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MEMORANDUM

August 5, 2010

To: File

FROM: Jerald LaVassar, Dam Safety Office (DSO)

SUBJECT: Failure Assessment of French Slough Impoundment; SN07-0651

This memorandum summarizes opinions and judgments of the DSO as to the cause of the April 2010 failure of the 30-million gallon Waste Storage Pond operated by the Bartelheimers near Snohomish, Washington.

The analysis and conclusion here are based upon a review of the design report, project plans, the construction records of the involved parties and agencies, and observations made in two post failure visits to the site. The memorandum has two Appendices. Appendix A provides relevant excerpts from design report, construction records, and post-failure interviews with the parties associated with the project. Appendix B is a copy of the DSO memorandum describing the site visit the day following the discovery of the failure.

The DSO investigation is one of two studies of the failure. The National Resource Conservation Service (NRCS) is conducting its own independent study. The DSO is investigating the failure as it was a jurisdictional impoundment. This means the DSO issued a Dam Construction Permit for the impoundment and conducted a number of site visits during construction. The NRCS is conducting its investigation as that agency designed the project and inspected the construction. The DSO understands that it is the policy of the NRCS to investigate the failure of any facility they design. Their investigations attempt to determine the cause of the failure, assign fault, and assess whether NRCS design practices need revision to avoid such failures in the future.

NRCS report describes potential failure mechanisms

By mid-May the NRCS had completed a draft report of its investigations. On May 21, 2010, Doug Johnson (DSO Supervisor) and I were given the opportunity to review that NRCS draft report. Larry Johnson[1] and Kip Yasamiishi[2] hand carried the document to our office. Kip verbally summarized the basic findings included in the report and then asked for any comments the DSO had on that NRCS assessment. At the conclusion of the meeting the draft report was returned to the NRCS. Copies of the report will be made available to all interested parties once the NRCS completes its internal review.

The draft NRCS report described a number of potential failure mechanisms, dismissing all but one. The most probable failure mechanism NRCS concluded was that pond seepage over time eroded a void through the 12-inch thick low permeability soil liner down to a decades old, field drain constructed of cedar planks. That field drain lay at a shallow depth below the pond bottom and extended several hundreds of feet northwest and southeast of the lagoon. (See Figure 1.) The eroded void served as a conduit to introduce full pond fluid pressures into the cedar field drain. Those elevated fluid pressures were transmitted down the field drain. A short distance outside the dike toe fluid pressures in the drain reached a level that overcame the strength of the overlying soil. There, the pressurized fluid forced open a pathway to the ground surface. Flow moving upwards rapidly eroded away the soils from the sidewalls of the exit pathway, continuously expanding the channel cross-section and increasing the outflow. At some point the capacity of the exit pathway at the toe exceeded the flow capacity of the 12" by 16" cedar field drain cross-section. The cedar drain, in limiting the flow rate, would come under stresses that would disassemble it starting at the outside dike toe exit. Here presumably the wooden cross pieces that formed the top of the cedar drain would have begun to pop off. The unraveling of the wooden drain would proceed backwards under the dike footprint triggering an uncontrolled breach of the dike.

At the May 21st meeting the DSO expressed concurrence with the NRCS hypothesis that the cedar field drain was under fluid pressures driven by the pond. For that scenario the DSO also agreed that fluid pressures immediately outside the dike toe would have been sufficient to force an exit pathway to the surface. The remainder of this memorandum focuses solely on this one failure mechanism. The reader is referred to the final NRCS report for a discussion of other mechanisms they considered, ultimately rejected, and their basis for rejecting those mechanisms.

The DSO memorandum does not assign blame to any of the involved parties in the failure.

Site and soil descriptions

The site is an alluvial plain that extends northwest from French Slough and northeast of the Burlington Northern Santa Fe Railway embankment. In the vicinity of the pond 7 to 8 feet of fine grained soils mantle the site. Fine to medium silty sand underlies the fine grained mantle. The NRCS soil maps identify two principal soil units comprising the fine grained soil mantle in

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[1] NRCS State Engineer
[2] Principal geotechnical engineer for the NRCS investigating the failure

the pond area: Puget Silty Clay Loam and Sultan Silt Loam. (See Figure 2.) Table 1 lists properties of these soil units cited on the NRCS Soil Survey website[3].

TABLE 1 - Soil Properties of the Fine Grain Soil Layers Mantling the Pond Site

NRCS Map Unit	Map Unit Name	Percent Passing No 200	Liquid Limit	Plastic Limit	Plasticity Index	Natural Moisture Content	Comment
55	Puget Silty Clay Loam	31	33.6	20.7	12.9	Varies seasonally	
66	Sultan Silt Loam	25	25.3	19	6.3	" "	
Grab samples 4/2010	Dike Fill in Breach Area[4]	76 – 100	39 - 43	24 - 28	15	23 -27 (April 2010)	Borrow likely typical of soil bottom liner

The Clay Loam has a higher Plasticity Index than the Silt Loam. In general as the Plasticity Index increases, the soil behaves more like pure clay, i.e., it has greater cohesive strengths and lower friction angles. Conversely, as the Plasticity Index goes down the soil behaves more like sand, showing little to no cohesive strength and higher friction angles. Under similar deposition or placement conditions, the Puget Silty Clay Loam likely would have a higher cohesive strength and a lower friction angle than the Sultan Silt Loam. The distinction between clay-like and sand-like behavior has a significant influence on both the internal erosion resistance of the soil that formed the pond bottom and on the mechanism the pressurized fluid in the cedar drain used to force a pathway to the surface at the exterior toe of the embankment.

