



METHODS FOR TESTING EROSION THRESHOLD VELOCITY (ETV)

METHOD 1 – COLLECTION OF AN UNDISTURBED SOIL SAMPLE SUITABLE FOR LABORATORY-BASED ETV TESTING

Inland Rail Pty Ltd

April 2025

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Revision 1



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Report Title: Methods for testing erosion threshold velocity (ETV). Method 1 – Collection of an undisturbed soil sample suitable for laboratory-based ETV testing

Client: Inland Rail Pty Ltd (IRPL)

Landloch Internal Revisions

Revision	Prepared By:	Reviewed By:	Date
Draft A (IRPL)	E. Howard	T. Loch (Landloch) H. Bulcock (IRPL), W. Window (IRPL), K. Mitchell (IRPL)	09/08/2023

Inland Rail Submitted Revisions

Revision	Prepared By:	Reviewed By:	Date
Draft (Landloch) A (IRPL)	E. Howard	T. Loch (Landloch) H. Bulcock (IRPL), W. Window (IRPL), K. Mitchell (IRPL)	09/08/2023
B (IRPL)	E. Howard	T. Loch (Landloch), A. Flett (IRPL), B. Godfrey (IRPL), D. Cresswell (IRPL), D. Thompson (IRPL), E. Whittington (IRPL), H. Bulcock (IRPL), K. McKay (IRPL), M. Sams (IRPL), N. Stavropoulos (IRPL), O. Lupton (IRPL), P. Moore (IRPL)	04/03/2024
C (IRPL)	E. Howard	T. Loch (Landloch), B. Godfrey (IRPL), D. Cresswell (IRPL), E. Whittington (IRPL), H. Bulcock (IRPL), M. Sams (IRPL), O. Lupton (IRPL), W. Elliot (independent reviewer)	06/03/2025
O (IRPL)	E. Howard	T. Loch (Landloch), H. Bulcock (IRPL), J. Stewart (IRPL),	31/03/2025
I (IRPL)	E. Howard	-	30/04/2025

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PREFACE

Landloch Pty Ltd has developed a procedure by which large undisturbed surface soils samples can be collected and subjected to overland flows in a laboratory setting, with the outcome being the generation of a dataset from which Erosion Threshold Velocity (ETV) values can be determined.

This document outlines the method for the extraction of an undisturbed surface soil sample for use in laboratory-based determination of critical shear stress for the initiation of scour and the associated ETV for a range of slope gradients. The method was originally developed in August 2023 and used for 10 sites in southern NSW to demonstrate that undisturbed soil samples could be collected and used as part of a laboratory-based assessment of ETV. This document was reviewed by IRPL in 2023 and revised based on the review comments and the experience gained from the initial work, and assigned Revision A within IRPL's document management system.

Two further internal reviews (Revision B and C) were completed by IRPL when the method was used to collect additional samples in southern QLD.

Revision C of the document was reviewed by an independent reviewer, Dr William (Bill) Elliot. His review is given as Appendix A to this document. The review found that...

"This is a novel approach to obtaining minimally disturbed soil samples for measuring soil erodibility. The overall approach has advantages over onsite testing because the amount of equipment and supplies needed in the field are minimal. Controls over slope gradient, flow rates, and runoff collection are much more accurately controlled in a laboratory setting than in the field. The laboratory setting will also minimize experimental differences between soils as the same set of flow rates and flume slope gradients can be applied to every soil tested."

"The novel Landloch method for collecting minimally disturbed soil samples is sound and likely to provide reasonable samples for ETV testing in a laboratory setting. Landloch is to be commended for developing this unique approach to support the engineers who will be designing the hydraulic structures for the Inland Rail Project."

Several recommendations were made, and Revision 1 of the sampling method (this document) considered these comments and adjusted the method where appropriate. Revision 1 also incorporated additional changes requested by IRPL in Revision 0. These changes were limited to the inclusion of this Preface and the attachment of the independent review as a appendix to the method.

The recommendations and adjustments made in Revision C were incorporated in Revision 1 and are detailed in the table below.

