ECF-HANFORD-19-0110
Revision 0

Hydraulic Gradient and Average Groundwater Velocity Calculations - Quarter 2 Calendar Year 2019

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract 89303320DEM000030

CPCCo
Central Plateau Cleanup Company

P.O. Box 1600
Richland, Washington 99352

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P.O. Box 1600
Richland, Washington 99352

APPROVED
By Sarah Harrison at 1:42 pm, Feb 16, 2021

Release Approval Date

ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

Project: S&GRP Project Delivery	**RELEASE / ISSUE**
Date: 12/17/2020	DATE: Feb 16, 2021 HANFORD RELEASE
Calculation Title and Description: Hydraulic Gradient and Average Linear Groundwater Velocity Calculations - Quarter 2 Calendar Year 2019	

Qualifications Summary

Preparer(s):

Name: Kinsley Binard

Degree, Major, Institution, Year: MSE, Civil/Environmental Engineering, University of Michigan, Ann Arbor, 1994
BA, Physics, Denison University, 1991

Professional Licenses:

Brief Narrative of Experience: Ms. Binard provides engineering expertise in all phases of groundwater and soil-remediation projects and with a wide range of site contaminants and manages complex environmental remediation projects involving multiple responsible parties, coordination with ongoing industrial operations, and strict regulatory oversight. She has prepared design drawings, specifications, bid documents, and permit applications and has been responsible for materials procurement, construction supervision and management of system operations. Ms. Binard has experience in preparation of CERCLA and RCRA reports including feasibility studies, quality assurance project plans, field sampling plans and remedial action plans.

Checker(s):

Name: Toomas Parratt

Degree, Major, Institution, Year: MScF, Natural Resources Management, Lakehead University, Thunder Bay, Ontario, 2012
B. Eng, Civil Engineering, McMaster University, Hamilton, Ontario, 2007

Professional Licenses:

Brief Narrative of Experience: Mr. Parratt has extensive experience in surface-water and and groundwater modeling of complex sites, including contaminated soils, earth filled embankments and forested landscapes. He has incorporated ecological principles, with physical-based water flow models, to assess aquifer impacts due to pumping, land-use, and climate change. He has multiple years of experience in assessing the risk and uncertainty associated with the parameterization of boundary conditions and the effect on hydraulic gradients. At Hanford, Mr. Parratt has extensive experience in P&T system performance evaluations, numerical modeling of contaminant fate and transport as part of RI/FS and RD/RAWP efforts, analysis of water-level and water-quality data, including radiological dose evaluations as part of AEA monitoring and reporting.

ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

Senior Reviewer(s):

Name: Alex Spiliotopoulos

Degree, Major, Institution, Year: PhD, Civil and Environmental Engineering, University of Vermont, 1999
BS, Civil Engineering, University of Patras, Greece, 1994

Professional Licenses:

Brief Narrative of Experience: Dr. Spiliotopoulos' expertise is analysis to support water resources management. He has developed and applied analytical and numerical models for groundwater flow and contaminant transport, focusing on pump-and-treat system operations, reactive-transport modeling, and optimization applications for least-cost remediation designs. He has extensive experience in assessing water-resources management in support of inter- and intra-state water-resource allocation and conflict resolution, assessment of water quantity and quality data, development and application of statistical tools and numerical interpolation techniques for mapping water-level and water-quality data, and the application of advanced parameter estimation techniques for model calibration. At Hanford, he has designed RPO and RI/FS remedial alternatives, including large-scale pump-and-treat networks and/or MNA and other in-situ treatment technologies for the River Corridor OUs, conducted sitewide multi-constituent plume delineation, and co-authored Remedial Design and Remedial Action Work Plans. He has provided technical support on system performance evaluations and modifications, characterization of plume migration patterns, aquifer test data interpretations as well as practical and theoretical aspects of aquifer hydraulics and their applications. He developed and contributed to numerous presentations to stakeholders, illustrating elements of the proposed remedies, and their impacts on containment and recovery performance.

SECTION 2 - Completed by Preparer

Calculation Number: ECF-HANFORD-19-0110 | Revision Number: 0

Revision History

Revision No.	Description	Date	Affected Pages
0	Initial Issue	12/17/2020	ALL

SECTION 3 - Completed by the Responsible Manager

Document Control:

Is the document intended to be controlled within the Document Management Control System (DMCS)? ◉ Yes ◯ No

Does document contain scientific and technical information intended for public use? ◉ Yes ◯ No

Does document contain controlled-use information? ◯ Yes ◉ No

SECTION 4 - Document Review and Approval

Preparer(s):

Print First and Last Name	Position	Signature	Date
Kinsley Binard	S. Engineer	[signature]	12/17/2020

Checker(s):

Print First and Last Name	Position	Signature	Date
Toomas Parratt	Project Scientist	Per email approval attached	12/17/2020

ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

Senior Reviewer(s):

Alex Spiliotopoulos	Senior Hydrogeologist	Per email approval attached	12/17/2020
Print First and Last Name	*Position*	*Signature*	*Date*

Responsible Manager(s):

William R. Faught	Manager	Faught, William R Digitally signed by Faught, William R Date: 2021.02.10 13:03:39 -08'00'	
Print First and Last Name	*Position*	*Signature*	*Date*

SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

Prior to Initiating Modeling:

Required training for modelers completed:
Integration Lead:

Print First and Last Name	*Signature*	*Date*

Safety Software Approved:
Integration Lead:

Print First and Last Name	*Signature*	*Date*

Calculation Approved:
Risk/Modeling Integration Manager:

Print First and Last Name	*Signature*	*Date*

Kinsley Binard

From: Toomas Parratt
Sent: Thursday, December 17, 2020 1:12 PM
To: Kinsley Binard; Kristen Pekoske
Subject: ECF-HANFORD-19-0110, REV. 0

The subject ECF, titled “Hydraulic Gradient and Average Linear Groundwater Velocity Calculations - Quarter 2 Calendar Year 2019” and dated 12/17/2020, was reviewed and updated. I approve it for publication as of today, December 17, 2020.

Toomas Parratt
Project Scientist
S.S. Papadopulos & Associates, Inc.
1801 Rockville Pike, Suite 220, Rockville, MD 20852
Direct: (301) 500-2286 | Office: (301) 718-8900 | Cell: (301) 674-5174
tparratt@sspa.com

Kinsley Binard

From: Alex Spiliotopoulos
Sent: Thursday, December 17, 2020 10:49 AM
To: Kinsley Binard
Cc: Kristen Pekoske
Subject: ECF-HANFORD-19-0110, REV. 0

The subject ECF, titled "Hydraulic Gradient and Average Linear Groundwater Velocity Calculations - Quarter 2 Calendar Year 2019" and dated 12/17/2020, was reviewed and updated. I approve it for publication as of today, December 17, 2020.

Alex Spiliotopoulos
Associate, Senior Hydrogeologist, PhD
S.S. Papadopulos & Associates, Inc.
1801 Rockville Pike, Suite 220, Rockville, MD 20852
Direct: (301) 500-2288 | Office: (301) 718-8900 | Cell: (301) 787-3506
alex@sspa.com

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Terms

ASCII	American Standard Code for Information Interchange
AWLN	automated water-level network
CY	calendar year
DWMU	Dangerous Waste Management Unit
ECF	environmental calculation file
HSU	hydrostratigraphic unit
IDF	Integrated Disposal Facility
MEUK	Multi Event Universal Kriging
LERF	Liquid Effluent Retention Facility
LLBG	Low-Level Burial Grounds
TRIM	Tikhonov Regularized Inverse Method
WMA	waste management area

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1 Purpose

This environmental calculation file (ECF) describes quarterly hydraulic gradient and average linear velocity calculations at the Hanford Site *Resource Conservation and Recovery Act of 1976* facilities located in the 200 East and West Areas. Gradient and average linear velocity calculations for the April-June 2019 quarter were made for the Dangerous Waste Management Units (DWMUs)[1, 2, 3] listed below and depicted in Figures 1-1 and 1-2:

200 East Area Facilities (Figure 1-1):

- 216-A-29 Ditch
- 216-A-36B Crib
- 216-A-37-1 Crib
- 216-B-3 Pond
- 216-B-63 Trench
- Integrated Disposal Facility (IDF)
- Liquid Effluent Retention Facility (LERF)
- Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-1
- LLBG WMA-2
- WMA A-AX
- WMA B-BX-BY
- WMA C

200 West Area Facilities (Figure 1-2):

- LLBG Trenches 31 and 34
- LLBG WMA-3
- LLBG WMA-4
- WMA T
- WMA TX-TY
- WMA U
- WMA S-SX
- 216-S-10 Pond and Ditch

This ECF provides the conceptual basis for the hydraulic gradient and velocity calculations performed, details the specific methods and codes used to undertake the calculations, and presents results of calculations based on the average quarterly water-table elevation map for each facility.

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[1] The Single-Shell Tank System unit group includes WMA A-AX, WMA B-BX-BY, WMA C, WMA S-SX, WMA T, WMA TX-TY, and WMA U.

[2] Under interim status, the LLBG unit group includes LLBG WMA-1, LLBG WMA-2, LLBG WMA-3, and LLBG WMA-4. At each WMA, there are specific locations where dangerous waste was disposed after the effective date of RCRA regulation. Where possible, the groundwater evaluation includes the entire WMA; however, in cases where pump and treat remedial action operations affect flow conditions, the specific locations of the dangerous waste within the WMA are the focus of groundwater evaluation.

[3] Under final status, LLBG Trenches 31 and 34 (located within LLBG WMA-3) will become a separate DWMU; therefore, it is included as a distinct 200 West Area Facility for evaluation.

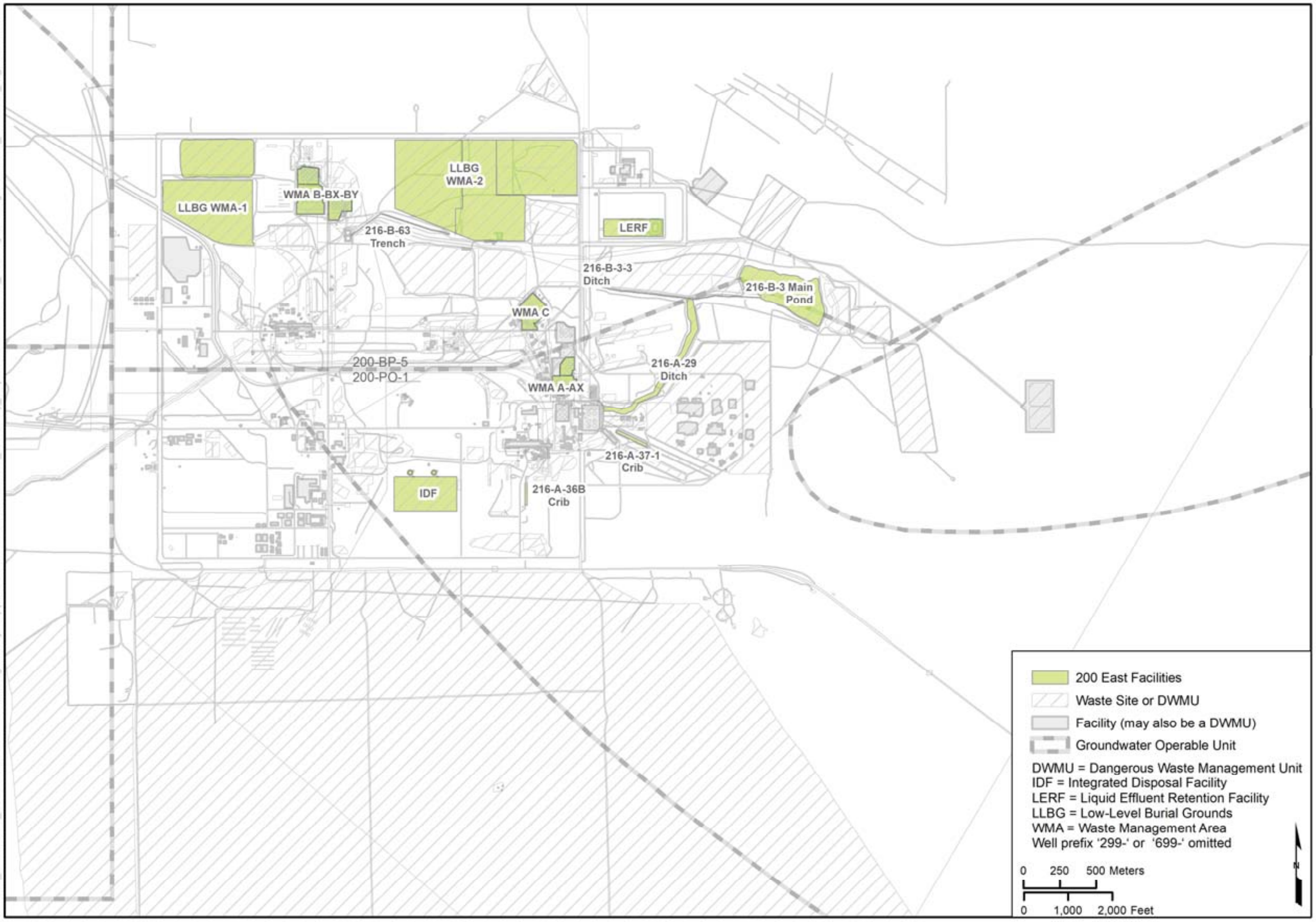

Figure 1-1. 200 East Area DWMUs Evaluated in this ECF

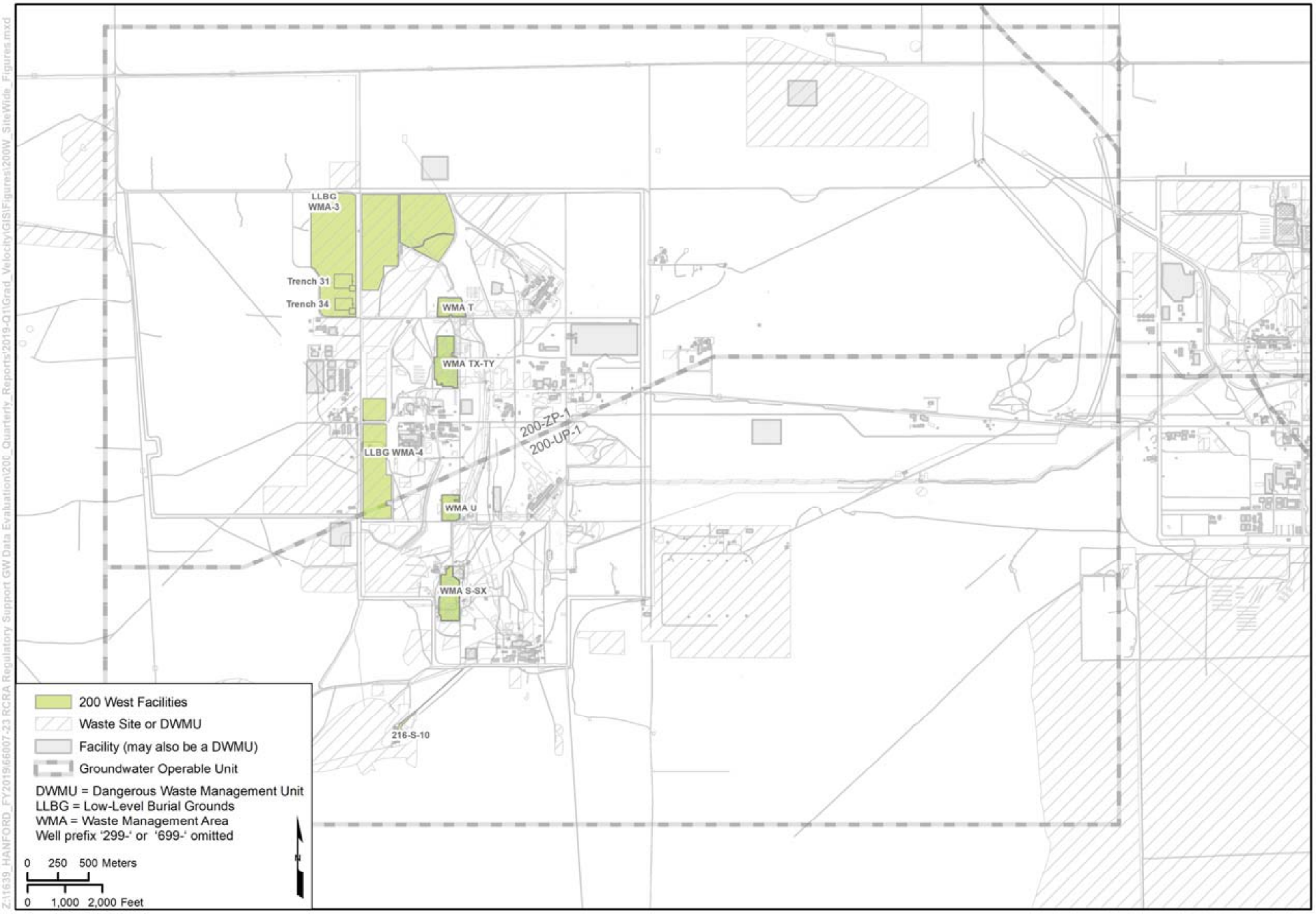

Figure 1-2. 200 West Area DWMUs Evaluated in this ECF

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2 Background

To meet the objectives of this ECF for the 200 Area, water-table elevation maps were obtained for the 200 East and West Areas using two different methods. For the 200 East Area a regularized inverse interpolation technique that is referred to as the Tikhonov Regularized Inverse Method (TRIM) (Tikhonov, 1977, "Solutions of Ill-Posed Problems") is used as described in ECF-200E-19-0081, *Groundwater Elevation Mapping for 200 East Area – Quarter 1 Calendar Year 2019*. For the 200 West Area groundwater elevations were interpolated using Multi Event Universal Kriging (MEUK) as described in ECF-200W-19-0082, *Groundwater Elevation Mapping for 200 West Area – Quarter 1 Calendar Year 2019*. Both the TRIM and MEUK were used to obtain piecewise, continuous grids of groundwater elevations. The resulting groundwater elevation grids comport well with subject matter expert knowledge of the system and other independent sources of information, and consequently are suitable for tracking particles to evaluate the likely paths of groundwater. Particle tracking also facilitates the evaluation of (1) hydraulic gradients by integrating the calculated movement of particles between two points along a pathline over a specified time interval and, (2) average linear velocities by adding the principal velocity components of the particle.

For the purposes of this ECF the magnitude and directions of gradients along with the average linear velocities specific to each facility within the 200 Areas were calculated and are presented herein.

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3 Calculation Methods

This chapter describes the calculation methods used to support this ECF.

3.1 Data Used

The hydraulic gradient and average linear velocity calculations rely on water-table elevation maps developed using water-level measurements from the 200 areas.

In the 200 East Area depth-to-water measurements are mainly obtained from the wells of the low-gradient network, supplemented with data from other wells when necessary. The low-gradient network is comprised of wells in which gyroscope surveys were performed to correct for verticality error. The tops of all the well casings were resurveyed for elevation using a highly accurate leveling technique. This is done to reduce the borehole deviation (i.e., non-verticality) that was identified as the most critical source of error in the 200 East Area water-level measurements.

For the 200 West Area water levels are obtained from wells that are part of the water-level measurement and groundwater sampling networks. For wells in the automated water-level network (AWLN), monthly averages of AWLN data are used if no representative manual measurements are available.

The average quarterly values of the water levels in the 200 areas were then calculated from the mentioned monitoring well measurements over April to June 2019 in ECF-200E-19-0108, *Groundwater Elevation Mapping for 200 East Area – Quarter 2 Calendar Year 2019* and ECF-200W-19-0109, *Groundwater Elevation Mapping for 200 West Area – Quarter 2 Calendar Year 2019*.

3.2 Generation of General Groundwater Flow Directions Using Particle Tracking

After the groundwater elevation grid for the second quarter of calendar year (CY) 2019 were generated for the 200 areas, they were used as the basis for particle tracking within a localized region of each facility. Particle tracking was performed using mod-PATH3DU (Muffels et al., 2018, *User's Guide for mod-PATH3DU, A Groundwater Path and Travel-Time Simulator*).

Ten particles were released from evenly spaced locations along a line upgradient of each facility and tracked considering only advective transport. The resulting particle pathlines allow for (1) visualization of the general groundwater flow directions in the local region of each facility and, (2) the calculation of gradients and average linear velocities based on those general flow directions.

3.3 Calculation of Average Linear Velocity

The Darcy flux, q, across a unit cross section of porous media is given by:

$$q = -Ki \qquad \textbf{Eq. (1)}$$

where, K is the hydraulic conductivity of the aquifer cross section and i is the hydraulic gradient.

Darcy flux at any point is then divided by the effective aquifer porosity, η, to yield the average linear velocity, ALV as follows:

$$ALV = \frac{q}{\eta} \qquad \textbf{Eq. (2)}$$

Mod-PATH3DU internally computes the average linear velocity components (i.e., in x- and y-directions) at each tracked point using Darcy's Law. Gridded surfaces of aquifer hydraulic conductivities and effective porosities were provided as inputs to mod-PATH3DU. The output was then used to compute the resultant average linear velocity along the calculated pathlines for each facility.

3.4 Calculation of Facility-Wide Gradients

Gradients specific to each facility were back-calculated from the calculated average linear velocities and aquifer properties using Darcy's Law. Substituting Equation 1 into Equation 2 and rearranging for the hydraulic gradient, i, yields,

$$i = ALV\left(-\frac{\eta}{K}\right) \quad \textbf{Eq. (3)}$$

The magnitude of the gradient, i, may then be taken as the absolute value of Equation 3.

The azimuth of the gradient is calculated as the horizontal angle in degrees between north and a vector represented by two pathline points in a clockwise direction.

4 Assumptions and Inputs

This chapter outlines the assumptions and inputs that underlie the calculations presented in this ECF.

4.1 Assumptions

Calculations of hydraulic gradients and average linear velocities were based upon particle pathlines generated using mod-PATH3DU which in turn rely upon outputs (i.e., grids of groundwater elevations) computed using TRIM (for 200 East Area) or MEUK (for 200 West Area). As a result the assumptions and limitations that underlie the generation of those maps and associated particle pathlines are implicit in any subsequent calculations of gradients and average linear velocities.

Particle tracking that considers advection as the sole transport mechanism relies upon:

- The assumptions in the underlying tracking scheme
- Limitations in the groundwater flow model, including discretization and boundary effects

The average linear velocity components are evaluated using Darcy's Law in mod-PATH3DU and as such corresponding assumptions of steady-state, laminar flow of incompressible fluid at a constant temperature also apply.

4.2 Input Data

This section summarizes the general input requirements for the calculations described in this ECF.

4.2.1 Water-Table Elevation Maps

Contour maps of water levels generated from compiled automated and manual elevation measurements, used in this calculation are described below.

4.2.1.1 200 East Area

The average quarterly water-table elevation map computed using TRIM (ECF-200E-19-0108) is used as the basis for gradient and average linear velocity calculations in the 200 East Area (Figure 4-1).

4.2.1.2 200 West Area

The average quarterly water-table elevation map computed using MEUK (ECF-200W-19-0109) is used as the basis for gradient and average linear velocity calculations in the 200 West Area (Figure 4-2). The water-table elevation map also illustrates the extraction/injection and monitoring wells used in the kriging dataset.

4.2.2 Migration Parameters for Particle Tracking

The hydraulic conductivity and effective porosity values were defined specific to each hydrostratigraphic unit (HSU) in CP-47631, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5* or RPP-CALC-61032, *Vadose Zone and Saturated Zone Flow and Transport Calculations for the Integrated Disposal Facility Performance Assessment*. The values for the HSUs underlying the average linear velocity calculation domains are listed in Table 4-1.

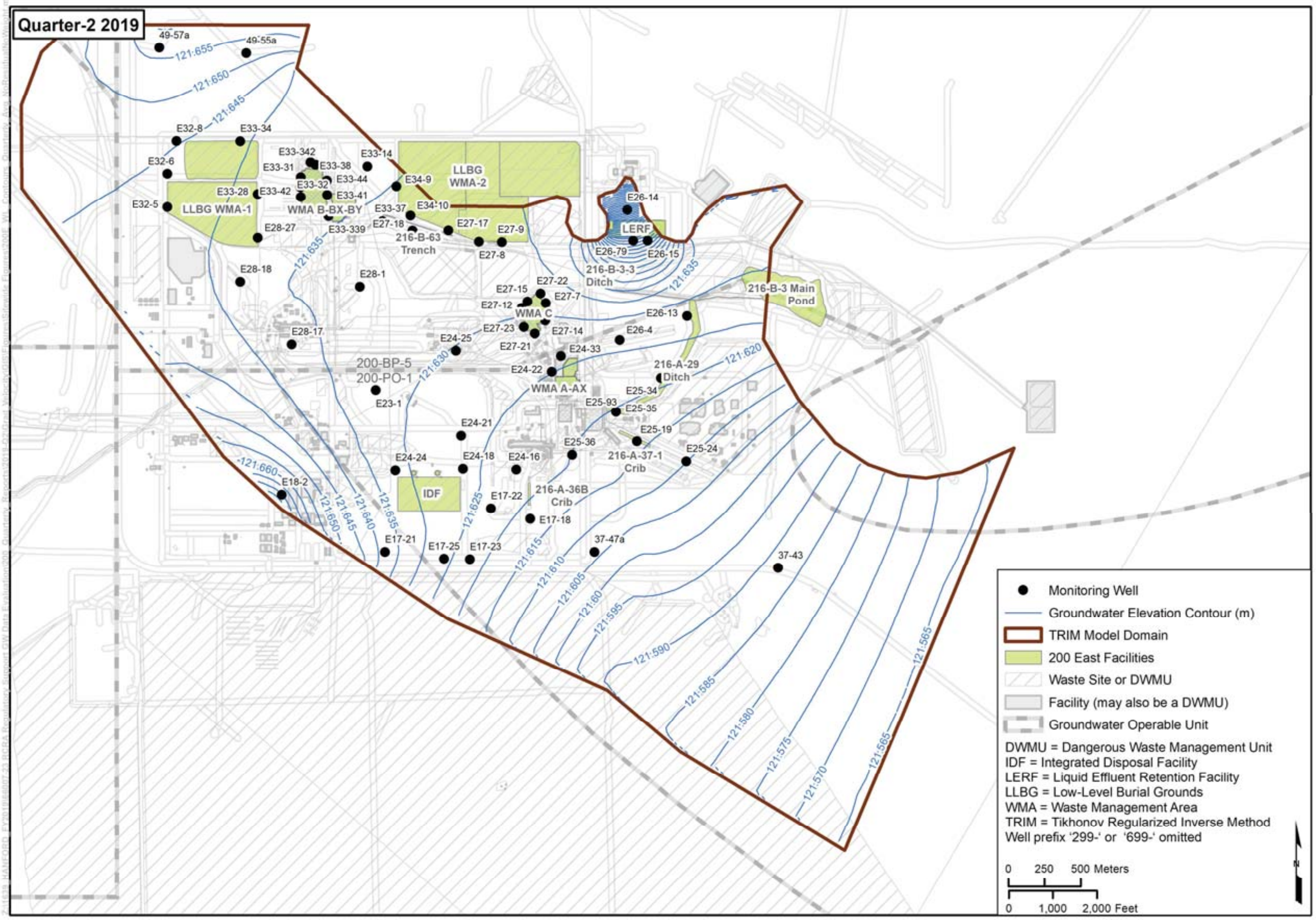

Figure 4-1. 200 East Area Mapped Groundwater Elevations: Second Quarter 2019

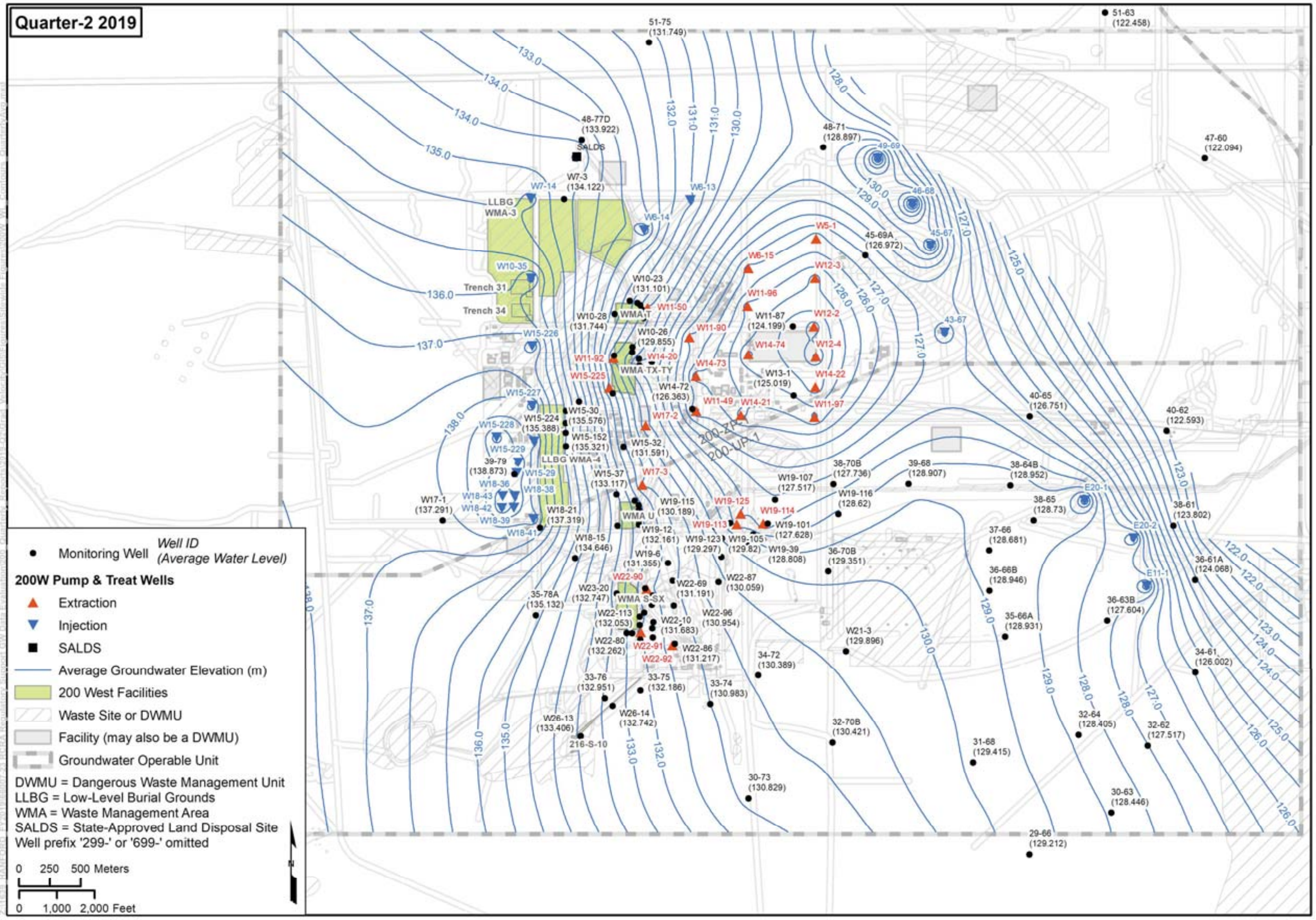

Figure 4-2. 200 West Area Mapped Groundwater Elevations: Second Quarter 2019

Table 4-1. Aquifer Transport Parameter Values

Property		Value	Comments
Hydraulic conductivity	Hanford formation	17,000 m/d (55,800 ft/d)	From RPP-CALC-61032, Rev. 0
	CCU gravel	18,200 m/d (59,700 ft/d)	From RPP-CALC-61032, Rev. 0
	Rwie	5 m/d (16 ft/d)	From RPP-CALC-61032, Rev. 0
Effective/ mobile porosity	Hanford formation	0.25	CP-47631
	Rwie	0.15	CP-47631

References: CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 8.4.5*.

RPP-CALC-61032, *Vadose Zone and Saturated Zone Flow and Transport Calculations for the Integrated Disposal Facility Performance Assessment*

CCU = Cold Creek unit

Rwie = Ringold Formation member of Wooded Island – unit E

4.2.3 Particle Release Locations

Ten particle release locations were placed at evenly spaced intervals along straight lines immediately upgradient of each facility with some exceptions discussed in the following sections. Six release locations were used for the IDF. The lines were oriented such that the resulting pathlines provide uniform coverage of the respective facilities. This was possible for all 200 East Area facilities except LLBG WMA-2, LERF, and the 216-B-3 Pond. The TRIM grid assumes no flow in portions of those 200 East Area facilities due to the presence of basalt or mud at or above the water table. The extents of the TRIM grid cover the unconfined aquifer underlying the 200 East Area facilities (ECF-200E-18-0066, *Groundwater Flow and Migration Calculations to Assess Monitoring Networks in the 200 East Area Dangerous Waste Management Units*). Full coverage was possible for all 200 West Area facilities except LLBG WMA-3 and Trenches 31 and 34. Due to the locations and operations of injection wells in the vicinity of LLBG WMA-3 and Trenches 31 and 34, the curvature in the flow field upgradient of these facilities would cause particles to travel parallel to the facility if released from upgradient locations. As such, particle release locations were placed upgradient of the Green Islands[4] and the sumps within LLBG WMA-3 and Trenches 31 and 34, respectively, in order to obtain pathlines projecting downgradient over areas of concern.

Figures 4-3 and 4-4 show the particle release locations for the 200 East and 200 West Area facilities, respectively.

4 The LLBG Closing Units "Green Islands" unit group comprises multiple locations of regulated dangerous waste within the LLBG unit. The Green Islands within each LLBG Closing Unit are addressed within their respective WMAs for groundwater monitoring.

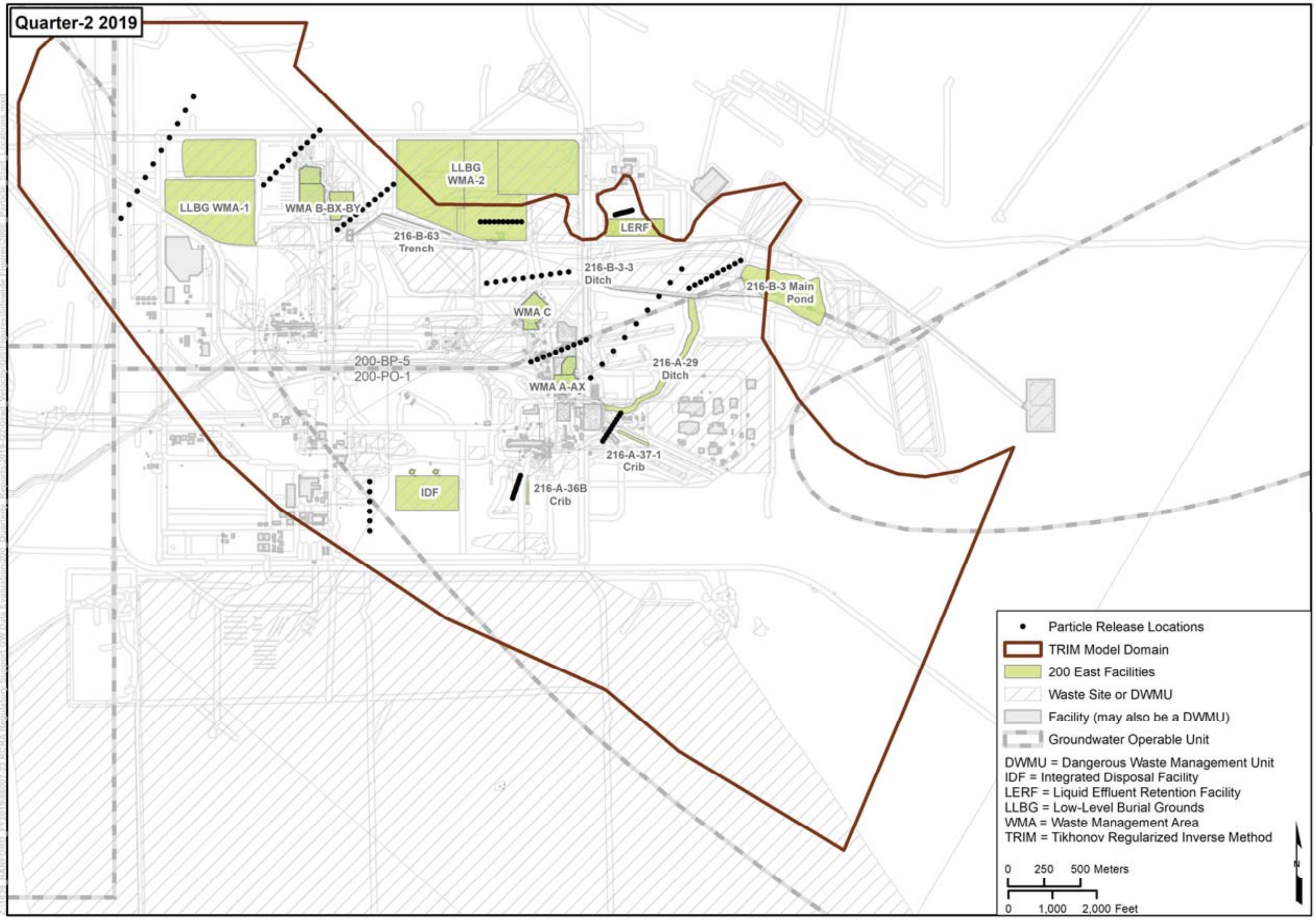

Figure 4-3. Release Locations at 200 East Area Facilities

Figure 4-4. Release Locations at 200 West Area Facilities

5 Software Applications

The software used to create the water-table elevation maps used as the basis for the calculations performed herein are described in ECF-200E-19-0108 and ECF-200W-19-0109. Only support software was used to perform the post-processing calculations detailed in this ECF.

