Standard Operating Procedures (2.1): Soil Salinity, Texture, and Pore Water

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Standard Operating Procedures:
Soil Salinity, Texture, and Pore Water

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Protocol Suitability Evaluation

A habitat suitability table containing appropriate estuarine wetland habitat types (of those evaluated) to implement soil salinity and soil characteristic protocols is displayed in Table 1. A comparative assessment of cost, effort, and data quality are shown in Table 2. A matrix of additional detailed categorical evaluations of soil salinity and soil characteristic protocols can be found in Appendix 2.1A.

Table 1. Appropriate habitat types for soil salinity and texture survey protocols.

	Habitat Types					
Survey Protocol	**Tidal Channel**	**Mud/sand flat**	**Emergent salt marsh**	**Non-tidal salt marsh**	**Salt pan**	**'Degraded' / fill**
Soil Salinity		X	X	X	X	X
Pore Water Salinity	X	X	X		X	
Soil Texture	X	X	X	X	X	X

Table 2. Categorical assessment of cost/effort and data quality for soil salinity and texture survey protocols.

	Evaluation Metric	**Soil Salinity**	**Pore Water Salinity**	**Soil Texture**	**Notes**
Time / Effort	Office Preparation Time	0-10 minutes	0-10 minutes	0-10 minutes	Site selection and any GPS locations
	Equipment Construction Time (one time)	0-10 minutes	0-10 minutes	0-10 minutes	Collect field supplies
	Field Time (per transect)	10-30 minutes	10-30 minutes	10-30 minutes	Additional time is occasionally required for pore water to saturate within holes
	Laboratory Time (per transect)	> 60 minutes	0 minutes	0-10 minutes	Sample drying time, 48 hours to 1.5 weeks; sample processing, 30-60 minutes; post-processing, 24 to 48 hours
	Post-Survey Processing / QAQC Time	10-30 minutes	0-10 minutes	0-10 minutes	---
	Minimum Repetition (site-dependent)	Many Repetitions	Many Repetitions	Many Repetitions	---
	Relative Cost (equipment and supplies)	> $50	$15 - $50	$0	Cost will vary whether a refractometer or conductivity meter is used
Survey / Data Quality	Accuracy (at a survey area level)	High	High	Medium	---
	Precision (at a survey area level)	High	High	Medium	---
	Qualitative-Quantitative Score	Quantitative	Quantitative	Qualitative	---
	Subjectivity-Objectivity Score	Objective	Objective	Subjective	---

Resulting Data Types

The application of soil salinity and pore water protocols will yield quantitative salinity data displayed in parts per thousand. Data can be extrapolated up to the transect- or habitat-level. Salinity data can be correlated with vegetative cover or invertebrate biomass for assessing higher levels of wetland function.

Soil texture is a qualitative analysis meant to provide a general understanding of the broad categorization of different grain sizes in the soil (e.g., sandy clay).

Objective

Along with hydrology, soil salinity is one of the primary factors influencing vegetation communities and alliances in wetland habitats (James-Pirri et al. 2002). Salt composition and distribution within the soil profile affects many biological and chemical parameters including plant response, ion effects, and nutritional imbalances (NSSC 2009). Soil texture and individual phenotypic characteristics of each plant species are also widely understood to influence vegetation growth under various saline soil conditions.

The primary purpose of this sampling method is to understand the distribution of surface soil salinity and texture across estuarine wetland habitats. These data can be analyzed in conjunction with vegetation cover as well as seed bank data to better understand the responses of the vegetative community to general edaphic conditions. Soil salinity may also be assessed with other constituents to determine additional soil characterization at a particular location.

Equipment

The following supplies are recommended for full soil sampling (all three parameters); a subset may be appropriate if soil texture is the only target of the survey:

Figure 1. Salinity hand refractometer (courtesy: Extech).