Recommendation from Reviewer	Adjustment Made to Revision C and Incorporated into Revision 1
Were there other observations made while collecting the soil trays, like latitude & longitude, slope steepness, vegetation cover or plant community (grassland, cropland, fallow ...), soil horizons? If so, I suggest the authors add a paragraph summarizing those observations as they are not likely included in other documents associated with the ETV project.	Detail on information to be recorded prior to site sampling has been added to Section 5, noting that some/all of this information may be recorded as part of site inspections that occur prior to deployment to site to collect the undisturbed samples.
A suggestion for improving the sampling methodology is to give a bit of thought to inserting the end plate in the sampling box. The method states "Hammer in the end plate." The vibration caused by hammering could induce internal stress cracks in the soil, and hammering may damage the end plates. Perhaps the end plates could be designed to have a top surface or adapter face that allows the excavator bucket to push the plates into place.	Field experience on sampling of dozens of sites across a range of soil types has shown that insertion of the end plates is straightforward and the 'hammering' of the end plate is only light. Therefore, modification of the end plate was not adopted.
The dimensions of the sampling tray and the depth of the soil sample are not fully stated. Could the authors please provide the material (steel? aluminum? stainless?) and thickness (mm, inches or gauge) of the sampling box, the depth of the sampling box. and the depth of the soil sample that is to be collected? In addition, could the length, width, height and thickness of the aluminum sleepers be provided? How many anchors were necessary for the sleepers to ensure they didn't move?	These details were included in Section 4.1 for the sampling frame and 4.2 for the guide sleepers.
Section 4.1, paragraph 3, how was the bulk density measured? Was the soil in the sample tray disturbed, or was a sample taken from nearby in the field? Was the bulk density measured in the lab from the tray before or after the runoff treatment?	Detail on how the sampling for bulk density was achieved was added in Section 4.1.
Section 4.1, paragraph 4, how was the soil water content measured? Was it on the same core as the bulk density?	Yes, moisture content was from the same core that was used to measure bulk density. This is stated in paragraph 5 in Section 4.1.
Page 5, last line before step 5, it is not clear what the author means when he states, "However the indirect testing should still occur." What is the "indirect testing?"	The reference to "Method 2" in the last line before step 5 was changed to "Landloch (2025)". It is in this document (flume testing method) that the indirect testing is outlined.
The reviewer suggested corrections to the method review section	The method has now been reviewed and as such, the method review section has been removed. The review that has been undertaken is detailed in this Preface and the reviewers document in Appendix A.

1 SCOPE

This document describes the method for the extraction of an undisturbed surface soil sample for use in laboratory-based determination of critical shear stress for the initiation of scour and the associated Erosion Threshold Velocity (ETV) for a range of slope gradients.

2 RELATED DOCUMENTS

Landloch (2025) *Methods for testing erosion threshold velocity (ETV). Method 2 – Direct laboratory-based ETV testing*, Revision 1, IRPL Document O-0080-900-IHY-00-PR-0002.

3 CONCEPTS

3.1 Need for undisturbed sample

Controls of scour potential in the engineering design of surface water control structures (channels, culverts) commonly use the concept that for the soil at the location of the structure, there is a characteristic threshold value of flow velocity or shear stress that if exceeded will produce scour. According to this threshold concept, the rate at which soil particles detach can be related to the amount by which a variable characterising the hydraulics of the flow exceeds a critical value of flow shear stress or Erosion Threshold Velocity (ETV).

The Erosion Threshold Velocity (ETV) can be determined through a process of application of overland flows to a soil surface until such point as the soil's critical low shear stress is reached. The ETV is then determined for specific land gradients for the soil being studied.

At low land gradients, such as those observed on flood plains, the overland flow depths and volumes required to achieve the necessary critical shear stress and ETV values can be large, making field-based methods of assessment both difficult, costly, and unsuitable. Therefore, a laboratory-based method using hydraulic flumes has been developed (Landloch 2025). This approach allows for slope gradients to be modified so that the critical shear values can be applied with less water. The critical shear values can then be used to calculate the corresponding ETV value for a range of slope gradients.

The laboratory-based method for determining ETV requires the collection of an undisturbed sample from the soil surface.