The following software programs are classified as support software.

- Groundwater Vistas™: Rumbaugh and Rumbaugh, 2017, *Groundwater Vistas Version 7*. Provided graphical tools used for model quality assurance and model input/output review (Rumbaugh and Rumbaugh, 2017, *Groundwater Vistas Version 7*).
- **ArcGIS**®: Visualization and post-processing tool for assessing simulated plume distributions, identifying extraction/injection well coordinates, and mapping auxiliary data (Mitchell, 1999, *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns & Relationships*).
- **mod-PATH3DU**: Particle-tracking code for calculating the three-dimensional flow pathlines and travel times of solute particles.
- **writep3doutput**: Post-processing program to convert mod-PATH3DU binary output files to commonly used file types i.e., American Standard Code for Information Interchange (ASCII) text files, dBase database file tables, and ESRI shapefiles.
- **Python:** Python™ is a general-purpose, object-oriented programming language. A Python script was used to: (1) calculate gradients and average linear velocities from the water-table elevation mapping and particle tracking results and, (2) generate facility-specific histogram plots. The script was executed from the command-line using the ArcGIS® Python distribution (Python Version 2.7.16, distributed with ArcGIS 10.7 [32 bit]). The following Python packages are utilized within the script.
  - Numpy (Version 1.9.3)
  - Pandas (Version 0.18.1)
  - Matplotlib (Version 1.5.2)

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® ArcGIS is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, California.
™ Python is a registered trademark of Python Software Foundation, Beaverton, Oregon 97008, (www.python.org).

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6 Calculations

This chapter describes the calculations performed to examine all 200 Area Facilities. The following steps were taken to develop the necessary input files, perform the calculations, and post-process the outputs to produce the results presented in this ECF.

6.1 Generation of General Groundwater Flow Directions Using Particle Tracking

Particle tracking was performed using mod-PATH3DU.

The grids of groundwater elevations generated for the second quarter of CY 2019 using TRIM and MEUK were used as the basis for particle tracking. Gradients and average linear velocities specific to each facility were then calculated from the tracked particle pathlines representing the general groundwater flow directions within a localized region of the facility.

The calculated groundwater elevations generated throughout the domain were first imported into the Groundwater Vistas Graphical User Interface software and then exported as a regular grid using the Surfer grid format to serve as an input file for mod-PATH3DU. Two ASCII text files, each representing grids of hydraulic conductivities and mobile porosities as presented in Table 4-1, were prepared to serve as the per-cell property input files for mod-PATH3DU.

Particle tracking calculations were carried out for each facility using the following steps:

1. Particle release locations were set up in ArcMap® and then exported as a point ArcGIS shapefile to serve as the particle release location input file for mod-PATH3DU.The particle release locations for each facility in the 200 East and 200 West Areas are shown in Figures 4-1 and 4-2, respectively.
2. The primary mod-PATH3DU input file was generated with the following:
   a. A maximum tracking time that allowed the majority of the particles released to migrate beyond the locations of the facility's boundary during the calculations. Thus, the tracking time varied for each facility, resulting in a different number of data points.
   b. Particles were tracked via advective transport only.
3. mod-PATH3DU was executed to make the particle-tracking calculations and produce a binary pathline output file containing the pathlines for each tracked particle. mod-PATH3DU calculates the advective velocity at any point along the pathline using the hydraulic gradient at that point and the provided cell porosity and hydraulic conductivity.
4. A post-processing program (writep3doutput.exe) was executed to convert the mod-PATH3DU binary pathline output file into an ASCII text file format which lists particle coordinate locations, travel time, and the advective velocities in the x- and y-directions.

The post-processed mod-PATH3DU output files were then used for visualizing the particle pathlines and calculating the facility-specific average linear velocities and gradients.

® ArcMap is a registered trademark of the Environmental Systems Research in Redlands, California.

6.2 Calculation of Average Linear Velocity

The advective velocity at any point along the pathline is calculated by mod-PATH3DU using the gridded groundwater-elevation surface, cell porosity and hydraulic conductivity provided as inputs.

For each facility a binary pathline output file was produced by mod-PATH3DU containing the pathlines for each tracked particle. The output files were converted into an ASCII text file format as detailed in Section 6.1. The text file lists the advective velocities in the x- and y-directions at each point along the pathline.

The x- and y- components of the advective velocity vector for each tracked point were then added to yield the resultant average linear velocity vector, ALV, as follows:

$$ALV = \sqrt{{v_x}^2 + {v_y}^2} \qquad \textbf{Eq. 4}$$

where, v_x and v_y are the advective velocities in the x- and y-directions respectively.

6.3 Calculation of Facility-Wide Gradients

For each facility a binary pathline output file was produced by mod-PATH3DU containing the pathlines for each tracked particle. The binary pathline output file was converted into an ASCII text file format as detailed in Section 6.1.

Gradient magnitudes and azimuths for each pathline segment were then calculated using (1) the calculated average linear velocities and (2) the gridded surfaces of aquifer hydraulic conductivities and effective porosities as described in Table 4.1.

7 Results

This chapter presents outputs from the previously described calculations. The results presented include the following:

- Summary tables and corresponding plots of calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities for the 200 East and 200 West Area facilities
- Maps of particle pathlines that were calculated using the quarterly mapped water-table elevations throughout the 200 East and 200 West Areas, respectively, illustrating general groundwater flow directions in the vicinity of each facility
- Histogram plots of gradient magnitudes, gradient azimuths, and average linear velocities calculated from the particle pathlines for each facility

7.1 200 East Area

Summary statistics pertaining to the calculated hydraulic gradients and average linear velocities at the 200 East Area facilities for the second quarter of 2019 are presented in Table 7-1. Figure 7-1 through Figure 7-3 illustrate the same data graphically. The results for each 200 East Area facility are presented in the facility-specific sections below.

Table 7-1. Calculated Hydraulic Gradients and Average Linear Velocities at the 200 East Area Facilities for Second Quarter of 2019

Site	Gradient Magnitude (m/m)				Gradient Azimuth (degrees from North)				Average Linear Velocity (m/d)			
	Min	Max	Average	Median	Min	Max	Average	Median	Min	Max	Average	Median
216-A-29 Ditch	1.10E-05	6.90E-05	1.94E-05	1.75E-05	122	175	153	154	0.80	4.69	1.40	1.27
216-A-36B Crib	1.05E-05	2.23E-05	1.90E-05	1.96E-05	113	140	134	135	3.51E-04	7.42E-04	6.32E-04	6.54E-04
216-A-37-1 Crib	1.17E-05	2.41E-05	1.61E-05	1.56E-05	122	150	135	135	0.80	1.75	1.15	1.13
216-B-3 Main Pond	7.45E-06	3.61E-05	2.00E-05	1.83E-05	137	180	161	161	0.54	2.49	1.43	1.33
216-B-63 Trench	1.30E-06	4.12E-06	1.79E-06	1.59E-06	118	150	138	138	0.09	0.28	0.13	0.12
IDF	2.17E-06	3.70E-05	1.06E-05	1.34E-05	62	127	92	92	3.09E-04	2.52	0.54	0.59
LERF	8.72E-05	4.84E-04	2.59E-04	2.48E-04	148	206	172	170	2.91E-03	1.61E-02	8.63E-03	8.27E-03
LLBG WMA-1	1.16E-06	2.52E-05	8.70E-06	7.58E-06	85	158	126	128	0.08	1.75	0.61	0.53
LLBG WMA-2	1.98E-06	5.64E-06	3.23E-06	3.33E-06	180	253	213	210	0.13	0.38	0.22	0.23
WMA A-AX	9.48E-06	1.93E-05	1.19E-05	1.14E-05	140	169	154	153	0.67	1.41	0.85	0.82
WMA B-BX-BY	1.00E-06	9.69E-06	2.05E-06	1.73E-06	108	159	145	145	0.07	0.71	0.15	0.13
WMA C	7.10E-06	3.17E-05	1.31E-05	1.21E-05	158	230	183	178	0.48	2.15	0.90	0.82

IDF = Integrated Disposal Facility

LERF = Liquid Effluent Retention Facility

LLBG = Low-Level Burial Grounds

WMA = Waste Management Area

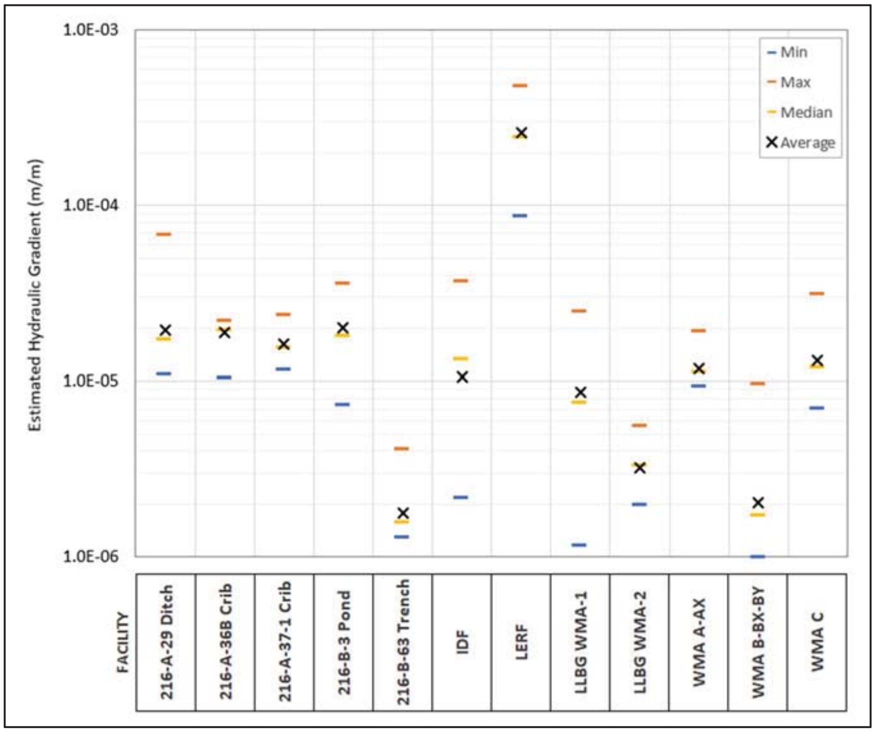

Figure 7-1. Calculated Hydraulic Gradient Magnitudes at the 200 East Area Facilities, for the Second Quarter of 2019

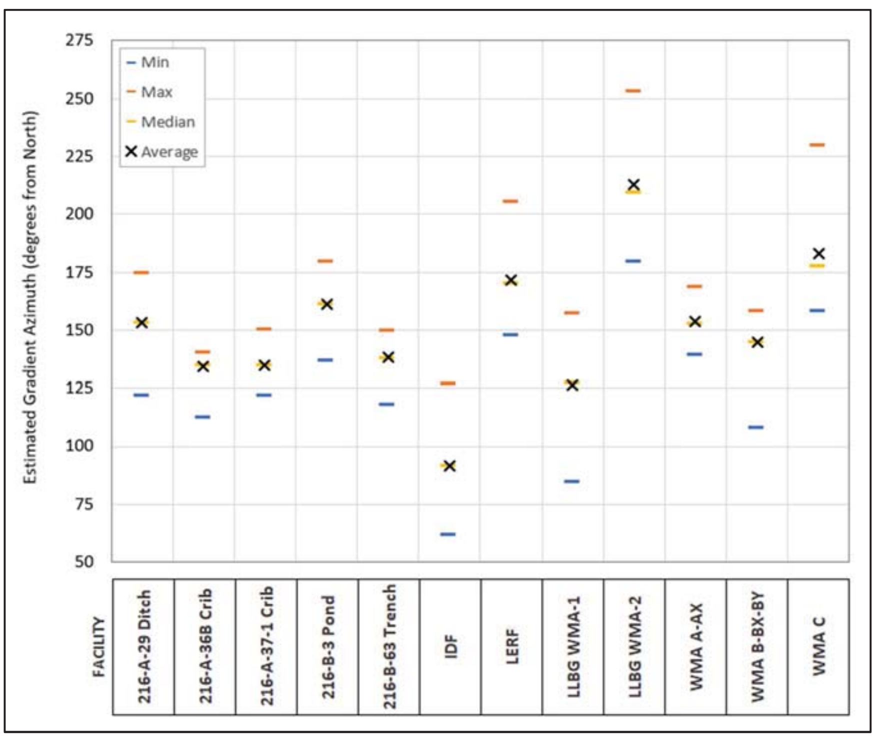

Figure 7-2. Calculated Hydraulic Gradient Azimuths at the 200 East Area Facilities, for the Second Quarter of 2019

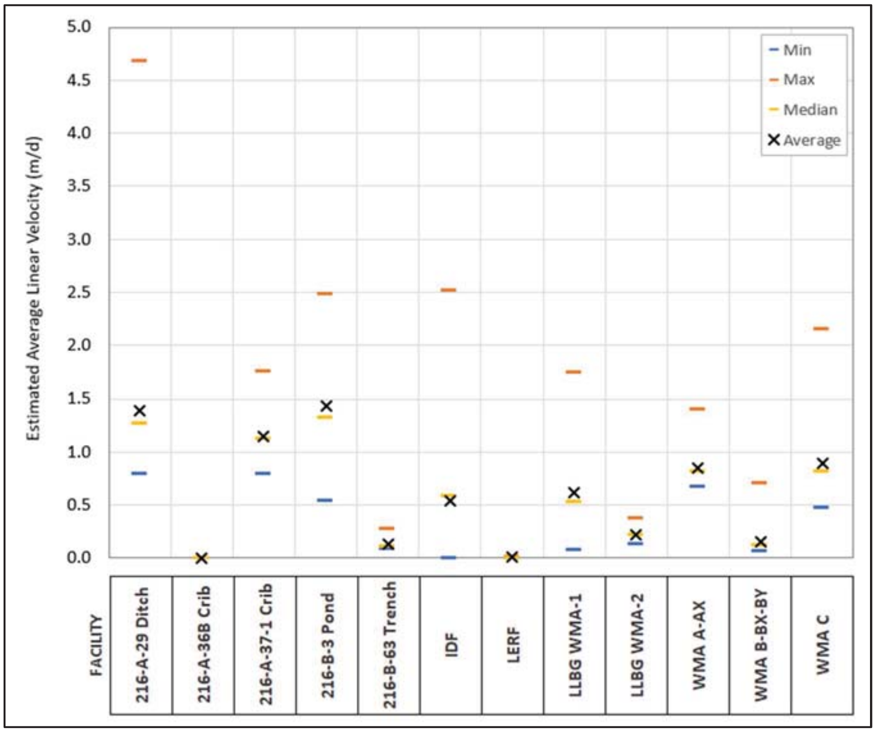

Figure 7-3. Calculated Average Linear Velocities at the 200 East Area Facilities, for the Second Quarter of 2019

7.1.1 216-A-29 Ditch

Figure 7-4 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the 216-A-29 Ditch. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-A-29 Ditch are presented in Figure 7-5 through Figure 7-7.

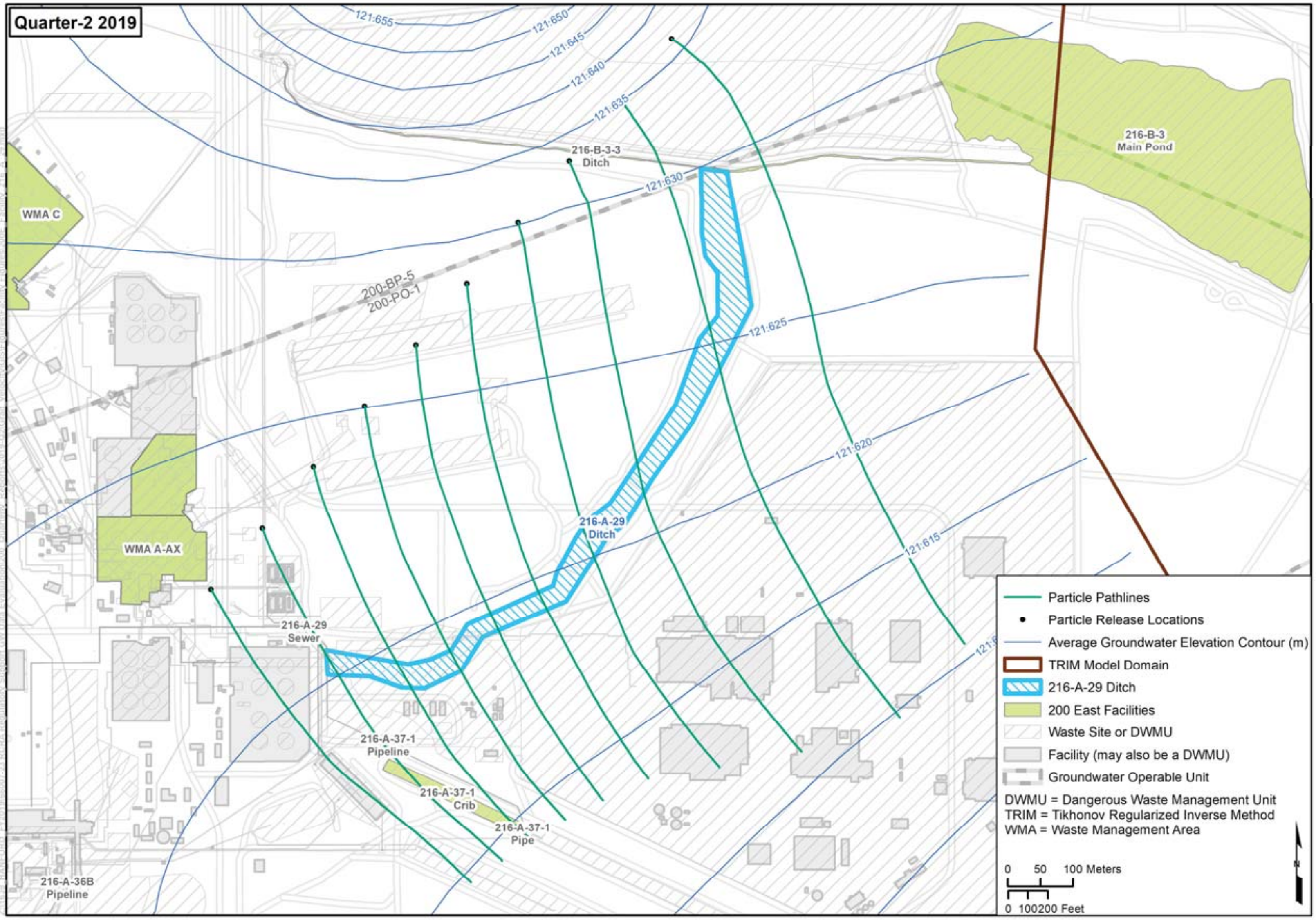

Figure 7-4. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-A-29 Ditch for the Second Quarter of 2019

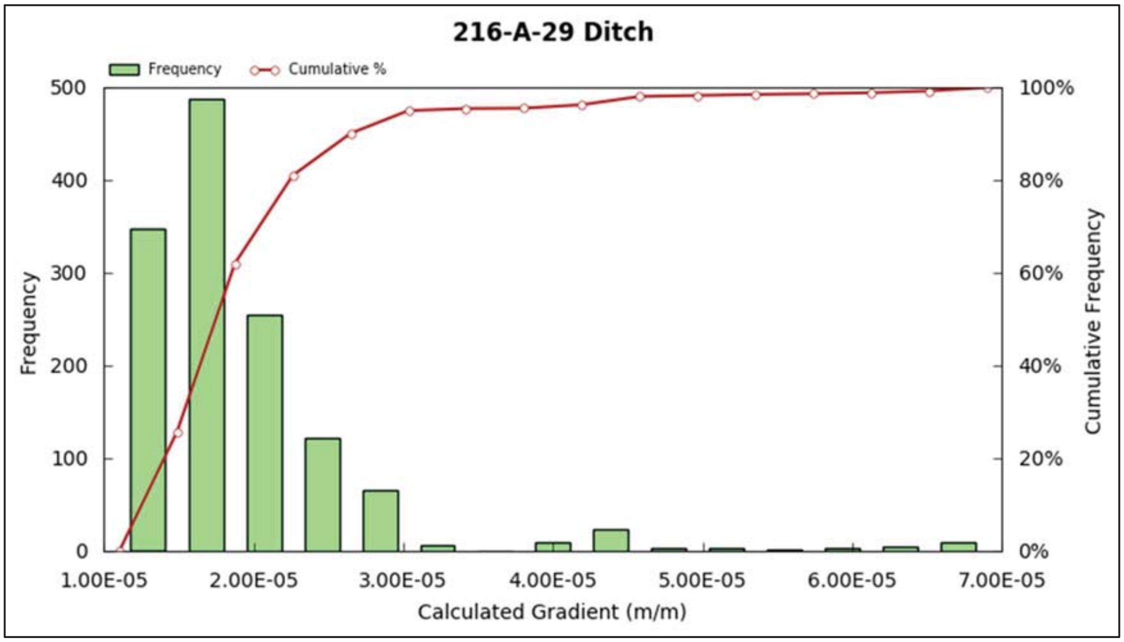

Figure 7-5. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-A-29 Ditch for the Second Quarter of 2019

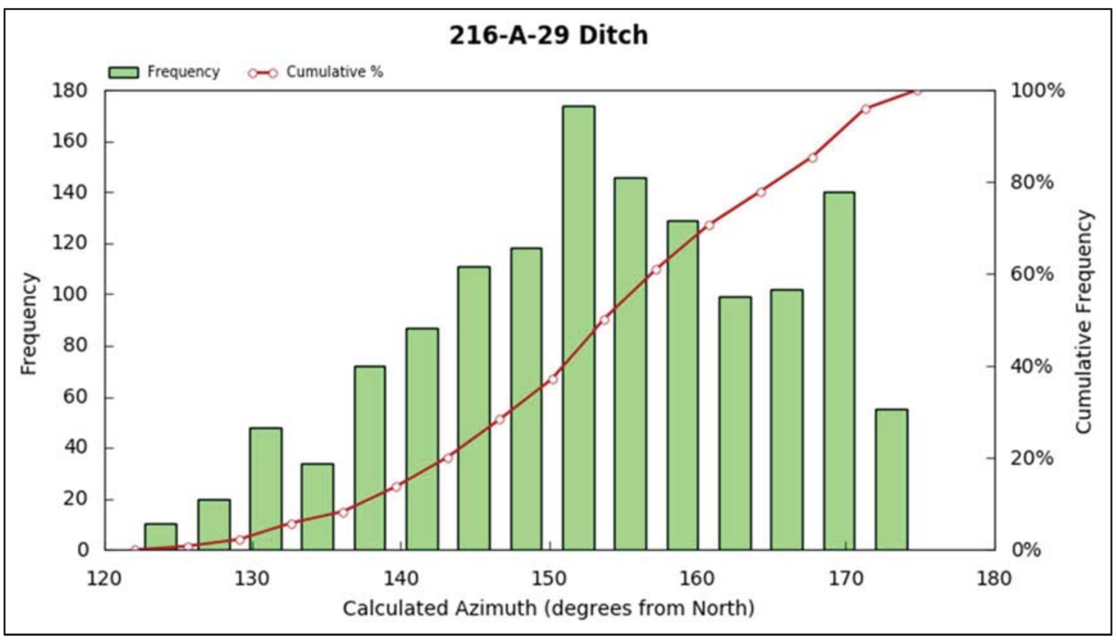

Figure 7-6. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-A-29 Ditch for the Second Quarter of 2019

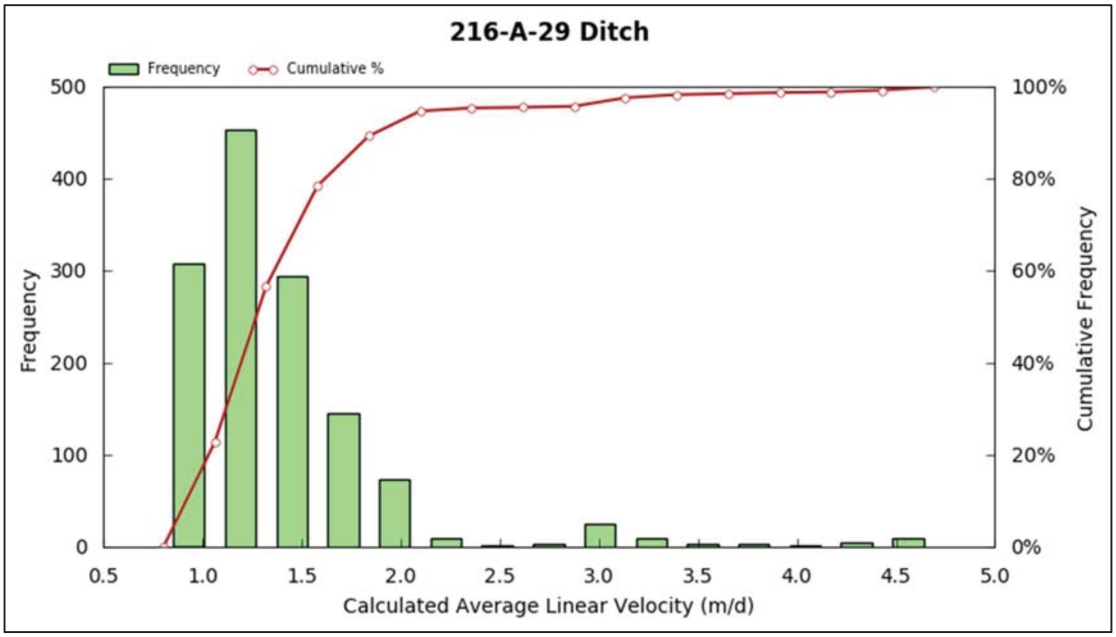

Figure 7-7. Histogram Plot of Calculated Average Linear Velocities at the 216-A-29 Ditch for the Second Quarter of 2019

7.1.2 216-A-36B Crib

Figure 7-8 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the 216-A-36B Crib. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-A-36B Crib are presented in Figure 7-9 through Figure 7-11.

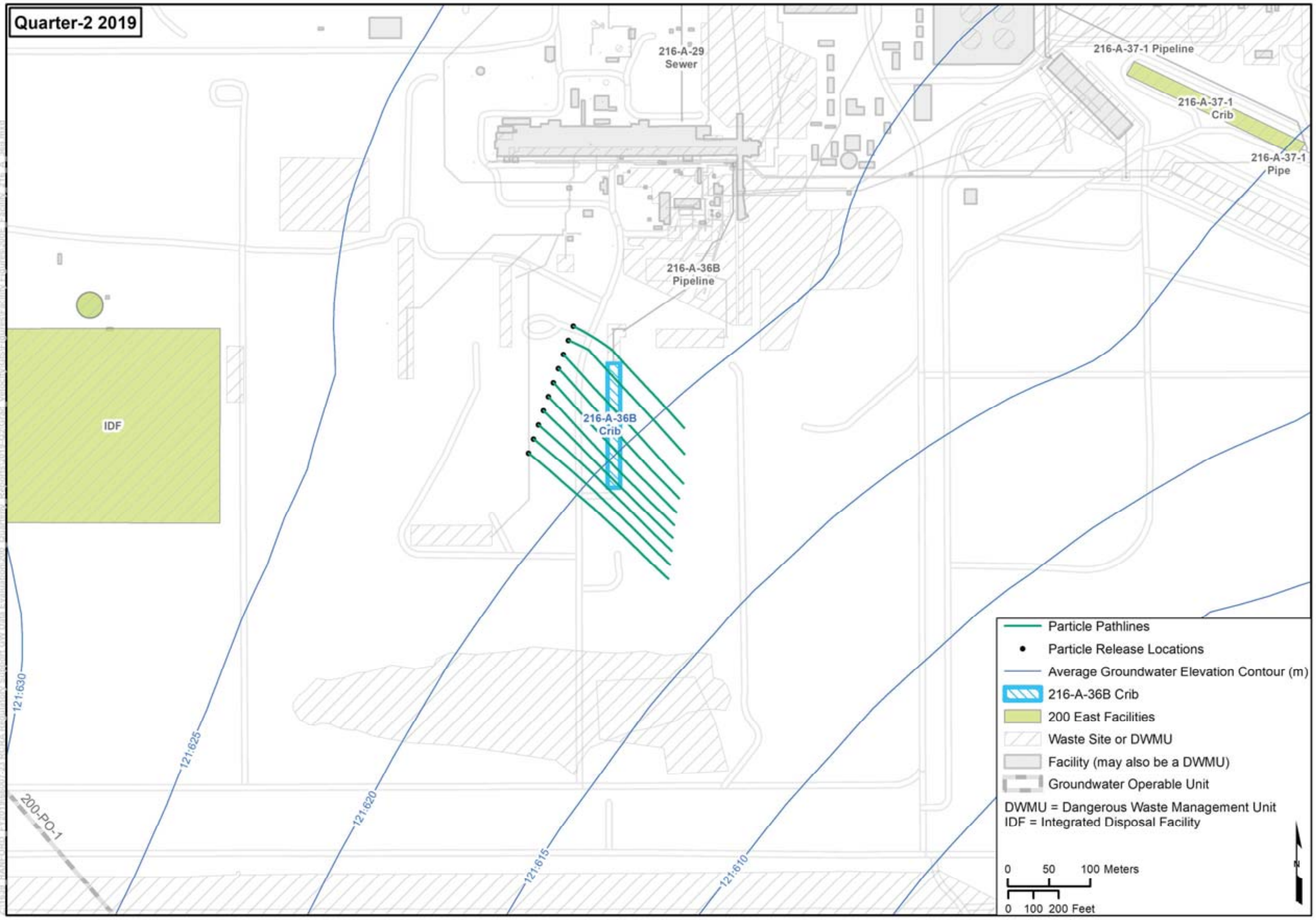

Figure 7-8. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-A-36B Crib for the Second Quarter of 2019

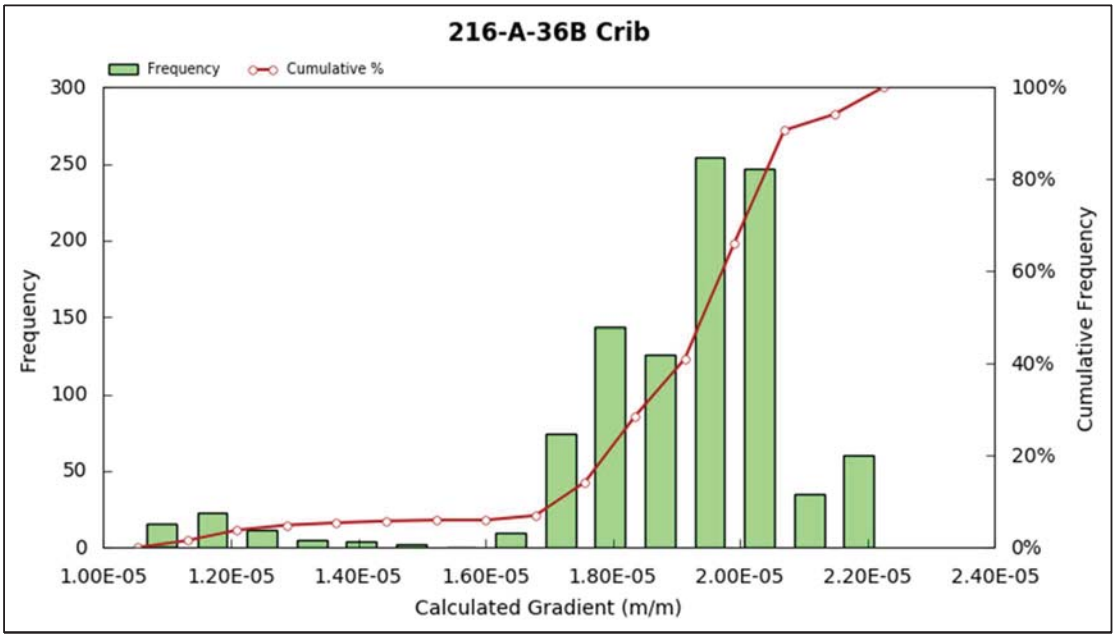

Figure 7-9. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-A-36B Crib for the Second Quarter of 2019

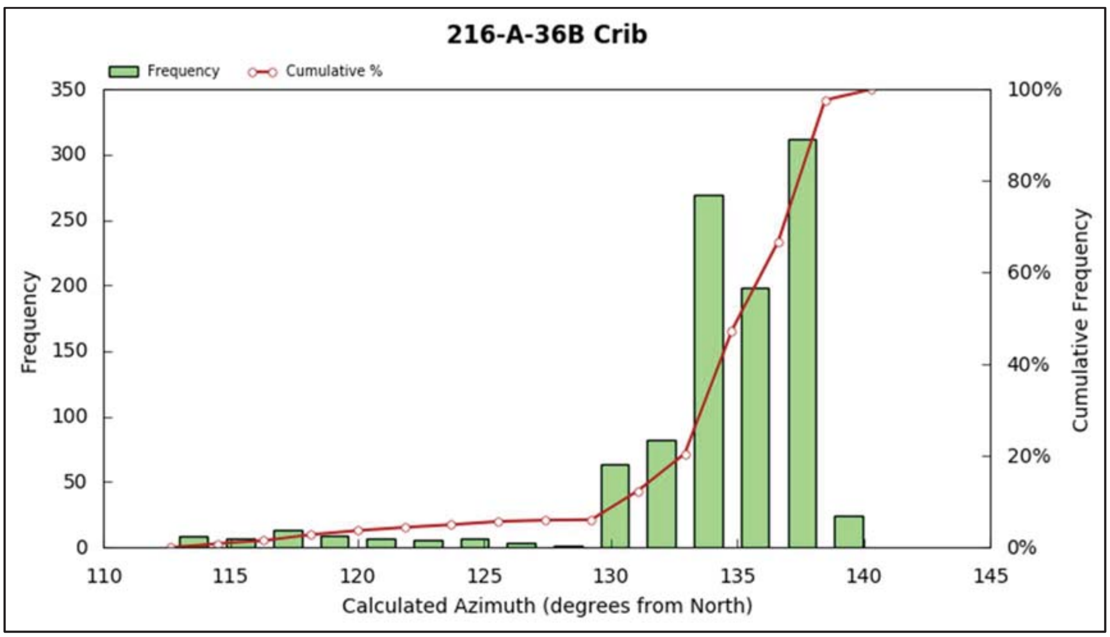

Figure 7-10. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-A-36B Crib for the Second Quarter of 2019

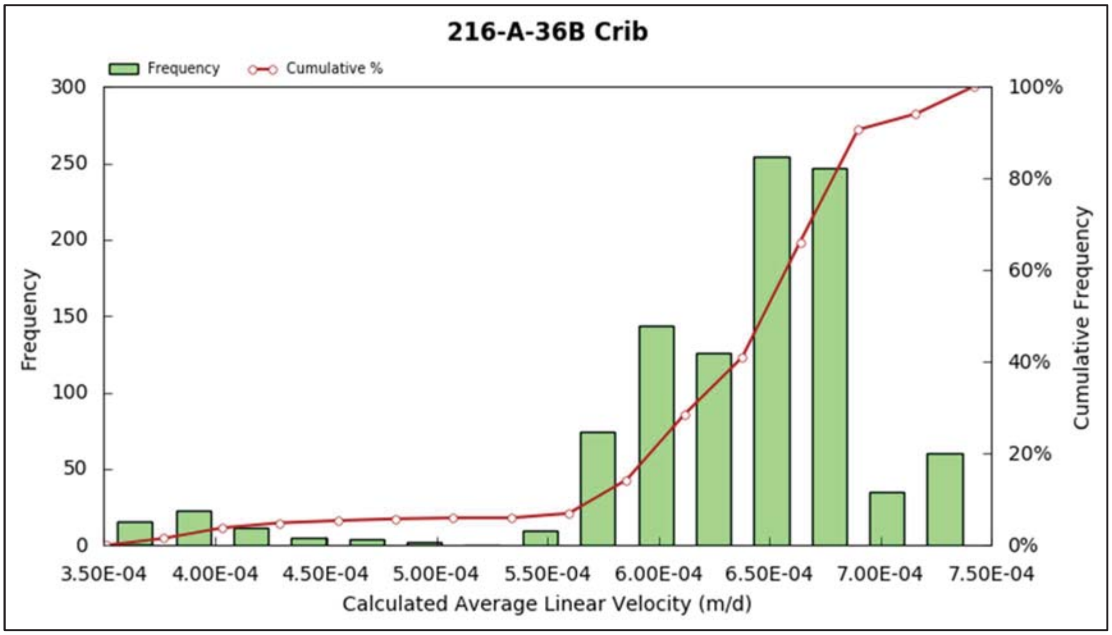

Figure 7-11. Histogram Plot of Calculated Average Linear Velocities at the 216-A-36B Crib for the Second Quarter of 2019

7.1.3 216-A-37-1 Crib

Figure 7-12 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the 216-A-37-1 Crib. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-A-37-1 Crib are presented in Figure 7-13 through Figure 7-15.