1. GPS and extra batteries
2. Refractometer (Figure 1) and eyedropper
3. Sealable plastic bags
4. Squirt bottles filled with distilled water
5. Data sheets (Appendix 2.1B) with clipboards and maps (optional)
6. “Determining Soil Texture By Feel Method” Flowchart card (Thien 1979; Appendix 2.1C)
7. Hand or gardening trawl (15cm long blade)
8. Glass jars (125 – 500 mL)
9. Conductivity meter
10. Clean plastic syringe
11. Graduated cylinder
12. Pens and markers
13. Duct or lab tape for labeling
14. Soil corer
15. Filter paper
16. Scoopula

Field Preparation

Equipment described above should be collected prior to the field shift. Batteries for all electronic devices should be checked and replaced as needed, and relevant data sheets should be printed and attached to the clipboards. The refractometer and/or conductivity meter should be calibrated before the start of each salinity survey. If a survey event extends over many days, calibration should occur weekly at a minimum frequency.

Field Methods

Field methods described below are detailed for each of the three different soil survey parameters including: soil salinity, pore water, and soil texture. Frequency should be project- or goal-dependent, but annual or bi-annual surveying on a low tide during the dry season is recommended. Additional targeted surveying may be undertaken after rain events or during the wet season to assess pooled or ponded areas of inundated soil or to explore variability across seasons. Salinity assessed using the soil collection method is not directly comparable to pore water salinity.

Survey locations are also project dependent, but can be in depressions (e.g., salt pans), along vegetation transects, between transition habitats, or in areas where there are specific questions about vegetation growth or targeted restoration areas. Transects should begin from the point of lower elevation and continue with a sample approximately every 3-5 meters (unless more intensive salinity mapping is desired). Points can be further spaced out if less precision is needed. An additional option includes geospatially allocating grid points throughout a targeted survey area.

The depth of the soil collected is also an important consideration. In the surface option, detailed below, soil is collected at a depth of 1 cm. This depth is likely ideal for germination studies, but it will not provide complete information on the soil conditions at the rooting depth of perennials, and it might be too disruptive for long-term monitoring plots that are visited annually. In the rooting depth option, the top 10 cm of soil is collected with less disruption to the sampling area, which might be a more appropriate method for studies of perennial marsh plants. Depth should be considered based on the objectives of the monitoring program.

Soil Collection Methods – Dry Soils:

Surface option:

Figure 2a. 15 x 15 cm soil square being removed by a trawl.

1. Clear desired patch of soil of any debris or above-ground vegetation, using the gardening trawl or knife.
2. Make a square on the soil surface with each side measuring approximately 15 cm in length (Figure 2a). *Helpful hint:* using the gardening trawl to measure the length of the soil square reduces equipment needed in the field.
3. Collect all soil within the square to a depth of 1 cm and place soil into a labeled and sealable plastic bag. Any noticeable vegetation (roots, runners, etc.) or subsurface debris should be removed to ease subsequent processing. This will provide approximately 200 mL of soil.

Figure 2b. Soil corer.

Rooting depth option:

1. Use a soil corer (Figure 2b) to extract the top 10 cm of soil, discarding any plant material that might be present.
2. Place soil sample into a labeled and sealable plastic bag. *Helpful hint: Some field samplers will prefer to use a gardening glove for this step, especially if repeated samples are required*.

Pore Water (for use on saturated soils):

1. Using the hand trawl, push it into the target soil area and swing side to side/spin the handle back and forth to create an indentation in the soil (approximately 5 cm deep). Be careful not to allow surface water to flow into the indentation.
2. Mark the precise location of the indentation on the GPS and properly label the waypoint. *Helpful hint*: *It is usually a good idea to make a few holes within the same area, to ensure one of them fills with soil pore water and to achieve repetition*.

3. Wait several minutes to allow pore water to pool into the depression. *Note: Soils with high clay content or less infiltration will require additional time to accumulate pore water and may take upwards of 30-40 minutes*.
4. Use the eyedropper to collect pore water (Figure 3A), placing several drops on the refractometer (debris or sediment in the eyedropper will result in inaccurate readings), read the salinity (Figure 3B, for refractometer), and record the value on the datasheet.