3.2 Required soil surface condition

The ETV assessment requires assessment of soil for a 'worst case scenario' from a detachment perspective. For soils with naturally low vegetation groundcover levels (i.e. more arid zones), this is a soil that is bare of surface groundcover and that has little to no root mass. Such a condition could occur after a drought or fire, or may occur naturally given the rainfall-limiting environment.

For soils with naturally high vegetation groundcover levels (i.e. higher rainfall zones), this is a soil that is bare of surface groundcover but that does contain a root mass. Such a condition could occur after a drought or fire that would remove the surface groundcover but leave a root mass behind that would have an impact of detachability of soil particles.

In both cases, the soil surface assessed aims to represent a surface that could exist in the long-term within the rail corridor, and excludes disturbed soils that exist soon after construction of the rail line.

4 APPARATUS

4.1 Sampling frame

Assessment of ETV values using laboratory-based methods requires the application of overland flow within a hydraulic flume to a surface that represents an undisturbed soil surface. This necessitates the collection of an undisturbed surface sample of the soil in question within a sampling frame.

The sample is collected in a custom-fabricated, reinforced steel sampling frame that ensures that the sample is delivered to the testing laboratory in the same condition as it was collected. The sampling frame has a length of 1.0m and a width of 0.4m. The benefit of the use of a larger sample is that changes in soil properties that can occur over small distances and their impact on ETV can be incorporated into the testing of a single sample. It also minimises potential edge effects such as the initiation of detachment from the disturbed soil surface at the interface between the sample and the sample frame. Sampling showed that this area of disturbance was in the order of 1cm, resulting in a disturbance of 5% (2cm of the 40cm plot width) of the plot area. Use of a narrower plot would increase this proportion of disturbance. Further discussion on reduction of impact on the disturbed interface can be found in Landloch (2025).

The frame consists of an open channel section and two end plates that are inserted once the sample is taken to enclose the sample on all sides except the top surface (Figure 1). The steel of the frame that houses the sample is 3mm thick. The section housing the sample is 0.3m deep, and allows for sampling of a ~0.2m thick layer of soil.

In order to assess whether sampling caused changes to the soils, the bulk density of the soils both in the field and as delivered to the laboratory were measured using bulk density rings (Figure 2). Bulk density in the field was measured directly adjacent (but outside) of the sampling frame. In the lab, it was measured within the frame on soil positioned below the inlet area after the application of overland flow in the flume (Landloch 2025). By sampling the soil in this way, the bulk density measure was of a sampled soil that had not been subjected to overland flow. The analysis showed that bulk density was maintained on average with the absolute mean variation between measured field and sample bulk density being 0.01g.cm^{-3} . The largest total variation was one sample having a bulk density of 1.4g.cm^{-3} in the field and 1.6g.cm^{-3} in the supplied sample.