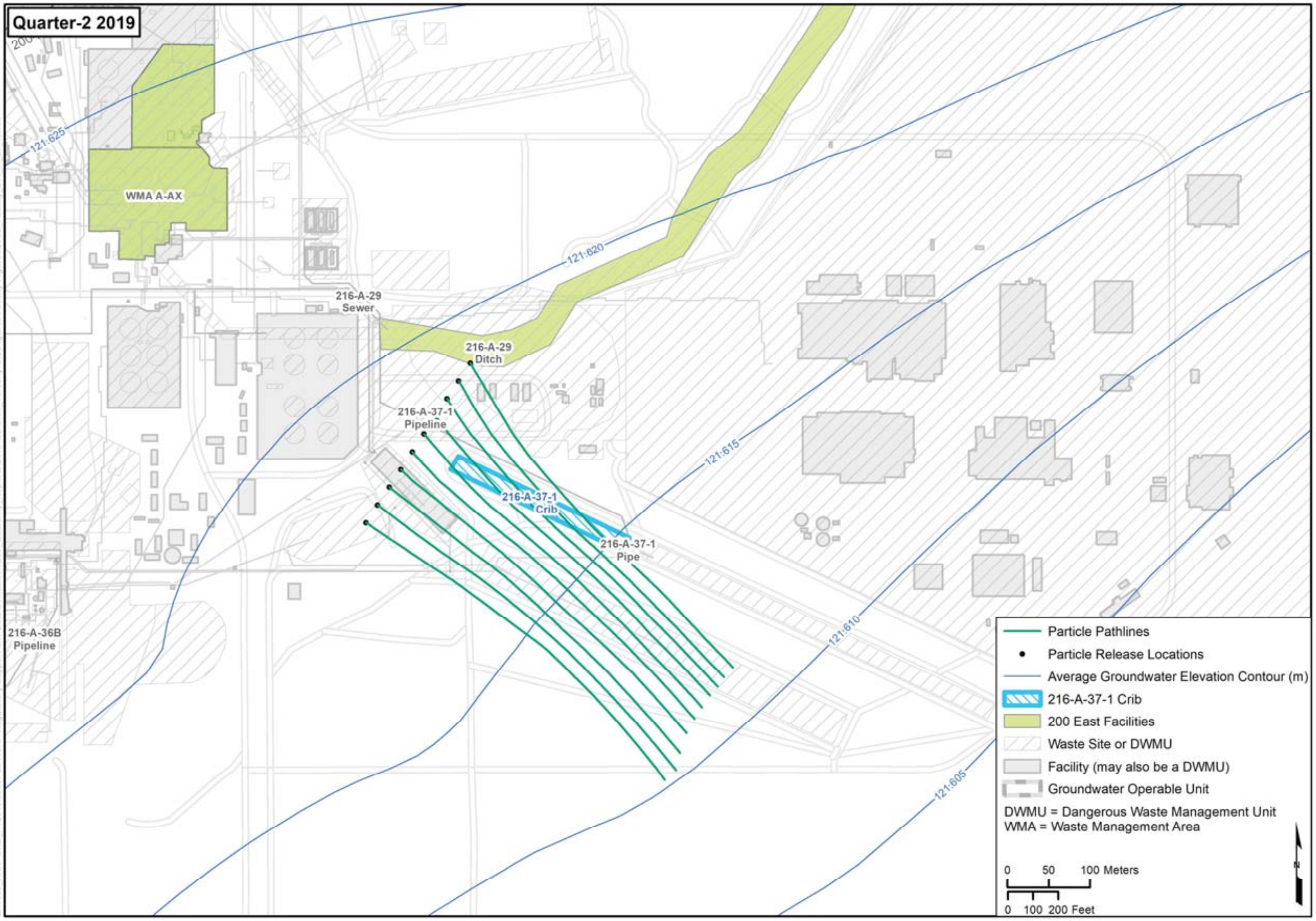

Figure 7-12. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-A-37-1 Crib for the Second Quarter of 2019

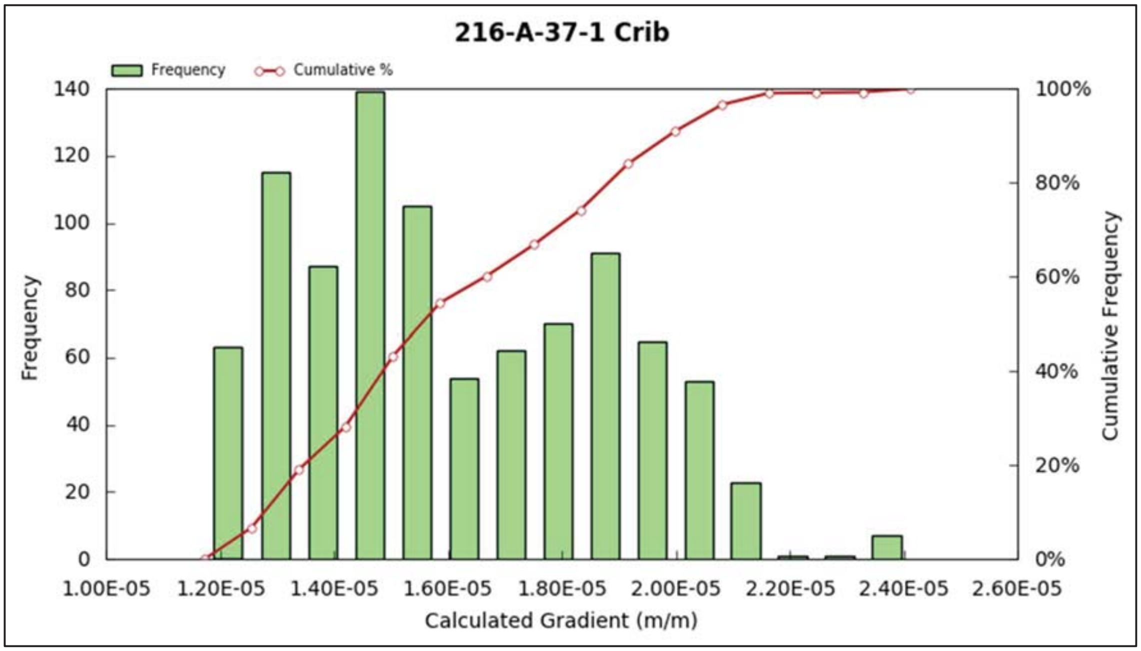

Figure 7-13. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-A-37-1 Crib for the Second Quarter of 2019

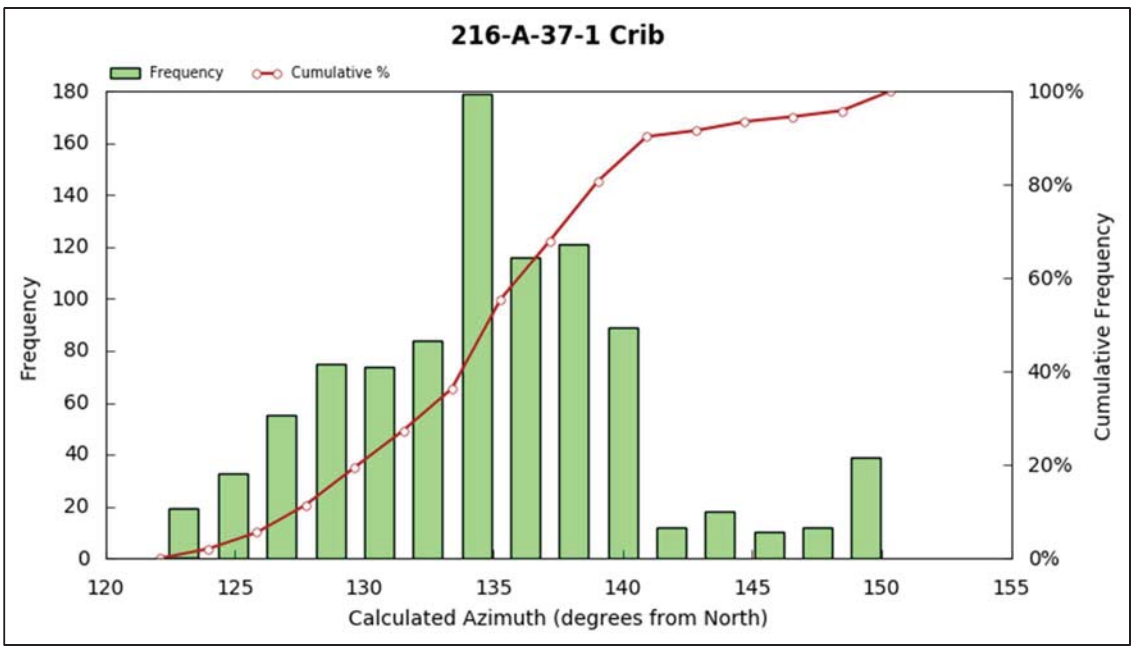

Figure 7-14. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-A-37-1 Crib for the Second Quarter of 2019

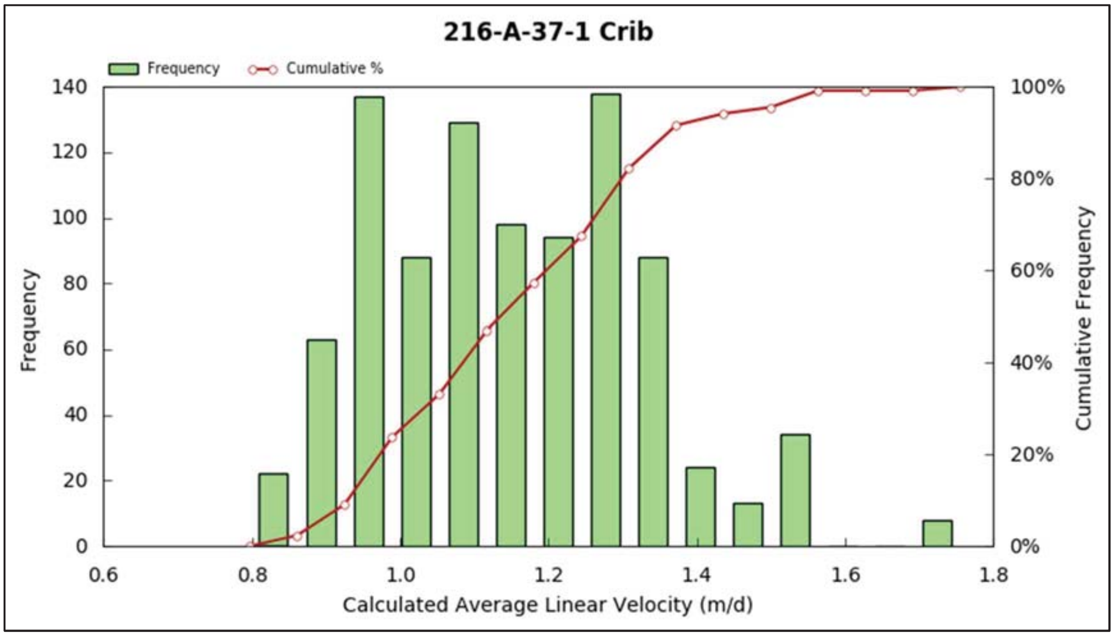

Figure 7-15. Histogram Plot of Calculated Average Linear Velocities at the 216-A-37-1 Crib for the Second Quarter of 2019

7.1.4 216-B-3 Pond

Figure 7-16 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the 216-B-3 Pond. The extents of the TRIM model domain precluded the placement of particle release locations upgradient of the entire facility. A portion of 216-B-3 Pond is located in an area of low conductivity sediments. The gradient and average linear velocities are calculated for the portion of the DWMU that is located in the Hanford Formation. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-B-3 Pond are presented in Figure 7-17 through Figure 7-19.

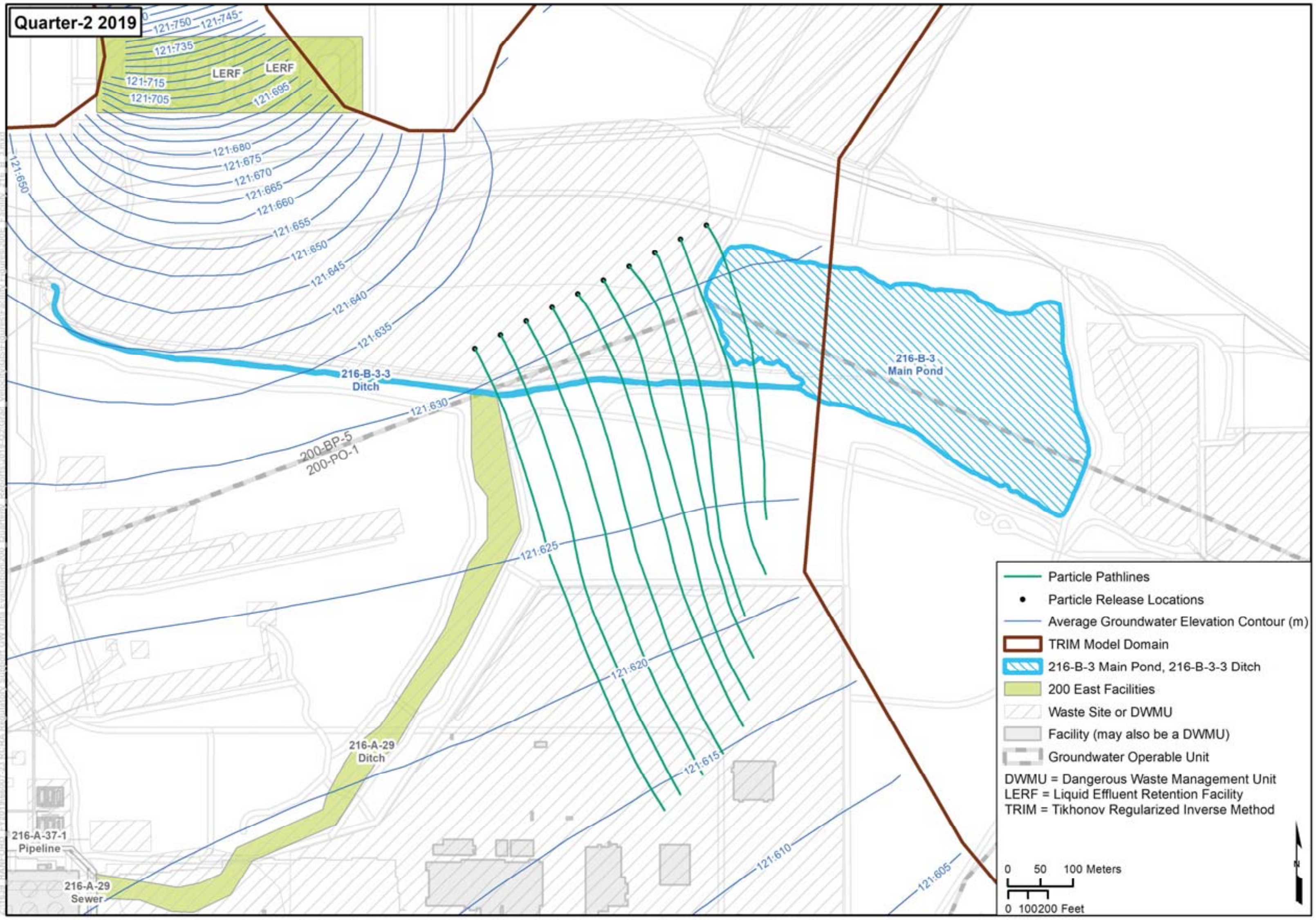

Figure 7-16. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-B-3 Pond for the Second Quarter of 2019

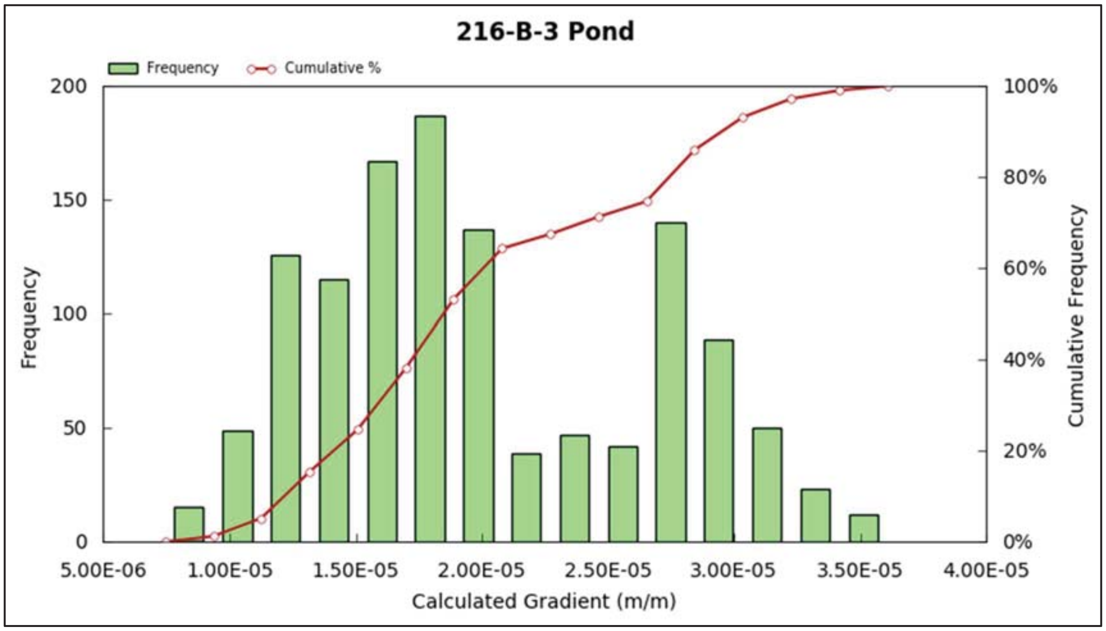

Figure 7-17. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-B-3 Pond for the Second Quarter of 2019

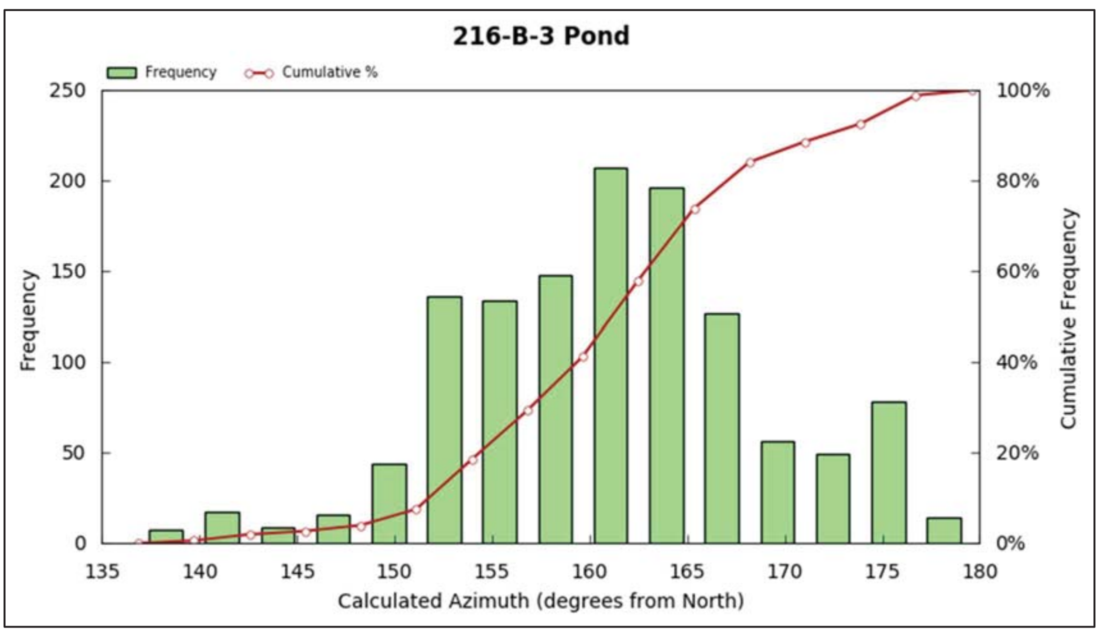

Figure 7-18. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-B-3 Pond for the Second Quarter of 2019

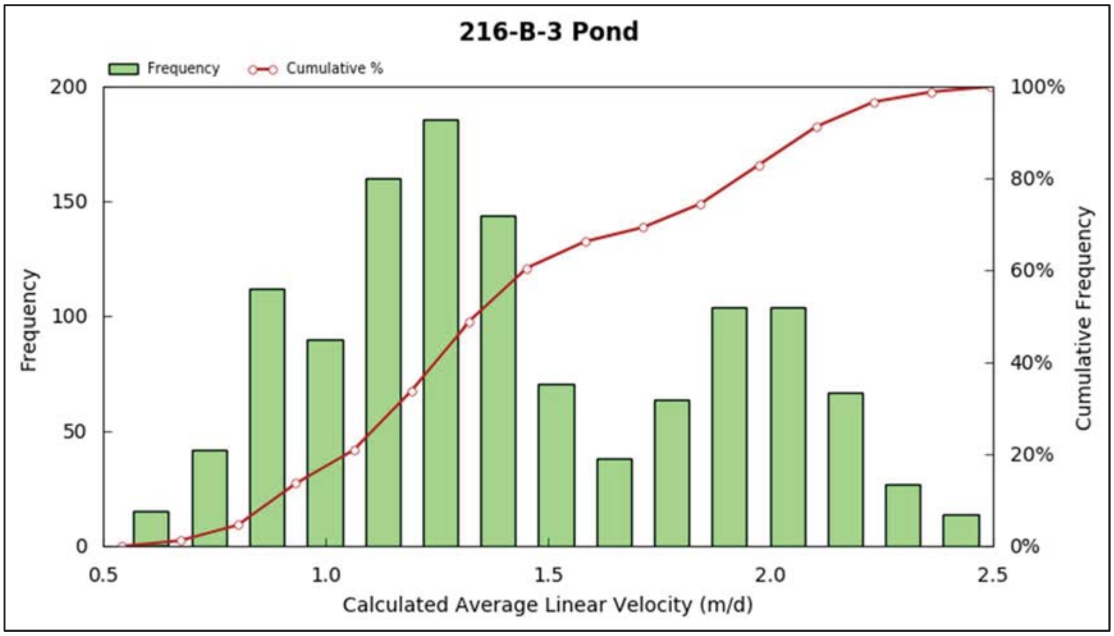

Figure 7-19. Histogram Plot of Calculated Average Linear Velocities at the 216-B-3 Pond for the Second Quarter of 2019

7.1.5 216-B-63 Trench

Figure 7-20 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the 216-B-63 Trench. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the 216-B-63 Trench are presented in Figure 7-21 through Figure 7-23.

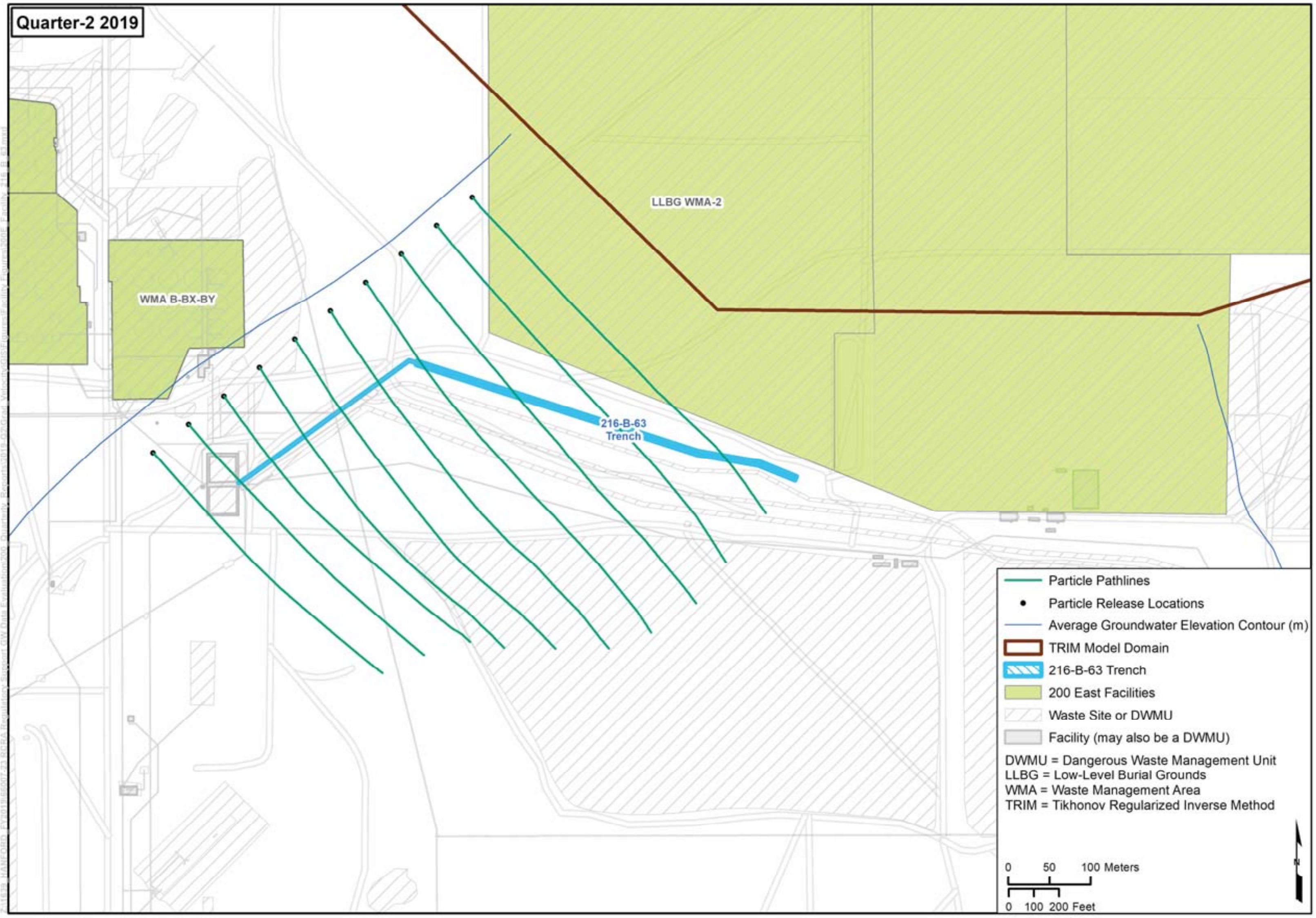

Figure 7-20. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-B-63 Trench for the Second Quarter of 2019

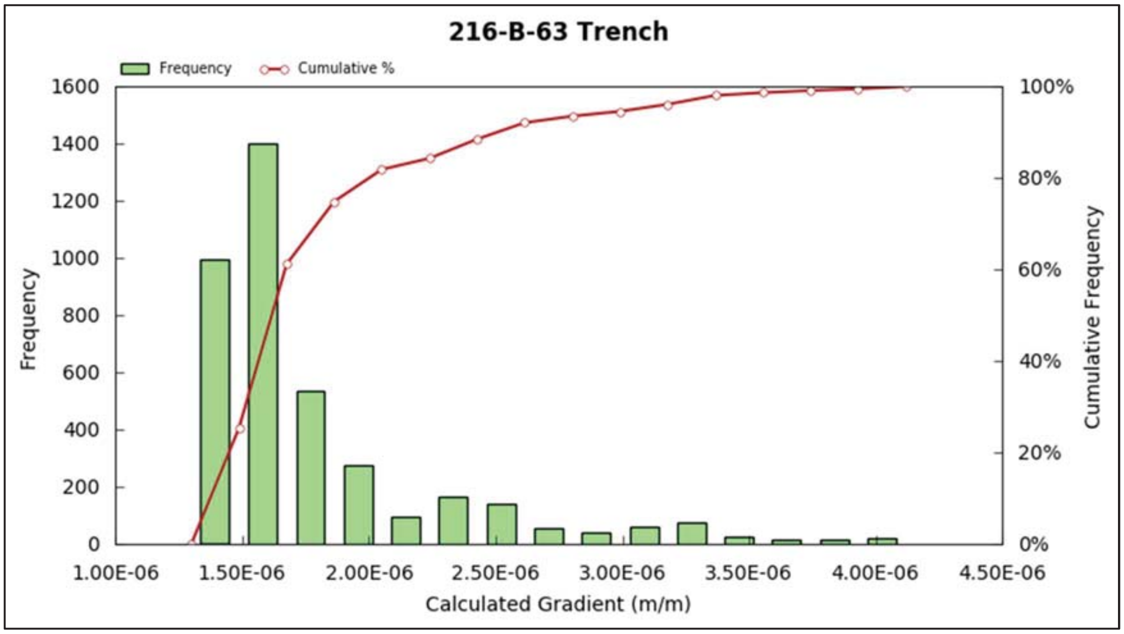

Figure 7-21. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-B-63 Trench for the Second Quarter of 2019

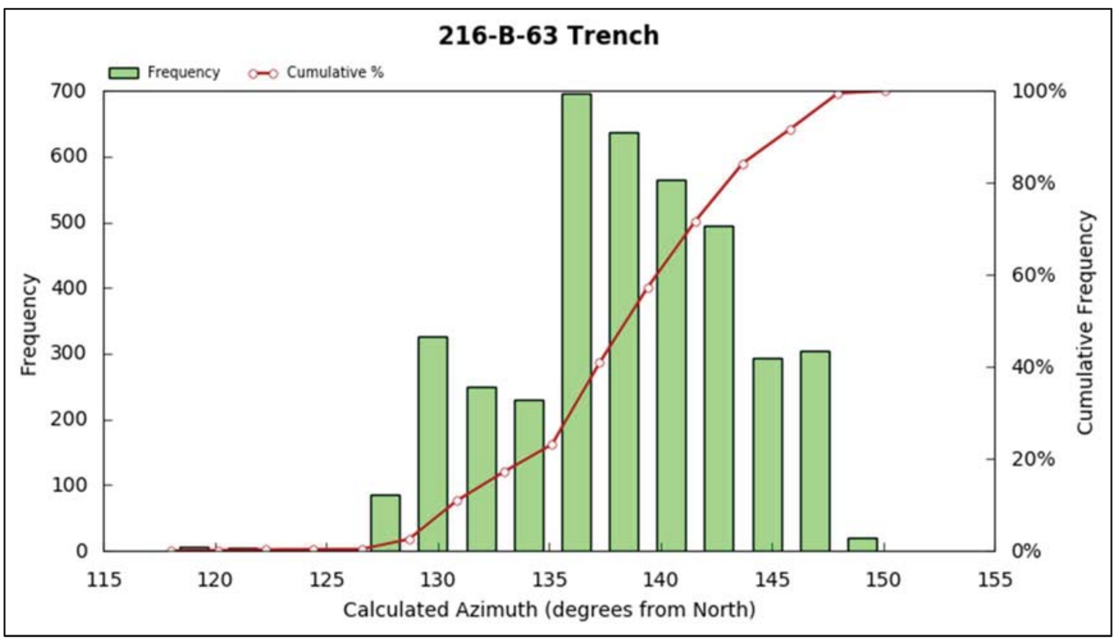

Figure 7-22. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-B-63 Trench for the Second Quarter of 2019

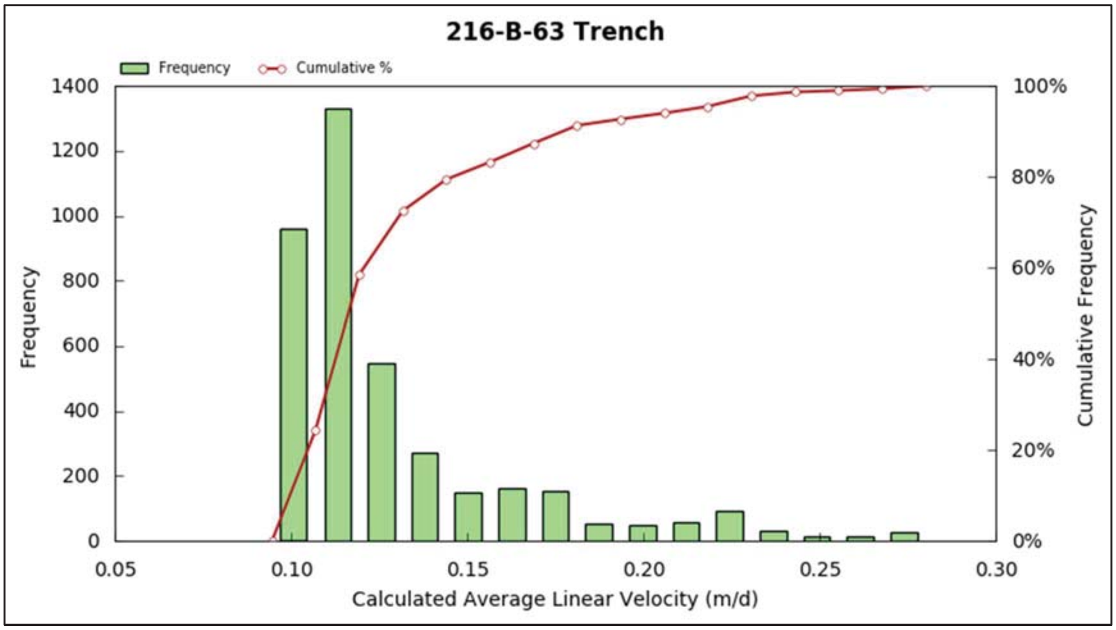

Figure 7-23. Histogram Plot of Calculated Average Linear Velocities at the 216-B-63 Trench for the Second Quarter of 2019

7.1.6 Integrated Disposal Facility

Figure 7-24 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at IDF. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at IDF are presented in Figure 7-25 through Figure 7-27.

