Appendix 5.
Fountain Head Gold Project Soil Infiltration and Solute Fate Assessment

ERIAS Group

Fountain Head Gold: Soil Infiltration Testing and Solute Fate Assessment

25 May 2021

listen. think. deliver.

Table of Contents

Figures

Plates

No table of figures entries found.

Tables

Appendices

Document history & status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
REVA	11/05/2021	P Howe	P Howe	12/05/2021	Draft
REV0	12/05/2021	R Cranswick	R Cranswick	12/05/2021	Final
REV1	24/05/2021	R Cranswick	R Cranswick	25/05/2021	Revised Final

Distribution of copies

Version	Date issued	Quantity	Electronic	Issued to
REV0	12/05/2021	1	Y	ERIAS Group
REV1	25/05/2021	1	Y	ERIAS Group

Last Saved:	25 May 2021
File Name:	CDMSmith-1001007-ERIAS-PNX_FHG_InfiltrationSoluteFate_REV1
Author:	R Cranswick
Project Manager:	R Cranswick
Client:	ERIAS Group
Document Title:	**Fountain Head Gold: Soil Infiltration Testing and Solute Fate Assessment**
Document Version:	REV1
Project Number:	1001007

Section 1 Introduction and objectives

1.1 Background

CDM Smith Australia Pty Ltd (CDM Smith) has been engaged by PNX Metals Limited (PNX), through ERIAS Group, to undertake water-related assessments in support of environmental approvals for the proposed Fountain Head Gold Project (the Project). The Project is located approximately 170 km south of Darwin within the Pine Creek region of the Northern Territory.

The Project involves brownfield development of the Fountain Head deposit, where gold mining and exploration dates back to the late-1800's. Mining at Fountain Head was most recently undertaken from 2007 to 2009 by GBS Gold. PNX acquired the tenements in 2018, following further exploration and a mining scoping study completed in 2019. Recent exploration drilling intersected notable gold mineralisation in the vicinity of the existing open (but flooded) pit, prompting a renewed focus on the Fountain Head site. As outlined in the Notice of Intent (ERIAS Group, 2019), PNX proposes to use open pit mining methods and a carbon in pulp plant (CIP) gold recovery process at the Project site with the following related activities:

- Dewatering of the existing Pit Lake
- Expansion of the existing open pit
- Expansion of the waste rock stockpile as an integrated waste landform (IWL)
- Construction of processing related areas, crushing facility and gold processing plant
- Construction of supporting infrastructure and expansion of the existing evaporation dam to an evaporation pond (EP) for water storage

Surface water and groundwater management are critical to the success of this project, which has prompted the need for more detailed assessment and water balance modelling. The CDM Smith scope of works has a number of components that will contribute to the development of a Mine Management Plan (MMP) and Environmental Impact Statement (EIS) related to the Project – these components include:

- Two short technical reports describing 1) a proposed shallow groundwater monitoring network, and 2) the soil infiltration testing and assessment of potential solute transport related to tailings stored within the IWL and temporary PAF stockpile (this report)
- A technical report documenting the model predicted water fluxes and quality changes related to Fountain Head Pit dewatering and Evaporation Pond storage through to the mine closure Stage, and other site water balance components (CDM Smith 2021a)
- A technical report related to other scoped components including catchment, surface water and flood modelling (CDM Smith 2021b)

1.2 Objectives

The objectives of this report relate to the development of the Fountain Head Gold Project approval documents to:

- Estimate saturated vertical hydraulic conductivity of soils at key locations across the Fountain Head site (Figure 1)
- Estimate the potential vertical seepage flux from tailings material stored in the IWL, and assess the related and other potential solute transport pathways in groundwater towards the Fountain Head Pit Lake

\\cdmnc.internal.cdm.com\offices\AUST\Project\1001007 - ERIAS_FountainHead2021_WaterModelUpdates_Soil Sampling\7Work\3GIS\QGZ\ERIAS_Infiltration.qgz

Figure 1 Soil infiltration testing locations with footprint of planned site infrastructure

Section 2 Infiltration testing

2.1 Method

Infiltration tests were performed to assist in deriving estimates of saturated vertical hydraulic conductivity (Kv) of the soils in key locations at the Fountain Head site, i.e. beneath the proposed IWL, PAF stockpile and evaporation pond. Talsma permeameters (Talsma and Hallam 1980) were used within shallow hand augered holes (10 cm diameter) to 30 cm below ground surface (Figure 2). The objective of these tests is to observe the rate of infiltration, which initially occurs through the unsaturated zone at a variable rate, until a steady infiltration rate is established. Once a steady infiltration rate is observed, the response is constrained by the saturated hydraulic conductivity of the soil. An example of this transition is shown in Figure 3, where the first 1500 seconds (25 minutes) of the test show a decreasing rate of water level decline before a stable rate is observed for the remainder of the test. Observations at regular intervals allow this transition to be clearly identified prior to estimating the steady infiltration rate for the calculation of the Kv (as indicated towards the end of the dataset shown in Figure 3).

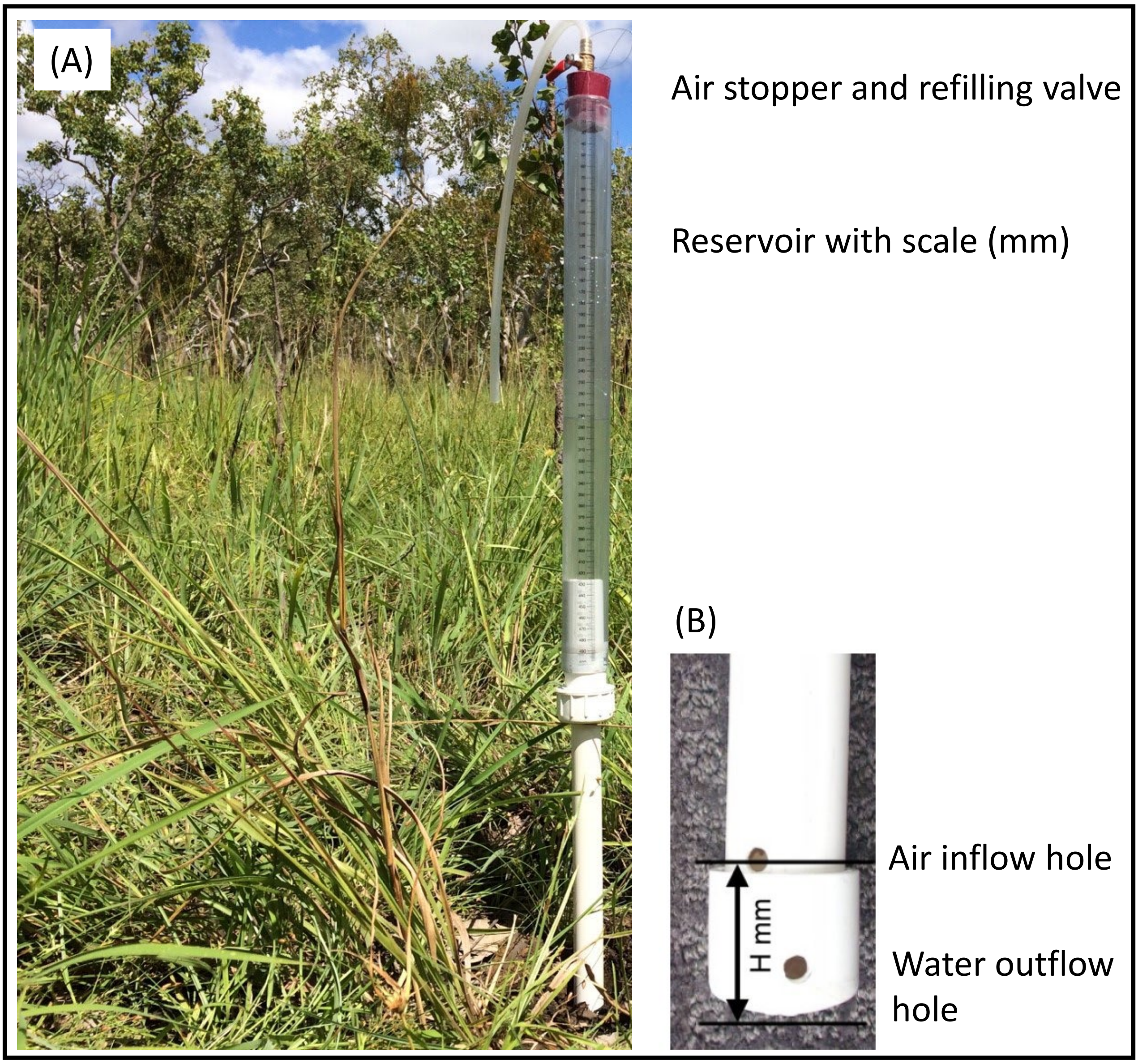


Figure 2 Talsma permeameter installed (A) with bottom dimensions allowing air in and water out of the reservoir (B)

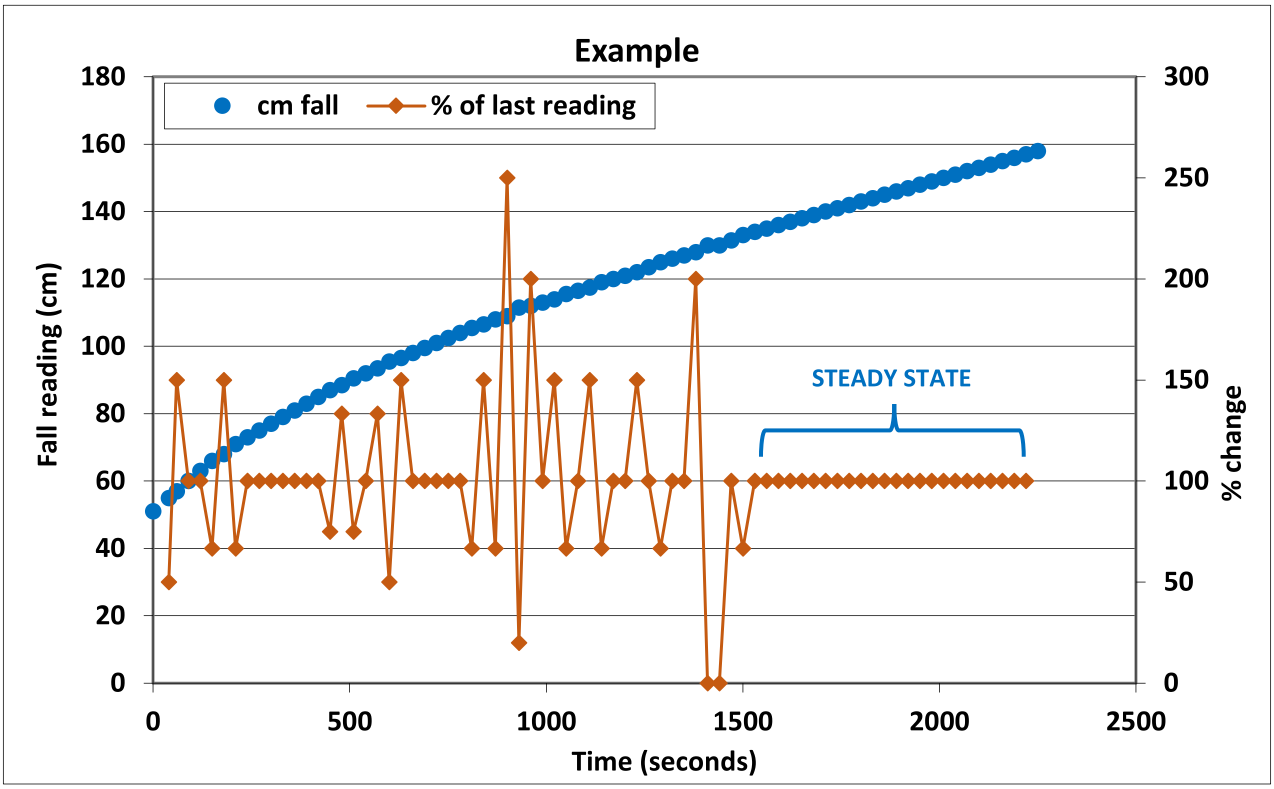


Figure 3 **Example of an infiltration test transitioning from unsaturated to saturated flow**

Tests were performed at five locations at site 2 on the 17th of March prior to large rainfall event overnight causing widespread flooding and no access. A second round of tests was performed from 30th of March to 1st of April at the additional four sites shown in Figure 1. A total of 24 tests were successfully completed and analysed using the appropriate dimensions and approach outlined in Talsma and Hallam (1980).