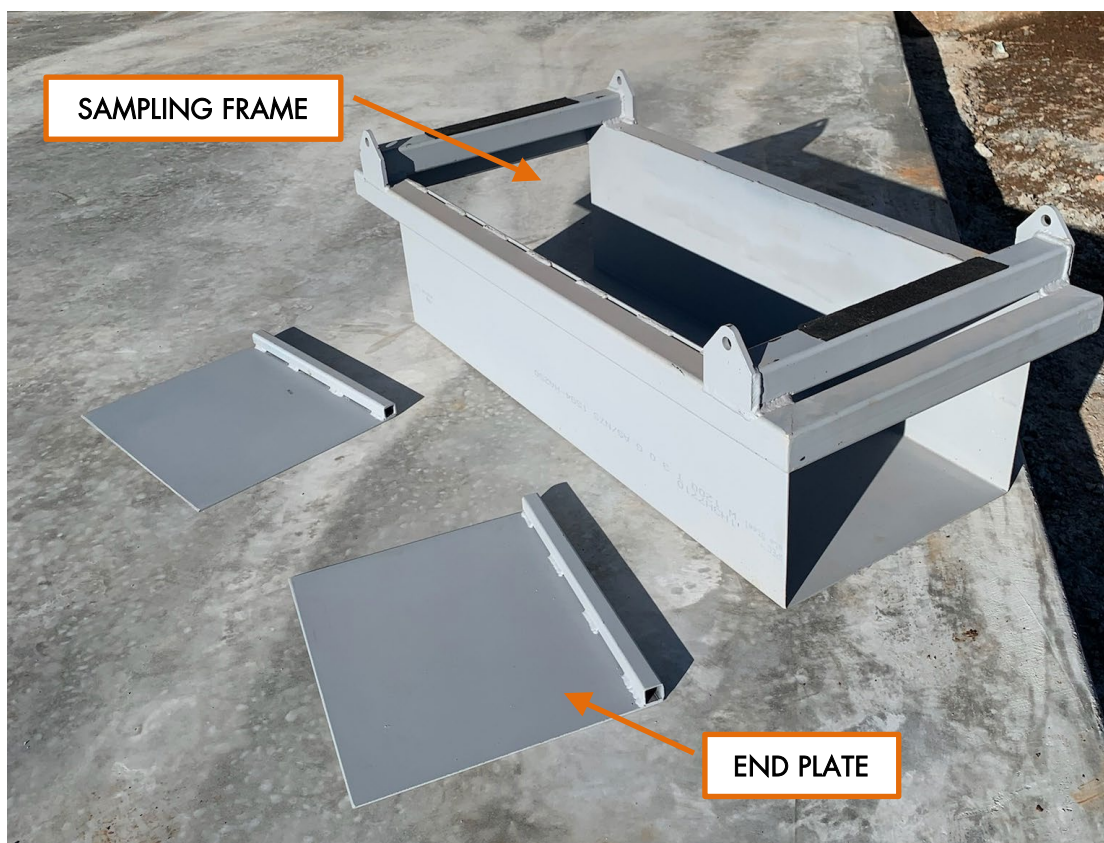


Figure 1: Sampling frame.

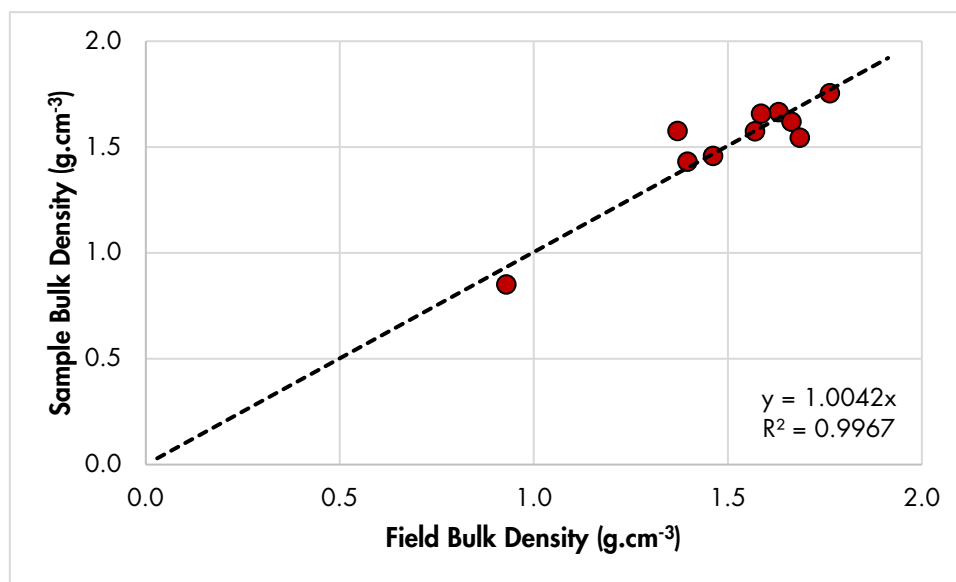


Figure 2: Relationship between sample bulk density and field bulk density.

The top surface (i.e., the surface that is tested in the laboratory) is enclosed prior to transport to the laboratory by placement of a foam layer that fills the void between the sample surface and the top of the frame. A board is placed over the foam prior to the sample being wrapped in plastic wrap. The sample is wrapped to maintain its moisture content. The moisture contents of the soils both in the field and as delivered to the

laboratory were assessed using the bulk density ring material (Figure 3), confirming that moisture content was maintained on average with the absolute mean variation between measured field and moisture content being 1%. The largest total variation was one sample having a moisture content of 14% in the field and 9% in the supplied sample.