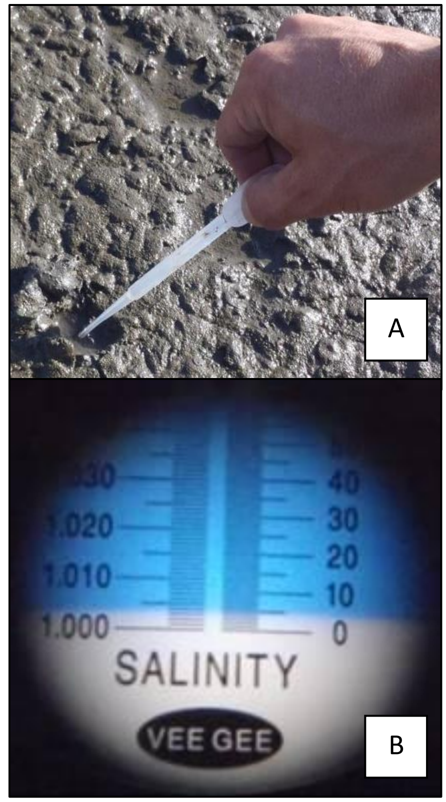

Figure 3. Eyedropper removing pore water from a shallow depression (A) and reading the refractometer (B).

Soil Texture (all soils):

1. Use approximately 100 mL of the collected soil sample (the rest will be returned to the lab for salinity processing).
2. Follow precise directions located on the "Determining Soil Texture by Feel Method" flowchart card (Appendix 2.1C).
3. Record the corresponding soil texture type on the datasheet (Appendix 2.1B).

Laboratory Methods (soil salinity only)

There are important differences in laboratory methods that will result in different readings and results. The saturated soil paste method is generally considered to produce results that are most representative of the conditions plant roots experience in the soil, but preparing a standard dilution is faster and therefore typically less expensive (Richards 1954). Results of the two methods are not directly comparable. While multiple studies have empirically calculated the relationship between the saturated soil paste method and standard dilutions, the resulting equations are variable and likely site specific (Zhang et al. 2005). If a reduced sample processing time is desired, it is recommended that a regression equation first be developed for the relationship between saturated soil paste and standard dilution for soil samples that represent the range of variability found at a particular site.

Initial steps:

1. Moist soil samples will need to be dried first. If necessary, dry the sample using a laboratory oven on a low heat setting (< 40° C) or by placing moist soil in direct sunlight. During this time, your plastic bag should be unsealed to allow the moisture to escape, taking care to not spill any of the sample. Depending on your method, the particular soil moisture content, and ambient humidity, drying may take anywhere from several days to 1.5 weeks.
2. Break up the dry sample so no large aggregates (clods of soil > 0.2 cm in diameter) remain using a coffee grinder, rolling pin, hammer, empty glass jar, etc.

3. Remove as much foreign matter, plant material, and stones from the sample as possible.
4. Transfer sample from sealable plastic bag to a glass jar.

Saturated soil paste:

1. Add distilled water to soil, mixing as water is added, until the sample is "glistening" (Richards 1954). The sample should be wet enough that the soil slides off the scoopula, but not so wet that water is standing on the surface. The sample, if turned upside-down, should not slide out of the container or jar.
2. Let samples sit, undisturbed, for 24-48 hours to allow salts to fully dissolve
3. Place filter paper at the end of a 5 mL plastic syringe, add glistening soil sample, and express the resulting soil water onto refractometer. Record salinity on datasheet. Alternately, a low-pressure vacuum pump may be used.

Standard 1:1 Dilution:

1. Add one part soil by volume to one part distilled water by volume (Zedler 2001), e.g., 100 g of soil sample should be mixed with 100 mL of distilled water.
2. Shake the container vigorously by hand (do not use a shaker table) for at least three minutes to ensure all salts dissolve. In clay loam to clay soils, more shaking will bring more salts into the solution and increase the accuracy of the test (NSW 2000).
3. Let samples sit, undisturbed, for 24-48 hours to allow salts to fully dissolve and create a less turbid sample (Figure 4).
4. Heavier salt water will concentrate towards the bottom of the jar, forming a halocline. To eliminate this salt gradient and form a homogenous salt water sample, take the eyedropper and gently stir the water while using caution not to re-suspend the sediment.
5. Using the eyedropper, collect a sample of water from the middle of the water column, place on the refractometer, and take a reading. Rinse the refractometer and the eyedropper with distilled water. Repeat two more times and record all values onto the datasheet (Appendix 2.1B). If a water conductivity meter is available, this may also be used to take more precise readings by extracting sample water using a plastic syringe and transferring it to a graduated cylinder to take the readings (Figure 5). *Helpful hint:*

Figure 4. Eyedropper collecting water to test salinity.

A graduated cylinder with a slightly larger diameter than the conductivity probe will reduce the amount of sample water required (Figure 5).