2.2 Results

The results of each infiltration test are shown in Appendix A while details are summarised in Table 1 and included in Figure 4. From this figure it is clear that there is considerable spatial variability within each site and across the wider Fountain Head area. When considered together, the median Kv estimate for the clayey silts of the two tailings storage area sites is of $6x10^{-2}$ m/d, with the 30th to 70th percentile range being $3x10^{-2}$ to $2x10^{-1}$ m/d . The relative consistency of these results (with notable outliers where minor sands or gravels were encountered), allows these data to be used to estimate the vertical fluxes through soils if required (see Section 3).

Access to the proposed temporary PAF storage area was limited due to inundation by recent flood waters. Three of the four locations described as silty clays had no observed infiltration during the 45–60 minute tests. The Kv at these locations is likely to be much less than $1x10^{-3}$ m/d, while the estimated Kv for the fourth silty clay site is $6x10^{-3}$ m/d. The estimated Kv for two additional locations described as clayey silts is $5x10^{-1}$ m/d. Overall it is expected that the site would be dominated by the lower hydraulic conductivities of the silty clays on the order of $1x10^{-3}$ m/d or less.

Both Evaporation Pond sites appear to have two main soil types 1) silty clays with a median Kv of $1.5x10^{-2}$ m/d and 2) more variable silty sands and clayey silts with minor sand having a median Kv of $1.2x10^{0}$ m/d. Given the spatial variability of these soil types and associated Kv results, it is challenging to provide a single representative estimate of Kv for the Evaporation Pond area. Larger scale infiltration tests may be required in order to determine a bulk Kv estimate for the site, or alternatively detailed soils mapping. To account for this, a probabilistic approach has been taken to capture the uncertainty of this parameter (see further discussion and modelled results in CDM Smith 2021a).

Considering all data collected together (including sands and sandy silts), the median saturated Kv is $4.6x10^{-2}$ with a 30th to 70th percentile range of $1.5x10^{-2}$ to $2.4x10^{-1}$ m/d.

Table 1 Summary of infiltration tests at five sites and 25 locations

Site	Test	Easting	Northing	Start time	Date	Soil type	Kv Sat (m/d)
Tailings_east	1_1	770900	8509530	11:10	30/03/2021	Clayey SILT	2.2E-01
Tailings_east	1_2	770923	8509522	11:20	30/03/2021	Clayey SILT	4.3E-02
Tailings_east	1_3	770931	8509475	12:40	30/03/2021	Clayey SILT	2.0E-02
Tailings_east	1_4	770902	8509445	12:45	30/03/2021	Clayey SILT	3.2E-02
Tailings_east	1_5	770860	8509477	13:30	30/03/2021	Silty CLAY	1.5E-02
Tailings_west	2_1	770649	8509586	15:25	17/03/2021	Clayey SILT	2.0E-01
Tailings_west	2_2	770662	8509558	11:20	17/03/2021	Clayey SILT	8.2E-03
Tailings_west	2_3	770648	8509554	12:25	17/03/2021	Clayey SILT	1.7E+00
Tailings_west	2_4	770610	8509582	14:10	17/03/2021	Clayey SILT	7.7E-02
Tailings_west	2_5	770623	8509600	14:10	17/03/2021	Clayey SILT	1.8E-01
Stockpile_undist	3_1	771321	8509773	15:00	31/03/2021	Clayey SILT	4.3E-01
Stockpile_undist	3_2	771381	8509798	16:15	31/03/2021	Silty CLAY	< 1E-03
Stockpile_undist	3_3	771397	8509828	8:10	1/04/2021	Silty CLAY	6.1E-03
Stockpile_undist	3_4	771439	8509785	8:20	1/04/2021	Clayey SILT	5.4E-01
Stockpile_undist	3_5	771420	8509780	16:20	31/03/2021	Silty CLAY	< 1E-03
Stockpile_undist	3_6	771335	8509766	15:10	31/03/2021	Silty CLAY	< 1E-03
EP_southeast	4_1	771735	8510189	10:00	31/03/2021	Clayey SILT	1.7E+00
EP_southeast	4_2	771787	8510186	10:05	31/03/2021	Sandy SILT	4.5E-01
EP_southeast	4_3	771782	8510134	10:55	31/03/2021	Clayey SILT	1.5E-02
EP_southeast	4_4	771732	8510114	10:45	31/03/2021	Clayey SILT	4.9E-02
EP_west	5_1	770971	8510543	13:20	31/03/2021	Silty SAND	2.6E+00
EP_west	5_2	770978	8510538	13:25	31/03/2021	Silty CLAY	1.7E-02
EP_west	5_3	770959	8510511	14:25	31/03/2021	Clayey SILT	1.2E+00
EP_west	5_4	770922	8510537	14:30	31/03/2021	Silty CLAY	1.2E-02

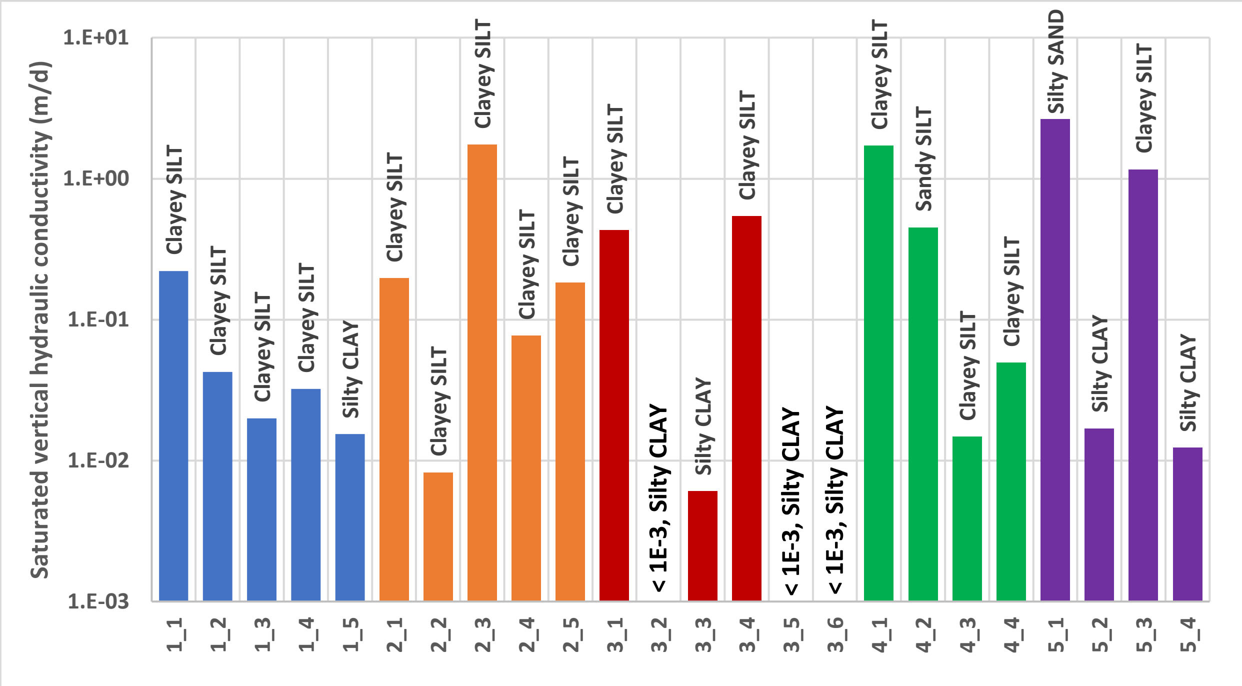


Figure 4 Summary of saturated vertical hydraulic conductivity

2.3 Summary

The infiltration tests conducted on site using Talsma permeameters and high frequency data collection, indicate that the saturated Kv is highly variable on a small spatial scale (i.e. within meters) and across the site. This makes it challenging to determine a representative single value for saturated Kv without more detailed soils mapping across the area, and larger scale infiltration tests may be needed to make more reliable estimates of potential infiltration rates. For this reason, a probabilistic approach is considered appropriate where a range of values are applied based on reasonable interpretation of the small-scale estimates of saturated Kv (see further discussion and modelled results in CDM Smith 2021a). Considering all data collected together (including sands and sandy silts), the median saturated Kv is $4.6x10^{-2}$ with a 30^{th} to 70^{th} percentile range of $1.5x10^{-2}$ to $2.4x10^{-1}$ m/d.

Section 3 Solute fate assessment

3.1 Data availability

Water extraction testing of likely tailings material reported by EGI (2021) shows that arsenic is relatively abundant in the samples tested and has the potential for increased solubility as a result of cyanide leaching. The geometric mean of arsenic concentrations in the water extraction tests is 1240 µg/L, which could be used as a conservatively high concentration for assessment of potential leakage from tailings areas. The simple conceptualisation of the hydrogeological structure is shown in the following sub-section.

Site data for groundwater and surface water bodies also shows arsenic is found naturally on site with concentrations in some cases exceeding ANZECC Guidelines (for more discussion see CDM Smith 2021a). Representative groundwater concentrations for Fountain Head Pit Lake, groundwater and surface runoff from the natural catchment are 567, 56 and 1.8 µg/L, respectively.

3.2 Conceptualisation

The conceptualisation of the unsaturated and saturated flow paths occurring through the IWL is shown in Figure 5. The tailings material is to be positioned on top of a compacted clay liner within the IWL, and then capped prior to closure with compacted clay and additional material to minimise generation of contact water and infiltration to the shallow groundwater system. The key limiting hydrogeological process in relation to the risk of water interacting with tailings material and then entering the groundwater environment, is the vertical flux through the clay liner (i.e. the material with the lowest Kv).

Water in contact with the tailings material may over time acquire a hydrochemical signature similar to the water extraction testing results, which would then be transported through the clay liner and into the unsaturated existing waste rock material and/or soil and fractured rock before reaching the watertable. Mixing and dilution processes are then expected to occur along a groundwater flowpath of approximately 300 m towards the Fountain Head Pit Lake (noting that geochemical interaction and attenuation through clays, soils, fractured rock would likely further reduce solute concentrations, but these processes are not included in this analysis for conservatism).

The risk pathway of solute transport from the tailings material through the clay liner is first assessed by estimating the vertical flux in the following section. Further detail on the IWL design related to internal water management can be found in REC (2021).

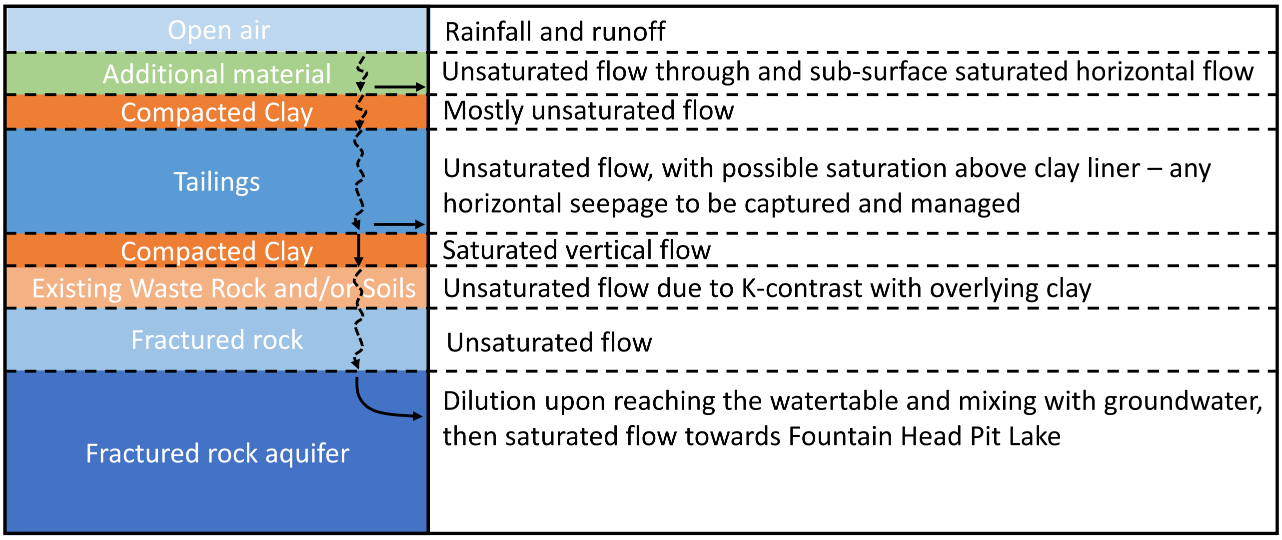


Figure 5 Conceptual model for 1D analysis of water fluxes, noting vertical flux is limited by lowest Kv layer

3.3 Vertical flux estimate

The vertical flux was estimated using a declining hydraulic gradient towards a unit gradient (i.e. from 0.5 m of saturated tailings above the 0.3 m thick clay liner, to the top of the clay liner) and the assumed saturated Kv value of the compacted clay liner ($5x10^{-9}$ m/s, equivalent to around $4x10^{-4}$ m/day) beneath the tailings material within the IWL. This assumption relies upon their being active recovery of tailings contact water during the mining period (e.g. water collection wells), such that the volume of saturated tailings material is small at closure.