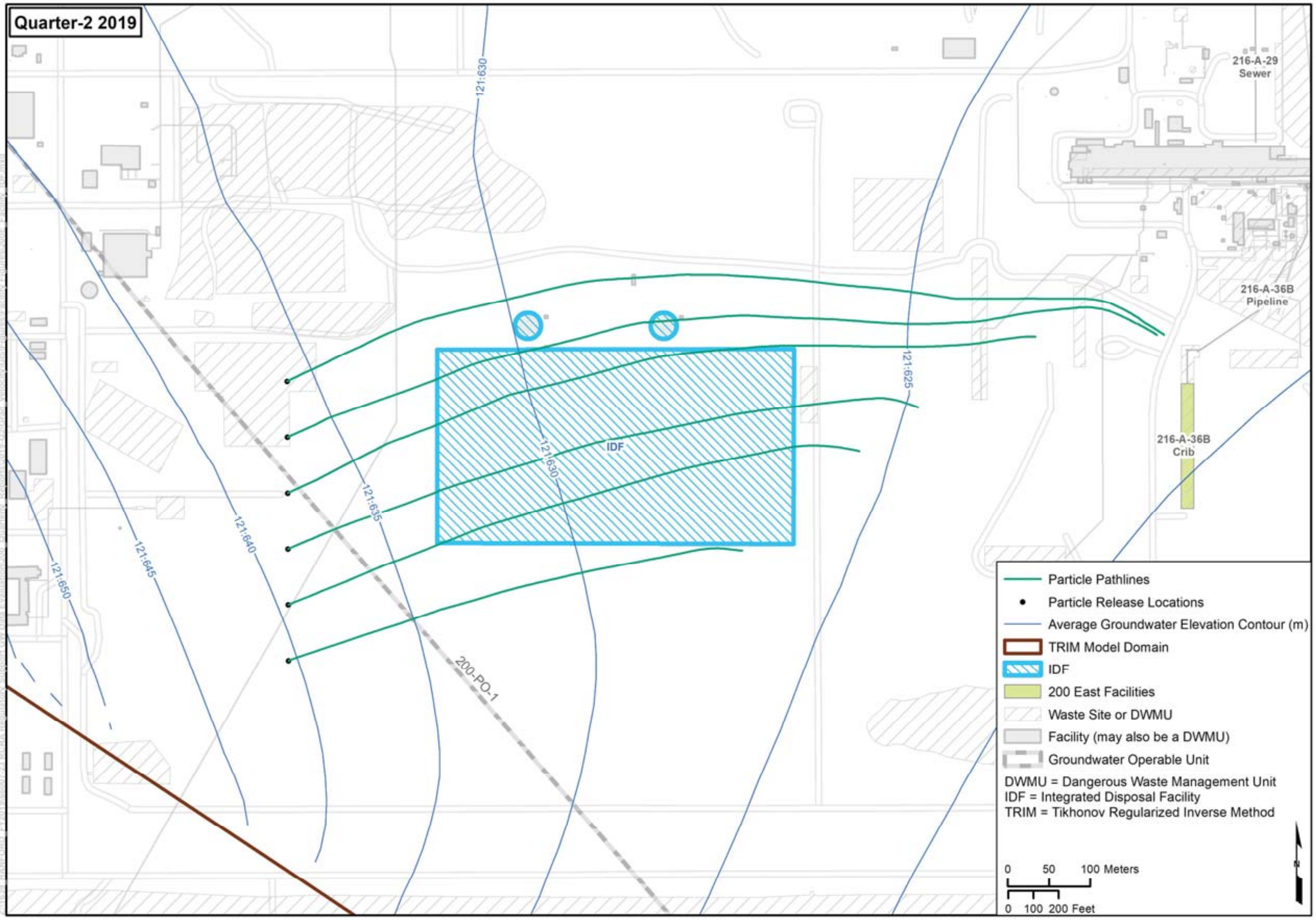

Figure 7-24. Calculated Particle Pathlines Representing General Groundwater Flow Directions at IDF for the Second Quarter of 2019

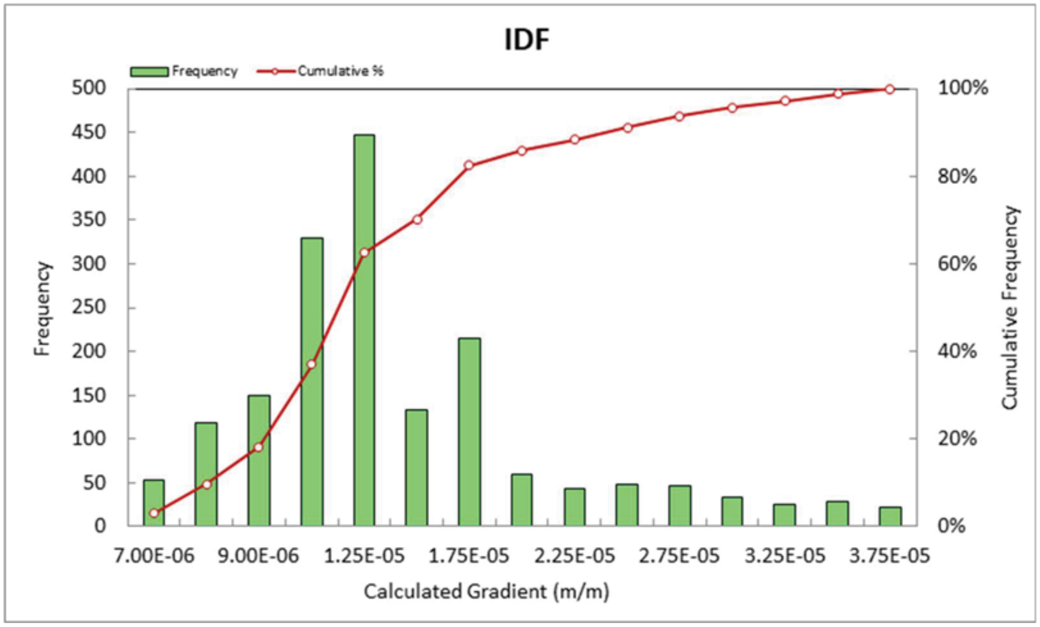

Figure 7-25. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at IDF for the Second Quarter of 2019

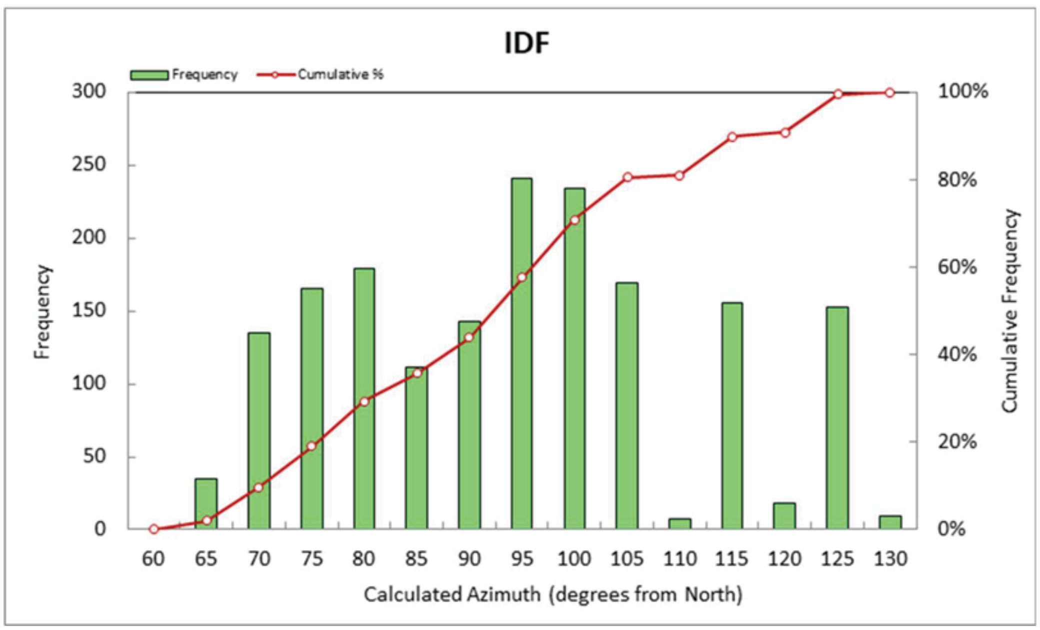

Figure 7-26. Histogram Plot of Calculated Hydraulic Gradient Azimuths at IDF for the Second Quarter of 2019

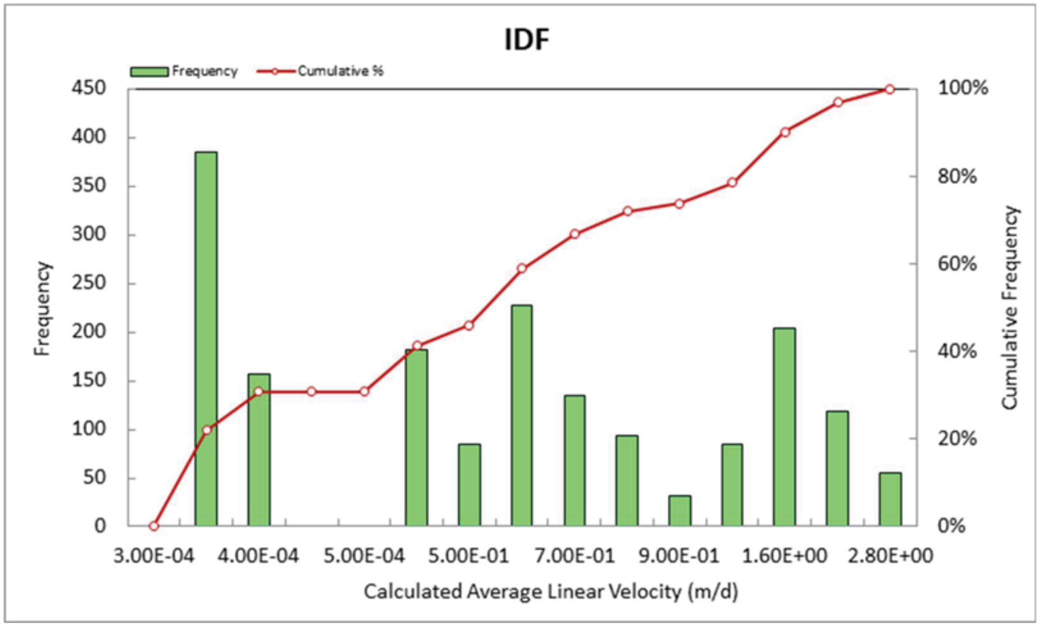

Figure 7-27. Histogram Plot of Calculated Average Linear Velocities at IDF for the Second Quarter of 2019

7.1.7 Liquid Effluent Retention Facility

Figure 7-28 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at LERF. The extents of the TRIM model domain precluded the placement of particle release locations upgradient of the entire facility. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at LERF are presented in Figure 7-29 through Figure 7-31. A portion of LERF is believed to be located in an area of low conductivity sediments overlying the basalt and underlying the Hanford formation. Because of this, the hydraulic properties of the Ringold Formation member of Wooded Island — unit E were considered more appropriate to use for calculations of the average linear velocity than those of the Hanford formation.

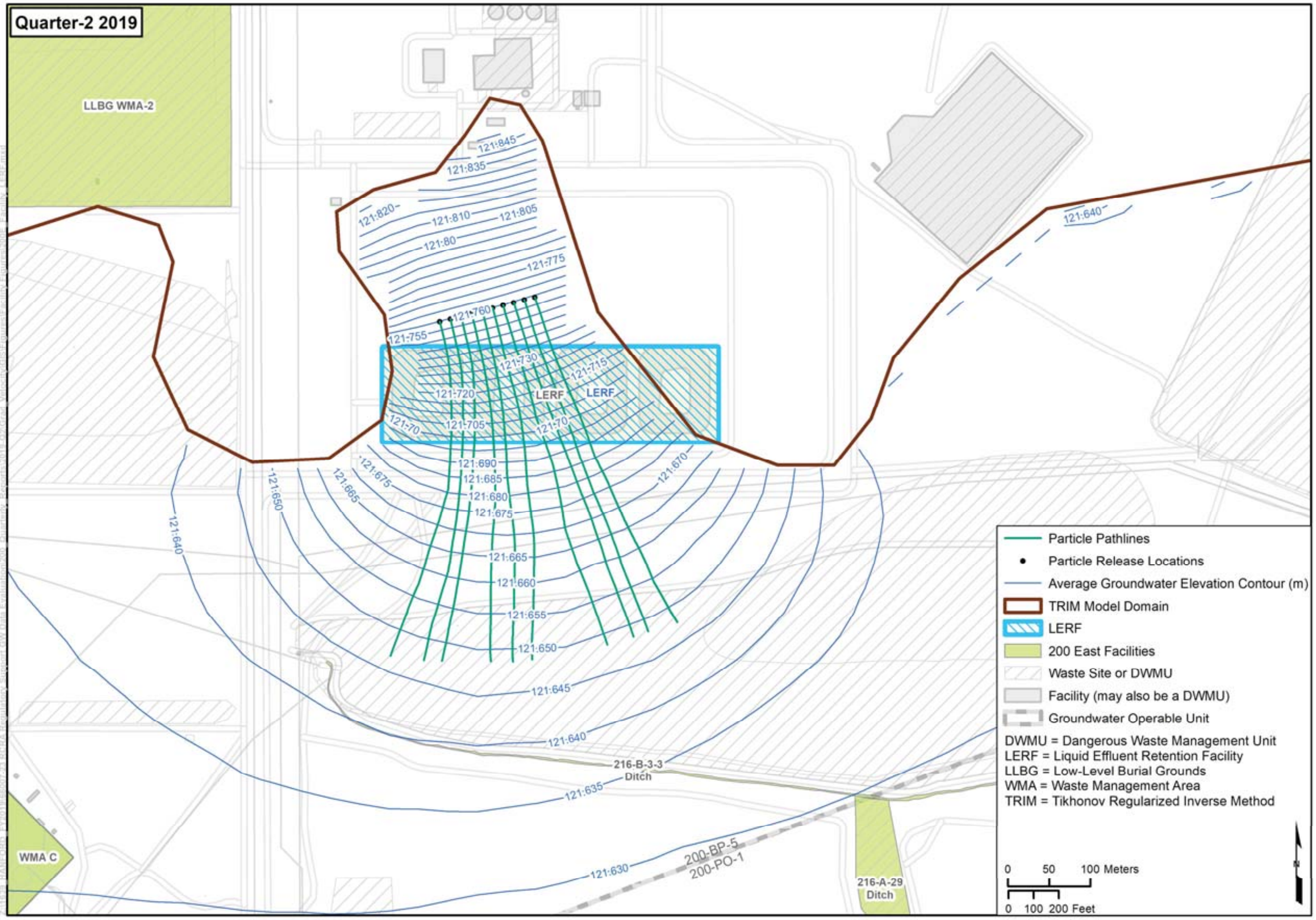

Figure 7-28. Calculated Particle Pathlines Representing General Groundwater Flow Directions at LERF for the Second Quarter of 2019

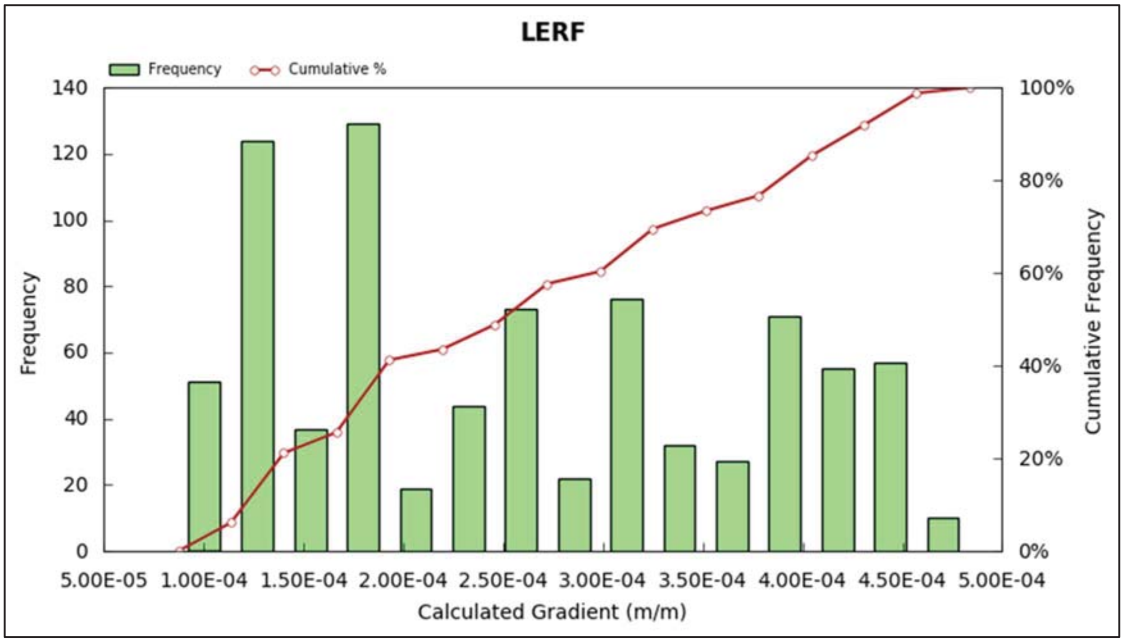

Figure 7-29. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at LERF for the Second Quarter of 2019

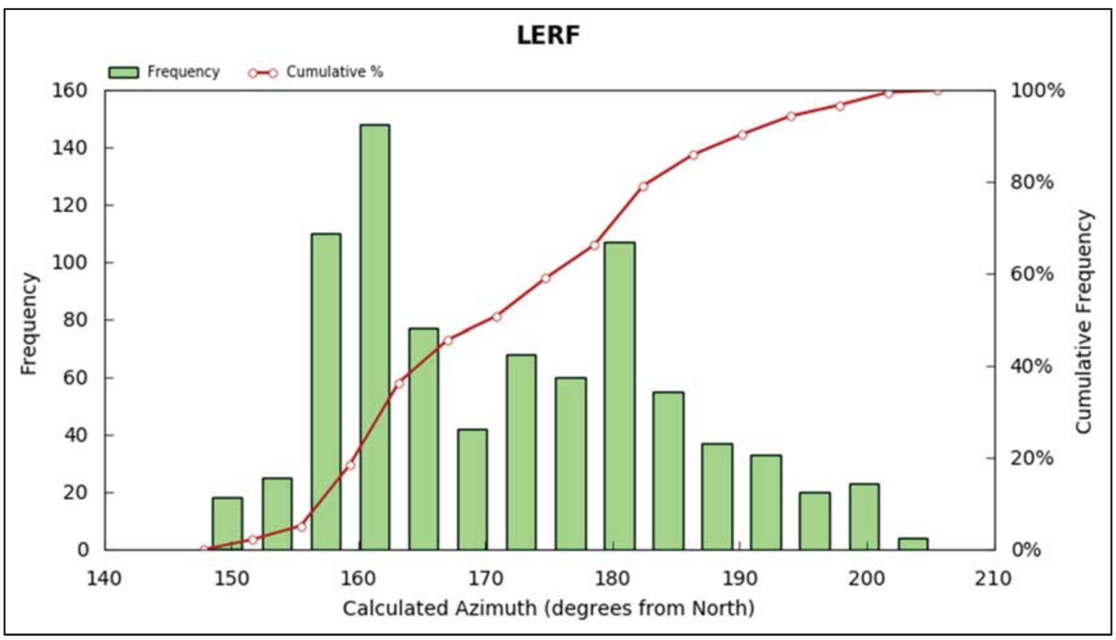

Figure 7-30. Histogram Plot of Calculated Hydraulic Gradient Azimuths at LERF for the Second Quarter of 2019

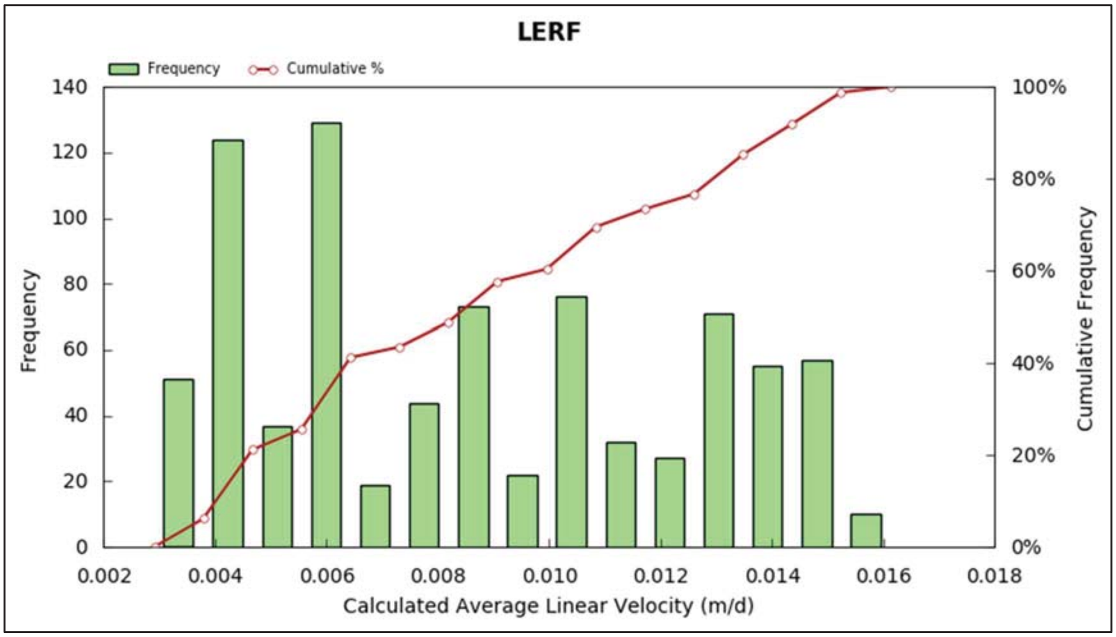

Figure 7-31. Histogram Plot of Calculated Average Linear Velocities at LERF for the Second Quarter of 2019

7.1.8 Low-Level Burial Grounds Waste Management Area-1

Figure 7-32 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the LLBG WMA-1. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the LLBG WMA-1 are presented in Figure 7-33 through Figure 7-35.

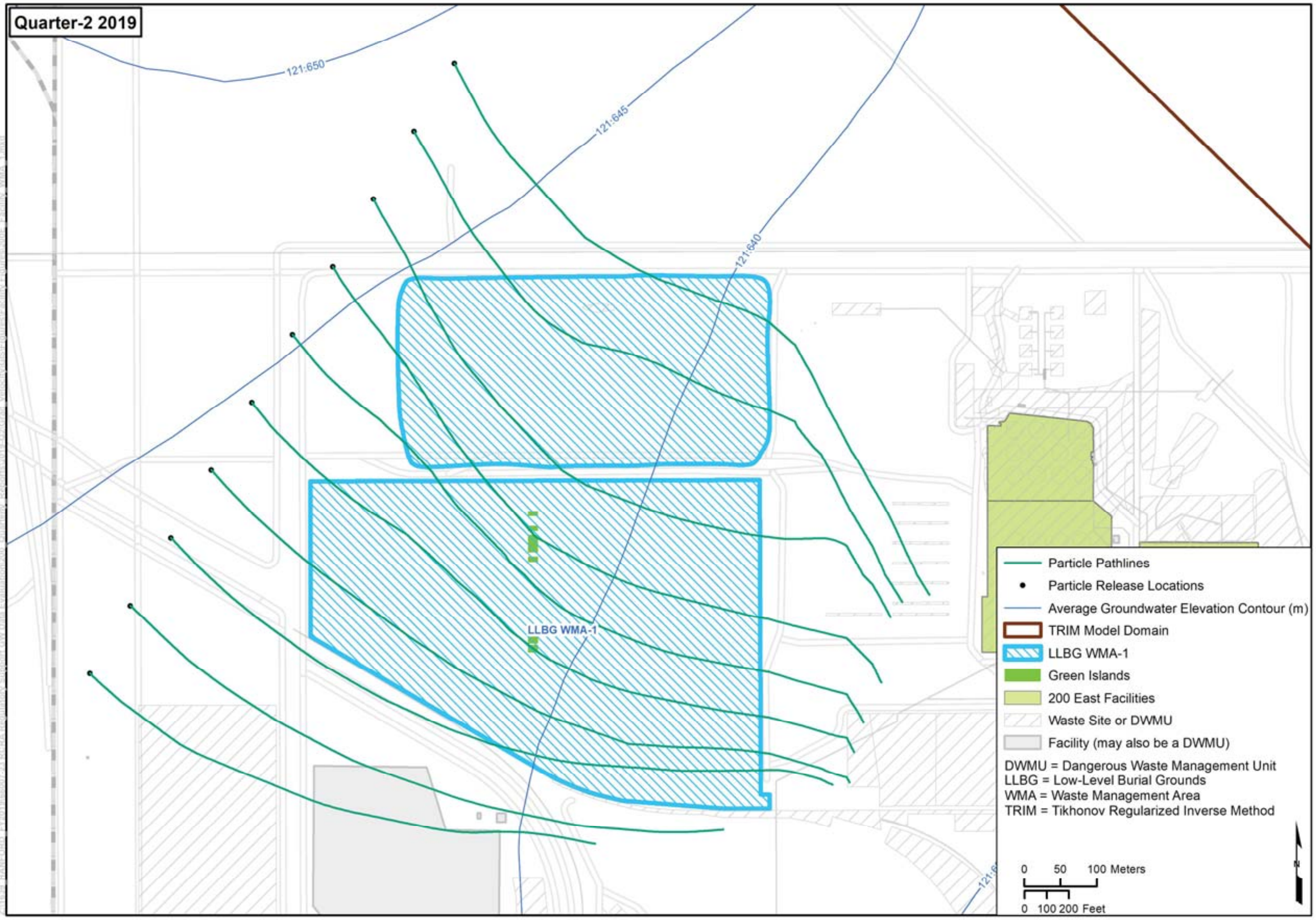

Figure 7-32. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the LLBG WMA-1 for the Second Quarter of 2019

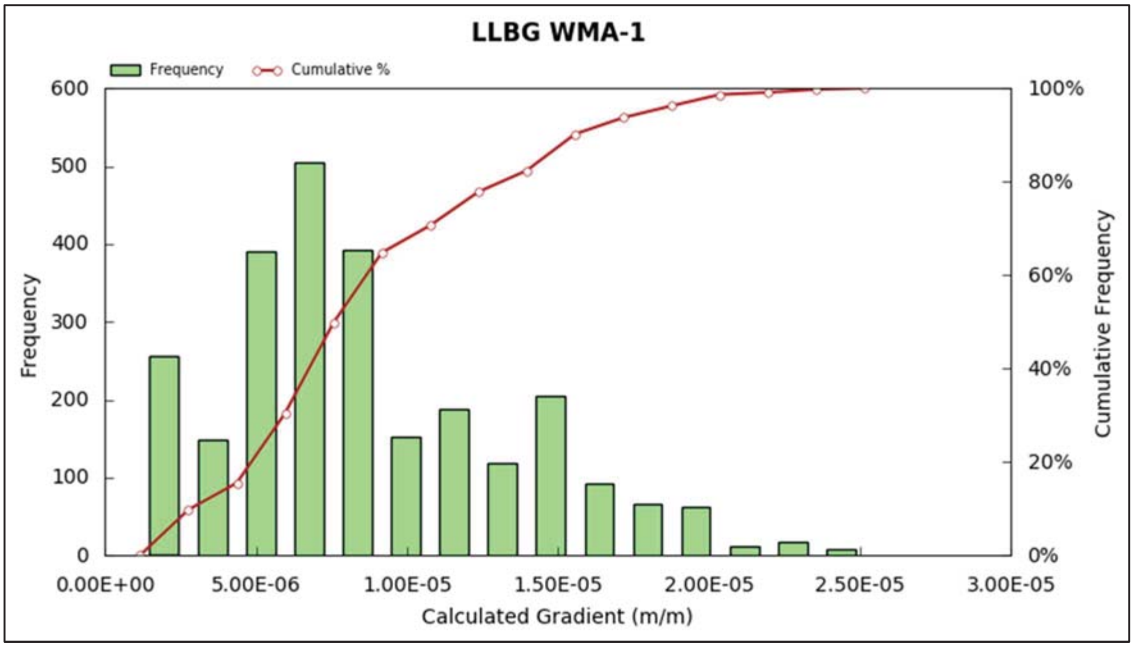

Figure 7-33. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the LLBG WMA-1 for the Second Quarter of 2019

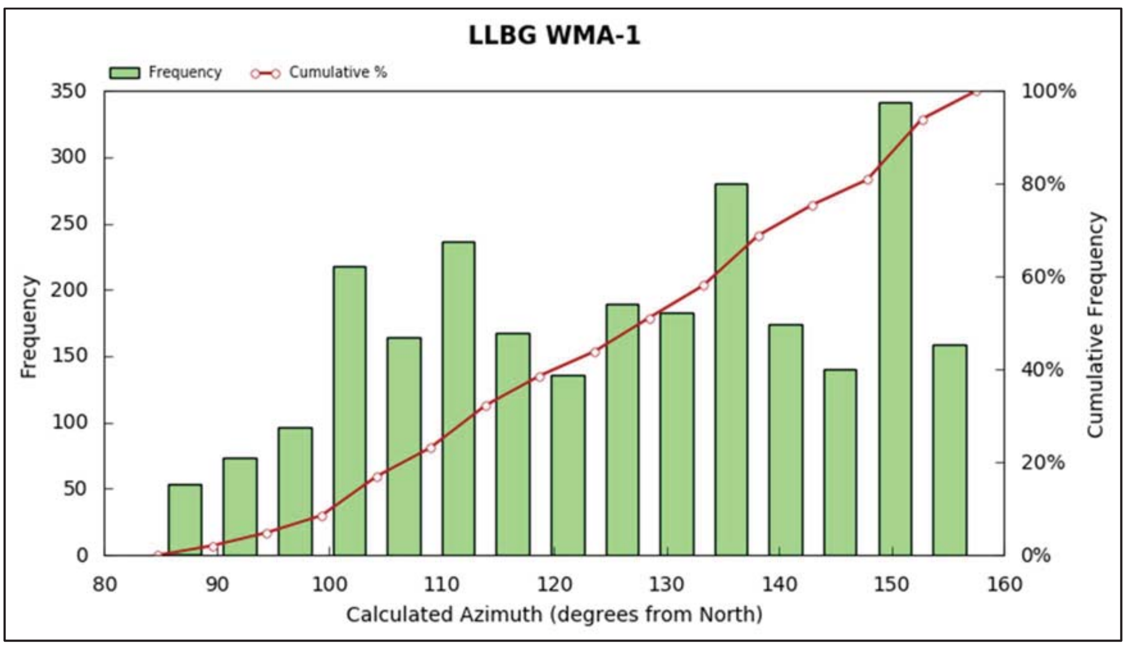

Figure 7-34. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the LLBG WMA-1 for the Second Quarter of 2019

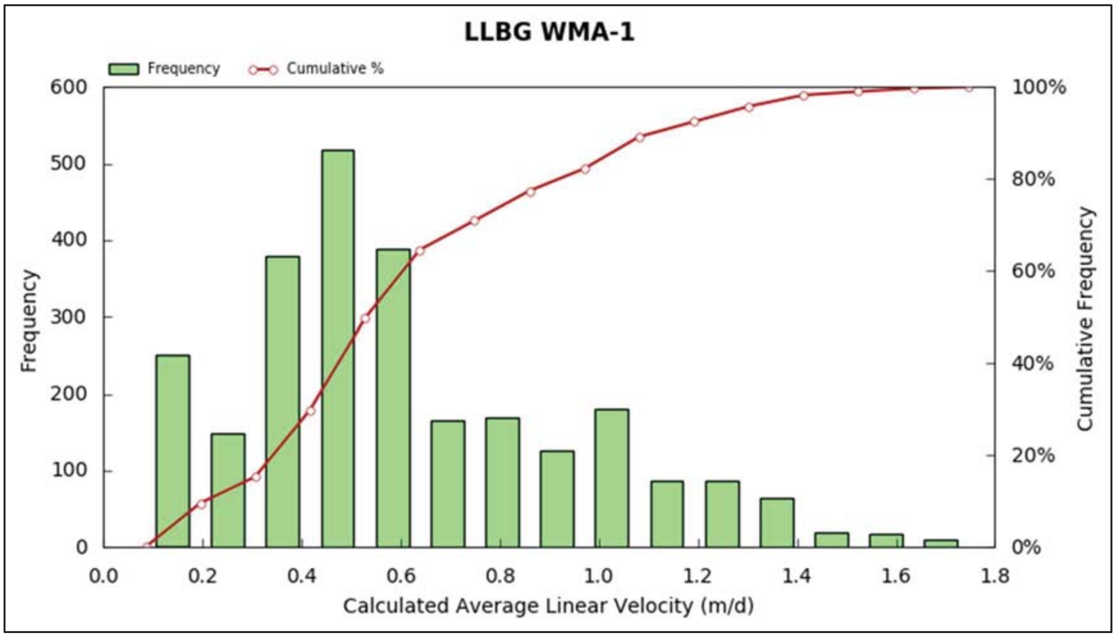

Figure 7-35. Histogram Plot of Calculated Average Linear Velocities at the LLBG WMA-1 for the Second Quarter of 2019

7.1.9 Low-Level Burial Grounds Waste Management Area-2

Figure 7-36 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the LLBG WMA-2. The particles were placed to cover Trench 94 (within LLBG WMA-2) to the extent possible, but the extents of the TRIM model domain precluded the placement of particle release locations upgradient of the entire facility. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the LLBG WMA-2 are presented in Figure 7-37 through Figure 7-39.