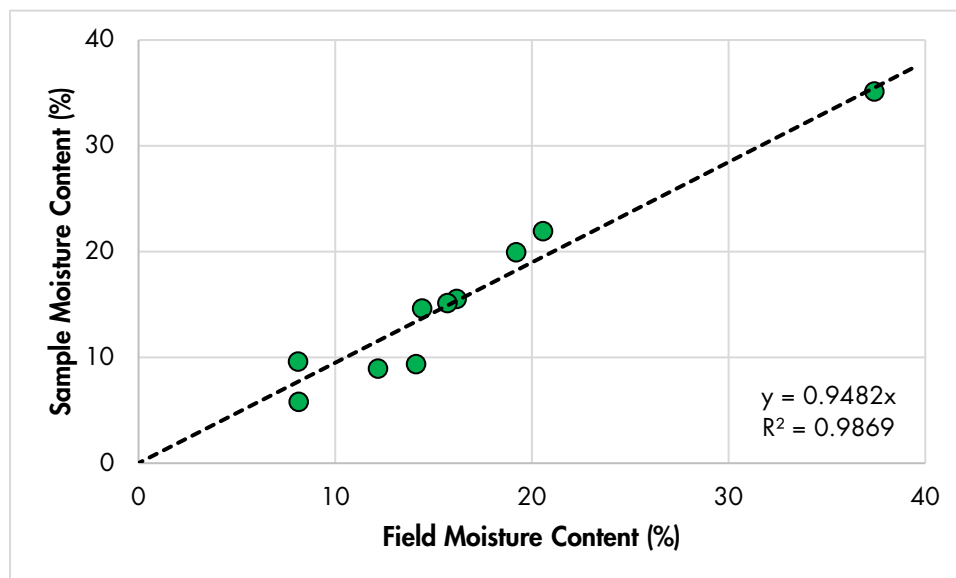


Figure 3: Relationship between sample moisture content and field moisture content.

4.2 Guide sleepers

Guide sleepers are used to provide a solid surface along which the sampling frame can be pushed with an excavator. The guide sleepers also protect the sampling surface from being impacted by the machinery (Figures 4 and 5). The tracks of the excavator are positioned outside of the guide sleepers. The guide sleepers are ideally made from aluminium and are pinned down every 1m to avoid them moving during sampling. Their exact dimensions are not critical, but can be in the order of 2m long, 0.2m wide and 0.05m thick.

4.3 Excavator and flatbed truck

A small (3.5 tonne) tracked excavator is used to push the sampling frame laterally through the soil profile being sampled and to lift the sampled soil (within the frame) from the ground (Figure 4).

A flatbed truck is used to transport the excavator to site and to transport the collected sample from site.

5 PROCEDURE

For each sampling the location, the following should be collected prior to sampling:

- GPS coordinates of the sampling site;
- Slope gradient;
- Surface land condition (fallow, cropping, pasture);
- Vegetation groundcover percent and type (grass, crop); and
- Photographs of the sampling area showing the general condition of the site.

The procedure for collecting an undisturbed surface soil sample suitable for laboratory-based ETV testing is as follows:

1. Excavate an access trench within the sampling area using an excavator.
 - The access trench is to be at least 1.2m long, 0.5m wide, and 0.3m deep (i.e., slightly larger than the sampling frame).
 - The access trench is to be positioned at one end of the area to be sampled (Figure 4).
2. Position the guide sleepers along the edge of the surface to be sampled (Figure 4) such that the tracks of the excavator can move outside of the guide sleepers.
3. Insert the sampling frame into the access trench (Figure 5).
4. Push the sampling frame laterally (i.e., horizontally) through the soil with blade of the excavator (Figure 6). Push until the frame is filled with an undisturbed section of soil. An undisturbed section of sample is one that does not contain visibly cracks caused by the sampling.
 - In instances where cracking occurs, samples should be moistened and sampling attempted again.
 - If cracking occurs after further moistening, there are two options:
 - A short sample can be collected and tested; or
 - A full sample with a crack can be collected and tested.
 - A short sample is an undisturbed section of sample no shorter than 0.8m long, with the remaining section packed with the same soil as has been sampled. The zone of packed soil is clearly marked on the sampling frame. Subsequent testing of a short sample will ensure that:
 - The packed soil portion of the sample is positioned under the inlet zone of the hydraulic flume and not subjected the application of overland flow. Hence, it will not impact the ETV measurement.
 - A full sample with a crack is one that fills the sampling frame but that has a one or two cracks visible at the surface. Testing of the cracked sample will ensure that:
 - The crack is treated with the Stonewall tackifier, the same tackifier used to make the sample edges non-erodible. In that way, scour in the area of the crack is eliminated and the ETV measure will be limited to the sample area away from the crack.
 - In instances where a short sample cannot be taken or where excessive cracking occurs, the collection of the undisturbed samples is to be