The transition from a 0.5 m head of water in the tailings material to desaturation assumes the IWL is designed to shed any infiltrating rainfall above the clay capping material (i.e. infiltration below the capping material is minimised, meaning effectively no new water inputs). The different combination of hydraulic gradient values as they decline to a unit gradient and corresponding vertical fluxes are shown in Table 2 and Figure 6. It is important to note that conservatively, if the porosity of the tailings material is 0.3 and the area 200 x 400 m, the half meter of saturated tailings (plus 0.3 m clay liner) equates to a total volume of around 20 ML.

Table 2 Range of vertical fluxes (mm/year) based on reducing hydraulic gradient and assumed Kv

Hydraulic gradient	Flux through compacted clay liner (mm/year)	Approximate volumetric flux (ML/y)*
2.7	389	31
2.3	341	27
2.0	292	23
1.7	243	19
1.3	195	16
1.0	146	12

*Assumes approximate tailings footprint of 200 x 400 m

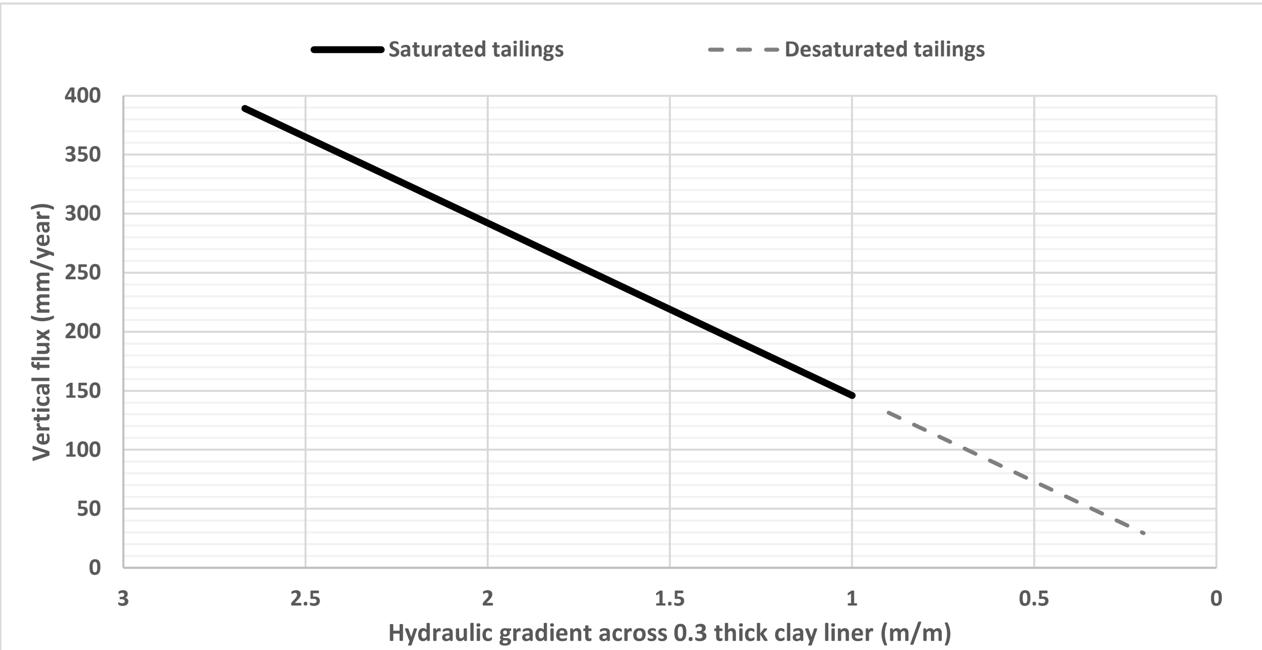


Figure 6 Vertical flux based on a declining hydraulic gradient through the clay lining towards desaturation

The estimated vertical flux through the clay liner will reduce from around 390 to 150 mm/year prior to desaturation of the tailings material. Conservatively, if the flux through the clay liner is multiplied by the approximate area of the tailings footprint (~200 x 400 m), the volumetric flux would reduce from around 31 to 12 ML/year. After the tailings is desaturated this flux would then reduce even further towards zero under unsaturated flow conditions. The vertical flux through the clay liner would then travel into the underlying unsaturated zone before reaching the watertable and following the shallow groundwater system flowpath towards Fountain Head Pit Lake (according to the groundwater flow direction indicated by model predictions in CDM Smith 2021a). It is likely that a groundwater mound will form under the IWL, which may increase the horizontal hydraulic gradient towards the Pit Lake. It should again be noted that the maximum volume of water stored in the tailings if there is 0.5 m of saturation at closure and a porosity of 0.3 (conservatively high) is around 20 ML. This means the tailings would be desaturated in less than a few years.

Assuming this vertical flux joins the watertable and flows towards the Pit Lake, it would represent a relatively small and temporary input compared to the predicted total groundwater flux entering the recovered Pit Lake (i.e. around 575 ML/year; CDM Smith 2021a). This additional vertical flux range represents 5 to 2 % of total groundwater contribution to the Pit Lake. If each of the solute loads from these fluxes (at 1240 μg/L) is added to the predicted groundwater flux, the resulting groundwater input concentration will increase from that of the ambient groundwater (i.e. median of 56 μg/L) to between 117 μg/L (for the 31 ML/y additional flux) to 80 μg/L (for the 12 ML/y additional flux). These are noted to be below the ANZECC guidelines discussed in CDM Smith (2021a) and within a few years, this influence would reduce towards zero following desaturation of the tailings material.

Any detailed reactive transport modelling along this groundwater flow path is therefore not considered necessary since the flux is small compared to the other water balance components of the Pit Lake, and resultant conservative solute load is unlikely to result in ANZECC guideline exceedances (noting again that no attenuation processes have been included in these approximations).

Any rainfall infiltrating through the temporary PAF stockpile and reaching the groundwater system will be captured by the groundwater inflow to the Fountain Head Pit Lake (according to the groundwater flow direction indicated by model predictions in CDM Smith 2021a). Detailed assessment of the solute concentrations of the Pit Lake, once PAF material is added at the end of mining, has not been conducted to date but is expected to be the primary driver of Pit Lake water chemistry with respect to potential contaminants of concern.

CDM Smith (2021a) describes a preliminary assessment of Fountain Head Pit Lake arsenic concentrations over time, that does not include the potential solute pathways described above (from tailings storage within the IWL and temporary PAF material surface storage) nor any geochemical modelling of planned sub-aqueous storage of PAF material.

3.4 Summary

Vertical flux through the compacted clay liner beneath the IWL is estimated to reduce from around 390 to 150 mm/y, which over an approximate area of 200 x 400 m equates to around 30 to 12 ML/year. If this water was to then mix with the shallow groundwater and flow into the Fountain Head Pit Lake, this would temporarily contribute around 5 to 2 % of the groundwater flux to the Pit Lake. The influence on Pit Lake solute concentrations is considered small, even when conservatively ignoring geochemical and other processes that would reduce the solute concentrations along unsaturated and saturated flow pathways. It should also be noted that in the long term (i.e. after a few years), the tailings material is likely to be desaturated and result in much smaller vertical fluxes.

References

CDM Smith (2021a). Fountain Head Gold Project: Site water and solute balance modelling. Prepared for ERIAS Group, May 2021

CDM Smith (2021b). Fountain Head Gold Project: Flood assessment and surface water management strategy. Prepared for ERIAS Group, May 2021.

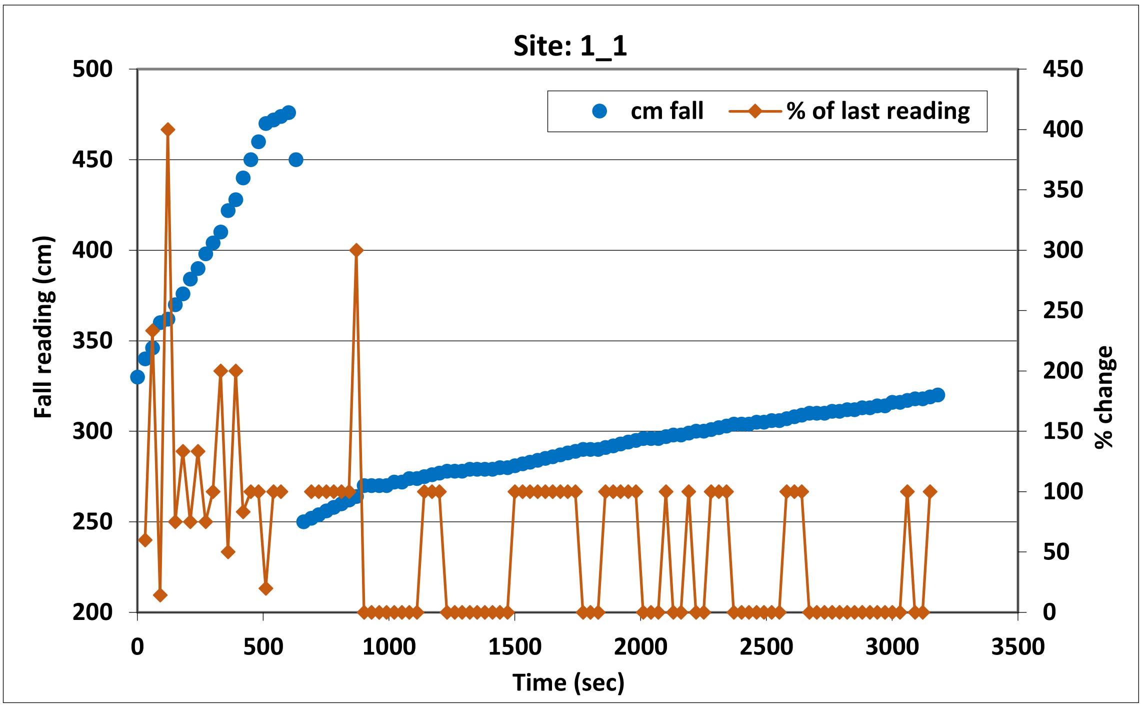
EGI (2021). Geochemical Characterisation of Fountain Head CIL Tailings. Prepared by Environmental Geochemistry International for ERIAS Group Pty Ltd, Document No: S1316/J00588/R1418, 16 March 2021.

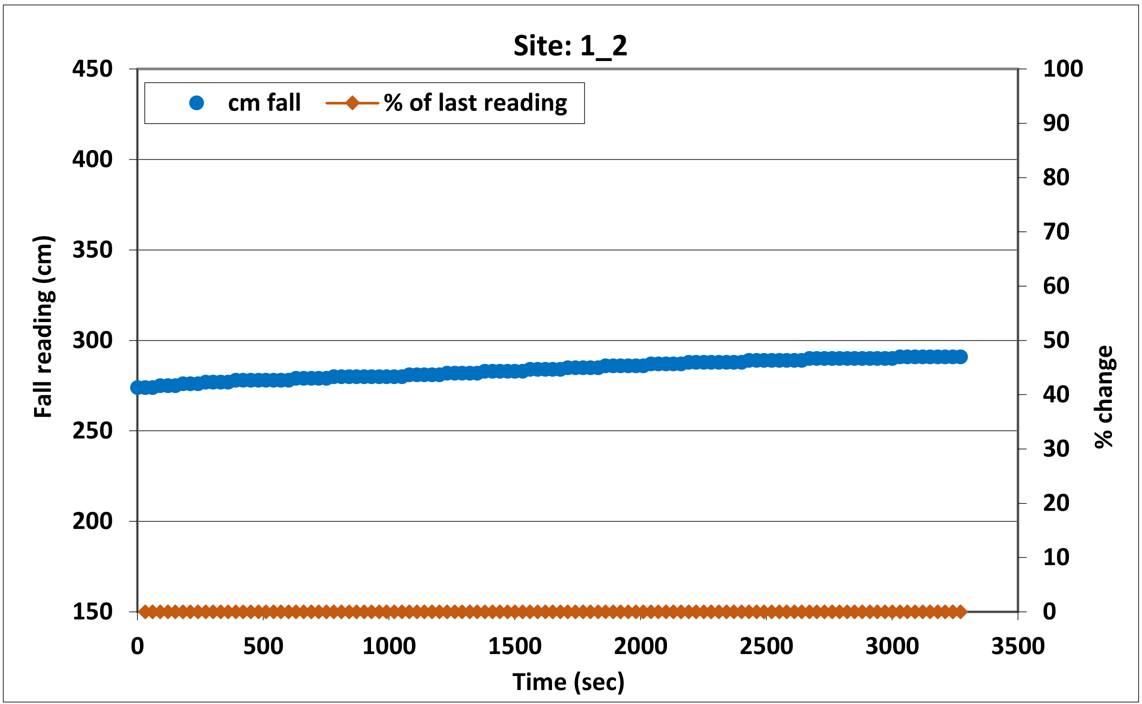
REC (2021). Tailings Storage Facility Scoping Study Fountain Head Gold Project, Northern Territory. Prepared by Resource Engineering Consultants Pty Ltd for PNX Metals Ltd. File P19-05-PR-04. Rev C May 2021.