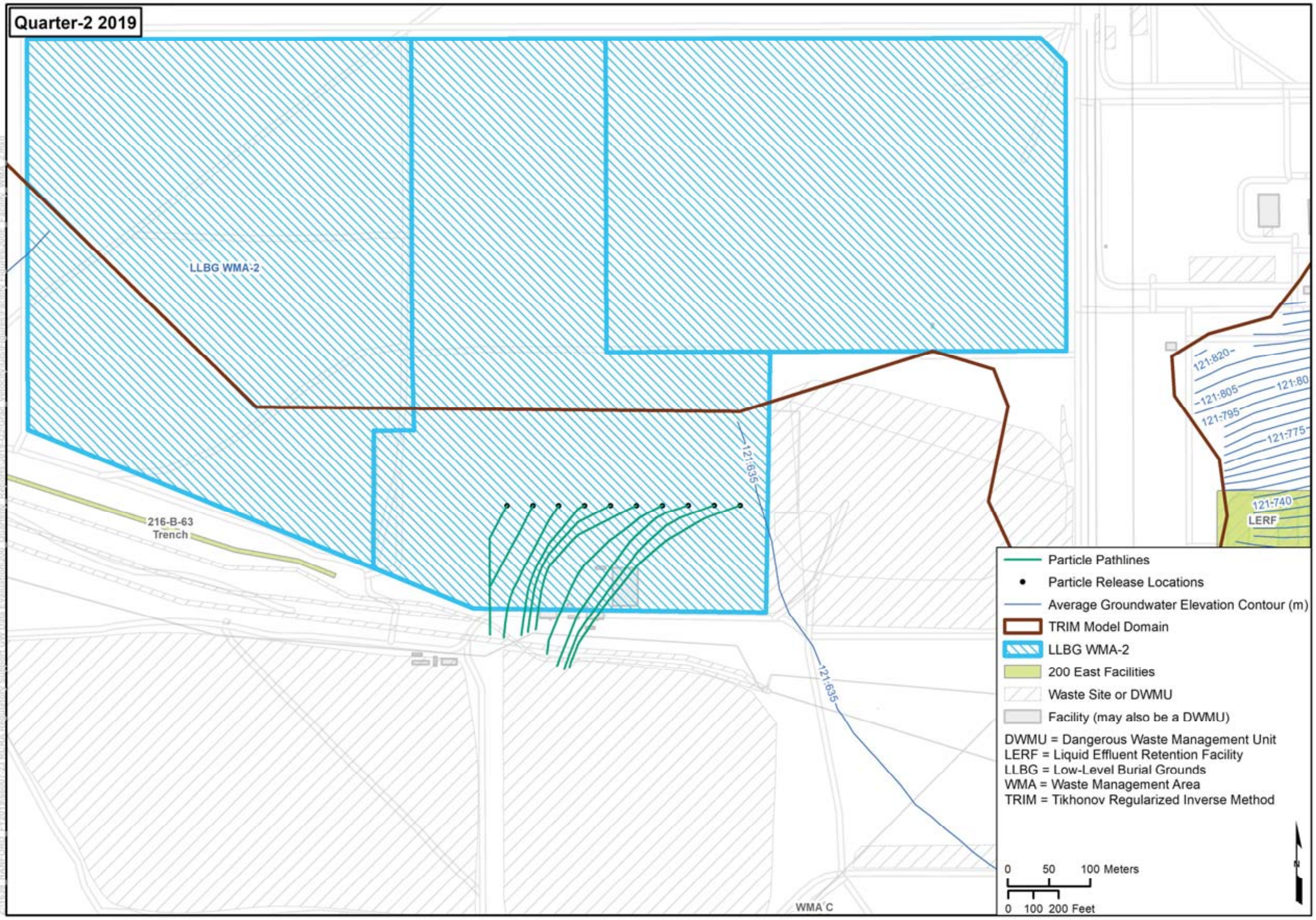

Figure 7-36. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the LLBG WMA-2 for the Second Quarter of 2019

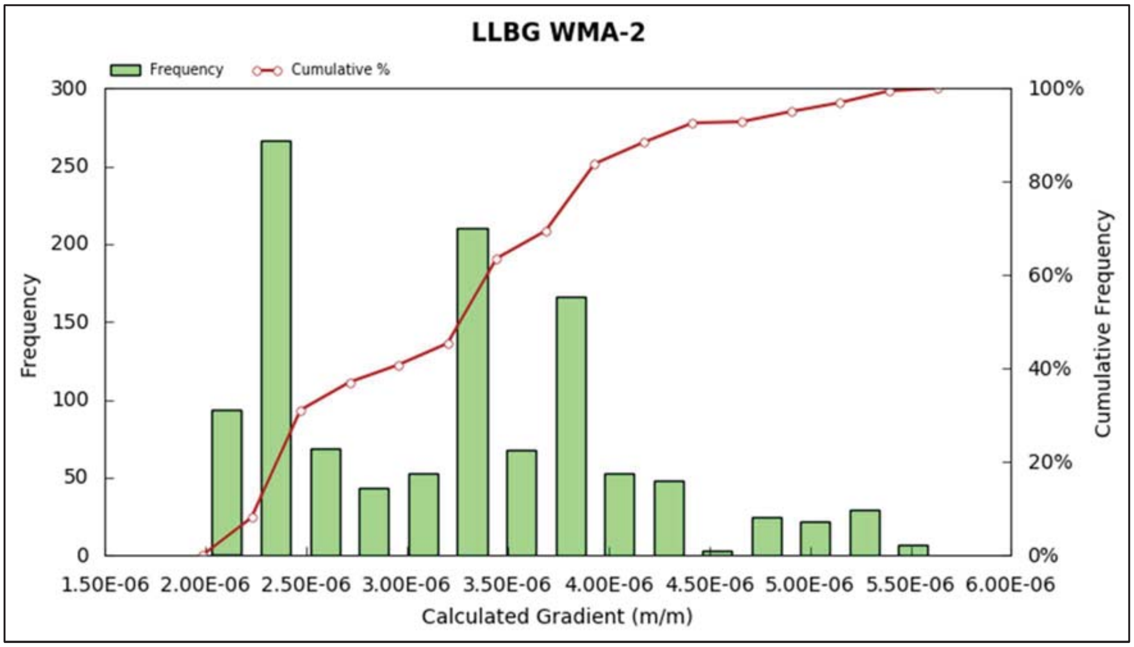

Figure 7-37. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the LLBG WMA-2 for the Second Quarter of 2019

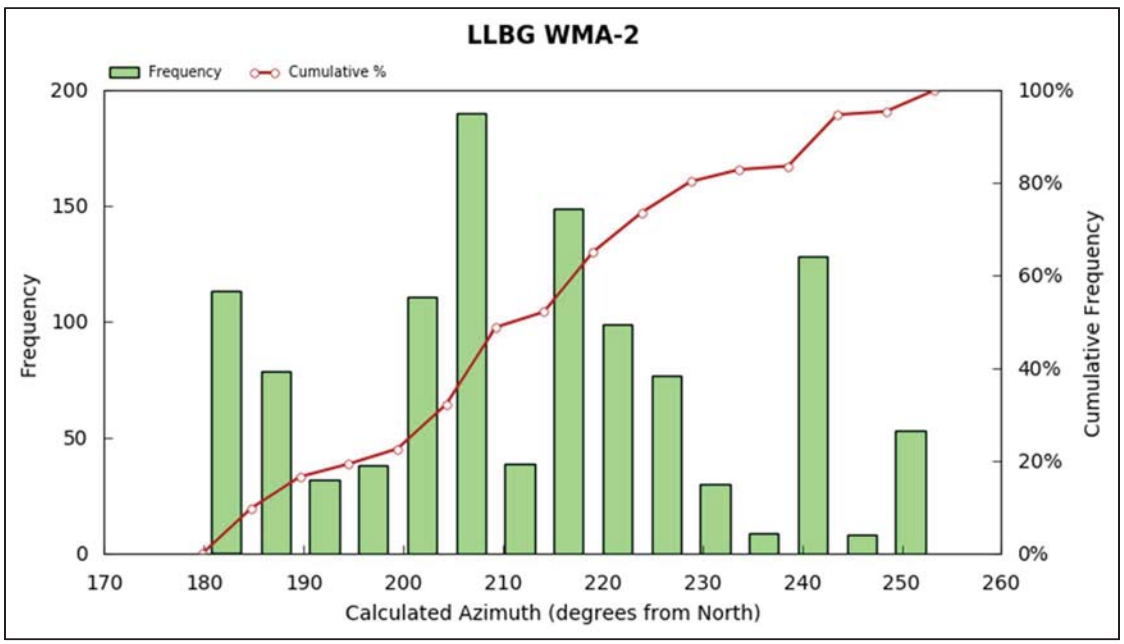

Figure 7-38. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the LLBG WMA-2 for the Second Quarter of 2019

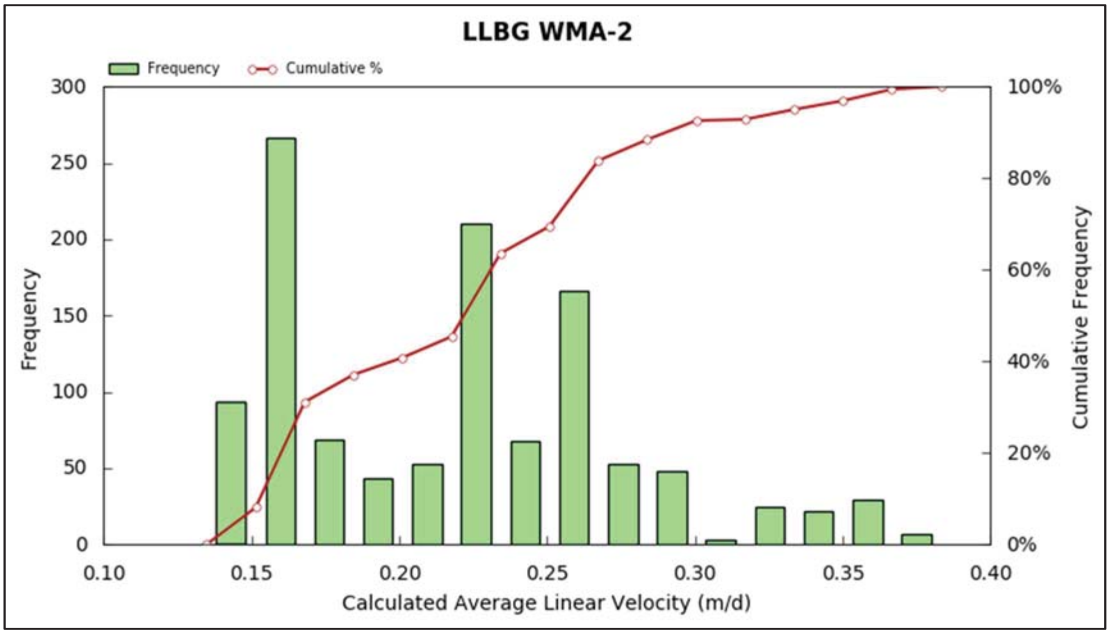

Figure 7-39. Histogram Plot of Calculated Average Linear Velocities at the LLBG WMA-2 for the Second Quarter of 2019

7.1.10 Waste Management Area A-AX

Figure 7-40 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at WMA A-AX. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA A-AX are presented in Figure 7-41 through Figure 7-43.

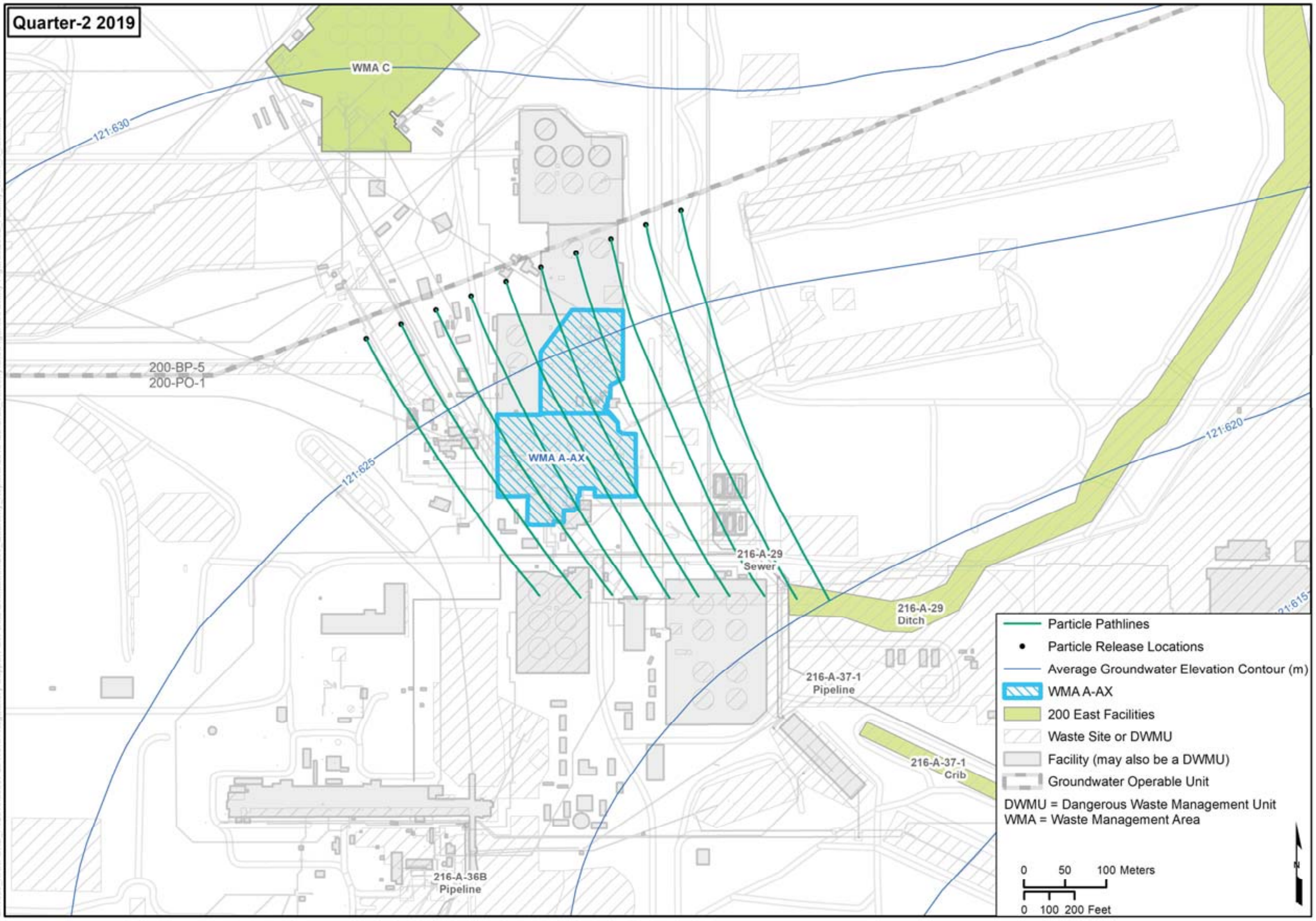

Figure 7-40. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA A-AX for the Second Quarter of 2019

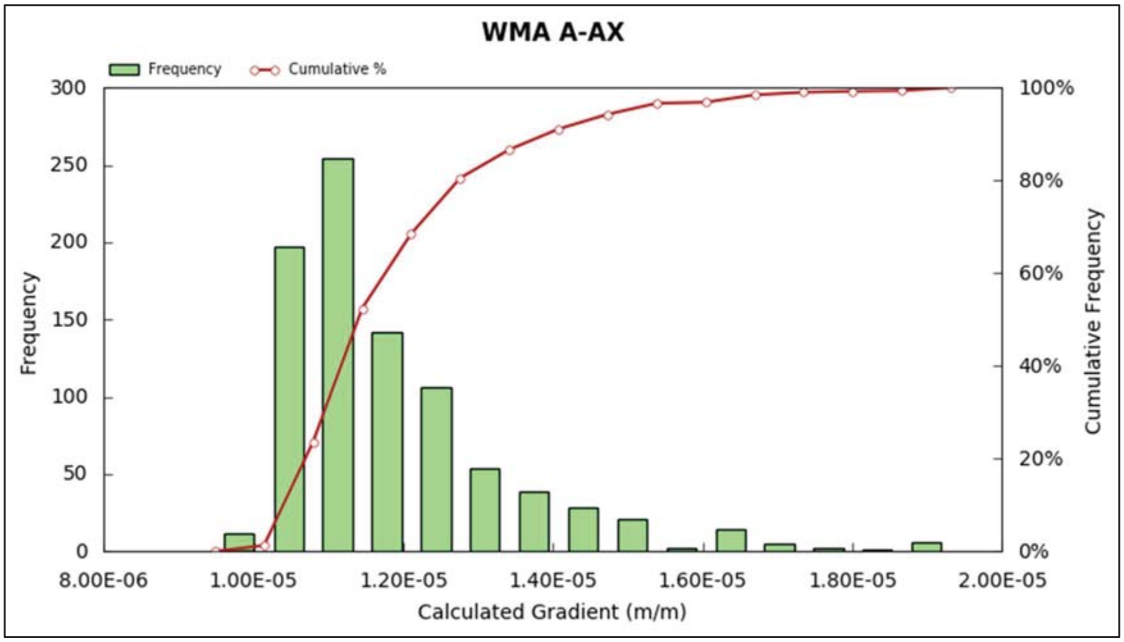

Figure 7-41. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA A-AX for the Second Quarter of 2019

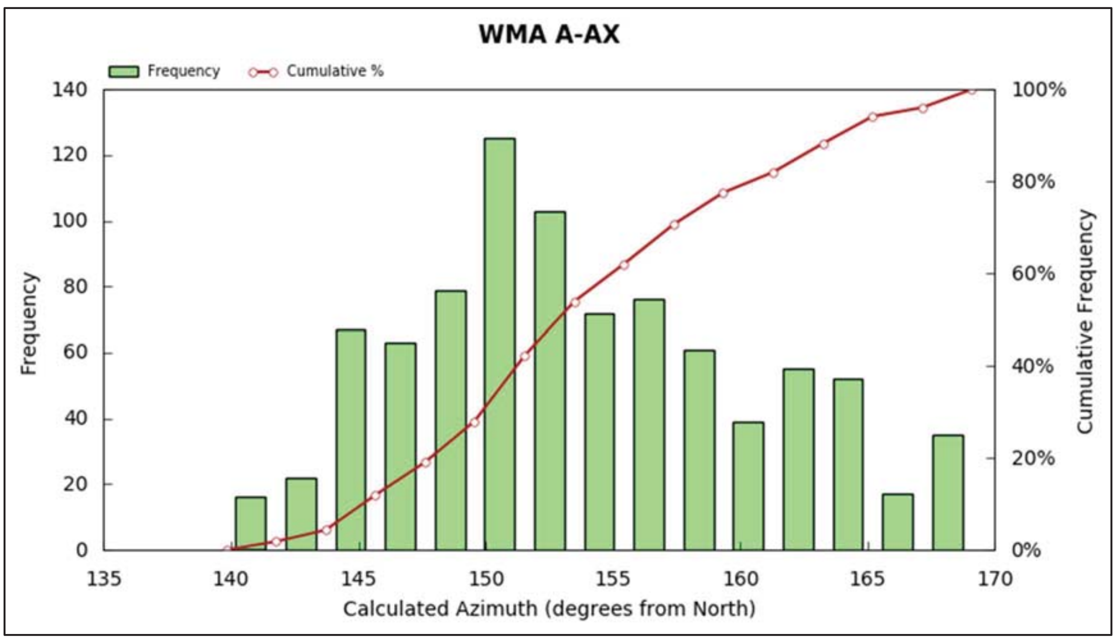

Figure 7-42. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA A-AX for the Second Quarter of 2019

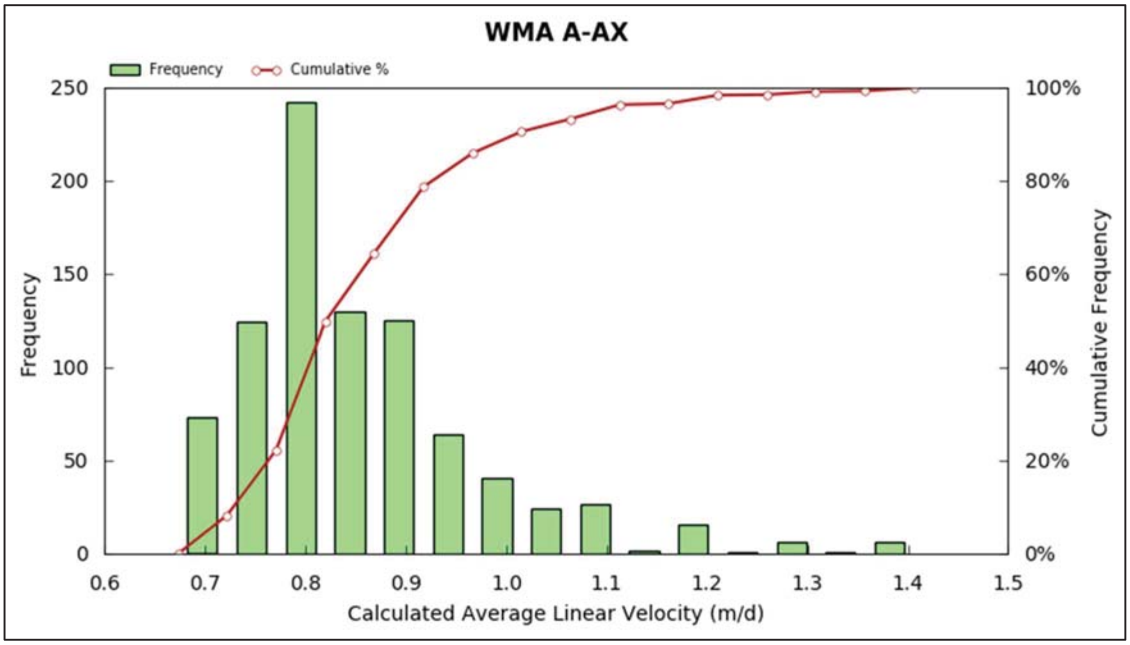

Figure 7-43. Histogram Plot of Calculated Average Linear Velocities at WMA A-AX for the Second Quarter of 2019

7.1.11 Waste Management Area B-BX-BY

Figure 7-44 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at WMA B-BX-BY. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA B-BX-BY are presented in Figure 7-45 through Figure 7-47.

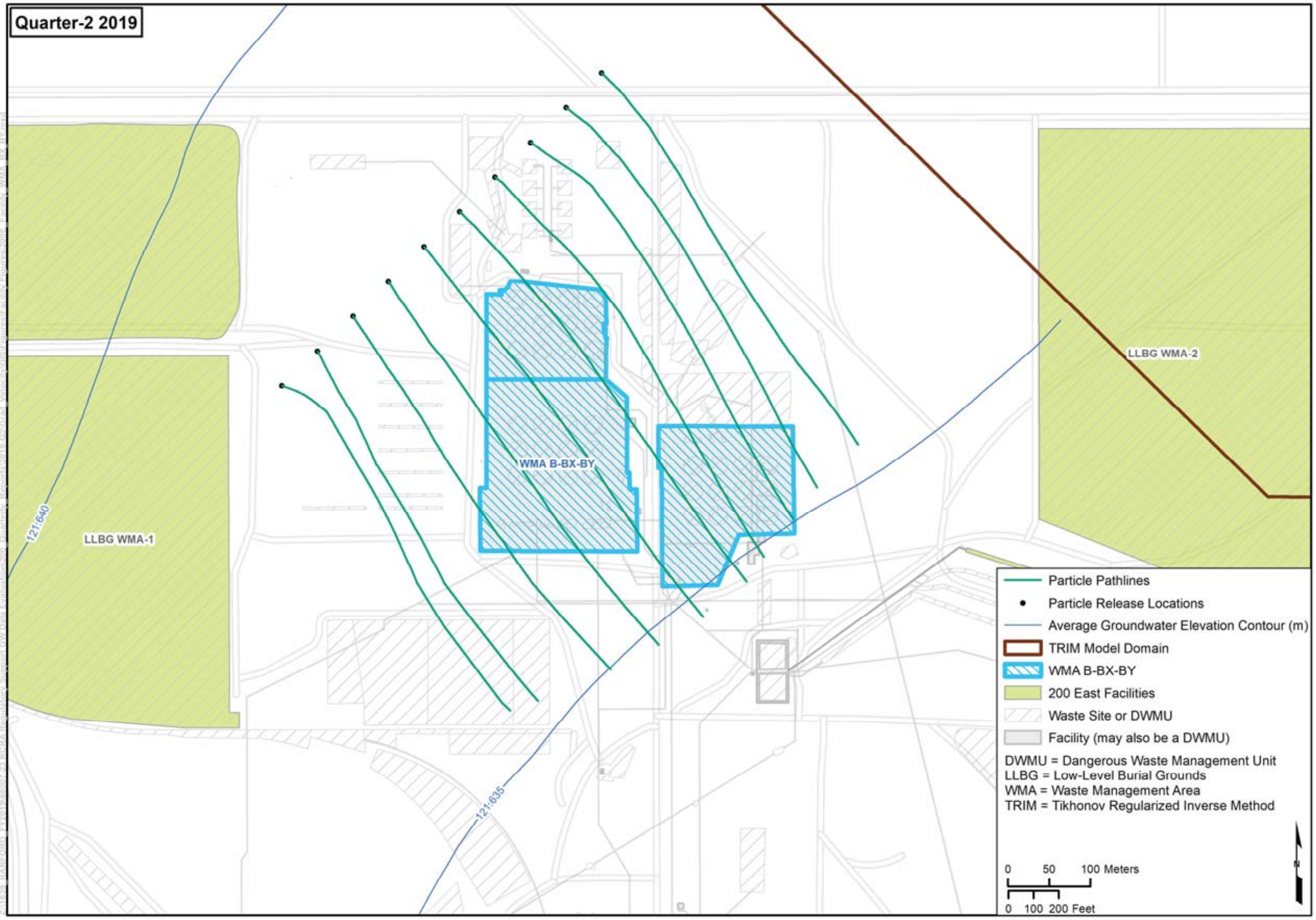

Figure 7-44. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA B-BX-BY for the Second Quarter of 2019

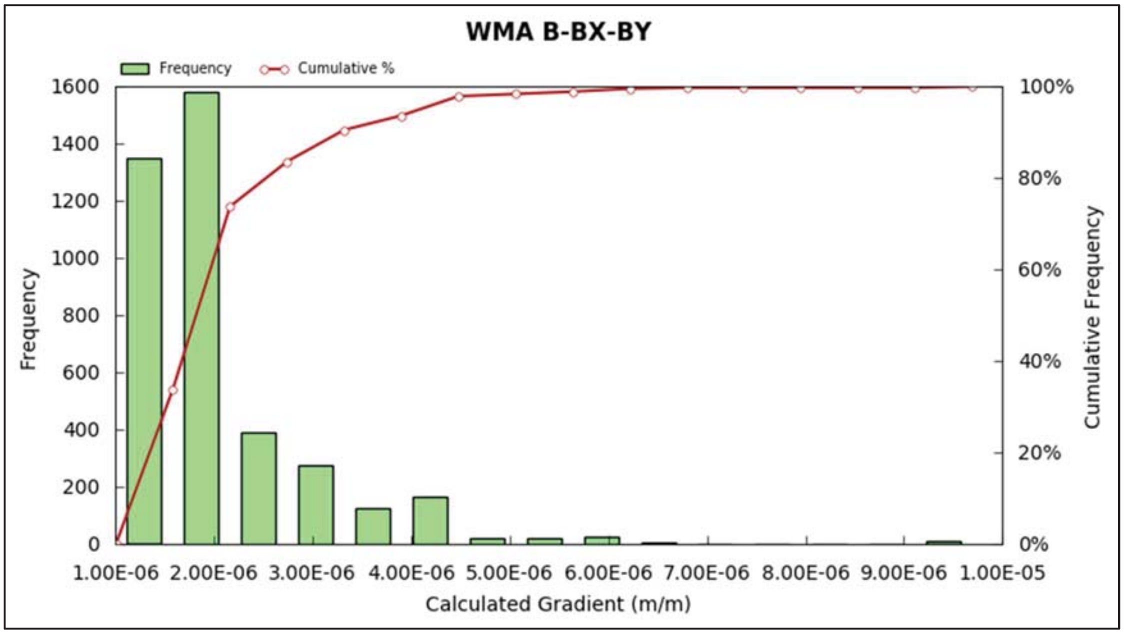

Figure 7-45. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA B-BX-BY for the Second Quarter of 2019

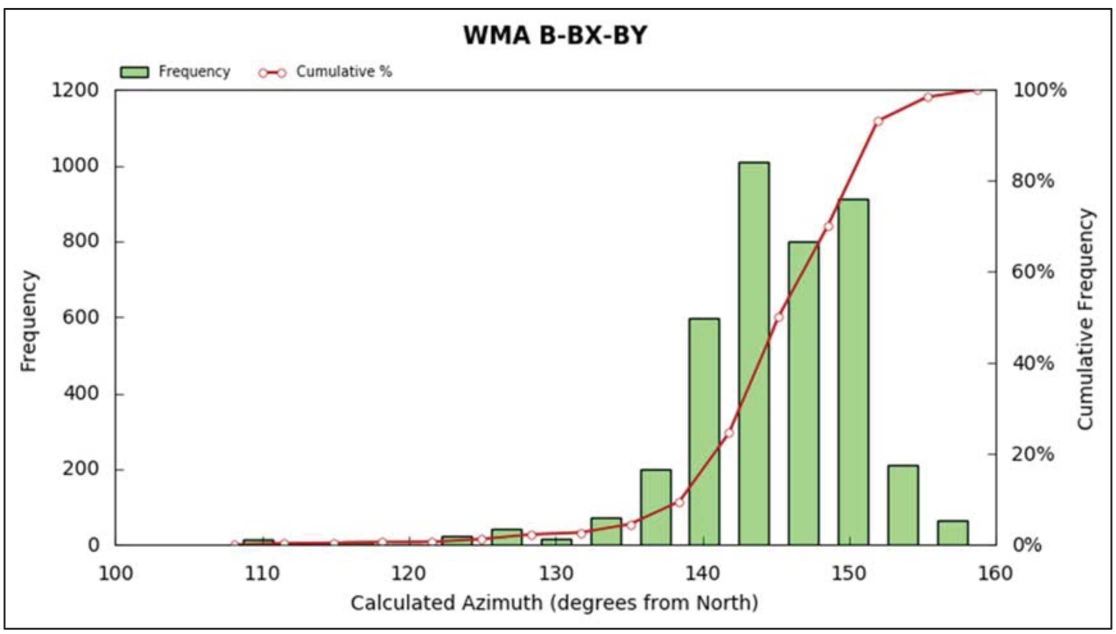

Figure 7-46. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA B-BX-BY for the Second Quarter of 2019

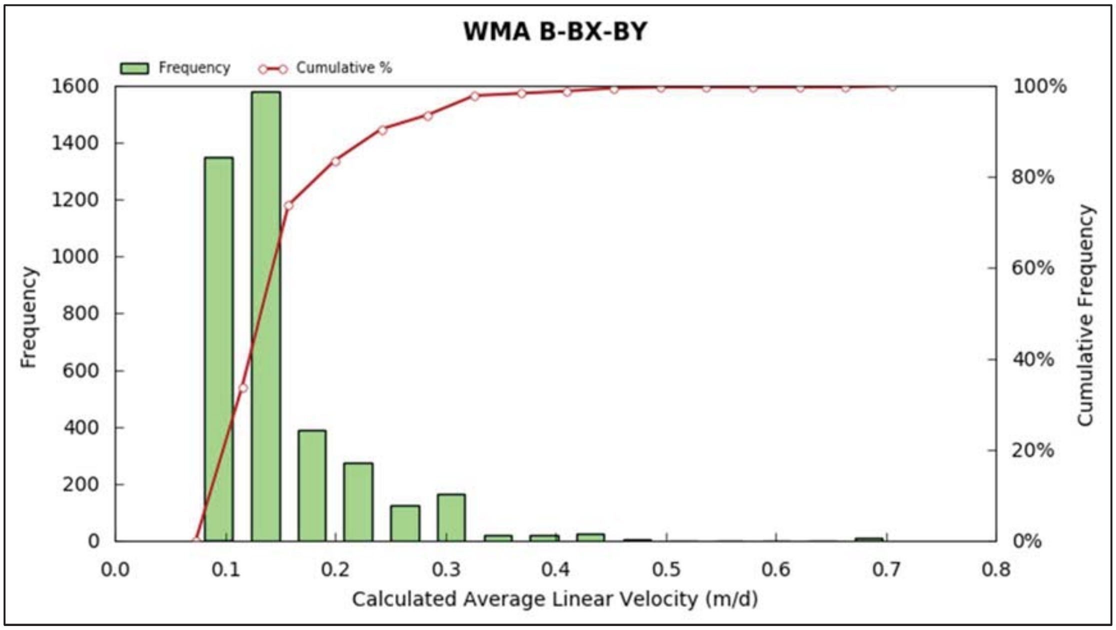

Figure 7-47. Histogram Plot of Calculated Average Linear Velocities at WMA B-BX-BY for the Second Quarter of 2019

7.1.12 Waste Management Area C

Figure 7-48 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at WMA C. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA C are presented in Figure 7-49 through Figure 7-51.