6. When complete, discard the sample, wash the refractometer and sample jar with distilled water and air dry.

Data Entry and QAQC Procedures

Data should be entered in the field for pore water samples and in the lab for soil samples using the appropriate data sheet (Appendix 2.1B). All required fields should be completed in full, and the data recorder should assign their name at the top of the document(s). Data should be transferred to the appropriate electronic database within three days, and the hard copies filed in labeled binders.

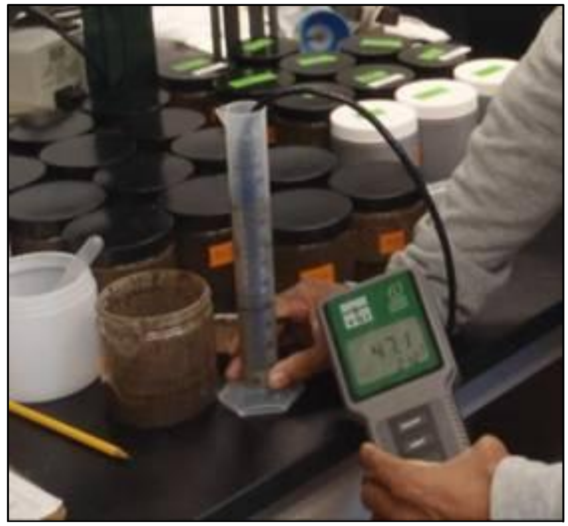

Figure 5. Reading the salinity in a graduated cylinder using a conductivity probe.

Electronic copies of all data should be housed on an in-house dedicated server and backed up to a cloud-based or off-site server nightly. Hard copies should be saved for five years. Electronic copies should be saved indefinitely.

Quality Assurance and Quality Control (QAQC) procedures should be conducted on all data. QAQC procedures should be conducted by the QA Officer and include a thorough review of all entries, double checking of all formulas or macros, and a confirmation that all data sheets, Chain-of-Custody forms, and field notes are filed appropriately with electronic back-up copies available. QAQC should verify that the entered data match the hard copies of the field data sheets. Any discrepancies should be corrected, and the initial data entry technician notified.

Data Analyses

After data have been entered, corrections made and QAQC procedures completed, data can be used in multiple analyses. Examples include maps of soil salinity (or pore water) gradients and analyses of salinities with elevation contours and associations of vegetation alliances. Other examples include averaging soil salinity by micro-habitat or identifying a range in a particular habitat type. Soil texture can be broadly associated with other characteristics or used as a reference for other surveys.

Health and Safety Precautions

Not applicable.

References and Applicable Literature

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APPENDIX 2.1A

	Evaluation Metric	Soil Salinity	Pore Water Salinity	Soil Texture	Notes
	Correlation to L2 CRAM	Not Applicable	Not Applicable	Not Applicable	----
Personnel Requirements	Specialty Equipment or Clothing Required	Few Specialty Items	Few Specialty Items	None	Refractometer or conductivity meter, trowel
	Ease of Transport (amount or weight of supplies)	Few items / Easy	Few items / Easy	Few items / Easy	Depending on the number of soil samples collected
	Ease of Implementation	Moderate	Easy	Easy	---
	Expertise / Skill Level	Some Technical Knowledge	Some Technical Knowledge	None Required	Understand how to read refractometer or conductivity meter
	Number of Personnel	1	1	1	Multiple persons will expedite the soil processing for soil salinity
	Training Requirements	Some Technical Knowledge	Some Technical Knowledge	Some Technical Knowledge	Understand how to read and calibrate refractometer or conductivity meter
	Seasonality of Survey Time	Before wet season	Before wet season	Anytime	---
	Suggested Frequency	Annual	Annual	Annual or Biannual	---
Survey / Data Quality	Type of Output	Numerical	Numerical	Categorical	---
	Active or Passive Monitoring Style	Active	Active	Active	---
	Specialty Computer Software Required	No	No	No	---
	Availability of Online / External Resources	Some	Some	Some	YouTube and various online sources
Potential Limitations	Wetland Type Applicability	All	All	All	---
	Images or Multi-Media Required	None Required	None Required	None Required	---
	Degree of Impact / Disturbance	Low Disturbance	Low Disturbance	Low Disturbance	---
	Vegetation Height Limitation	No Limitations	No Limitations	No Limitations	---
	Appropriate for Tidal / Wet Habitats	No	Yes	Yes	---
	Tide Height	Low Tide Only	Low Tide Only	Low Tide Only	---
	Regional or Broad Implementation *	Infrequently Used	Infrequently Used	Infrequently Used	---
	Potential for Hazards / Risk	Low to No Risk	Low to No Risk	Low to No Risk	---
	Restrictions	None	None	None	---