abandoned. However, the indirect testing should still occur (see Landloch (2025)).

5. Hammer in the end plates to enclose the ends of the sampling frame.
6. Lift the sample from the surface.
7. Place packing foam and board on the top surface to protect the top surface to be tested.
8. Wrap in plastic film to maintain soil moisture and tighten all parts of the sampling frame using a ratchet tie.
9. Place a second sampling frame into the location from which the first sampling frame was removed. Repeat steps 4–8 and in doing so produce a second undisturbed soil sample from the sampling area.
10. Place a third sampling frame into the location from which the second sampling frame was removed. Repeat steps 4–8 and in doing so produce a third undisturbed soil sample from the sampling area.
11. Once triplicate samples are taken, backfill the access trench with excavated material and remediate the sampling area to the satisfaction of the landowner.
12. Store samples in a weatherproof facility until testing for ETV determination is completed.

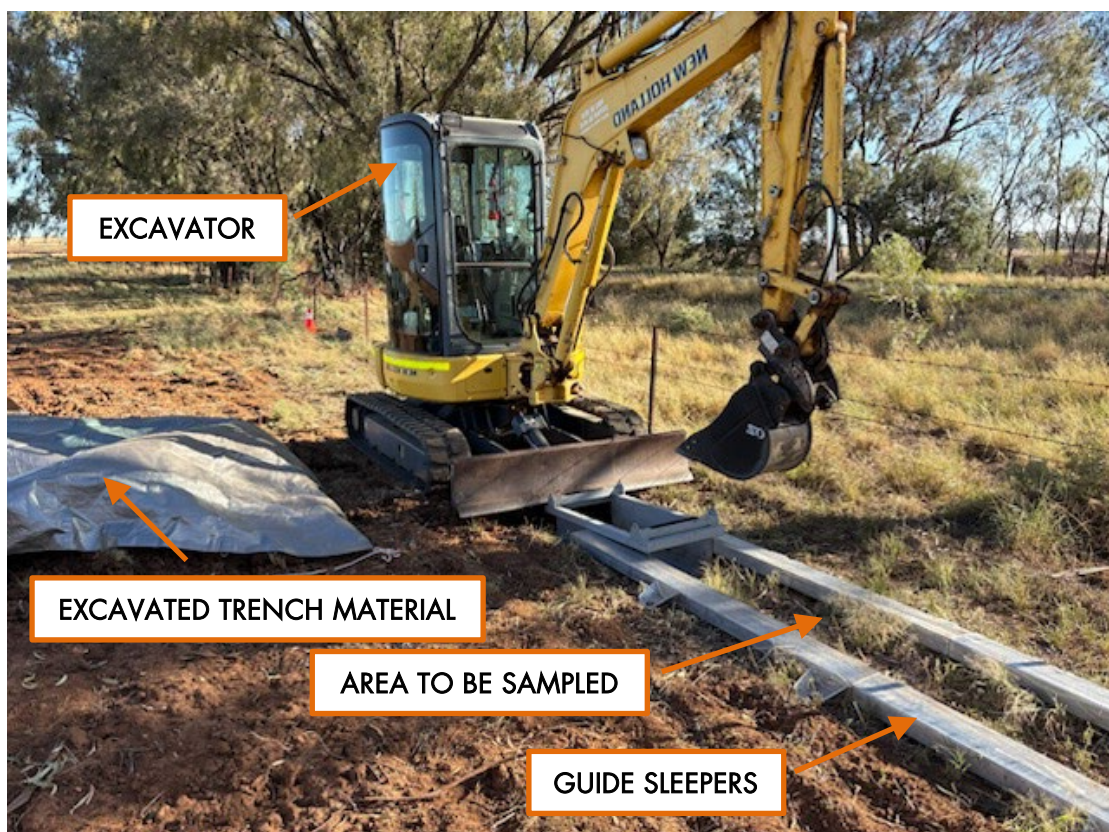


Figure 4: Access trench positioned at one end and guide sleepers positioned along the edge of the area to be sampled.