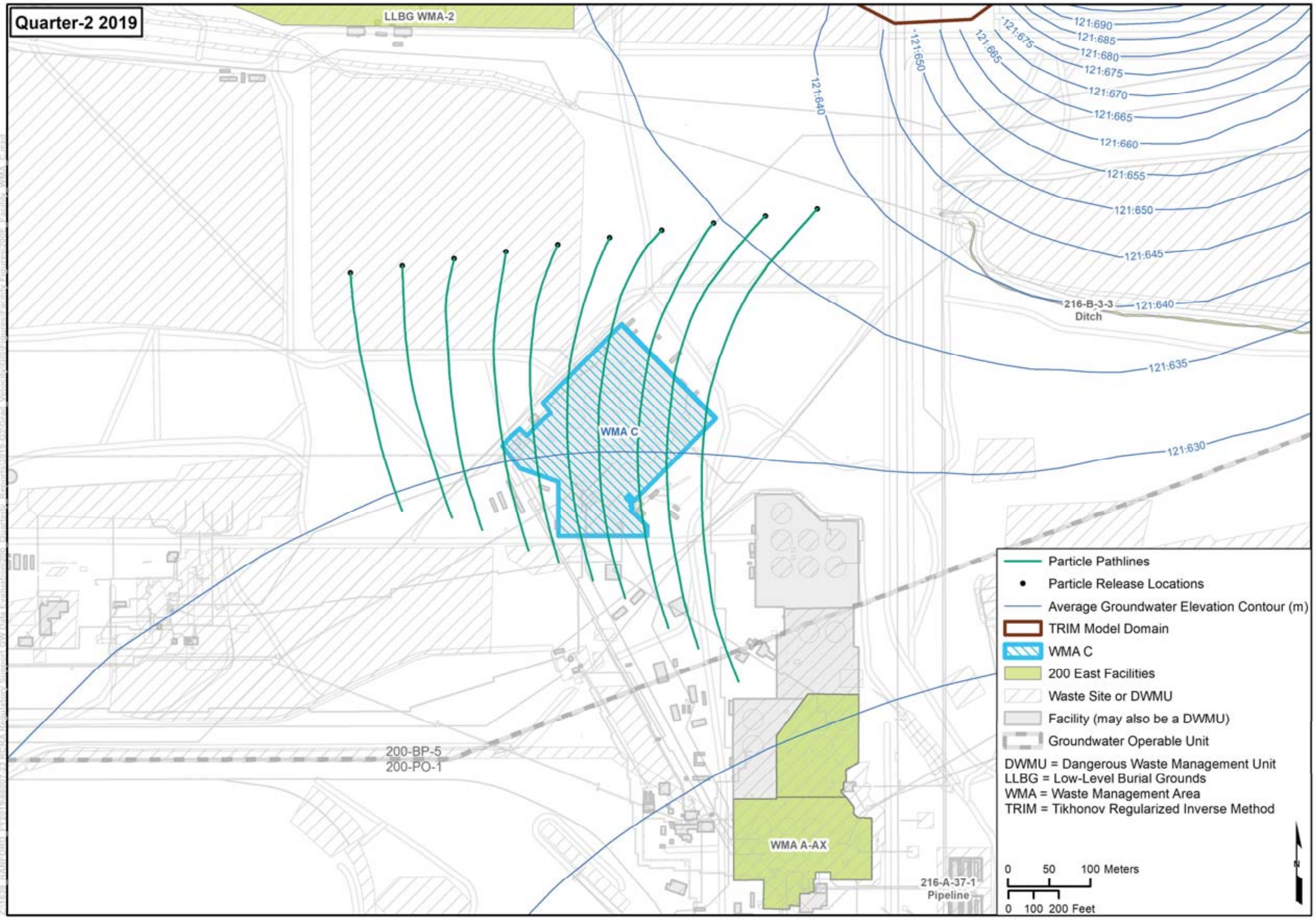

Figure 7-48. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA C for the Second Quarter of 2019

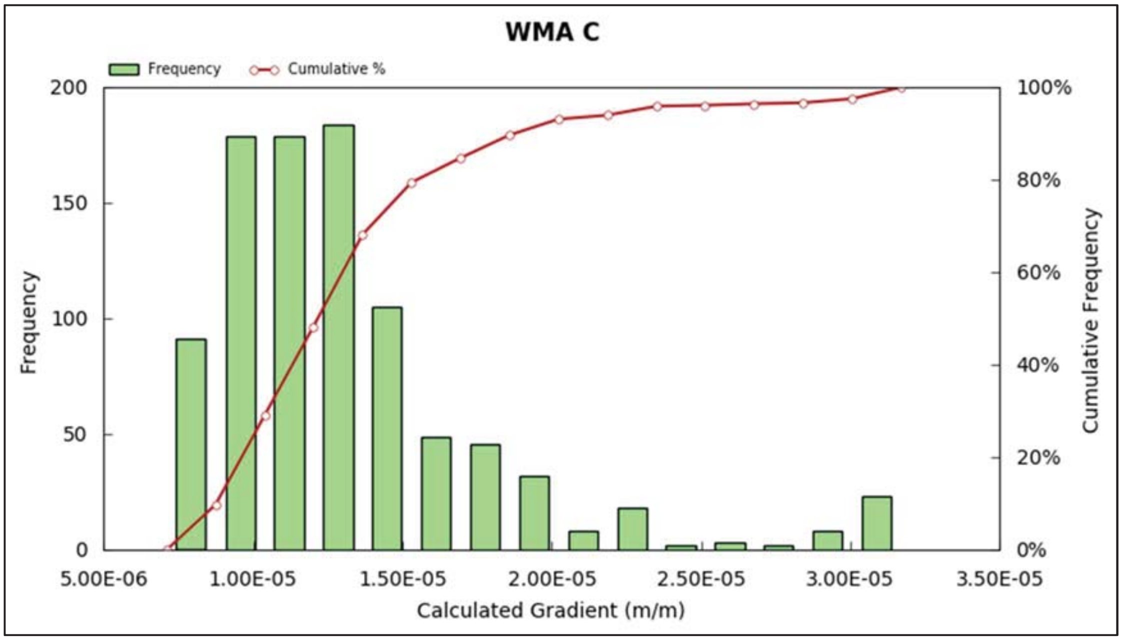

Figure 7-49. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA C for the Second Quarter of 2019

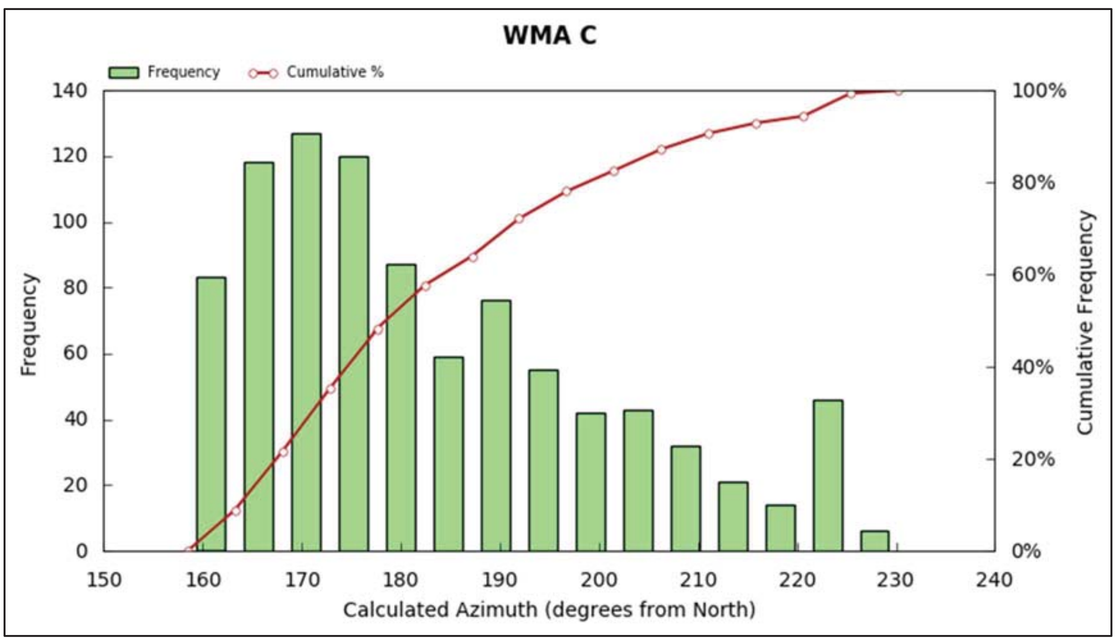

Figure 7-50. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA C for the Second Quarter of 2019

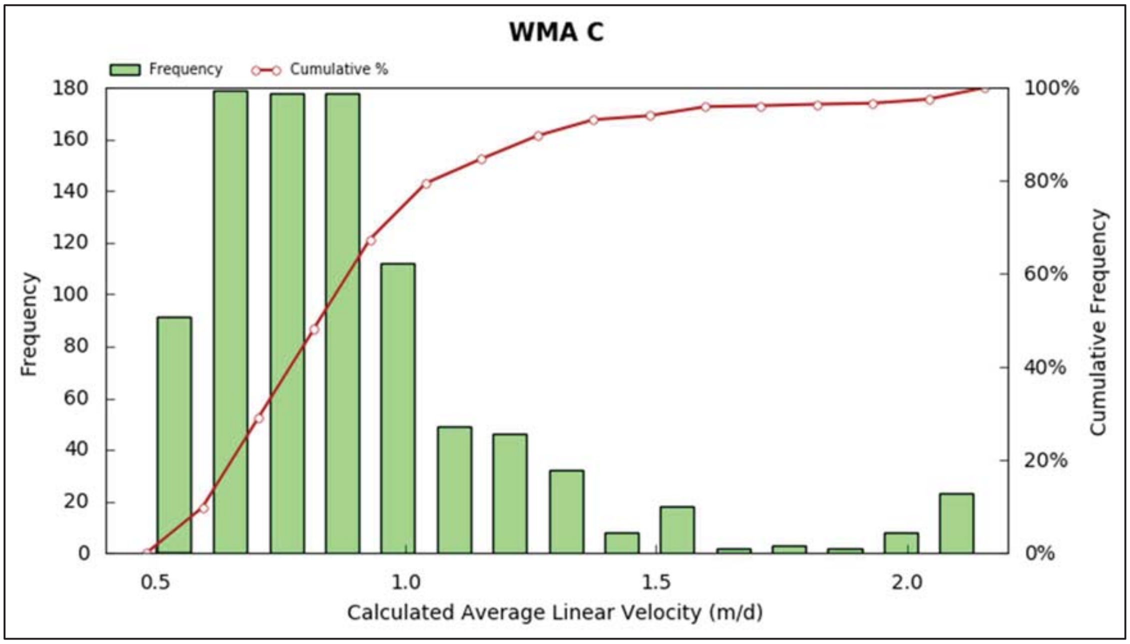

Figure 7-51. Histogram Plot of Calculated Average Linear Velocities at WMA C for the Second Quarter of 2019

7.2 200 West Area

Summary statistics pertaining to the calculated hydraulic gradients and average linear velocities at the 200 West Area facilities for the second quarter of 2019 are presented in Table 7-2. Figure 7-52 through Figure 7-54 illustrate the same data graphically. The results for each 200 West Area facility are presented in the facility-specific sections below.

Table 7-2. Calculated Hydraulic Gradients and Average Linear Velocities at the 200 West Area Facilities for the Second Quarter of 2019

Site	Gradient Magnitude (m/m)				Gradient Azimuth (degrees from North)				Average Linear Velocity (m/d)			
	Min	Max	Average	Median	Min	Max	Average	Median	Min	Max	Average	Median
216-S-10	2.09E-03	3.07E-03	2.52E-03	2.44E-03	72	105	87	84	0.07	0.10	0.08	0.08
Trenches 31 and 34	8.57E-04	6.61E-03	3.39E-03	3.23E-03	45	307	114	94	0.03	0.22	0.11	0.11
LLBG WMA-3	9.88E-04	7.86E-03	2.81E-03	2.62E-03	12	122	82	87	0.03	0.26	0.09	0.09
LLBG WMA-4	5.89E-03	1.75E-02	8.08E-03	7.96E-03	23	187	90	87	0.20	0.58	0.27	0.27
WMA S-SX	3.48E-03	5.98E-03	4.42E-03	4.39E-03	68	143	92	95	0.12	0.20	0.15	0.15
WMA T	5.77E-03	8.77E-03	6.66E-03	6.70E-03	94	122	112	111	0.19	0.29	0.22	0.22
WMA TX-TY	4.78E-03	1.55E-02	9.00E-03	9.09E-03	53	178	100	109	0.16	0.52	0.30	0.30
WMA U	4.92E-03	1.06E-02	6.06E-03	5.83E-03	40	97	83	86	0.16	0.35	0.20	0.19

LLBG = Low-Level Burial Grounds

WMA = Waste Management Area

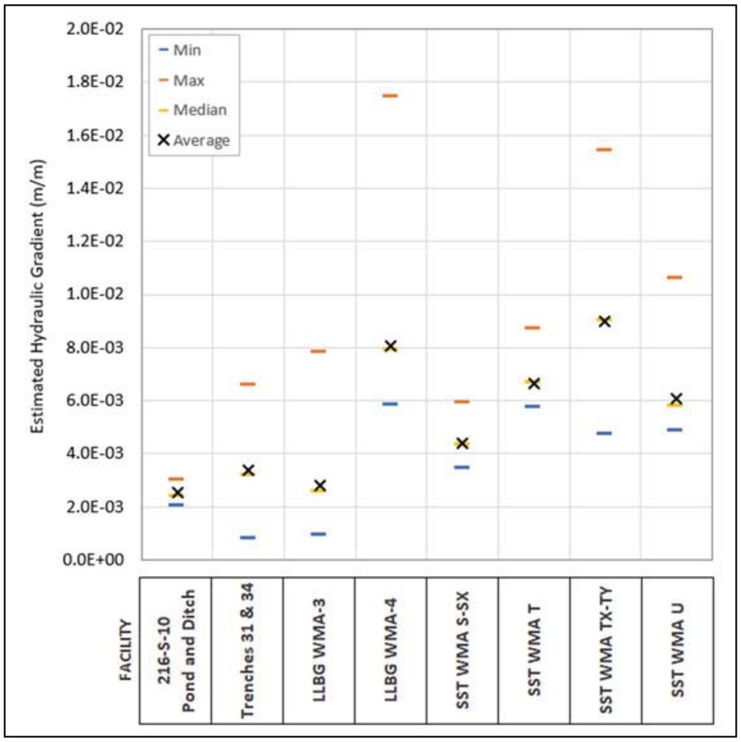

Figure 7-52. Calculated Hydraulic Gradient Magnitudes at the 200 West Area Facilities

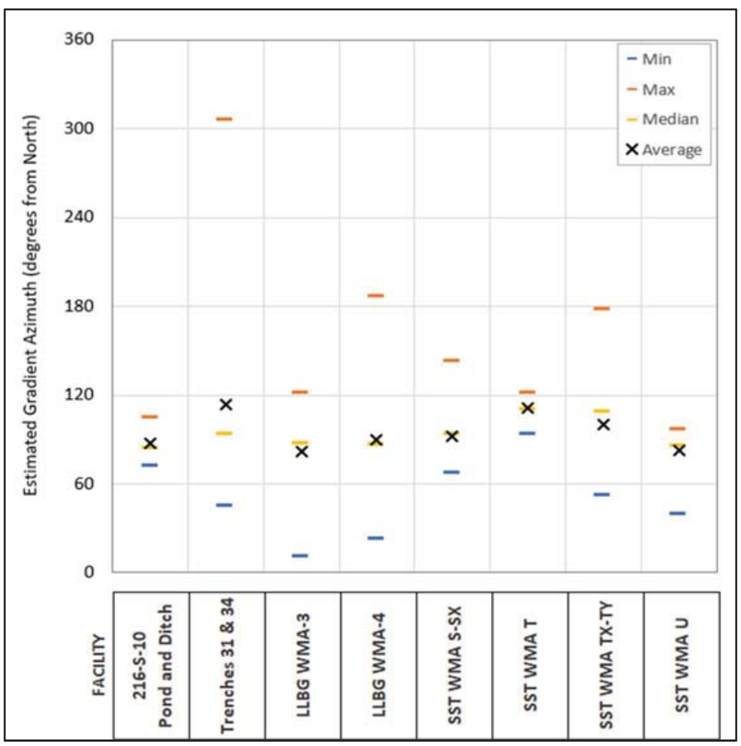

Figure 7-53. Calculated Hydraulic Gradient Azimuths at the 200 West Area Facilities

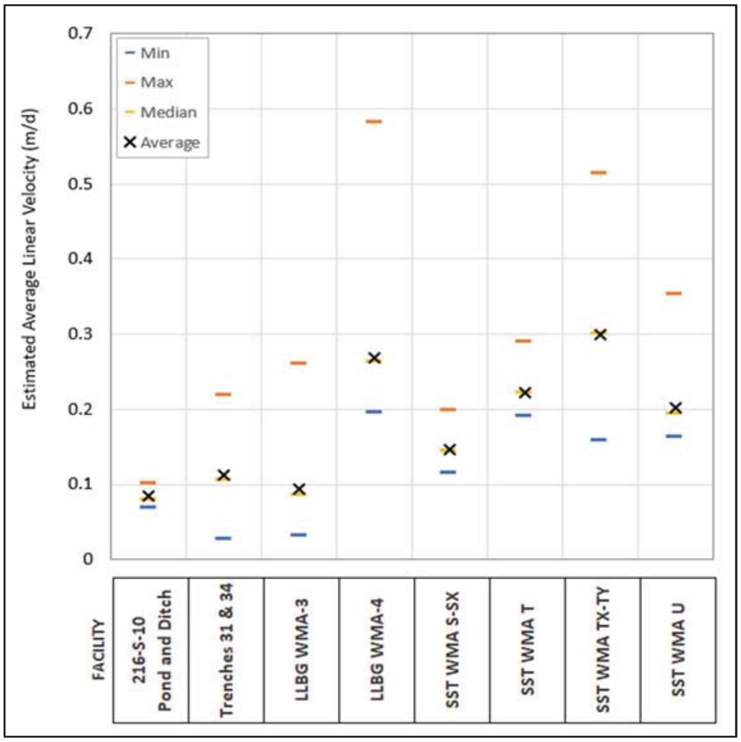

Figure 7-54. Calculated Average Linear Velocities at the 200 West Area Facilities

7.2.1 216-S-10 Pond and Ditch

Figure 7-55 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the 216-S-10 Pond and Ditch. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the S-10 Pond and Ditch are presented in Figure 7-56 through Figure 7-58.

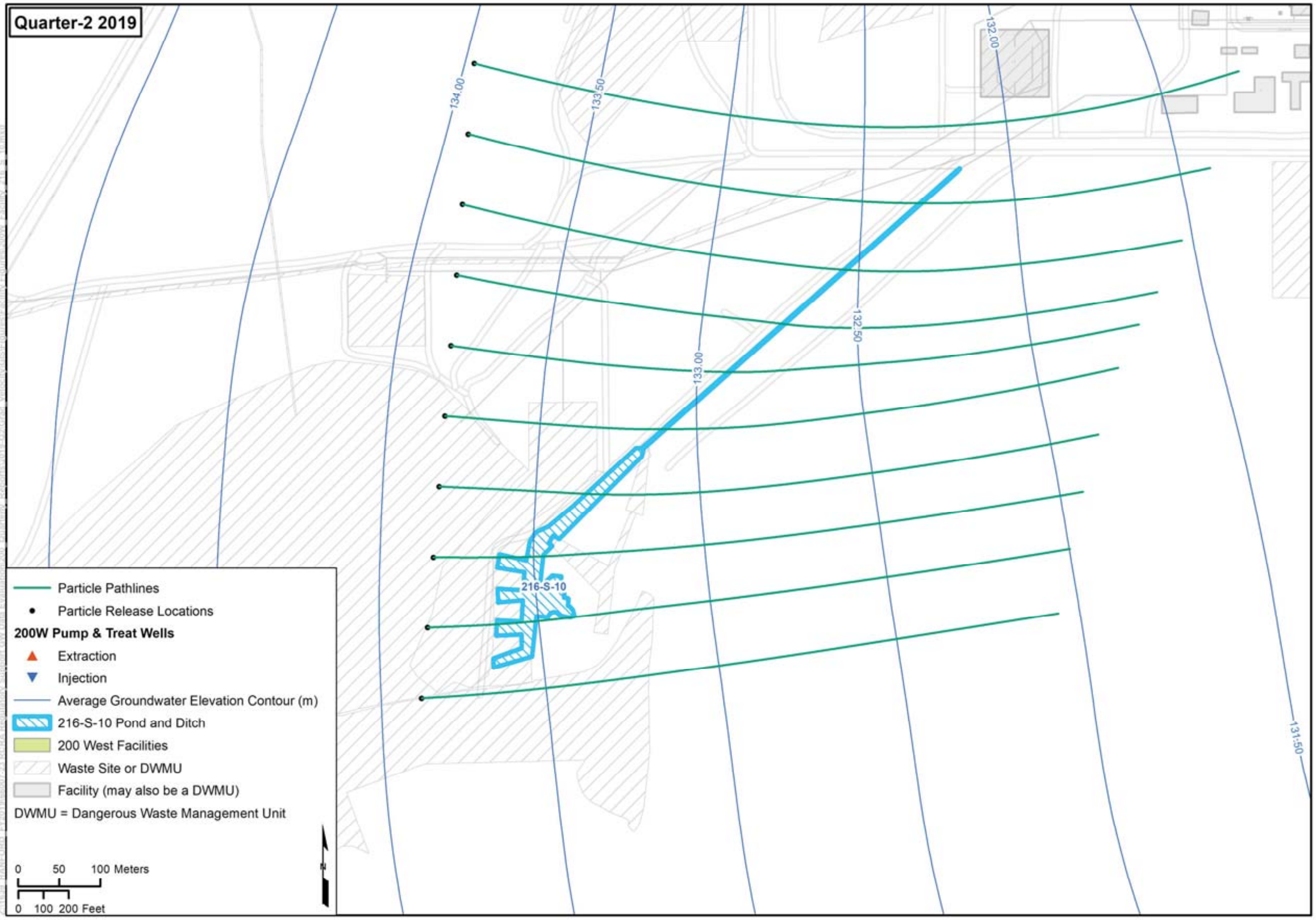

Figure 7-55. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the 216-S-10 Pond and Ditch for the Second Quarter of 2019

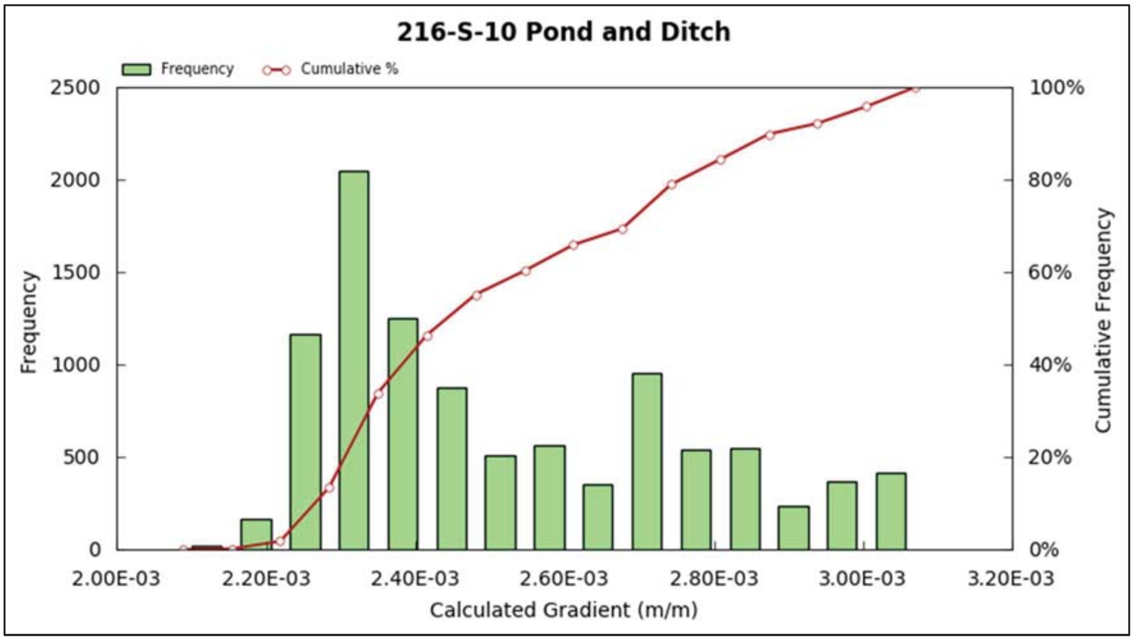

Figure 7-56. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the 216-S-10 Pond and Ditch for the Second Quarter of 2019

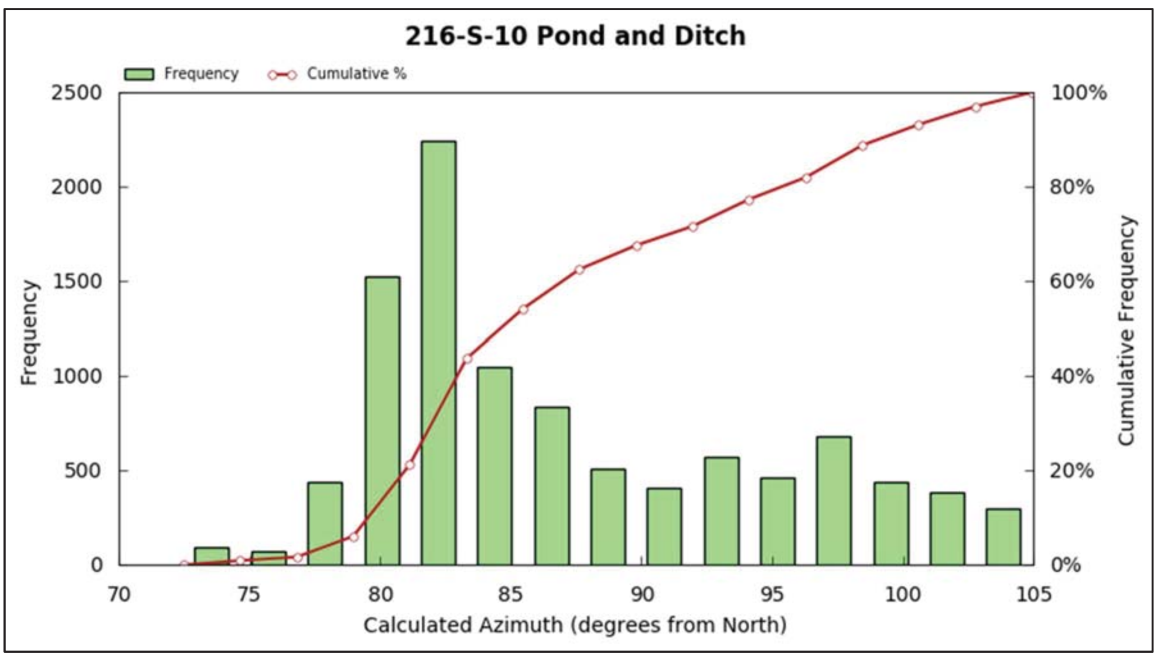

Figure 7-57. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the 216-S-10 Pond and Ditch for the Second Quarter of 2019

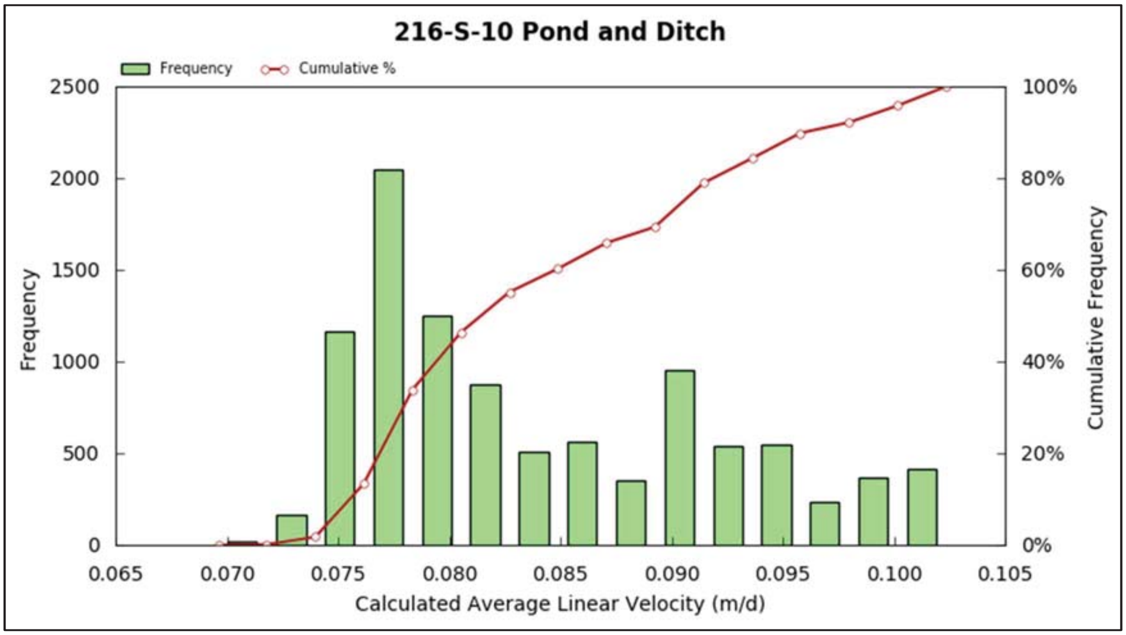

Figure 7-58. Histogram Plot of Calculated Average Linear Velocities at the 216-S-10 Pond and Ditch for the Second Quarter of 2019

7.2.2 Low-Level Burial Grounds Trenches 31 and 34

Figure 7-59 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the LLBG Trenches 31 and 34. Particle release locations were placed inside the trenches so that the resulting pathlines project downgradient. Placing particle release locations upgradient of the entire facility would not allow the resulting pathlines to traverse the facility due to the curvature in the adjacent flow field induced by treated groundwater injection operations. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the LLBG Trenches 31 and 34 are presented in Figure 7-60 through Figure 7-62.

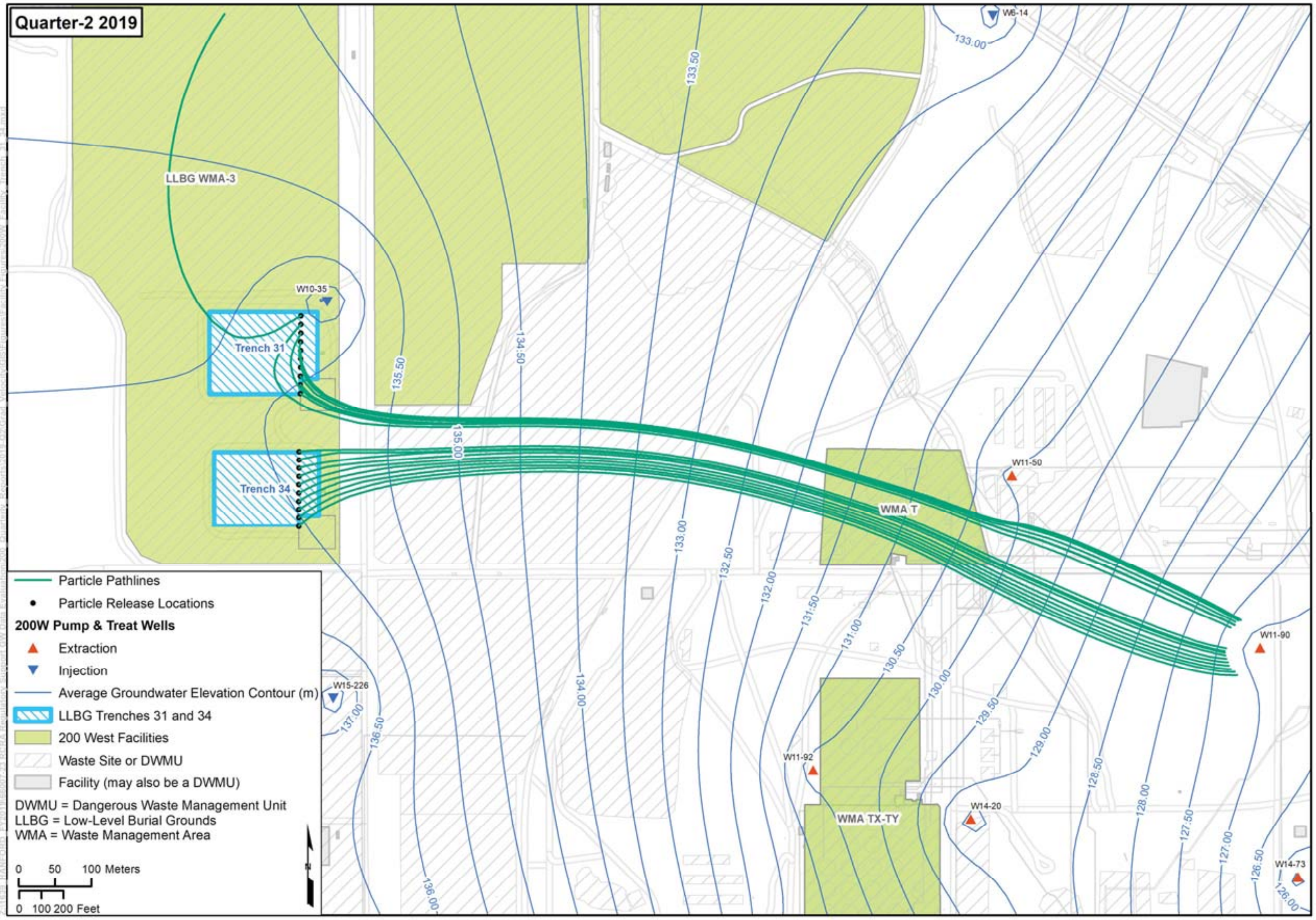

Figure 7-59. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the LLBG Trenches 31 and 34 for the Second Quarter of 2019

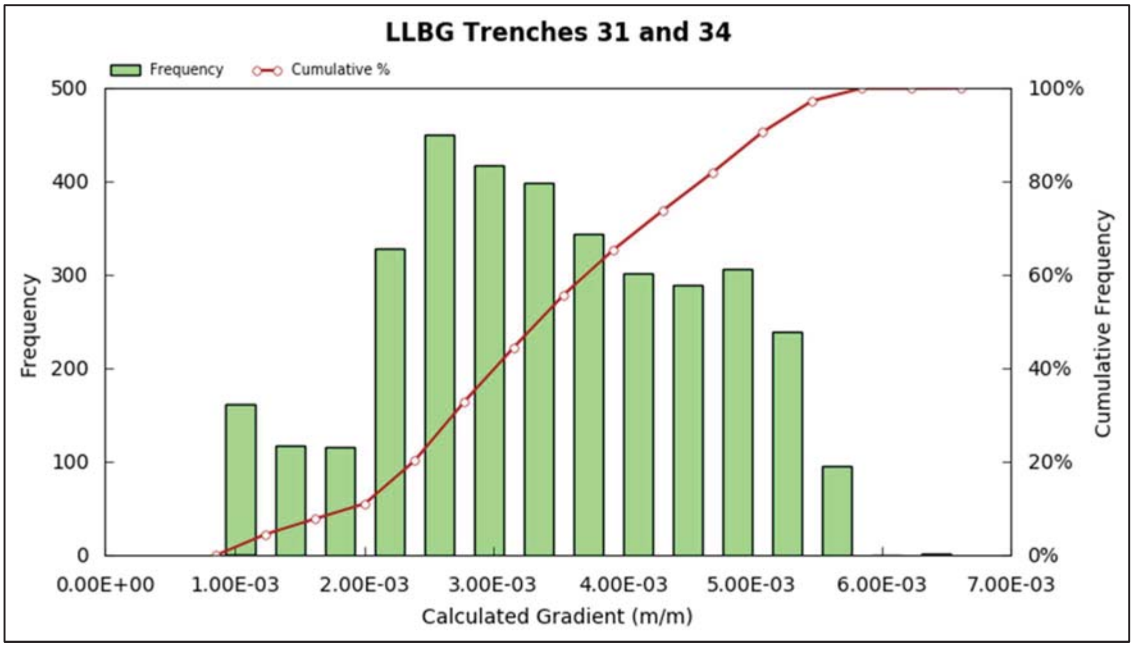

Figure 7-60. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the LLBG Trenches 31 and 34 for the Second Quarter of 2019

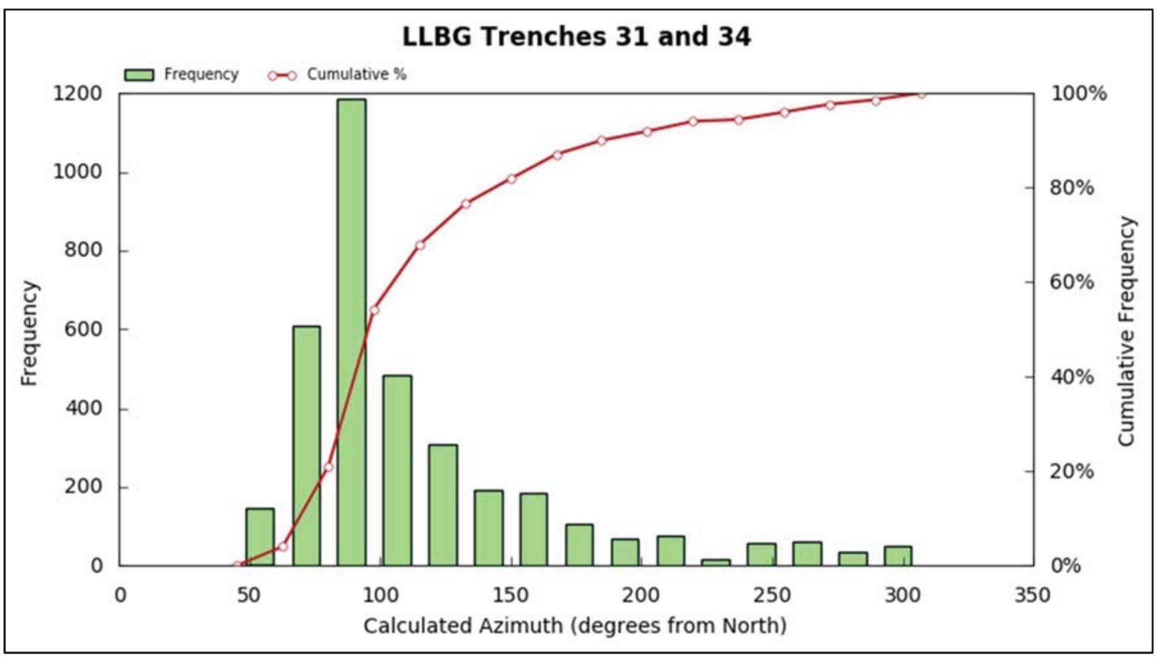

Figure 7-61. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the LLBG Trenches 31 and 34 for the Second Quarter of 2019

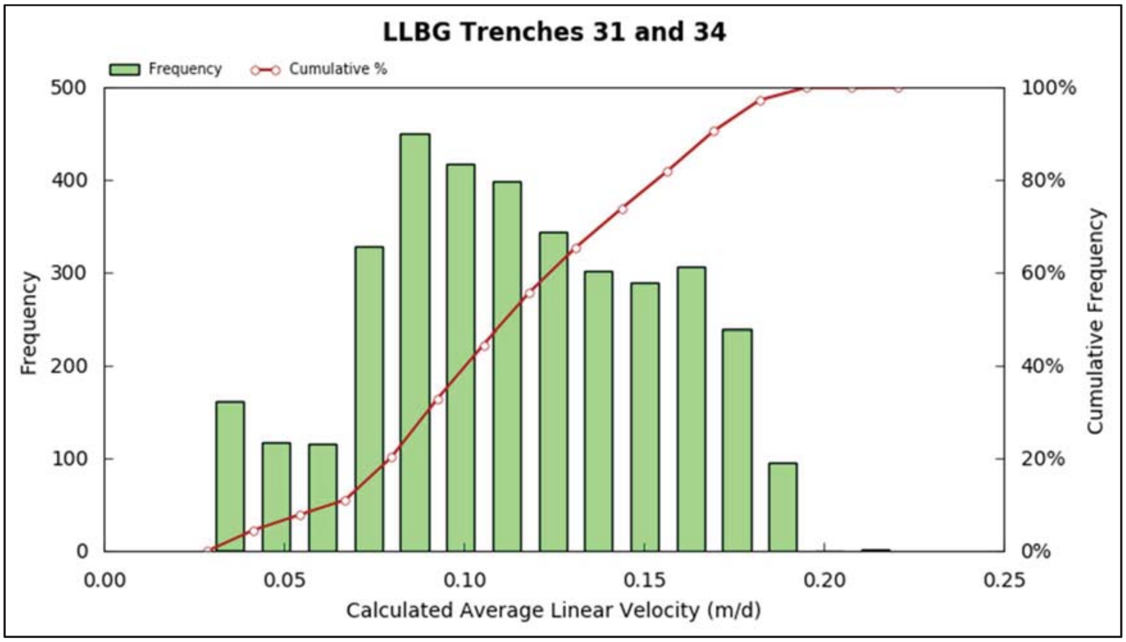

Figure 7-62. Histogram Plot of Calculated Average Linear Velocities at the LLBG Trenches 31 and 34 for the Second Quarter of 2019

7.2.3 Low-Level Burial Grounds Waste Management Area-3

Figure 7-63 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the LLBG WMA-3. Particle release locations were placed upgradient of the Green Islands within WMA-3 in order to obtain pathlines projecting downgradient. Placing particle release locations upgradient of the entire facility would not allow the resulting pathlines to traverse the facility due to the curvature in the adjacent flow field induced by treated groundwater injection operations. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the LLBG WMA-3 are presented in Figure 7-64 through Figure 7-66.