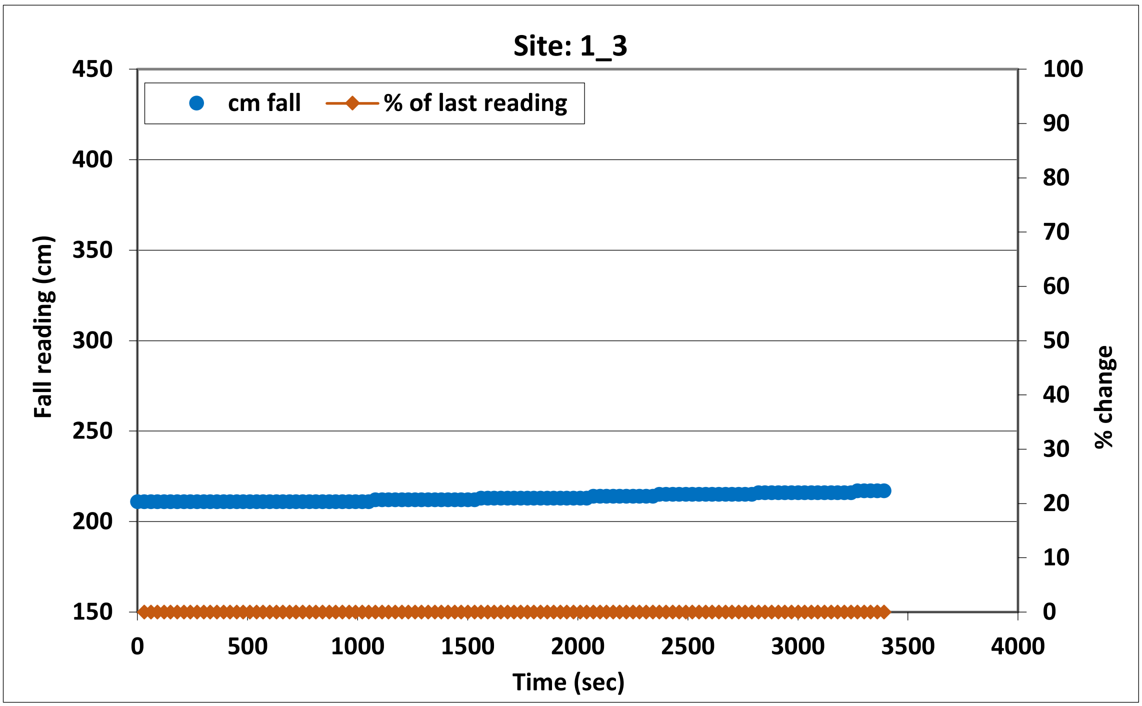
Talsma T & PM Hallam (1980). Hydraulic conductivity measurement of forest catchments. Aust. J. Soil Res. 18, 139-148.

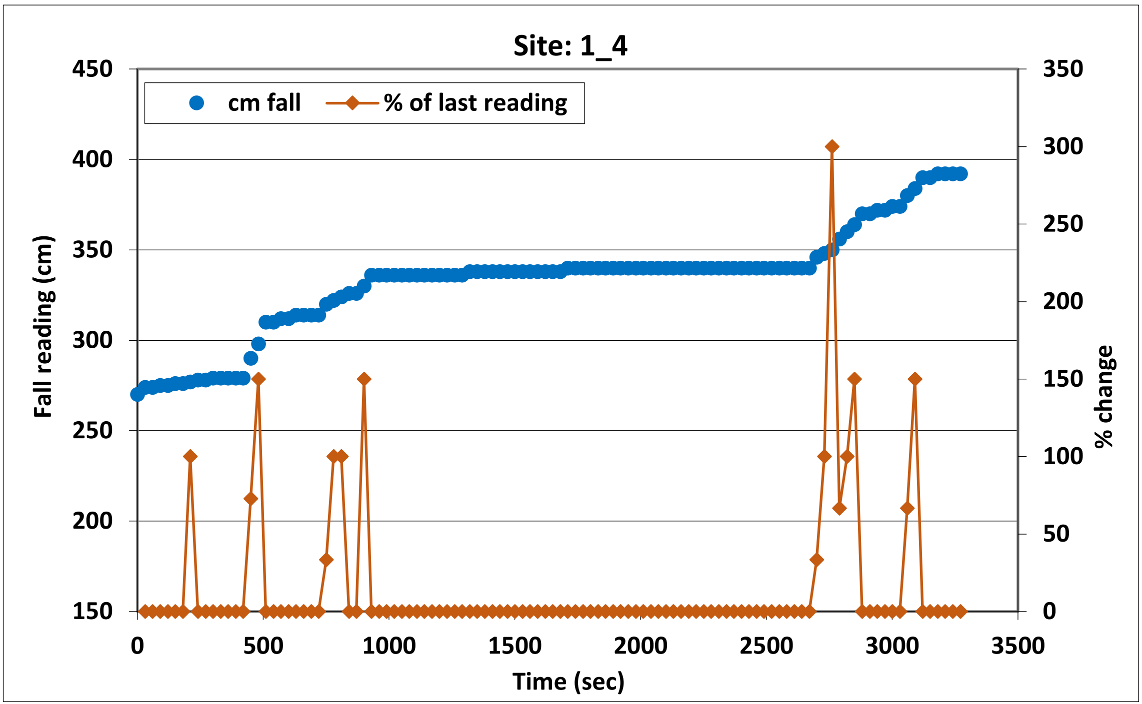
Appendix A Infiltration test results

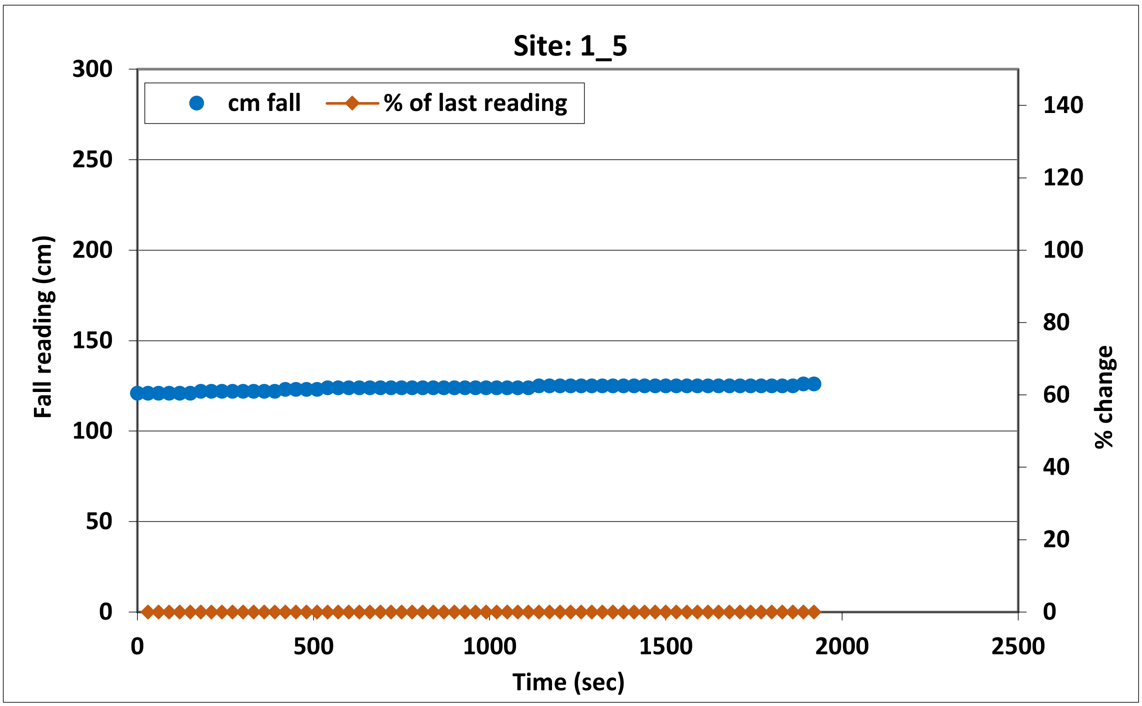
Charts of water level decline within Talsma Permeameter reservoir and % change