Figure 5: Sampling frame placed into access trench between the guide sleepers.



Figure 6: Sampling frame being pushed through the soil using the excavator blade.

REFERENCES

Landloch (2025) *Methods for testing erosion threshold velocity (ETV). Method 2 – Collection of an undisturbed soil sample suitable for laboratory-based ETV testing*, Revision 1, prepared for Inland Rail Pty Ltd.

APPENDIX A: INDEPENDENT REVIEW

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Review of Collection of Undisturbed Soil Samples, Revision C:
NSW/QLD Border to Gowrie Section of the Inland Rail Project

File Name: 0-0080-900-IHY-00-PR-0001-C.pdf

William Elliot, PhD

27 March 2025

Client: Evan Howard, Landloch Pty Ltd

Reviewer Background

The reviewer, Dr. William Elliot, holds BS and PhD degrees in Agricultural Engineering from Iowa State University and an MSc from the University of Aberdeen, Scotland. He has taught in colleges in Kenya, Liberia, and England, and in Universities in Scotland, and Iowa, Ohio, and Idaho USA. He has more than 100 peer-reviewed publications and book chapters, served on dozens of graduate committees, and mentored countless graduate students and junior scientists. He was a Research Engineer for the USDA Forest Service Rocky Mountain Research Station in Moscow, Idaho for 26 years, managing research teams of up to a dozen specialists and scientists. His area of expertise is soil erosion processes and prediction. He has carried out erosion field studies associated with natural rainfall and snowmelt, as well as erosion associated with simulated rainfall and runoff. Dr. Elliot has supported watershed researchers and managers including site visits throughout the U.S., Europe, Asia, South America, and Australia.

General Comments

This report describes the methods employed to collect large undisturbed rectangular soil samples from selected sites to transport to a laboratory where the erosion threshold velocity (ETV) for that soil will be determined. The report is clearly written and easy to follow.

The proposed sampling method involves pushing a sample box through the soil to slice out 0.4 x 1.0 m soil slabs. Three adjacent slabs are to be collected from each site and transported to the laboratory. A small, tracked excavator is used to dig a starting hole and push the sampling box through the soil to slice out the sample. Side sleepers are employed on either side of the box to ensure the horizontal or vertical orientation of the box does not change during the slicing operation.

All samples are carefully packed to ensure minimal disturbance to the soil samples as they are transported to the lab and stored until tested in the flume.

This is a novel approach to obtaining minimally disturbed soil samples for measuring soil erodibility. The overall approach has advantages over onsite testing because the amount of equipment and supplies needed in the field are minimal. Controls over slope gradient, flow rates, and runoff collection are much more accurately controlled in a laboratory setting than in the field. The laboratory setting will also minimize experimental differences between soils as the same set of flow rates and flume slope gradients can be applied to every soil tested.

The Procedure section describes how to address cracks in the soil by prewetting sites, placing any repacked “short samples” under the upstream intake lip of the flume in the lab, or applying a tackifier to cracks prior to applying surface flow. All three mitigation measures are reasonable and unlikely to significantly affect the estimated ETV for that sample.

Review of Collection of Undisturbed Soil Samples, Revision C:
NSW/QLD Border to Gowrie Section of the Inland Rail Project

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William Elliot, PhD

27 March 2025

Most laboratory erodibility experiments involve packing disturbed soils into a tray until a soil density similar to field densities is obtained prior to applying simulated rainfall or surface flow. This major disturbance of the soil means that biological, chemical and physical bonds between soil particles are broken, and the subsequent values for ETV or other soil erodibility properties would likely be underestimated for soils that are not regularly tilled.

The Landloch approach is unlikely to work well on soils that are high in rock content. The occurrence of such soils, however, is likely to be rare in the alluvial low gradient waterways associated with this study. For such rocky sites a disturbed sample would likely be sufficient as soil aggregation will be minor compared to the diameter of the gravel or rocks in determining ETV.