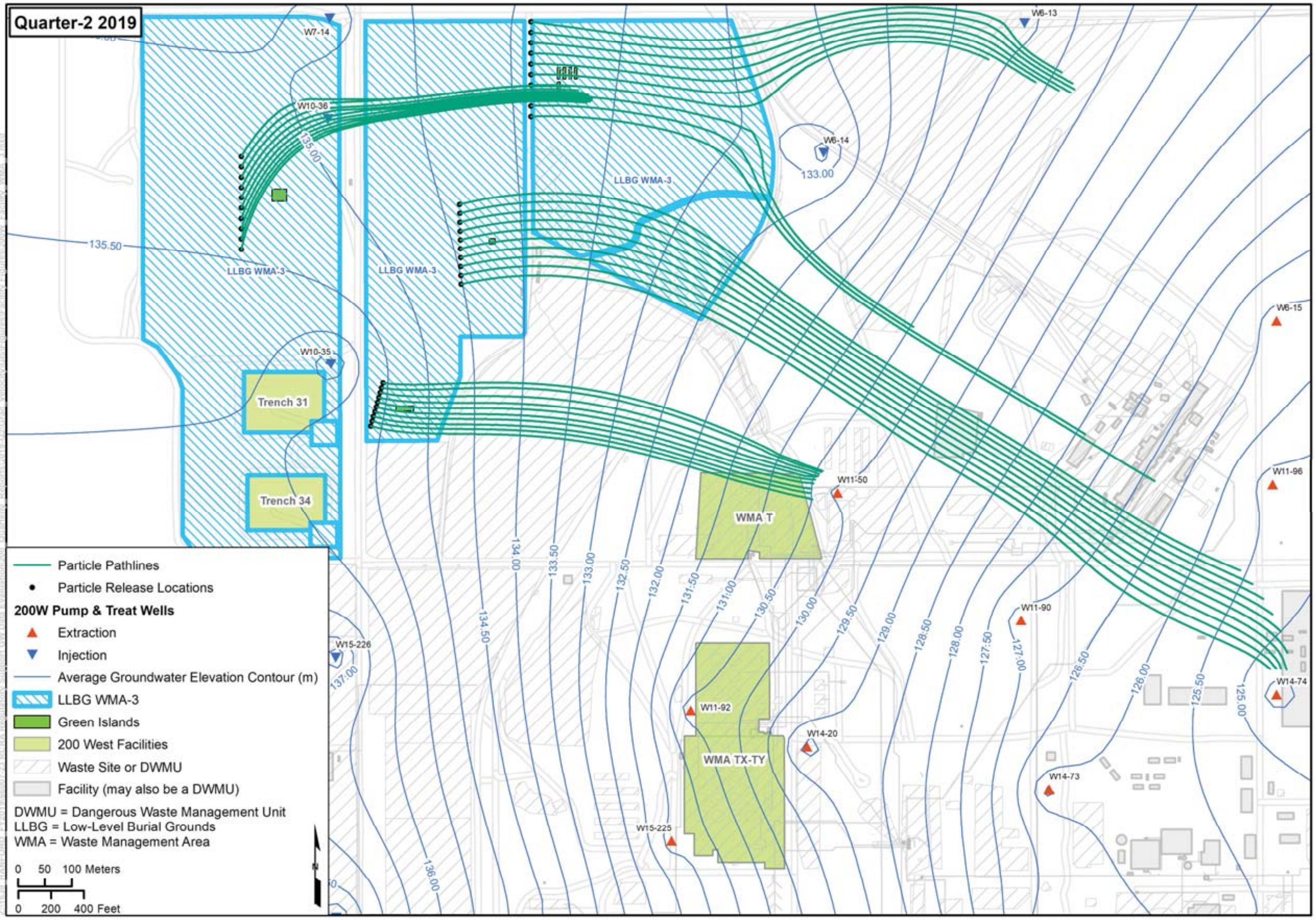

Figure 7-63. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the LLBG WMA-3 for the Second Quarter of 2019

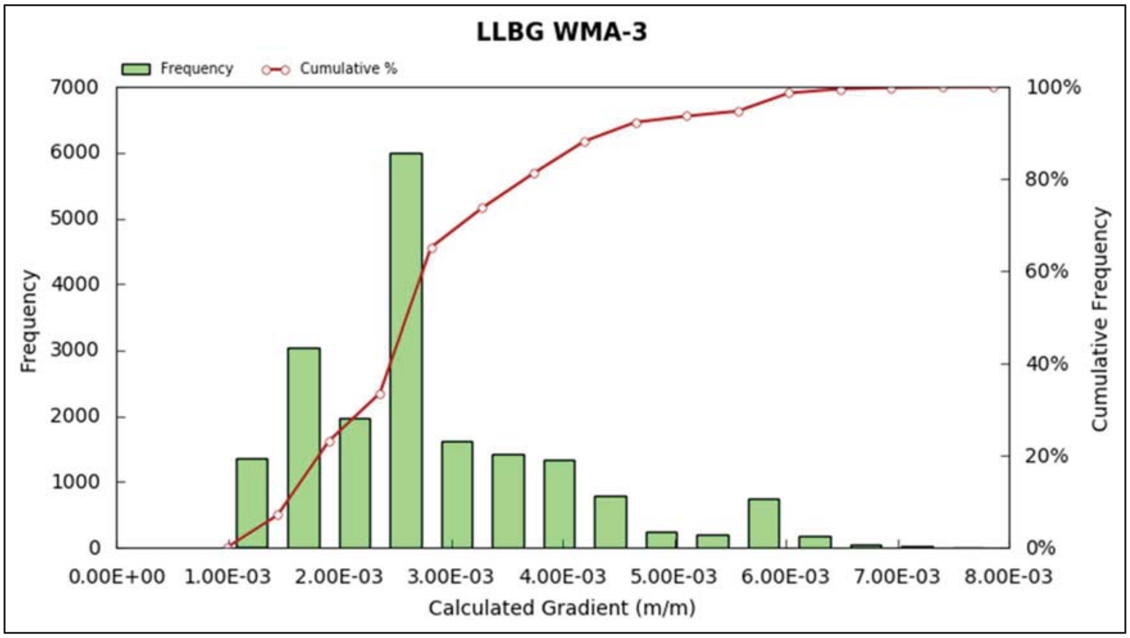

Figure 7-64. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the LLBG WMA-3 for the Second Quarter of 2019

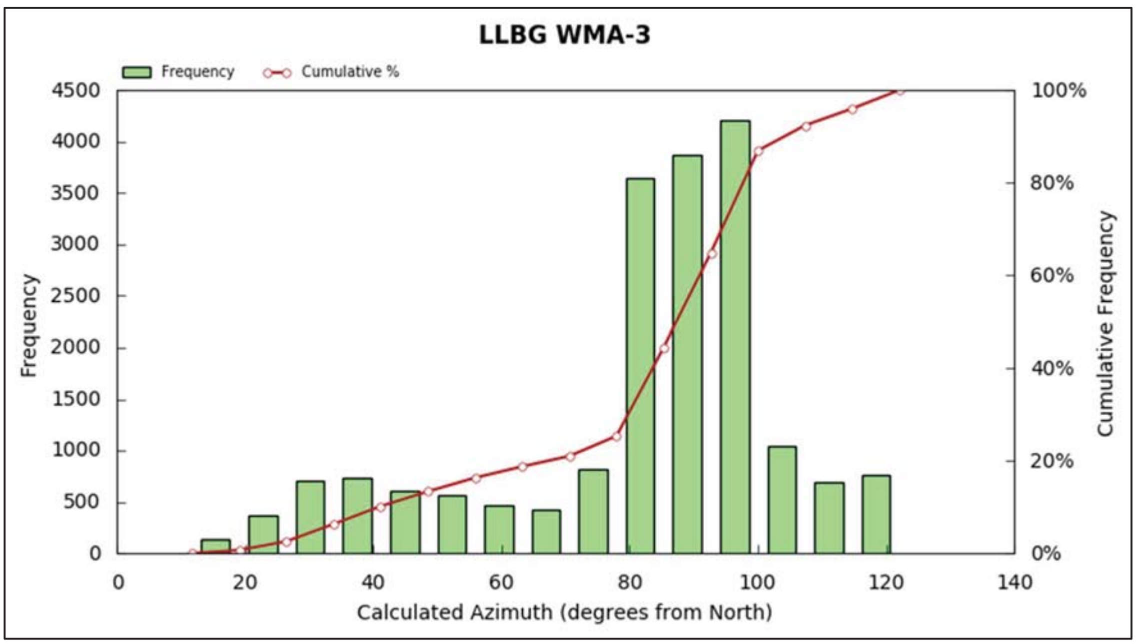

Figure 7-65. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the LLBG WMA-3 for the Second Quarter of 2019

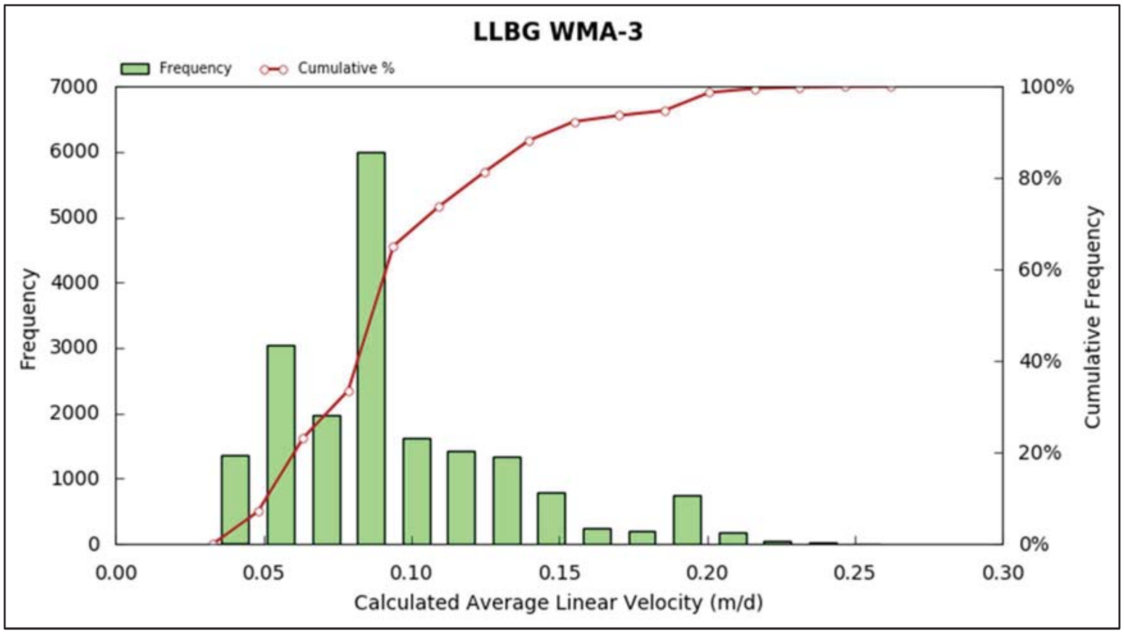

Figure 7-66. Histogram Plot of Calculated Average Linear Velocities at the LLBG WMA-3 for the Second Quarter of 2019

7.2.4 Low-Level Burial Grounds Waste Management Area-4

Figure 7-67 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the LLBG WMA-4. The figure shows that some pathlines appear shorter in length than other pathlines. This is due to the capture of the particles at the extraction well. Particle pathlines terminate when a particle comes within the capture radius of an extraction well. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the LLBG WMA-4 are presented in Figure 7-68 through Figure 7-70.

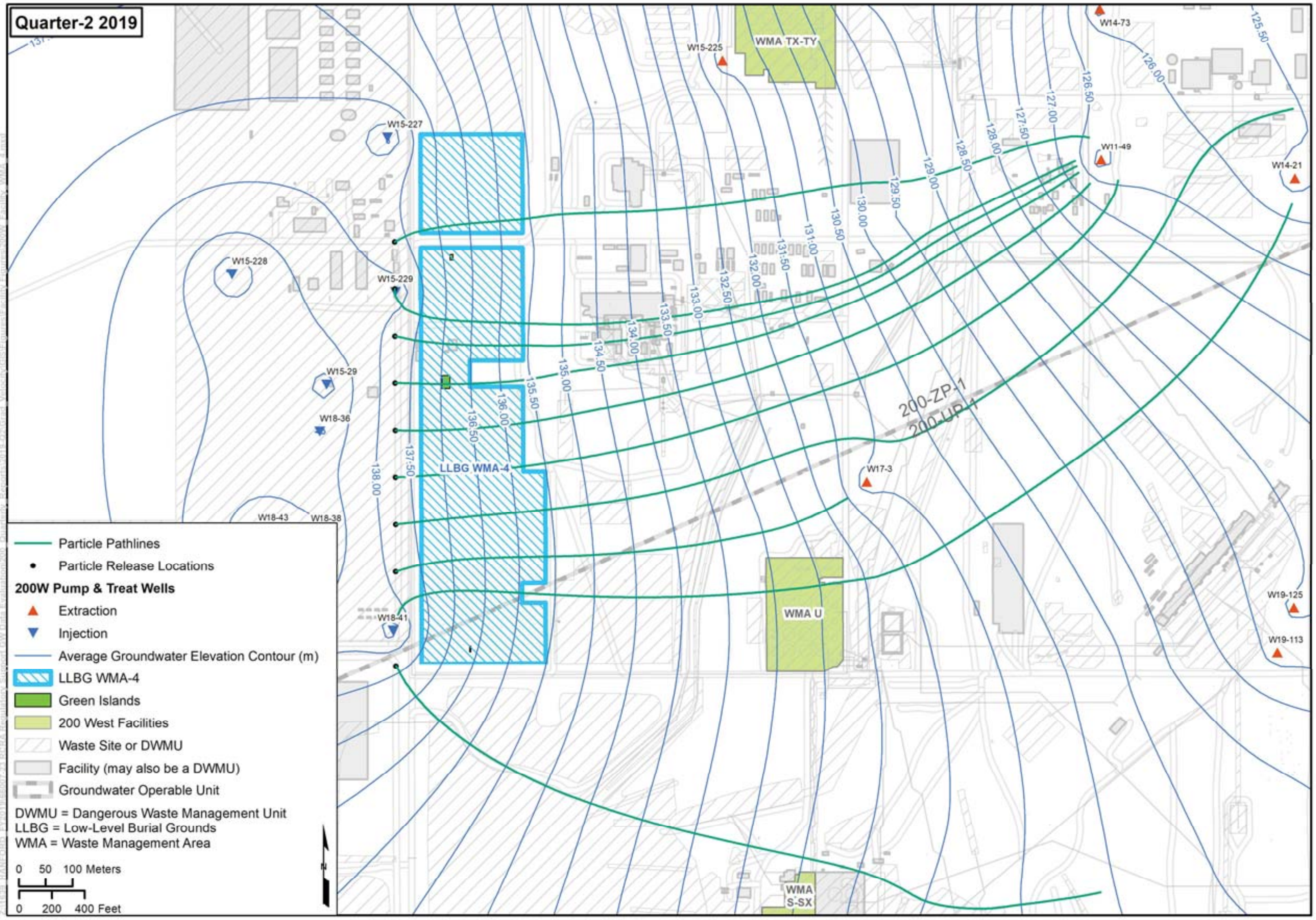

Figure 7-67. Calculated Particle Pathlines Representing General Groundwater Flow Directions at the LLBG WMA-4 for the Second Quarter of 2019

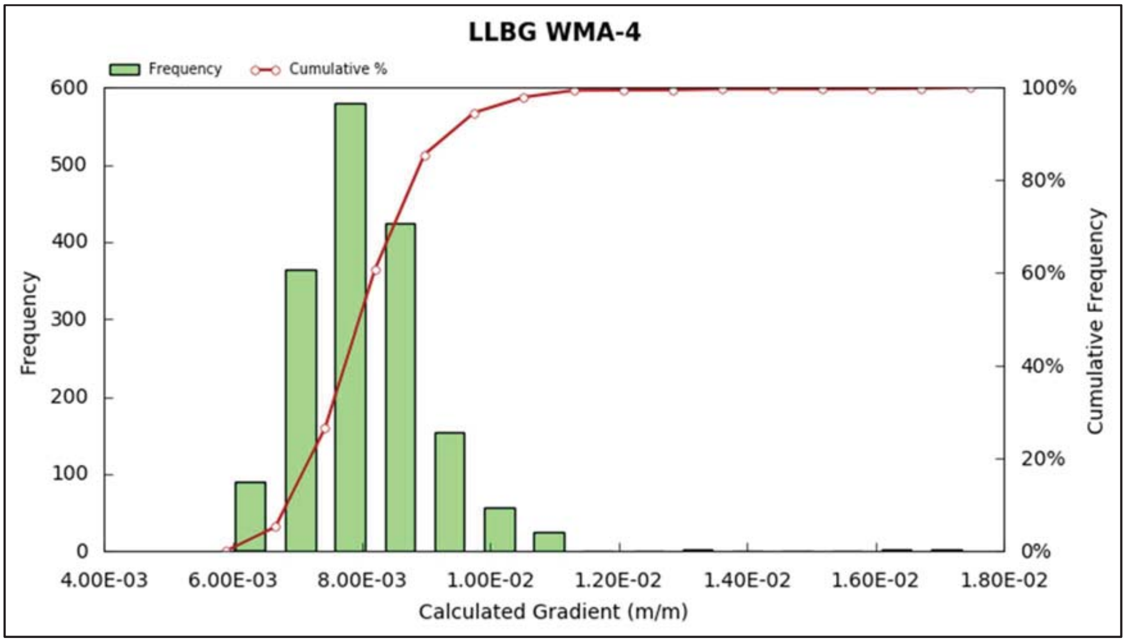

Figure 7-68. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at the LLBG WMA-4 for the Second Quarter of 2019

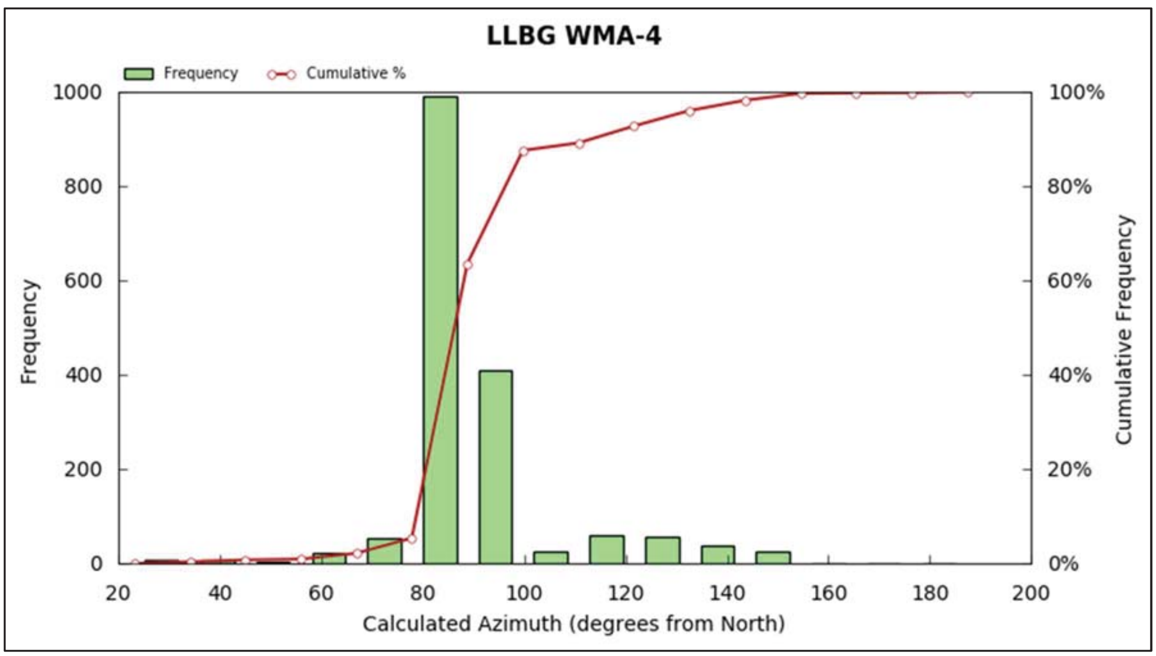

Figure 7-69. Histogram Plot of Calculated Hydraulic Gradient Azimuths at the LLBG WMA-4 for the Second Quarter of 2019

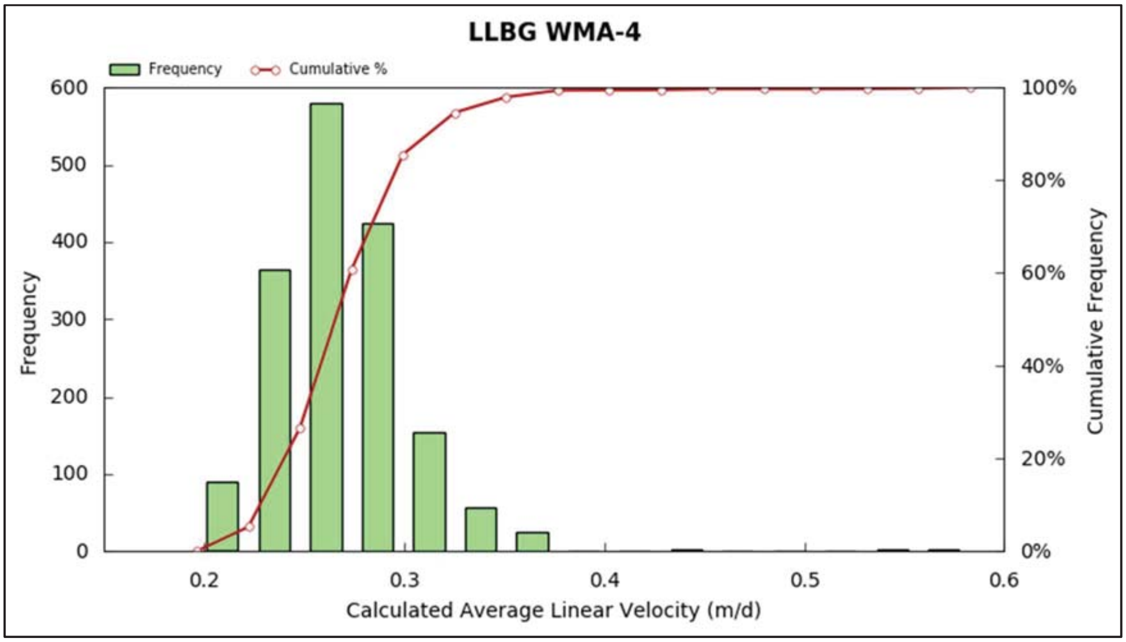

Figure 7-70. Histogram Plot of Calculated Average Linear Velocities at the LLBG WMA-4 for the Second Quarter of 2019

7.2.5 Waste Management Area S-SX

Figure 7-71 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at the WMA S-SX. The figure shows that some pathlines appear shorter in length than other pathlines. This is due to the capture of the particles at the extraction well. Particle pathlines terminate when a particle comes within the capture radius of an extraction well. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at the WMA S-SX are presented in Figure 7-72 through Figure 7-74.

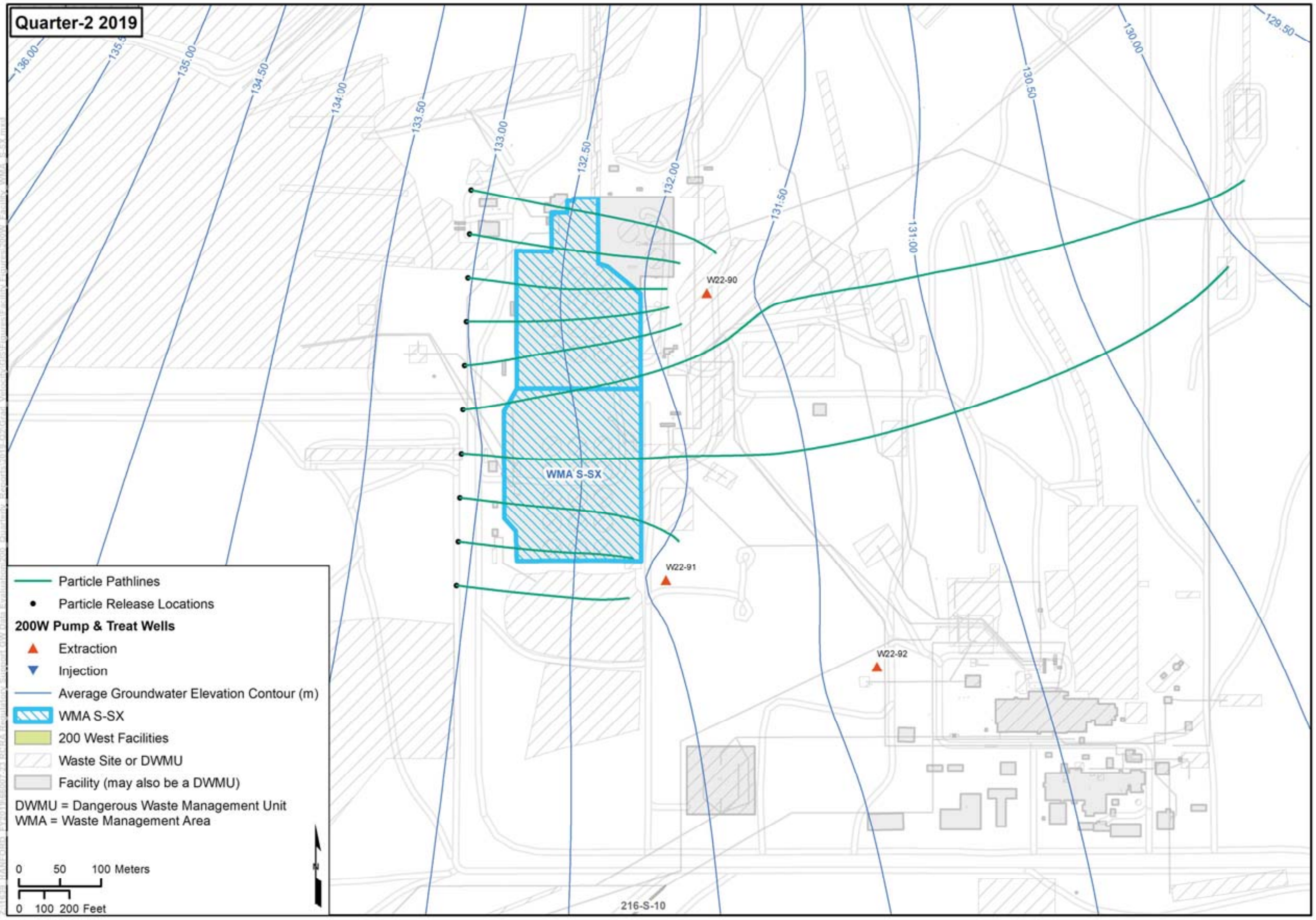

Figure 7-71. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA S-SX for the Second Quarter of 2019

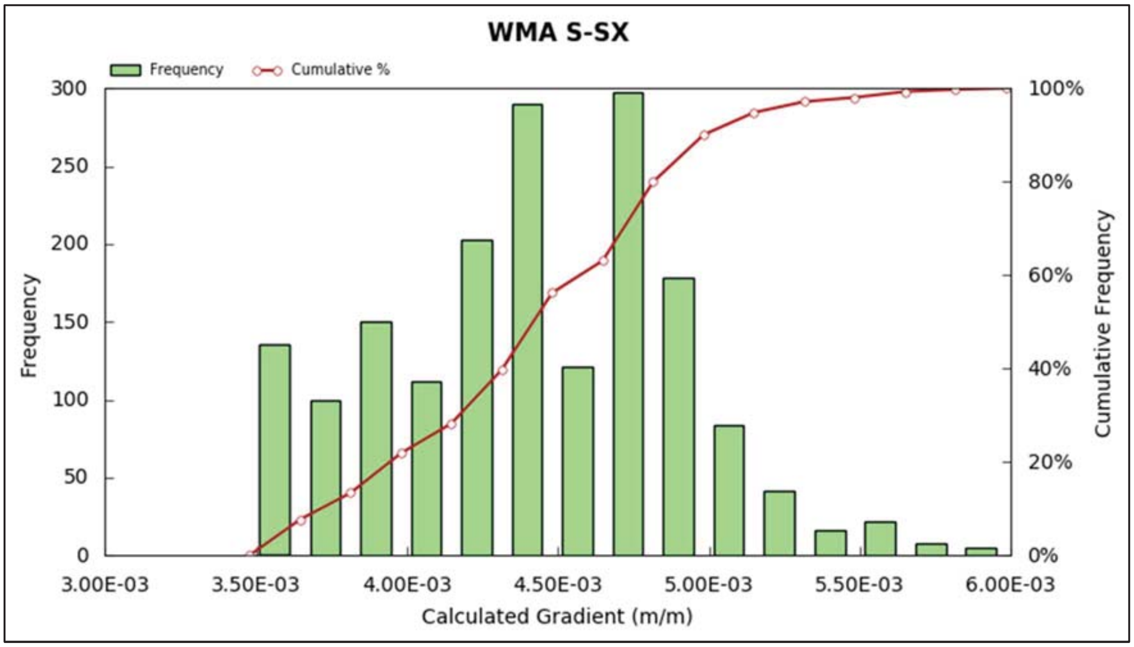

Figure 7-72. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA S-SX for the Second Quarter of 2019

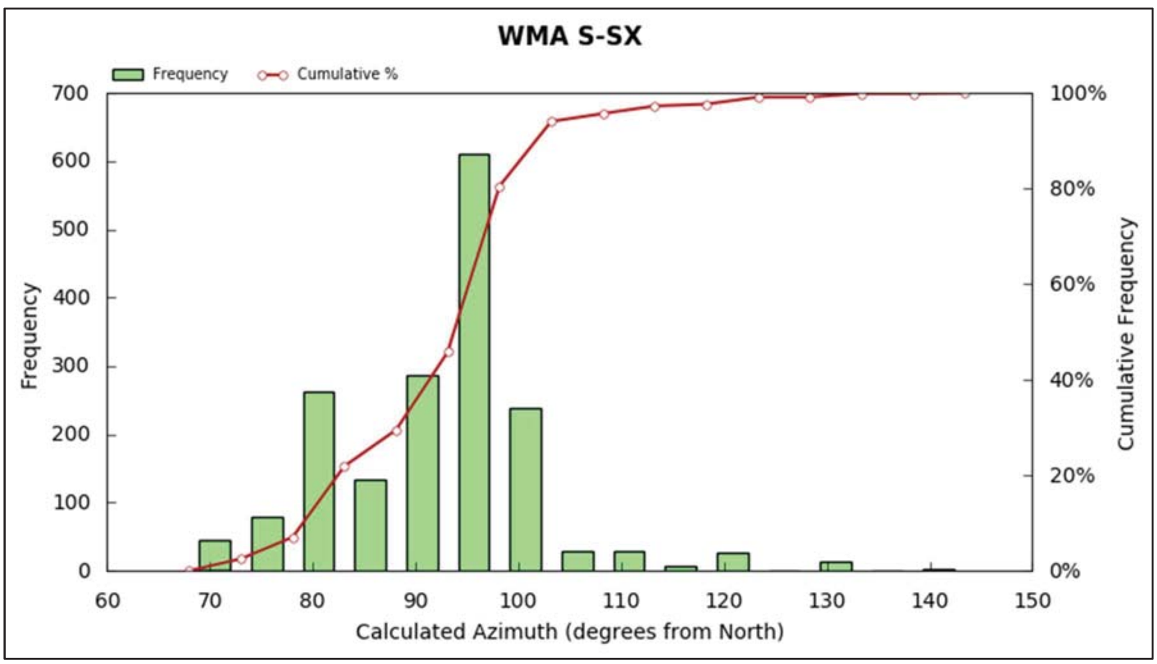

Figure 7-73. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA S-SX for the Second Quarter of 2019

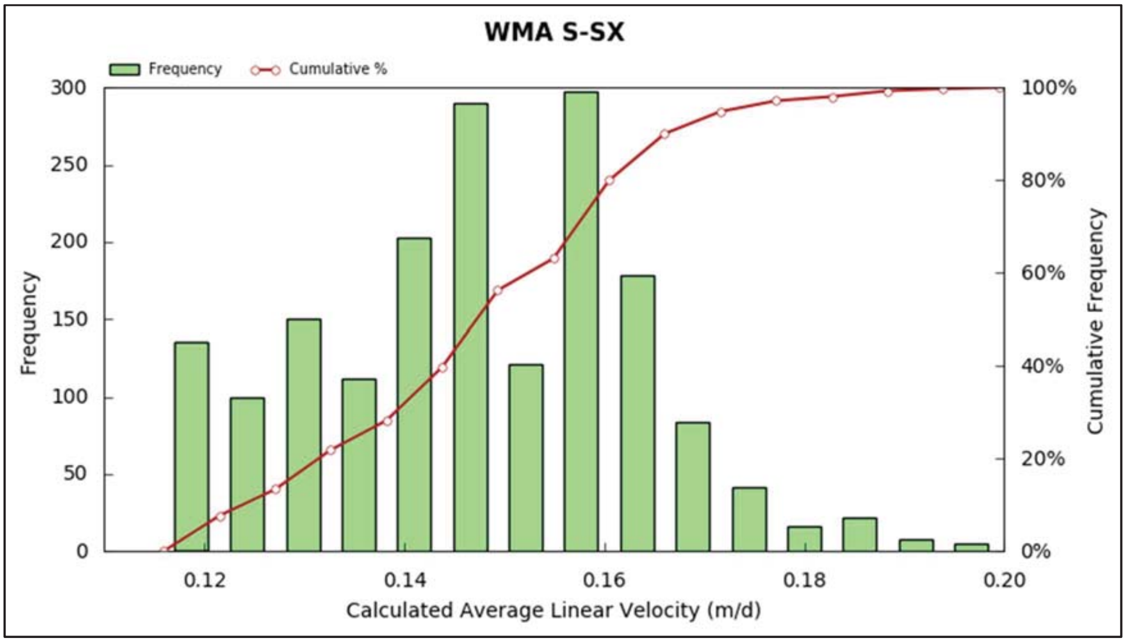

Figure 7-74. Histogram Plot of Calculated Average Linear Velocities at WMA S-SX for the Second Quarter of 2019

7.2.6 Waste Management Area T

Figure 7-75 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at WMA T. The figure shows that some pathlines appear shorter in length than other pathlines. This is due to the capture of the particles at the extraction well. Particle pathlines terminate when a particle comes within the capture radius of an extraction well. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA T are presented in Figure 7-76 through Figure 7-78.

