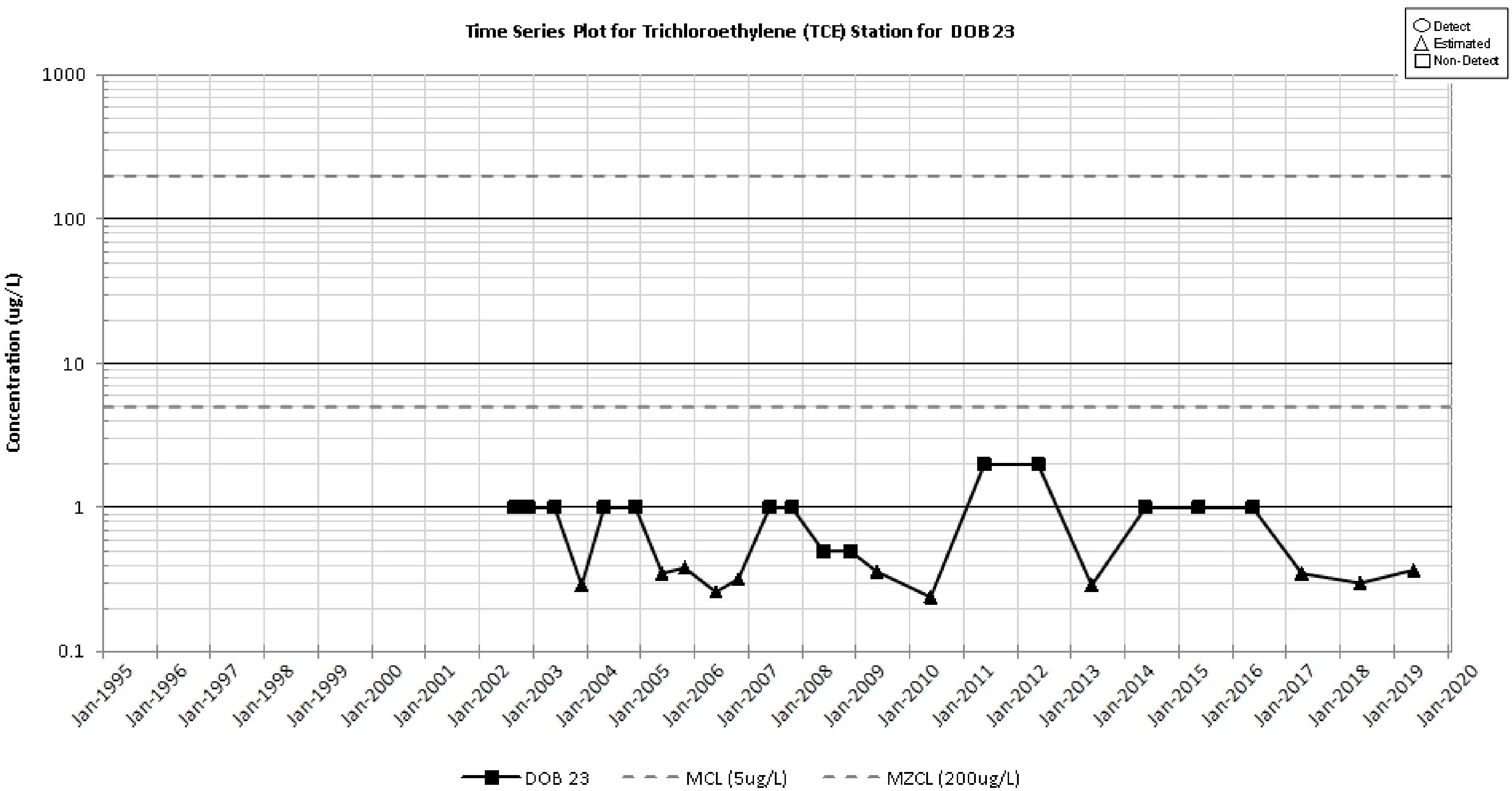


Figure D-158. Time Series Plot for Trichloroethylene (TCE) Station for DOB 23