The sampling box and sleepers shown in the figures 4, 5 and 6 appear to be very well fabricated. Kudos to the machine shop crew. Welding aluminum requires a high level of skill.

Were there other observations made while collecting the soil trays, like latitude & longitude, slope steepness, vegetation cover or plant community (grassland, cropland, fallow ...), soil horizons? If so, I suggest the authors add a paragraph summarizing those observations as they are not likely included in other documents associated with the ETV project.

A suggestion for improving the sampling methodology is to give a bit of thought to inserting the end plate in the sampling box. The method states "Hammer in the end plate." The vibration caused by hammering could induce internal stress cracks in the soil, and hammering may damage the end plates. Perhaps the end plates could be designed to have a top surface or adapter face that allows the excavator bucket to push the plates into place.

The novel Landloch method for collecting minimally disturbed soil samples is sound and likely to provide reasonable samples for ETV testing in a laboratory setting. Landloch is to be commended for developing this unique approach to support the engineers who will be designing the hydraulic structures for the Inland Rail Project.

Technical Concerns

On the second page, Report Title: The authors may want to append the title to note this is "Revision C".

On page number 1, the authors may want to note under Scope that this is Revision C, reference the earlier revisions, and briefly note any major changes or improvements in this revision.

The dimensions of the sampling tray and the depth of the soil sample are not fully stated. Could the authors please provide the material (steel? aluminum? stainless?) and thickness (mm, inches or gauge) of the sampling box, the depth of the sampling box and the depth of the soil

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William Elliot, PhD

27 March 2025

sample that is to be collected? In addition, could the length, width, height and thickness of the aluminum sleepers be provided? How many anchors were necessary for the sleepers to ensure they didn't move? Such information could be useful for others wishing to use a similar collection method, or for Landloch's archives should a similar study be carried out in the future following a staff turnover.

Section 4.1, paragraph 3, how was the bulk density measured? Was the soil in the sample tray disturbed, or was a sample taken from nearby in the field? Was the bulk density measured in the lab from the tray before or after the runoff treatment?

Section 4.1, paragraph 4, how was the soil water content measured? Was it on the same core as the bulk density?

Page 5, last line before step 5, it is not clear what the author means when he states, "However the indirect testing should still occur." What is the "indirect testing?"

Editorial Suggestions

Page 1 line above Section 3.2 heading, suggest changing "of" to "from"

Page 2, Section 4.1, Second Paragraph lines 2 and 3 change "ensured" to "ensures" and "was" to "is"

Third paragraph, line 3, change "was" to "were"

Line 4, change "It" to "The analysis"

Page 4, Section 4.2 line 2, suggest change "the excavator" to "an excavator"

Line 4, change "sleeps" to "sleepers"

Figure 4. This is not a problem, just an observation. The "New Holland" logo on the excavator is a mirror image of the logo. Was this intentional? The figure itself clearly shows the different components of the sampling procedure.

On page 7, under Method Review, note that I have had "nearly 40 year's experience" in erosion research (not 50). My erosion research career started in 1986.

In the second paragraph, second line, change "measurement within" to "measurements from"

In the last line under Method Review, change "reviewer" to "reviewers and others" as the method has also been reviewed by Drs. Gilley and Foley. I suspect other specialists, technicians and fabricators have also offered suggestions from improvements along the way that have been incorporated into the field and lab methodologies and equipment.

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William Elliot, PhD

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References

Page 1, Section 3.1, Paragraph 3, line 5, and Page 2, Section 4.1, Second Paragraph, Last line, Landloch (2023) is not in the references. I assume that this is the Laboratory Procedures report.

The Landloch (2025) reference is for revision B. I note that I am reviewing revision C dated 06/03/25. The second page of the report states that revision B was done in 04/03/2024. The 2024 revision is not cited in the text but would seem to be the correct year for this reference.

Let me know if there are questions or additional clarification needed on any of my comments.

Respectfully Submitted,

A handwritten signature in black ink that reads "William J. Elliot". The signature is written in a cursive style with a large, stylized 'W' and 'E'.

William J. Elliot, PhD