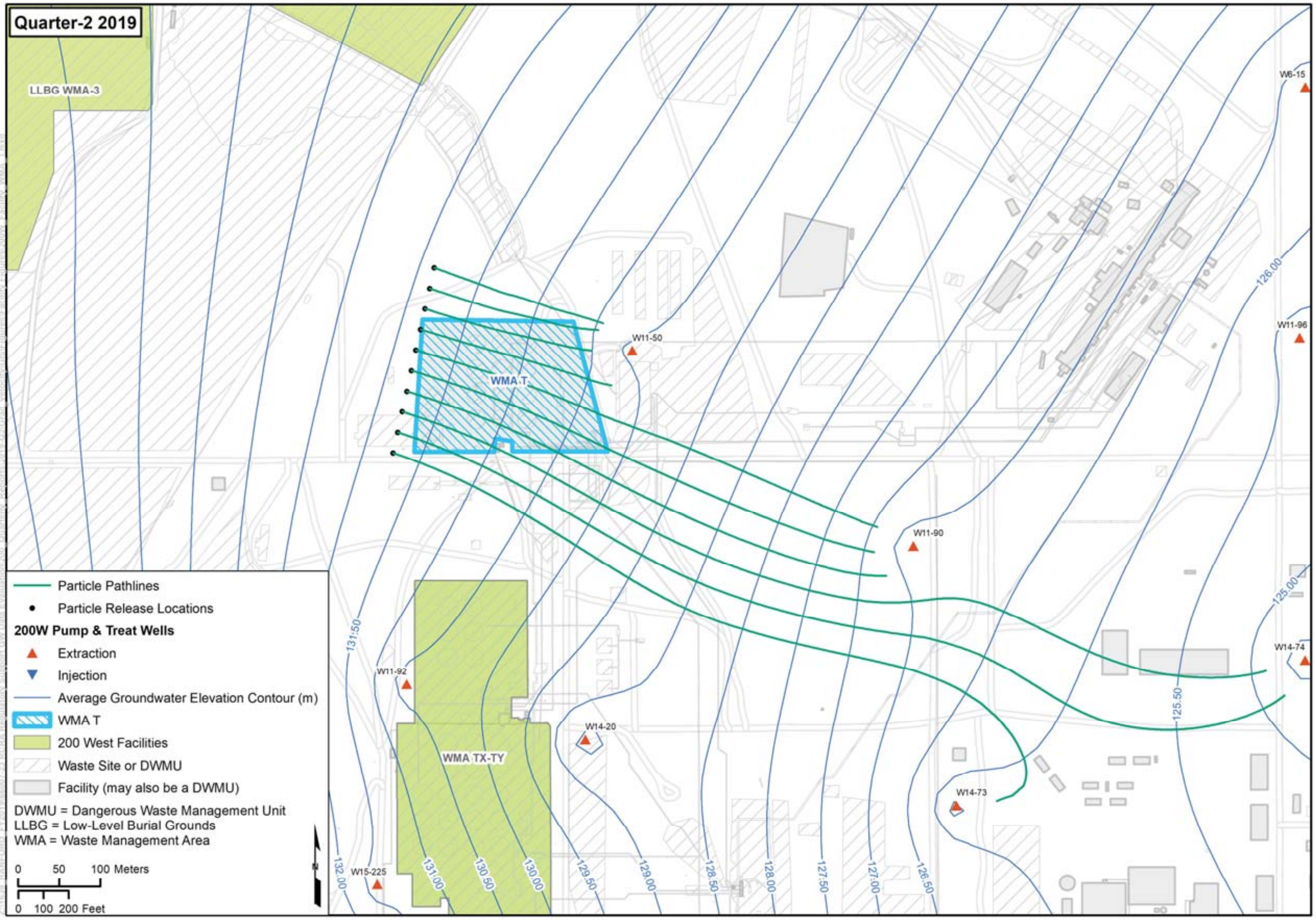

Figure 7-75. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA T for the Second Quarter of 2019

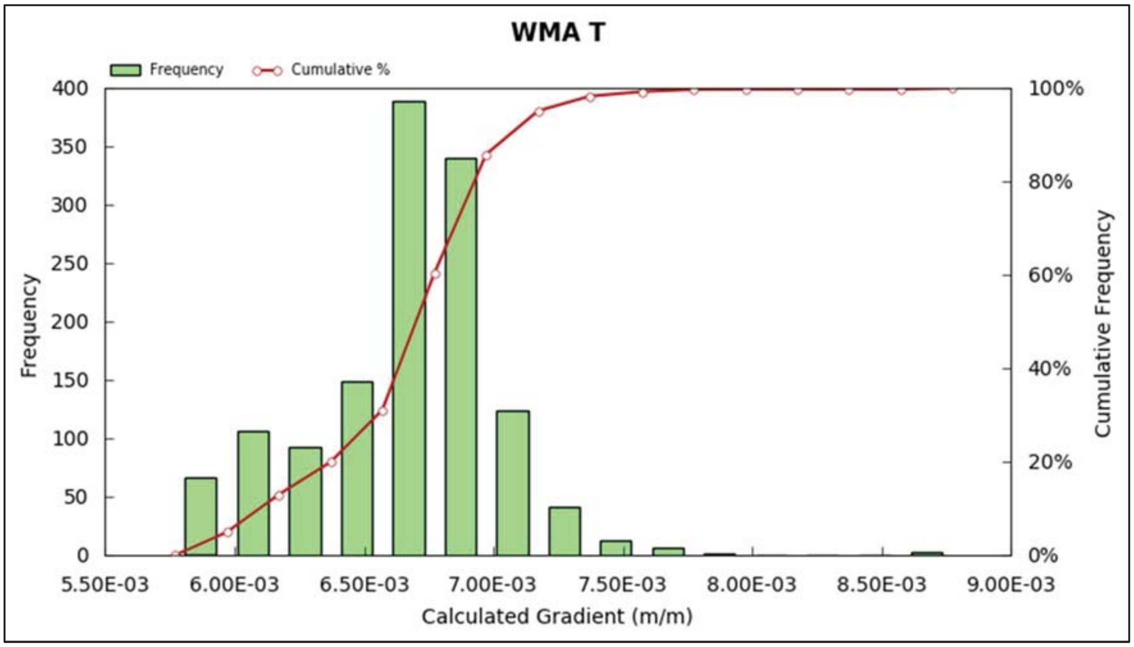

Figure 7-76. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA T for the Second Quarter of 2019

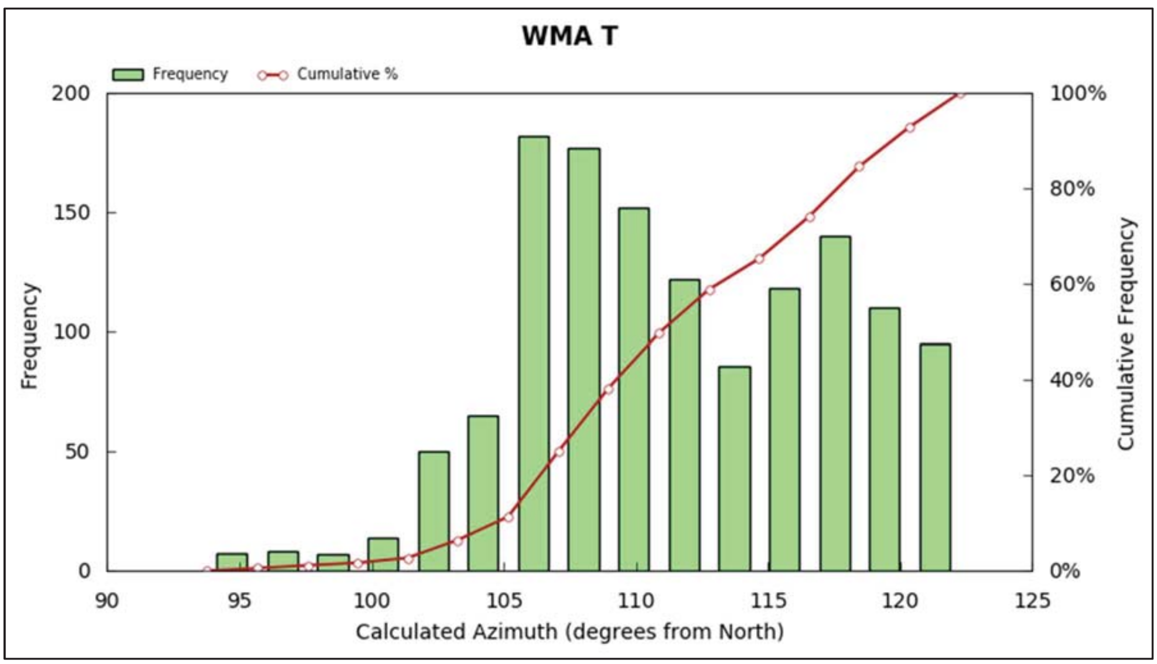

Figure 7-77. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA T for the Second Quarter of 2019

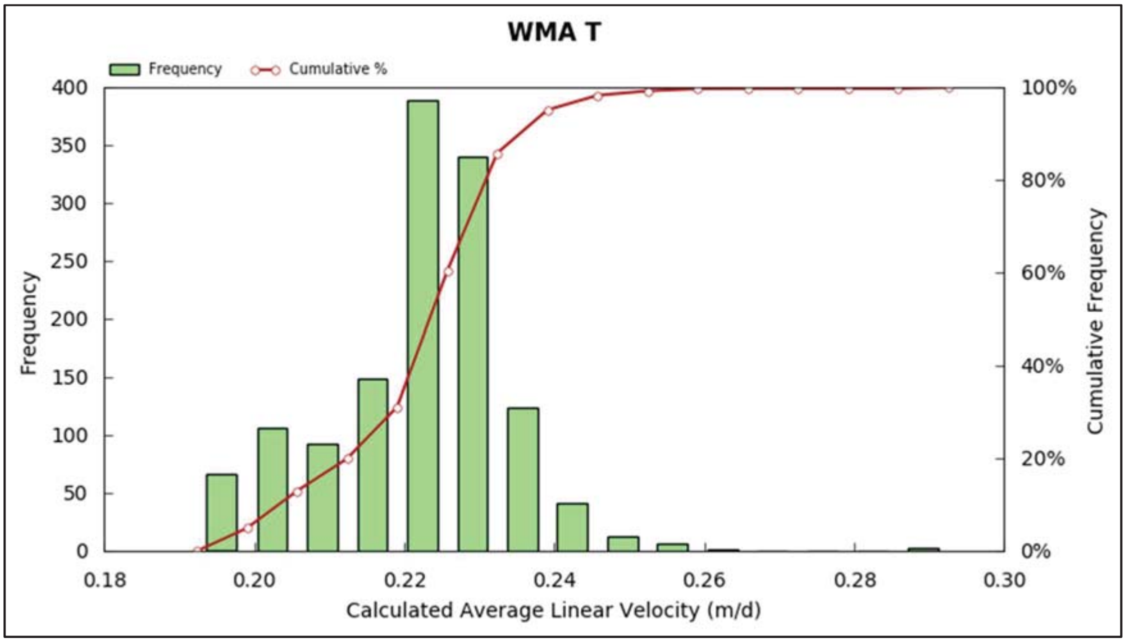

Figure 7-78. Histogram Plot of Calculated Average Linear Velocities at WMA T for the Second Quarter of 2019

7.2.7 Waste Management Area TX-TY

Figure 7-79 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at WMA TX-TY. The figure shows that some pathlines appear shorter in length than other pathlines. This is due to the capture of the particles at the extraction well. Particle pathlines terminate when a particle comes within the capture radius of an extraction well. At WMA TX-TY, some of the release locations are close enough to the capture radius of the extraction wells that they terminate immediately, leaving no discernable pathline. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA TX-TY are presented in Figure 7-80 through Figure 7-82.

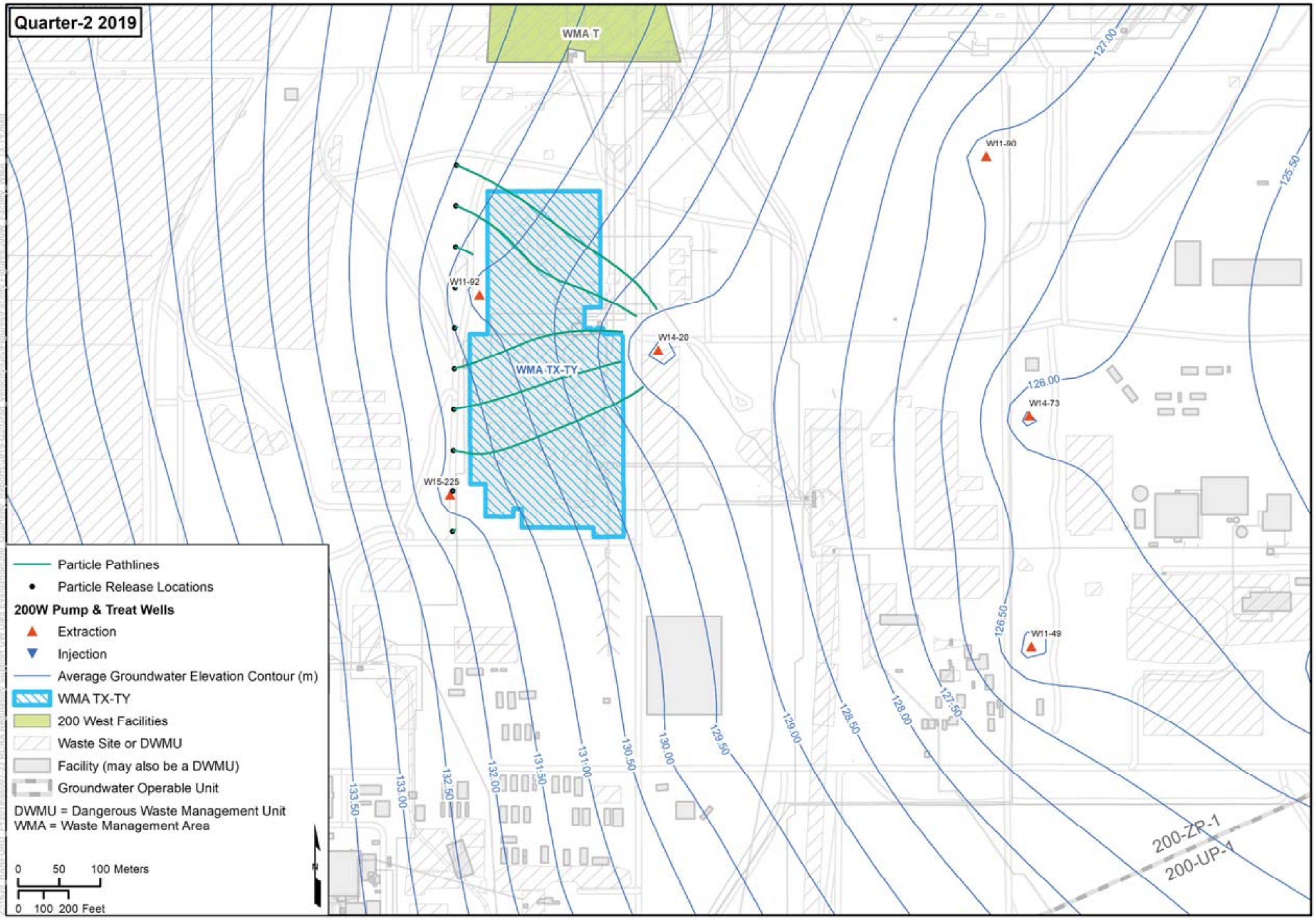

Figure 7-79. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA TX-TY for the Second Quarter of 2019

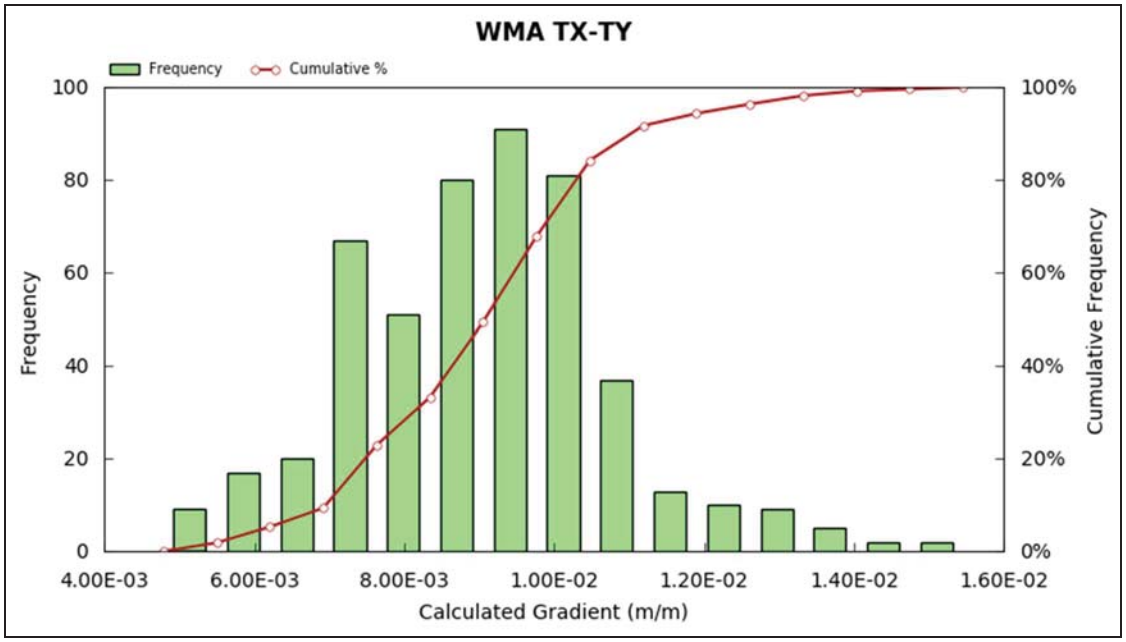

Figure 7-80. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA TX-TY for the Second Quarter of 2019

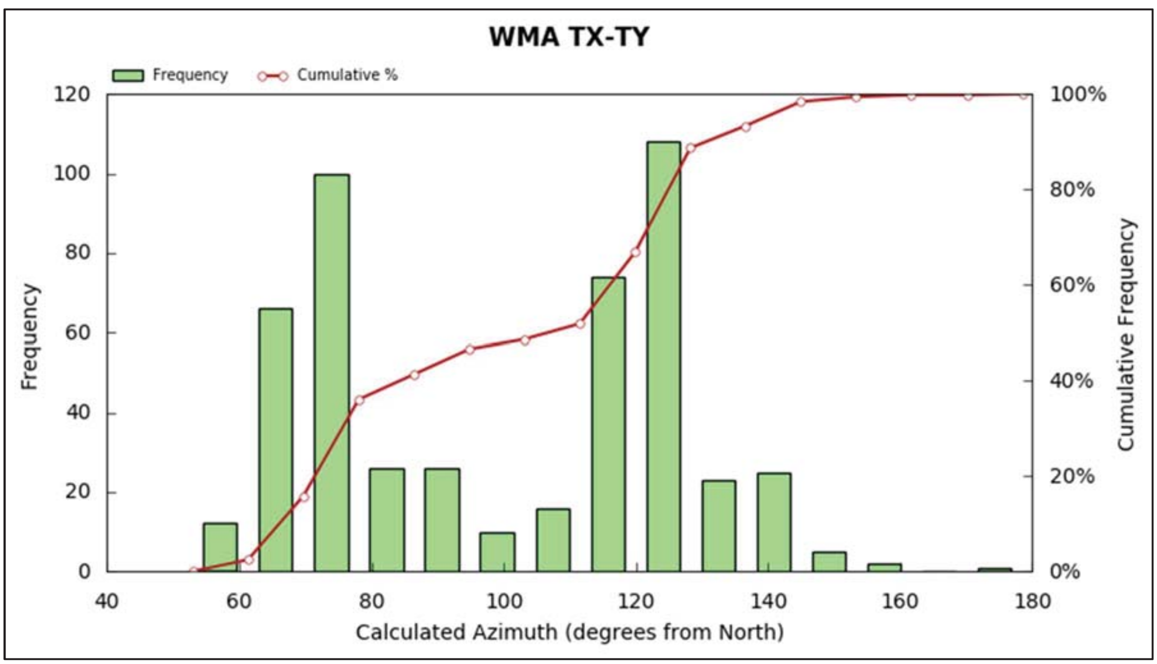

Figure 7-81. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA TX-TY for the Second Quarter of 2019

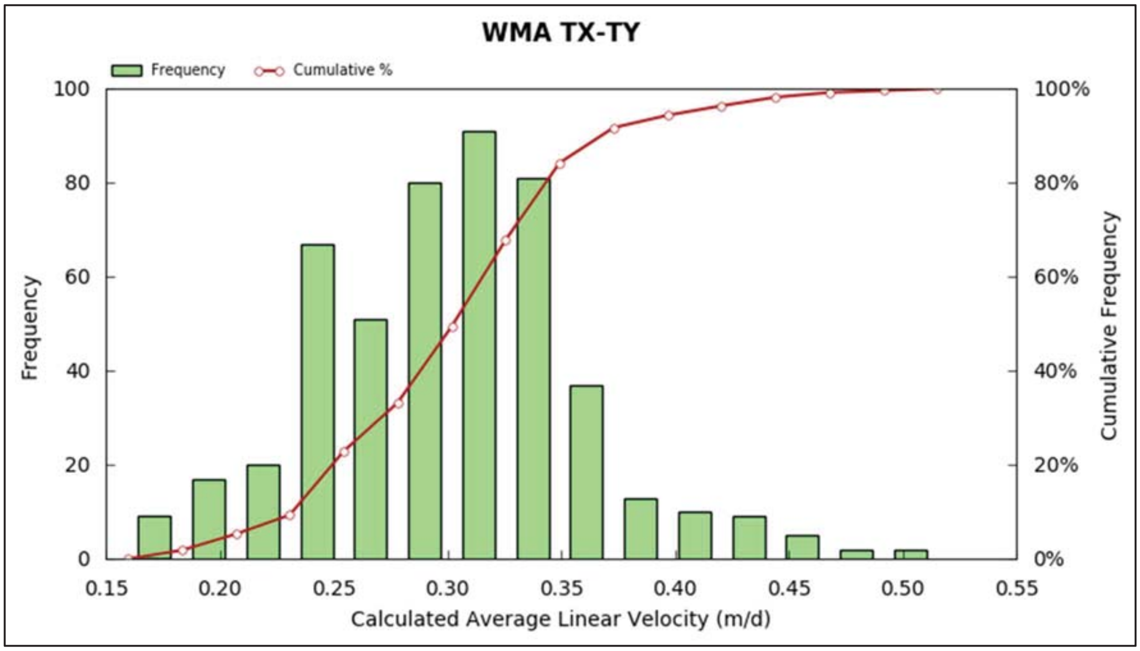

Figure 7-82. Histogram Plot of Calculated Average Linear Velocities at WMA TX-TY for the Second Quarter of 2019

7.2.8 Waste Management Area U

Figure 7-83 shows the calculated particle pathlines representing the general groundwater flow direction for the second quarter of 2019 at WMA U. The figure shows that some pathlines appear shorter in length than other pathlines. This is due to the capture of the particles at the extraction well. Particle pathlines terminate when a particle comes within the capture radius of an extraction well. The cumulative frequency plots for calculated hydraulic gradient magnitudes, hydraulic gradient azimuths, and average linear velocities at WMA U are presented in Figure 7-84 through Figure 7-86.

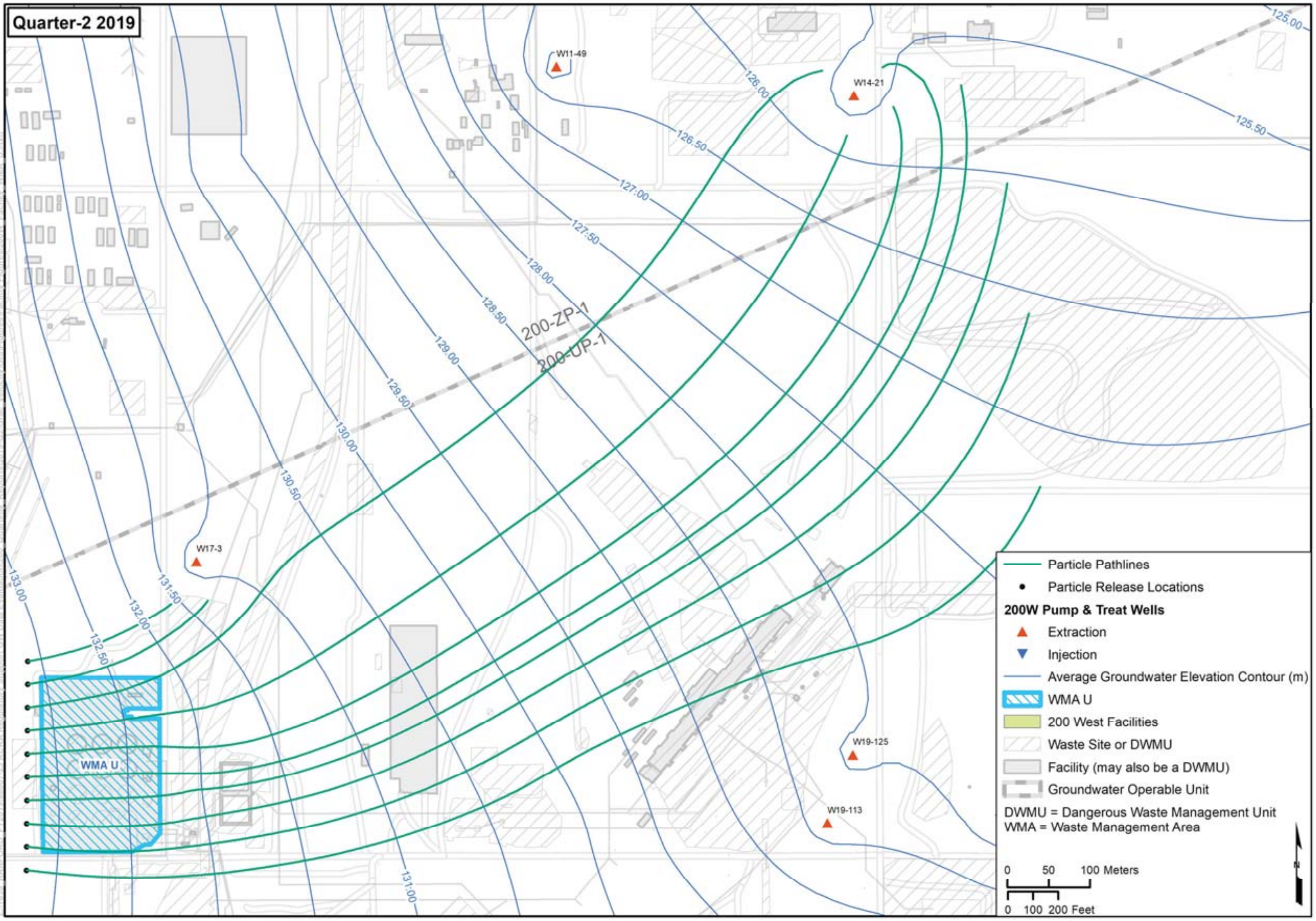

Figure 7-83. Calculated Particle Pathlines Representing General Groundwater Flow Directions at WMA U for the Second Quarter of 2019

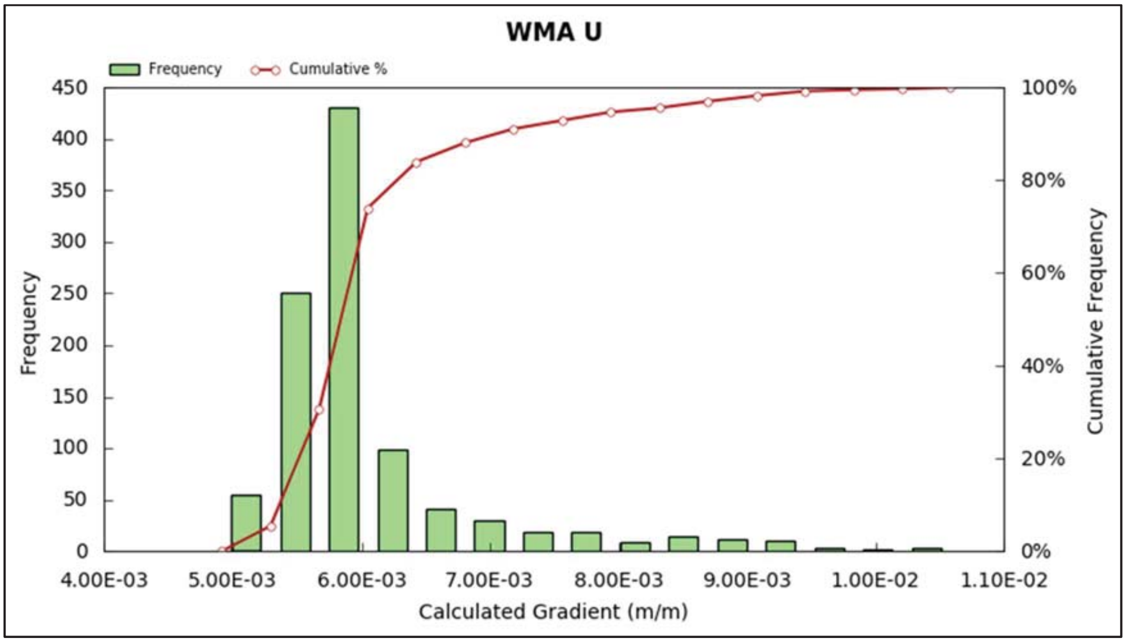

Figure 7-84. Histogram Plot of Calculated Hydraulic Gradient Magnitudes at WMA U for the Second Quarter of 2019

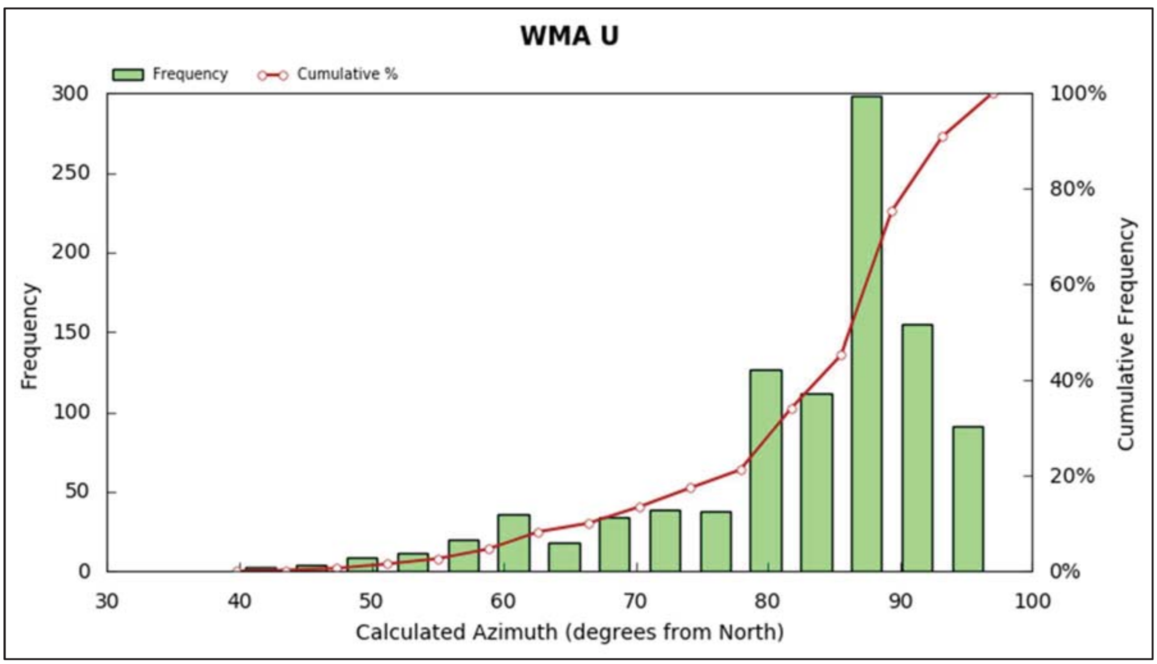

Figure 7-85. Histogram Plot of Calculated Hydraulic Gradient Azimuths at WMA U for the Second Quarter of 2019

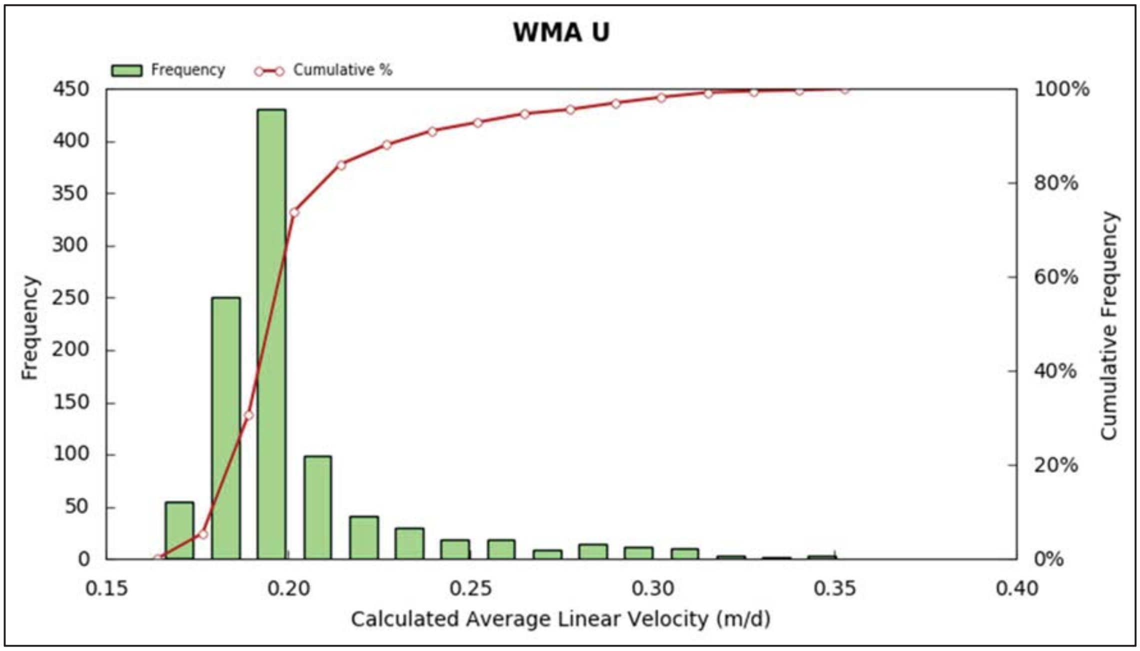

Figure 7-86. Histogram Plot of Calculated Average Linear Velocities at WMA U for the Second Quarter of 2019

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