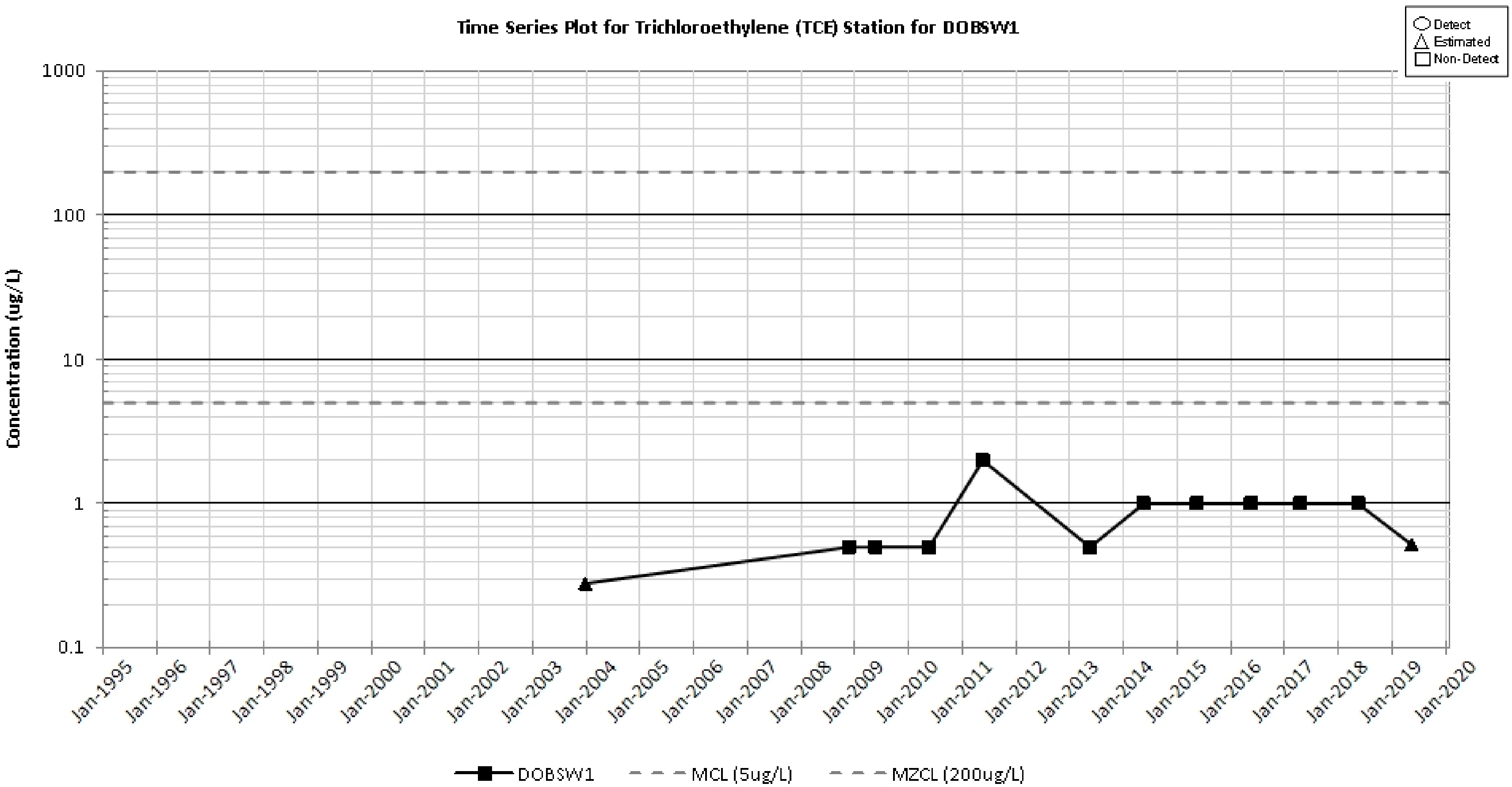


Figure D-159. Time Series Plot for Trichloroethylene (TCE) Station for DOB SW1

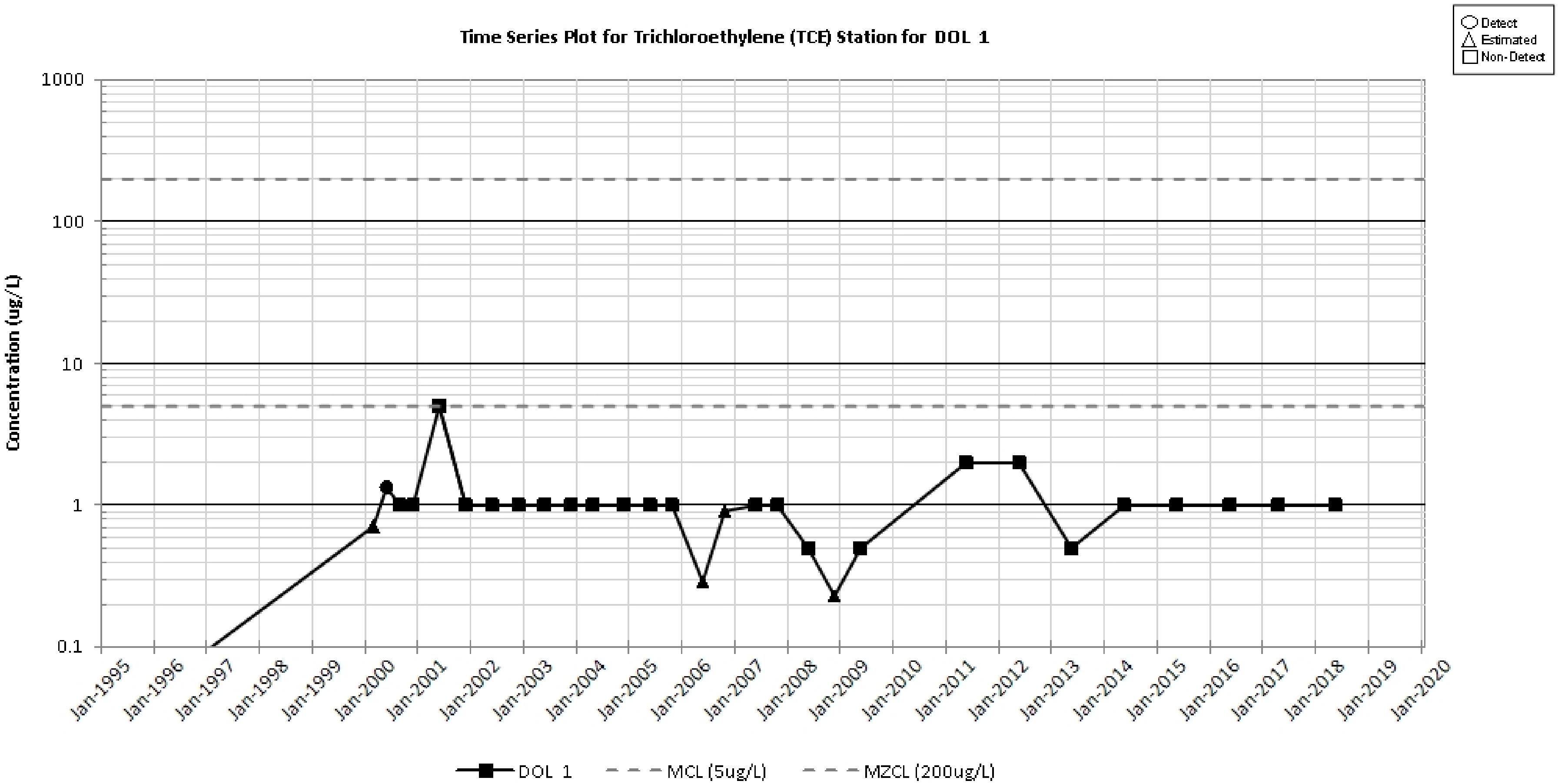