** based on monitoring literature review*

APPENDIX 2.1B

SOIL SALINITY DATASHEET

Survey Area / Habitat (e.g. "A / seasonal wetland"):

Date:	Staff (circle recorder initials):
Survey Start Time: Stop:	**Entered: _________ Date______ QAQC: ________Date______**
Weather:	Days Since Rain (approx):
General Soil Conditions:	Other Notes:
High Tide: Height: Time:	Page ____ of ____

Salinity Measurements & Station Info ***Sampling (circle one): Soil OR Pore Water***

Station ID	____________	**GPS Coordinates:**	**General Notes:**
Time Collected	_____:_____	**1**	
Time Read	_____:_____	**2**	
Saturated (Y/N)	____________	**3**	

Dilution (soil / H2O)	____ mL /_____ mL	**Dilution- (soil/H20)**	____ mL /_____ mL	**Vegetation (w/in 5m)**
Rep #1 (salinity)	Refr: _____ YSI: _______	**Rep #1 (salinity)**	Refr: _____ YSI: _______	**1**
Rep #2 (salinity)	Refr: _____ YSI: _______	**Rep #2 (salinity)**	Refr: _____ YSI: _______	**2**
Rep #3 (salinity)	Refr: _____ YSI: _______	**Rep #3 (salinity)**	Refr: _____ YSI: _______	**3**

Salinity Measurements & Station Info ***Sampling (circle one): Soil OR Pore Water***

Station ID	____________	**GPS Coordinates:**	**General Notes:**
Time Collected	_____:_____	**1**	
Time Read	_____:_____	**2**	
Saturated (Y/N)	____________	**3**	

Dilution (soil / H2O)	____ mL /_____ mL	**Dilution (soil/H20)**	____ mL /_____ mL	**Vegetation (w/in 5m)**
Rep #1 (salinity)	Refr: _____ YSI: _______	**Rep #1 (salinity)**	Refr: _____ YSI: _______	**1**
Rep #2 (salinity)	Refr: _____ YSI: _______	**Rep #2 (salinity)**	Refr: _____ YSI: _______	**2**
Rep #3 (salinity)	Refr: _____ YSI: _______	**Rep #3 (salinity)**	Refr: _____ YSI: _______	**3**

Salinity Measurements & Station Info ***Sampling (circle one): Soil OR Pore Water***

Station ID	____________	**GPS Coordinates:**	**General Notes:**
Time Collected	_____:_____	**1**	
Time Read	_____:_____	**2**	
Saturated (Y/N)	____________	**3**	