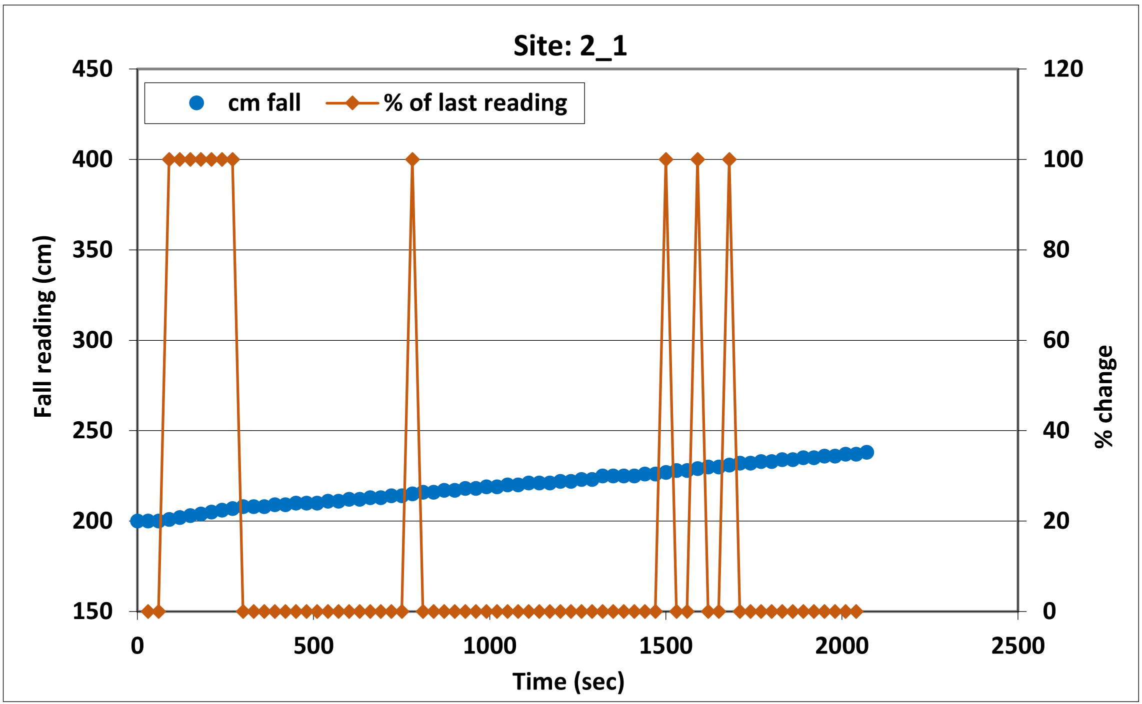


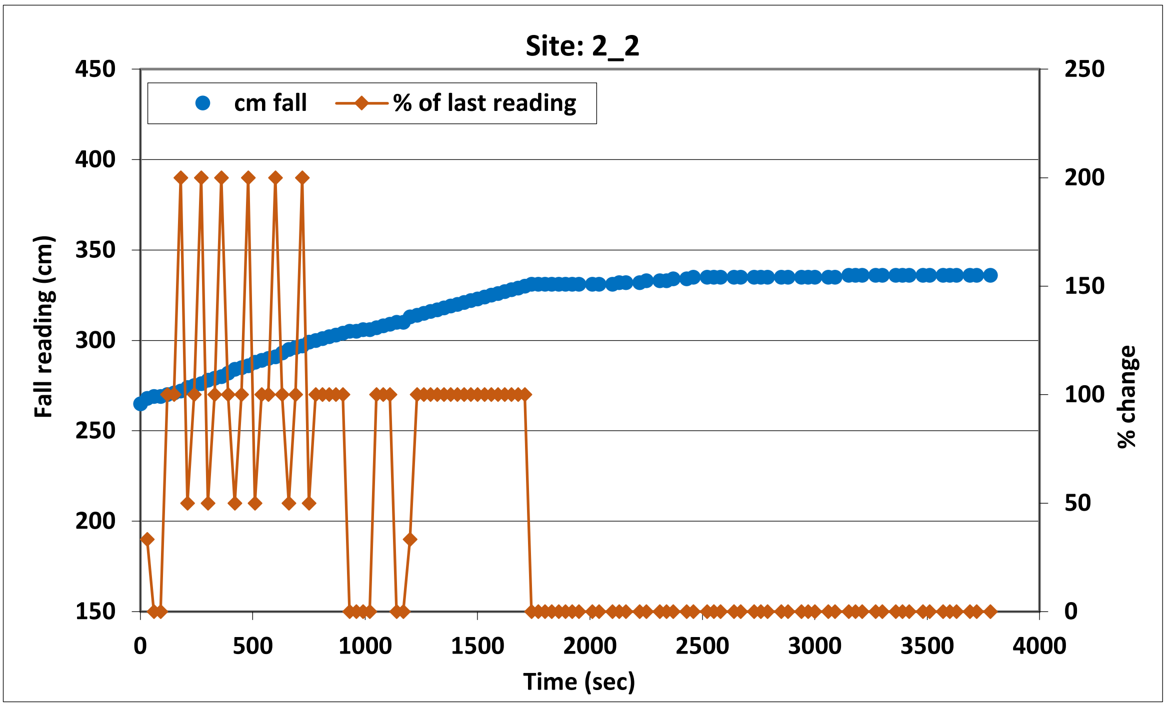


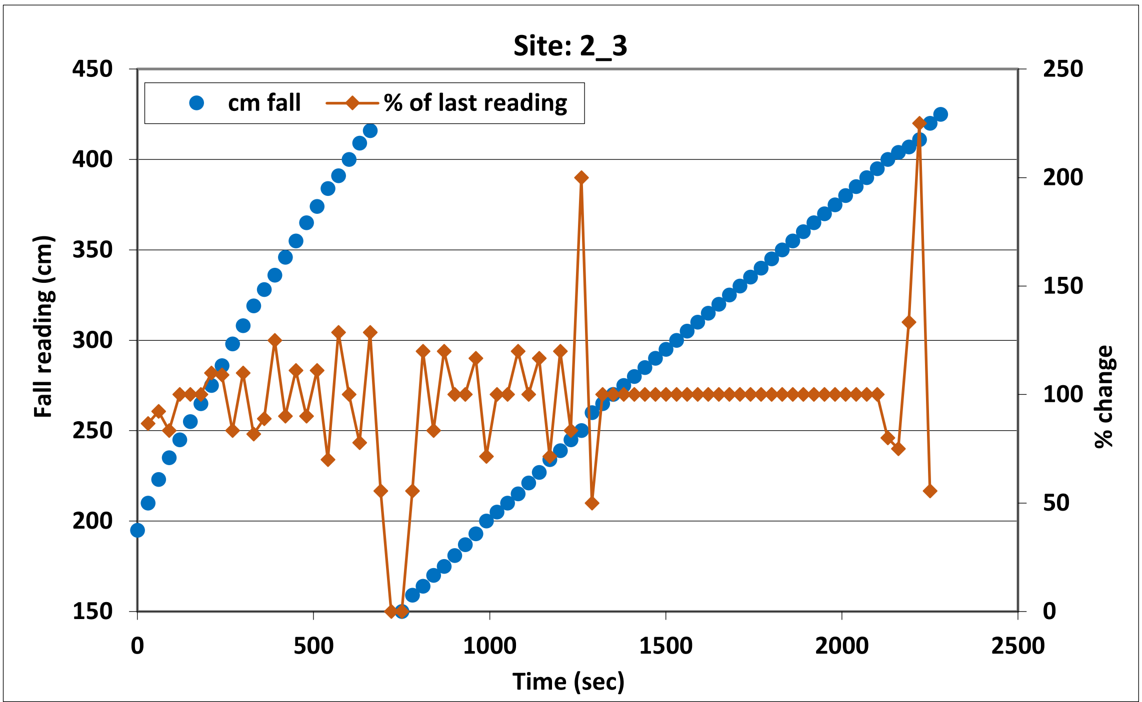

Site: 1_3
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000

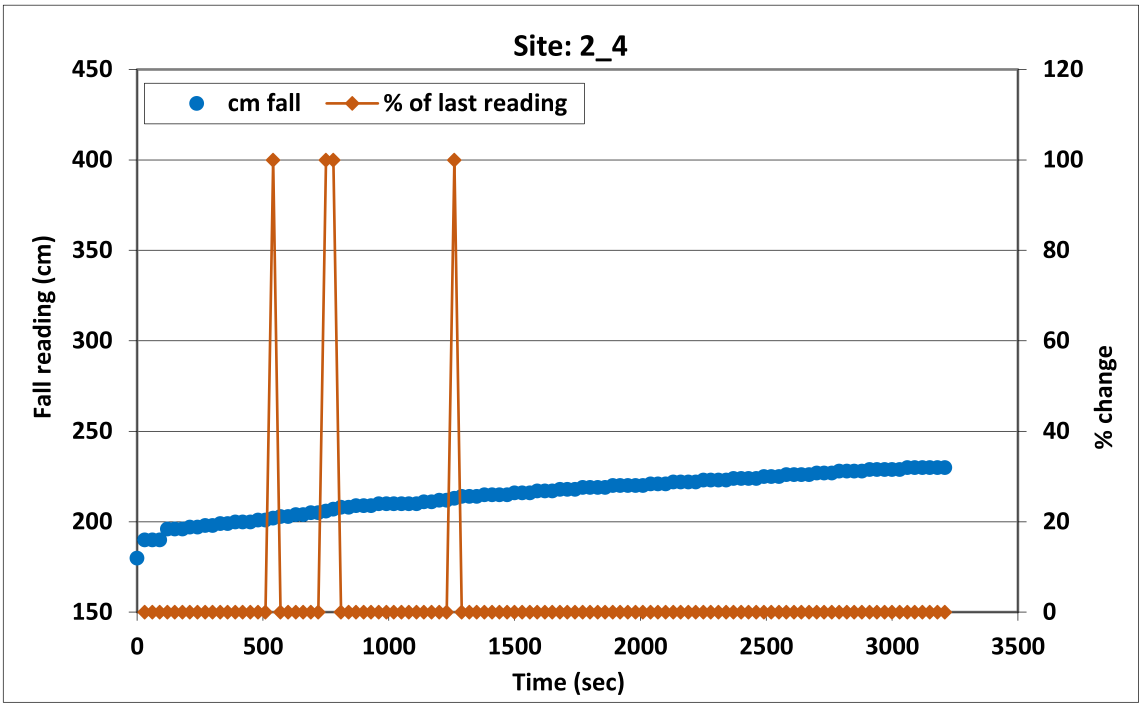

Site: 1_4
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500

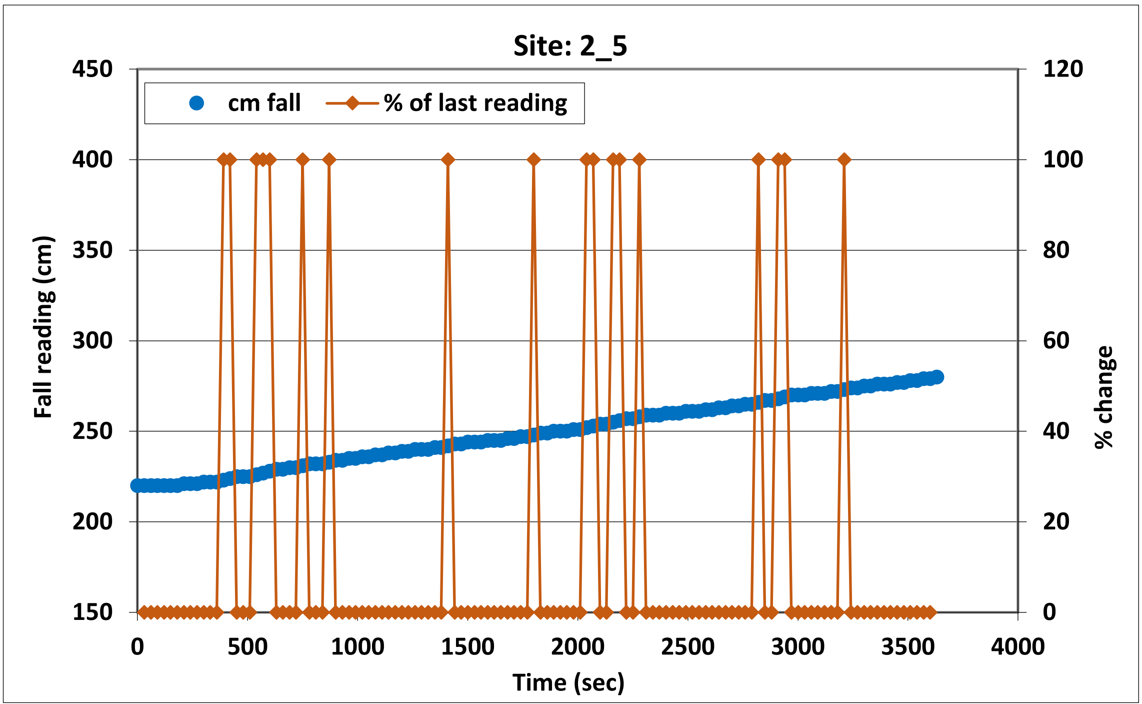

Site: 1_5
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
300
250
200
150
100
50
0
140
120
100
80
60
40
20
0
500
1000
1500
2000
2500

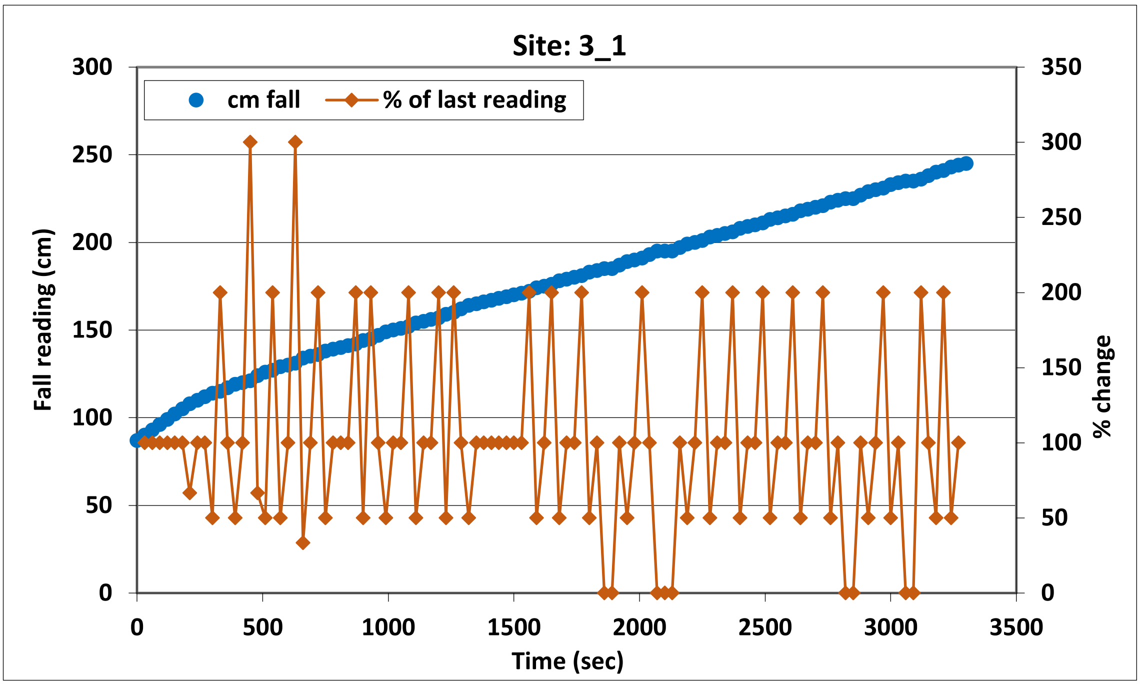

Site: 2_1
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
120
100
80
60
40
20
0
500
1000
1500
2000
2500