Figure D-160. Time Series Plot for Trichloroethylene (TCE) Station for DOL 1

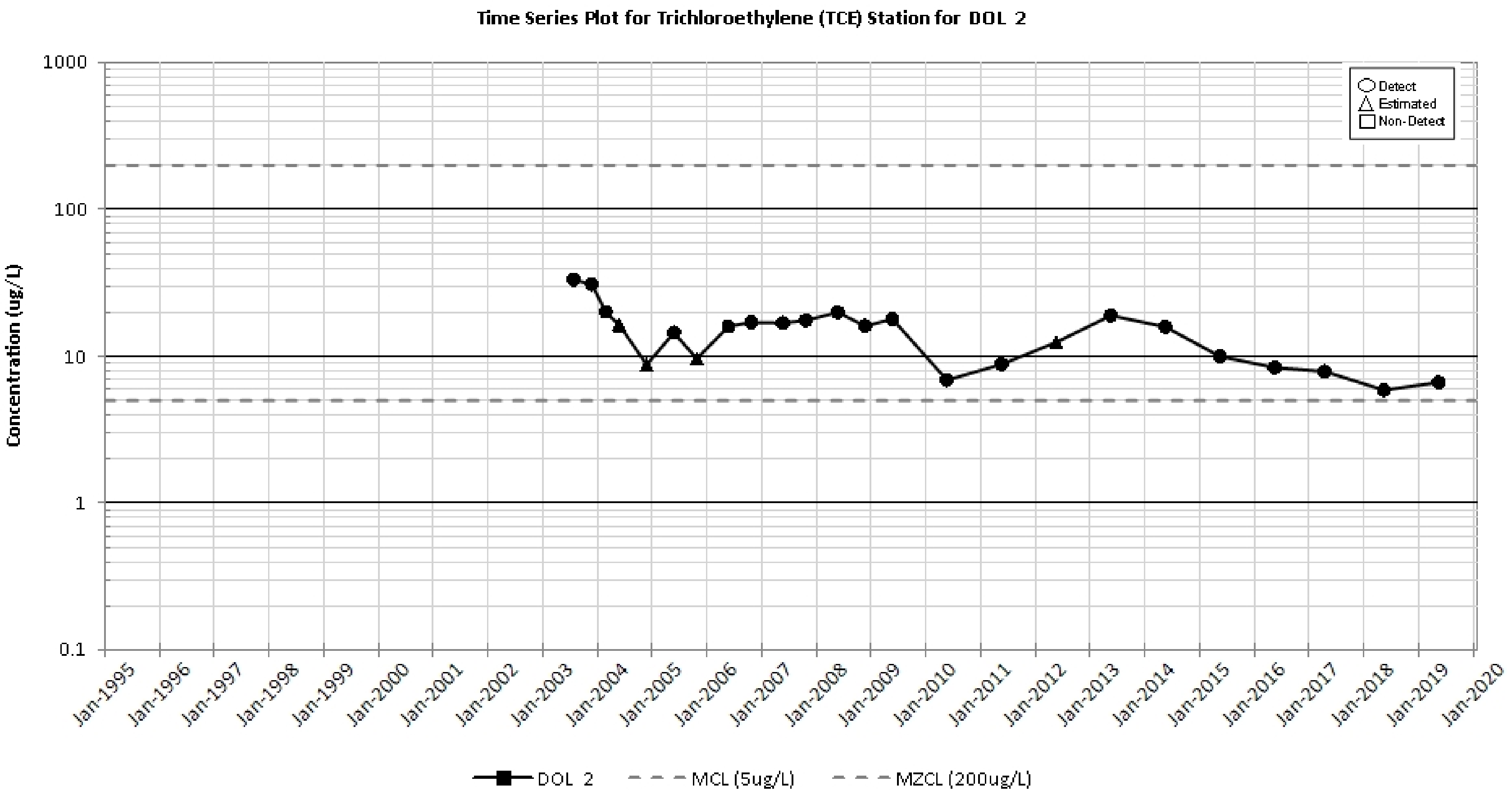


Figure D-161. Time Series Plot for Trichloroethylene (TCE) Station for DOL 2

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