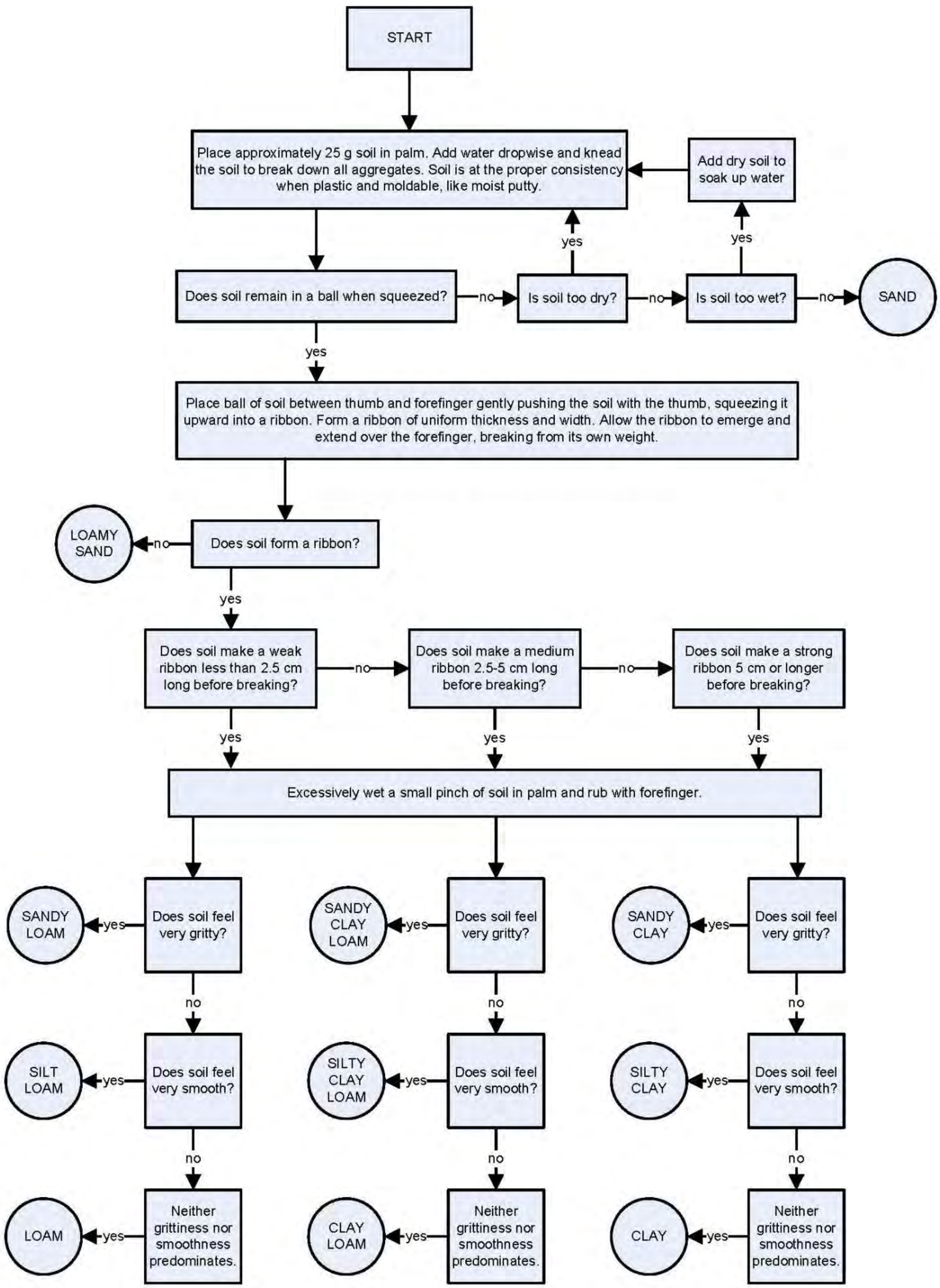
Dilution (soil / H2O)	____ mL /_____ mL	**Dilution (soil/H20)**	____ mL /_____ mL	**Vegetation (w/in 5m)**
Rep #1 (salinity)	Refr: _____ YSI: _______	**Rep #1 (salinity)**	Refr: _____ YSI: _______	**1**
Rep #2 (salinity)	Refr: _____ YSI: _______	**Rep #2 (salinity)**	Refr: _____ YSI: _______	**2**
Rep #3 (salinity)	Refr: _____ YSI: _______	**Rep #3 (salinity)**	Refr: _____ YSI: _______	**3**

Salinity Measurements & Station Info ***Sampling (circle one): Soil OR Pore Water***

Station ID	____________	**GPS Coordinates:**	**General Notes:**
Time Collected	_____:_____	**1**	
Time Read	_____:_____	**2**	
Saturated (Y/N)	____________	**3**	

Dilution (soil / H2O)	____ mL /_____ mL	**Dilution (soil/H20)**	____ mL /_____ mL	**Vegetation (w/in 5m)**
Rep #1 (salinity)	Refr: _____ YSI: _______	**Rep #1 (salinity)**	Refr: _____ YSI: _______	**1**
Rep #2 (salinity)	Refr: _____ YSI: _______	**Rep #2 (salinity)**	Refr: _____ YSI: _______	**2**
Rep #3 (salinity)	Refr: _____ YSI: _______	**Rep #3 (salinity)**	Refr: _____ YSI: _______	**3**

APPENDIX 2.1C



Modified from S.J. Thien. 1979. *A flow diagram for teaching texture by feel analysis.* Journal of Agronomic Education. 8:54-55.