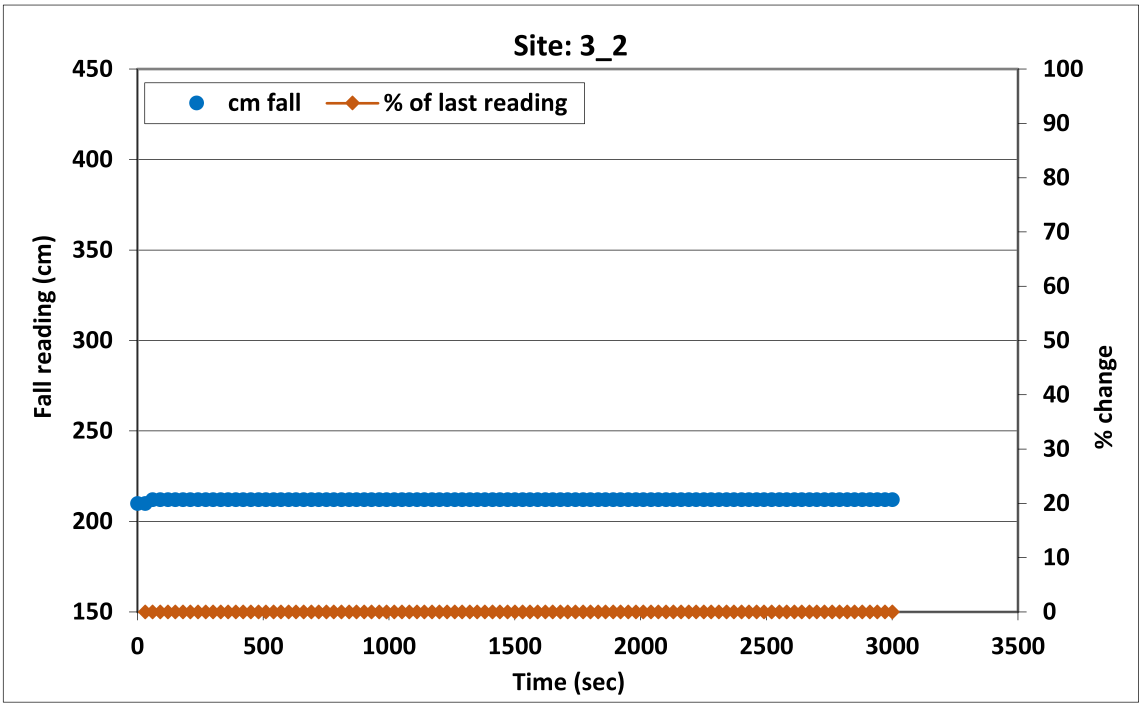

Site: 2_2
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
4000

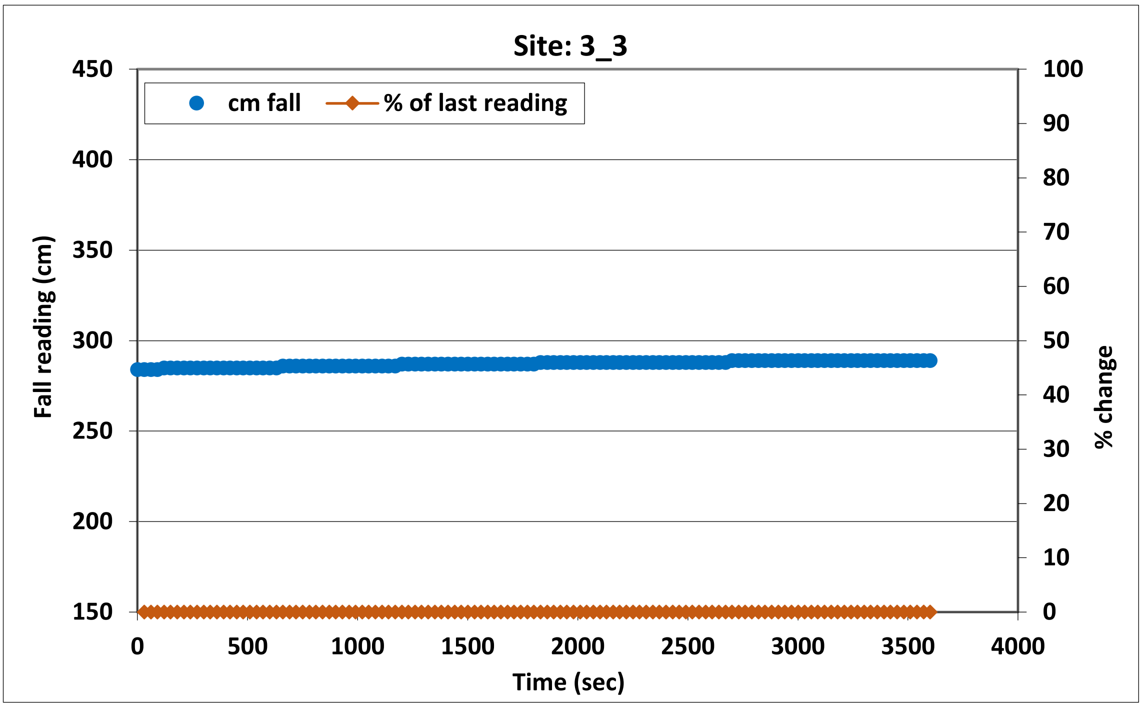

Site: 2_3
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
250
200
150
100
50
0
0
500
1000
1500
2000
2500

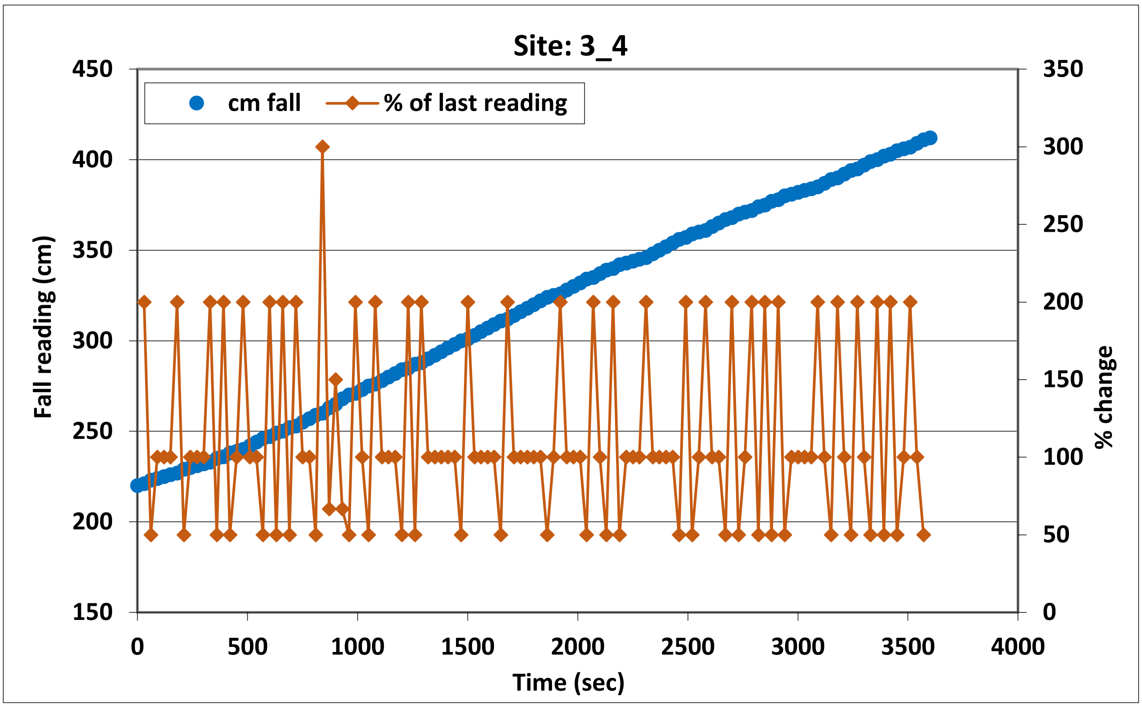

Site: 2_4
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500

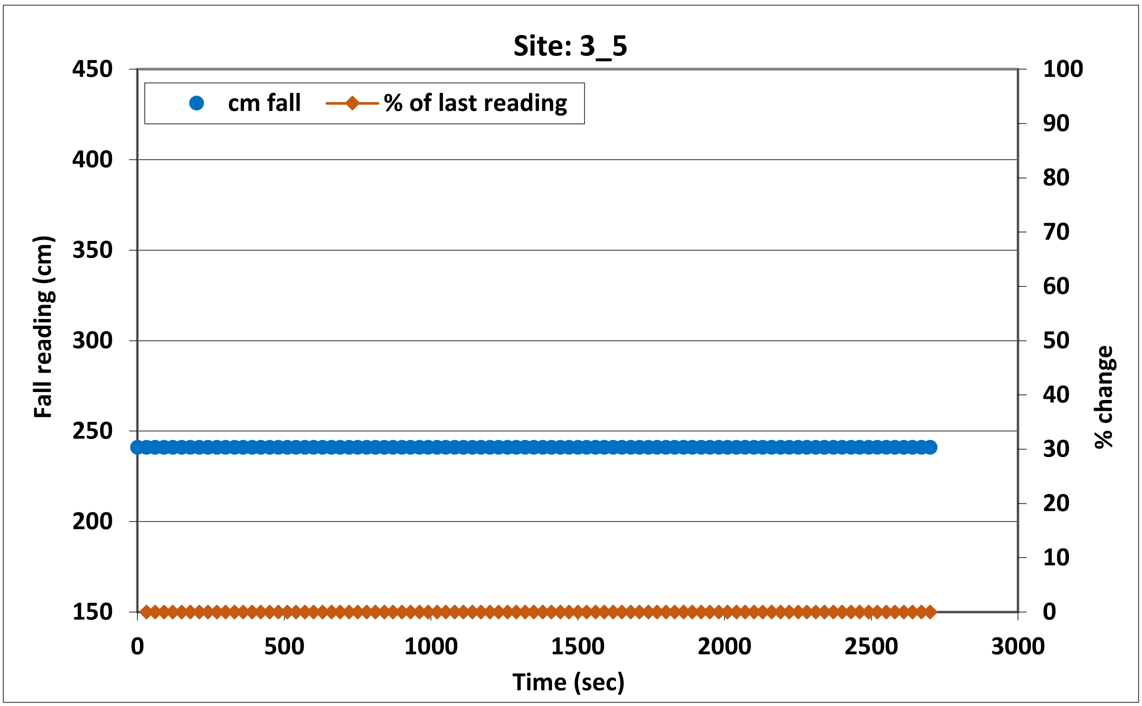

Site: 2_5
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000

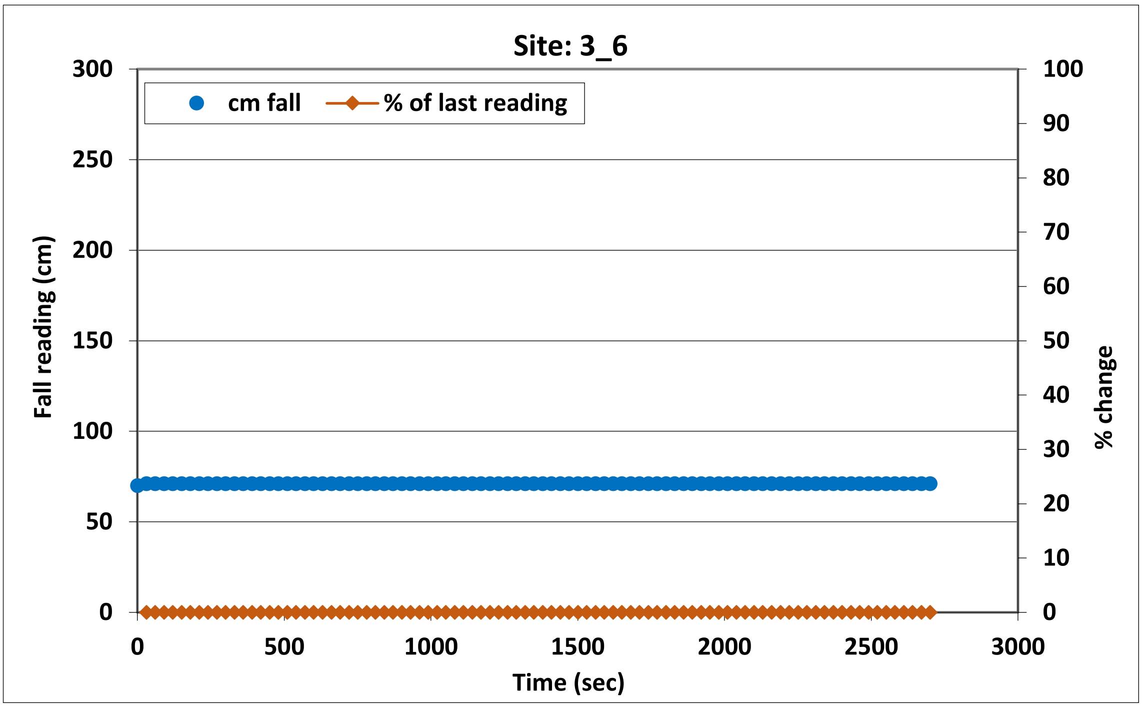

Site: 3_1
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
0
50
100
150
200
250
300
350
500
1000
1500
2000
2500
3000
3500

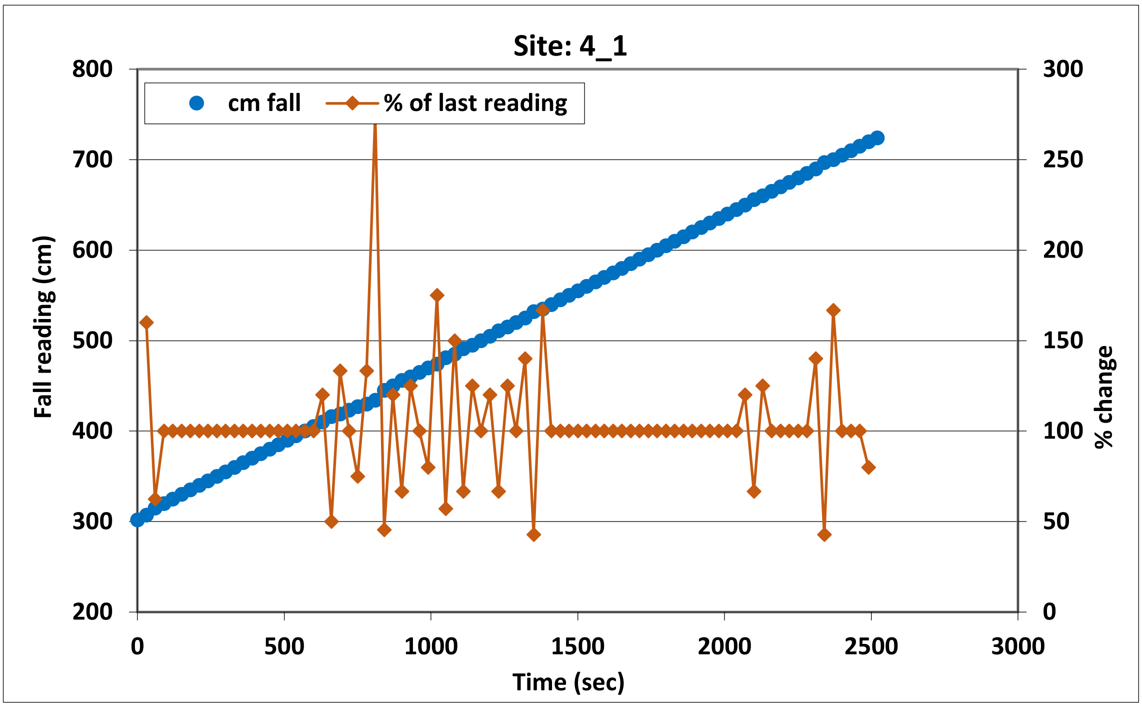

Site: 3_2
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
150
200
250
300
350
400
450
0
10
20
30
40
50
60
70
80
90
100
500
1000
1500
2000
2500
3000
3500

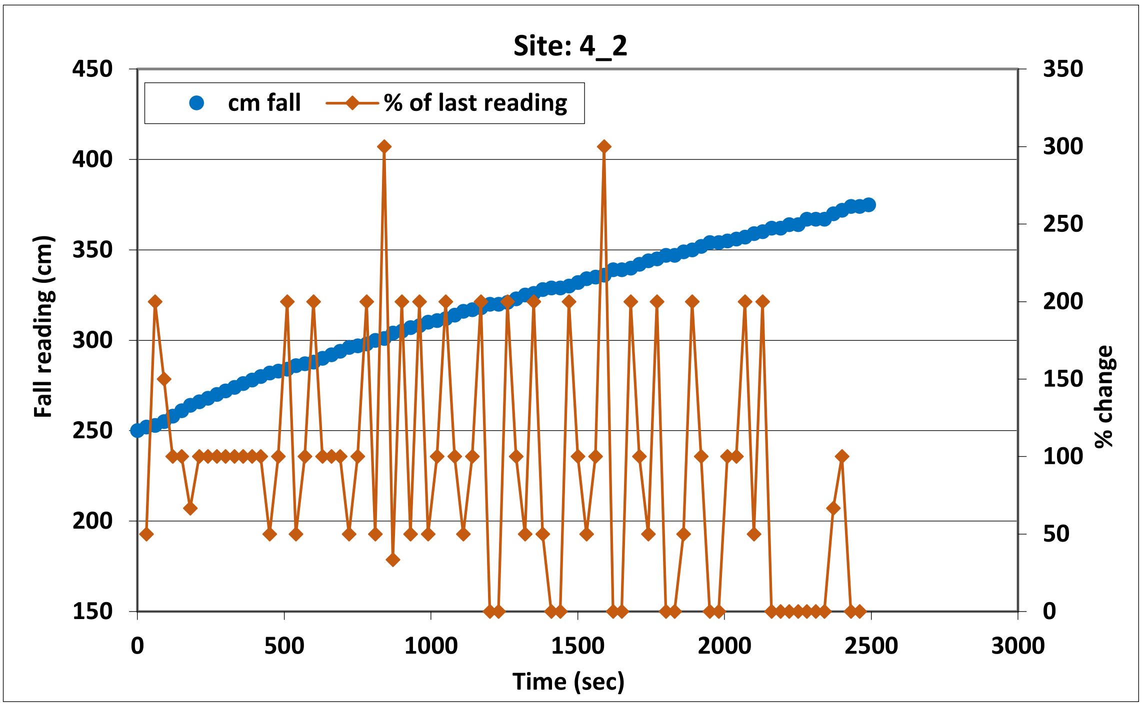

Site: 3_3
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000

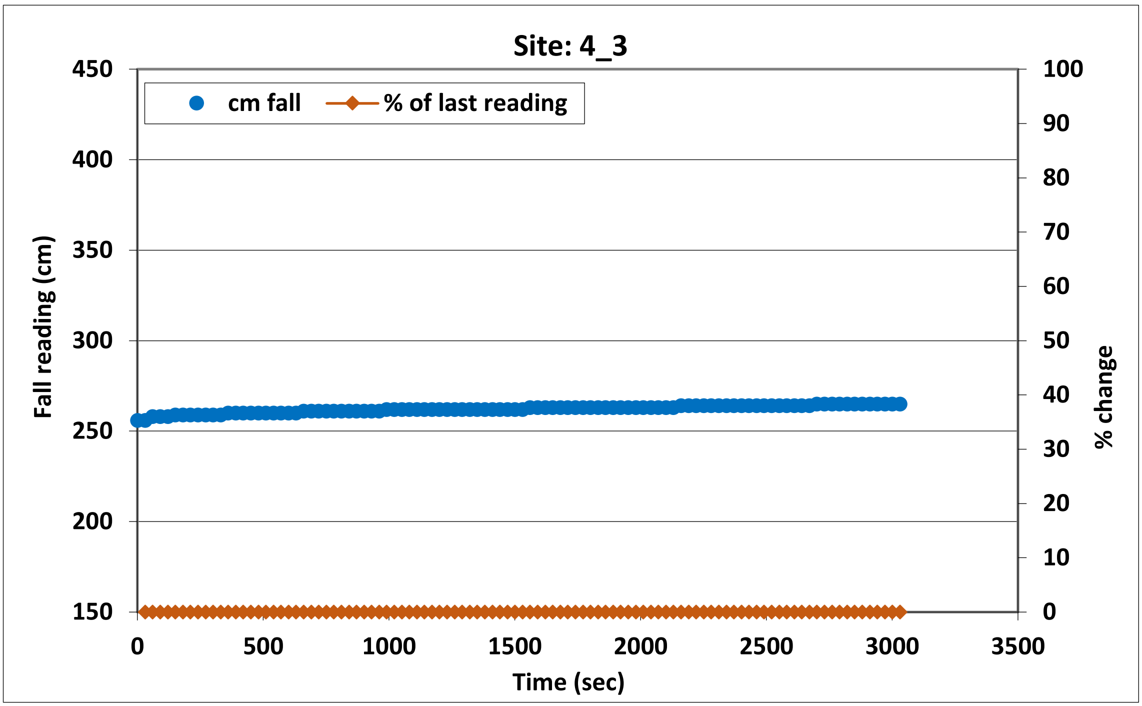

Site: 3_4
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
4000

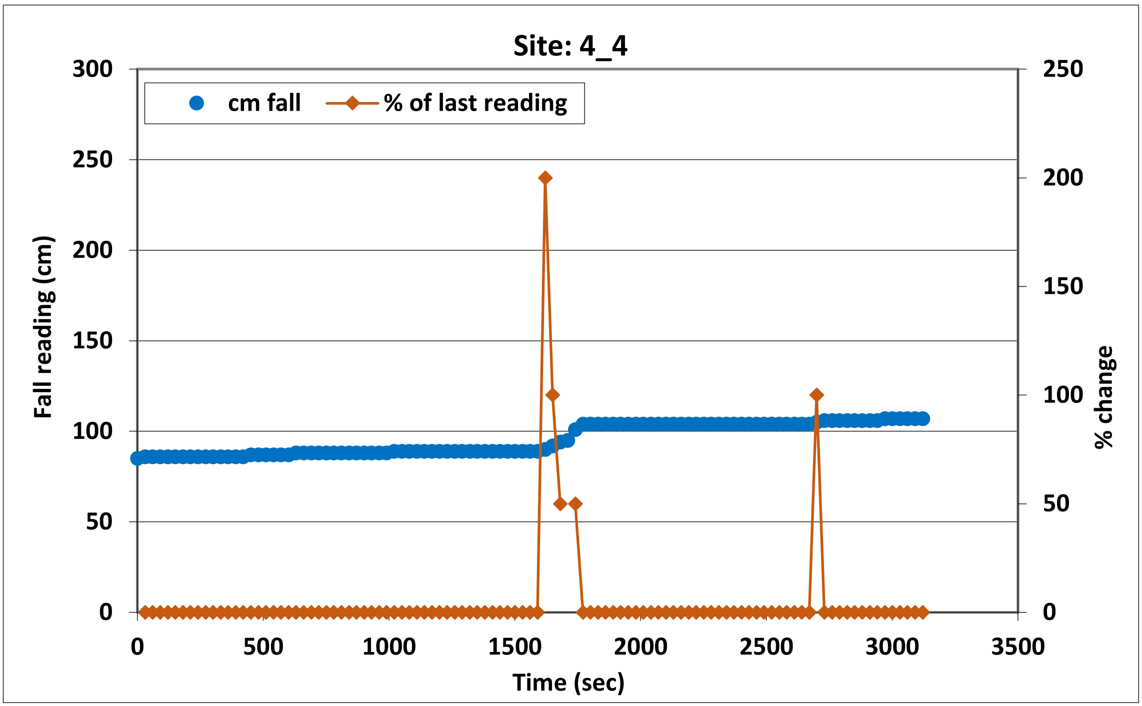

Site: 3_5
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000

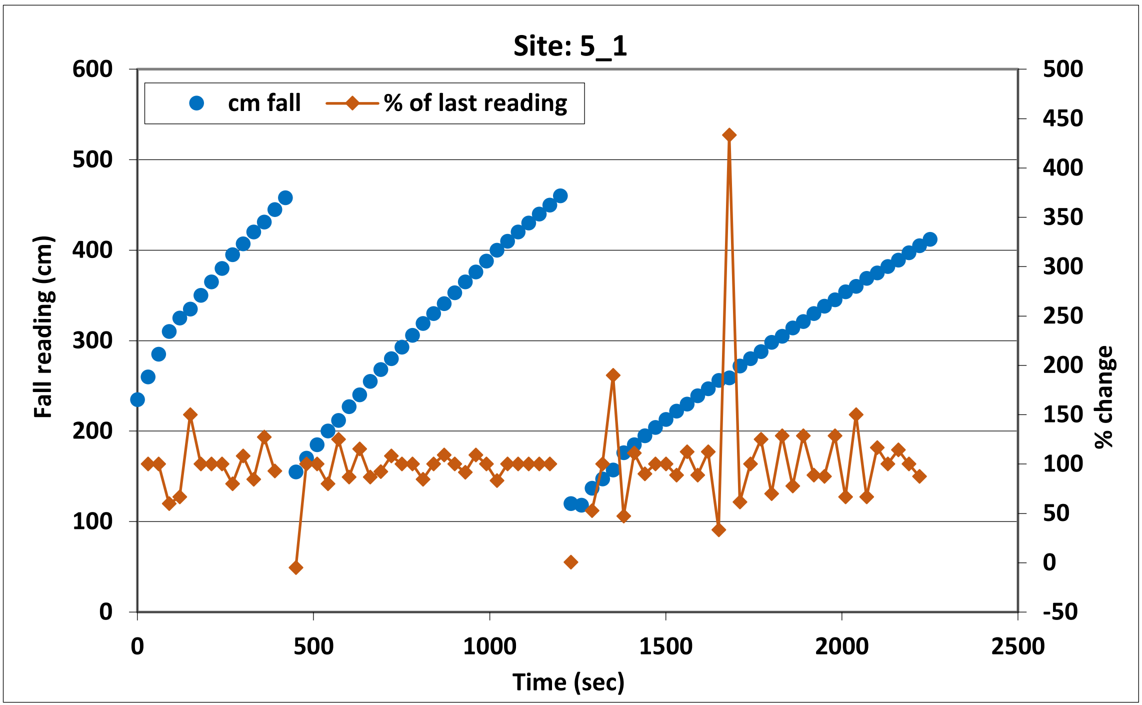

Site: 3_6
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
300
250
200
150
100
50
0
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000

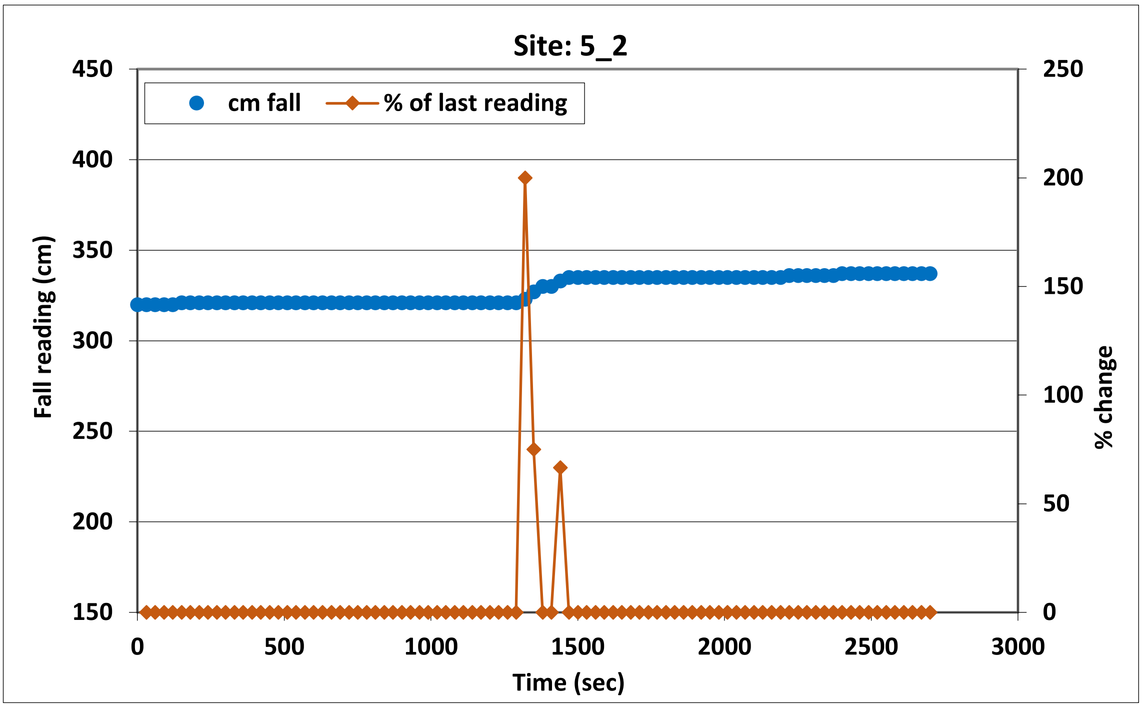

Site: 4_1
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
800
700
600
500
400
300
200
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000

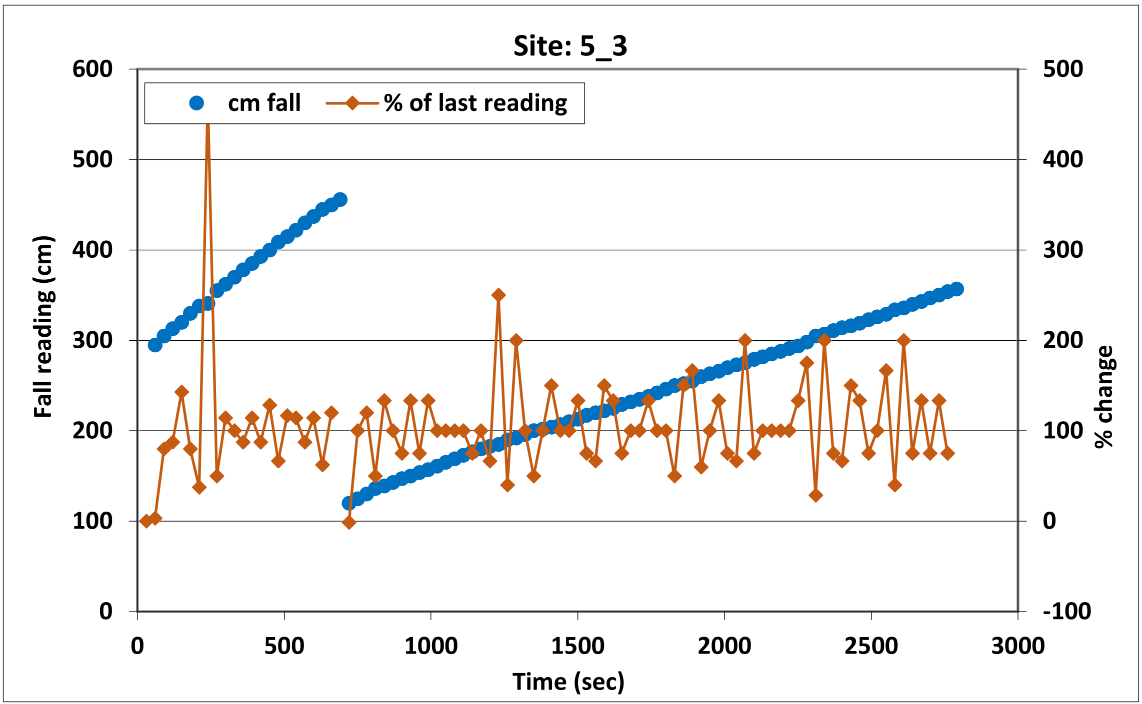

Site: 4_2
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
350
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000

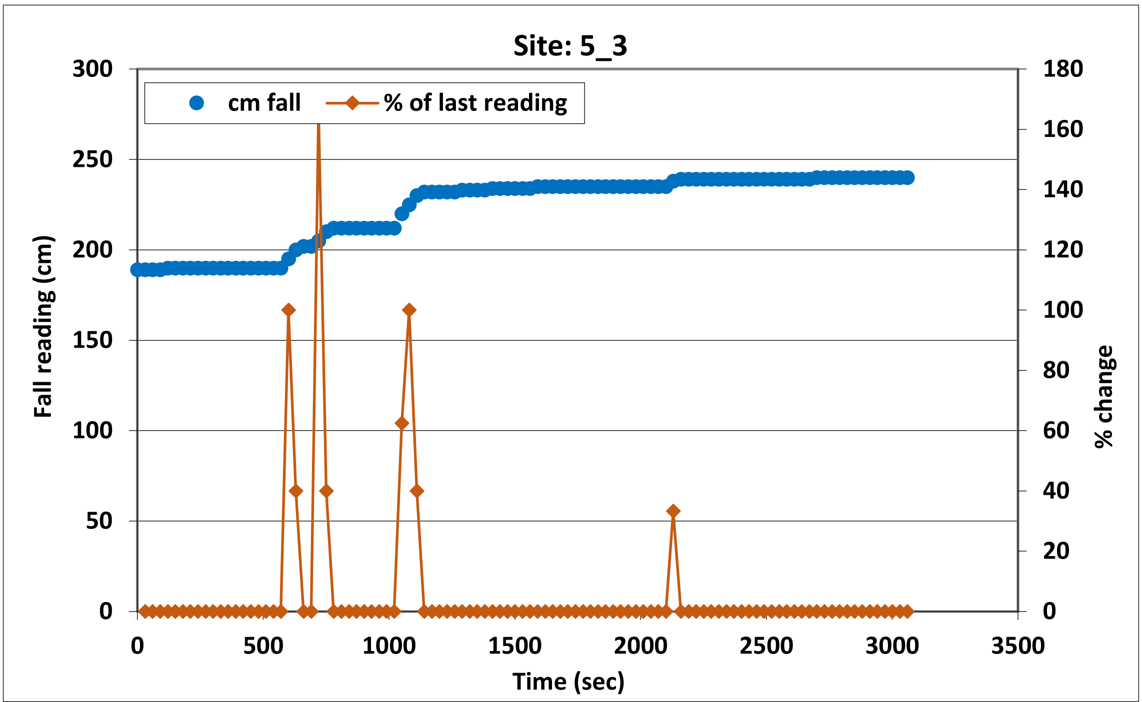

Site: 4_3
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500

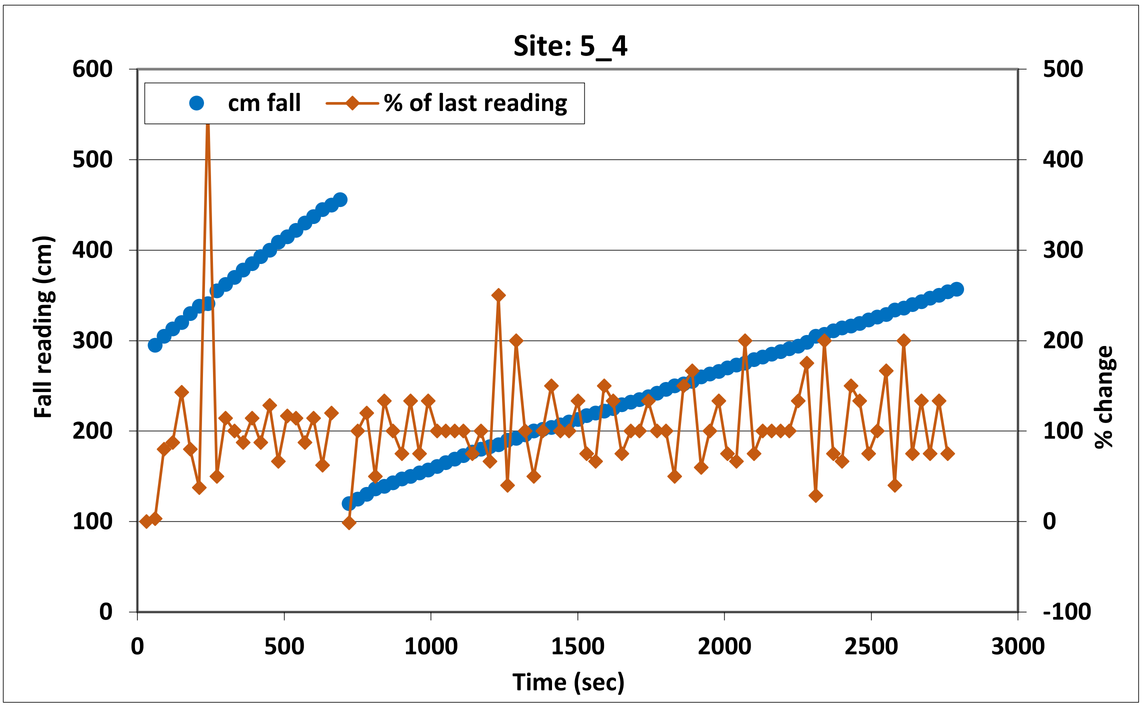

Site: 4_4
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
300
250
200
150
100
50
0
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500


Site: 5_1
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
600
500
400
300
200
100
0
450
350
250
150
50
-50
1000
1500
2000
2500


Site: 5_2
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
450
400
350
300
250
200
150
100
50
0
500
1000
1500
2000
2500
3000


Site: 5_3
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
600
500
400
300
200
100
0
-100
0
500
1000
1500
2000
2500
3000


Site: 5_3
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
300
250
200
150
100
50
0
180
160
140
120
100
80
60
40
20
0
500
1000
1500
2000
2500
3000
3500


Site: 5_4
cm fall
% of last reading
Fall reading (cm)
% change
Time (sec)
600
500
400
300
200
100
0
-100
1000
1500
2000
2500
3000