Groundwater levels at the site fluctuate seasonally. Mottling of the soils in the sidewalls of the exploratory trenches is evidence of that seasonal fluctuation. Mottling of soils was noted within 5 feet of the surface. It is likely in the rainy season that groundwater levels rise to the surface.

Notable history of field drains

Cedar Field Drain – The cedar field drain was installed decades before the impoundment was contemplated. The drain served to improve drainage and thereby aid in farming the field. The DSO understands that Figure 1, based on a 1947 aerial photo of the field, documents the presence of the cedar drain before 1947. Note the alignment of the cedar drain is inferred from isolated lineal features that reportedly were sinkholes that developed along sections of the drain line. There are anecdotal reports that the cedar drain sections where sinkholes occurred were replaced with concrete pipe lengths around the late 1940s. Interviews with the Bartelheimers disclosed that additional sections of the cedar drain were replaced in the 1980s. ADS pipe was

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[3] http://websoilsurvey.nrcs.usda.gov/app/

[4] Heibel, A. & Reinsch, S. (2010) **Soil Mechanics Report, Bartelheimer Brothers Dairy WSP, WA**, NRCS, May 17, 2010.

used to complete this second of drain modifications. The location of the ADS work was not cited in the information available to the DSO.

Figure 3 shows a conceptual view of typical design practice for field drains in the 1930s and 40s provided to the DSO by the NRCS. The photo insert in the corner of Figure 3 shows a short exposure of the cedar drain in one of the April 21st test pits dug to investigate the failure. There are notable differences between the conceptual view of such field drains and what was done at the Bartelheimer site. Those differences include elimination of the 1" wide gap between both the lid and sideboards and the sideboards and earthen floor of the drain section. Presumably, such gaps were provided to allow seepage to enter the drain from the top and bottom. At the Bartelheimer site the drain relied principally on seepage entering the unlined floor of the drain via lengthy sections where the bottom of the drain rested on relatively pervious silty sand. Narrow gaps between the individual boards forming the lid and between successive planks of the drain sidewalls provided some limited additional inlet capacity for seepage to enter the drain directly out of the fine grained soil mantle.

Planning & construction – The designers were aware that the pond would be situated in an area of buried field drains. Their June 6, 1995, design report comment (included in Appendix A) noted that there could be up to three tilelines in the pond footprint. Provisions[5] were included on the plans to remove and re-route all tilelines 25 feet outside the footprint of the pond. The inspectors knew that all buried drains were to be removed. That information was passed on to the owner via a phone call as documented in a Cooperation Assistance note of September 21, 1996, Appendix A.

Unfortunately, the plans only showed two tilelines within the footprint. That fact likely contributed to missing the buried cedar drain during construction.

The field inspector's notes during construction make multiple references to buried drains. In the interview notes[6] compiled by Erica Fifer, Mr. Rankin thinks he remembers discussing a wooden box drain, talk of digging to find all drains, and a consensus that the drain was too deep to be of concern. Those comments are consistent with the interview of Ryan Bartelheimer. The lead inspector Herb Klug does not remember any discussion of a wooden drain nor did he observe one. No interviewee remembered or observed any excavation to find the wooden tileline drain.

Service – The waste pond was put into service in 1997. It functioned without incident until the failure sometime after noon April 11th and before noon on the 12th.

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[5] Plan Sheet 2, Construction Note 8

[6] NRCS (2010) Engineering Investigation Report Waste Storage Pond near Snohomish. July 9, 2010, Appendix F Interview Notes

The DSO's April 13th site visit to the failed pond noted visual evidence that flow had exited the emergency spillway and that wind driven waves had broken onto the dam crest locally. In the latter case the resulting sheet flow crossed the 10 foot wide crest and ran down the exterior slope. The sheet flow left a number of meandering shallow depressions across the crest. The depressions were at most an inch or so deep. The import of the foregoing is that the waste level had risen to within a foot of the dike crest. The normal maximum operating pool and emergency spillway levels on the as-built plans are cited as 3.5 feet and 1.3 feet, respectively. The DSO is unaware of information as to how long and how recently the reservoir was operated at this level.

Sequence of events that led to failure

A seepage induced failure requires two things: 1) a continuous pathway for seeping fluid to escape the pond and 2) a flow quantity down that pathway sufficient to wash away soils faster than the pathway can heal[7] itself. In this case there are three separate reaches to this continuous pathway: the short reach between the pond bottom and the field drain, the field drain beneath the embankment, and the upward pathway through the soil layer to reach the ground surface. (See Figure 4.)

As is often the case in such failures, the dam breach flood washed away evidence necessary to explain with confidence the key factors that led to this failure. Consequently, it is necessary to make reasoned presumptions as to the sequence of events that led to the failure.

Pond Bottom to Field Drain Path – The soil liner reportedly was constructed in two 6-inch lifts. The bottom lift consisted of the native fine grained soils exposed at the base of the pond excavation. Those soils were scarified with farm equipment and then compacted with a self-propelled smooth drum roller. This is not the ideal compactor for such soils. It is preferable to use a kneading type compactor such as a sheepsfoot roller. None the less, the rubber tires of the smooth drum compactor still likely achieved a reasonable minimum level of compaction given the wetness of soil at that depth. The soil for the top lift of the liner presumably was obtained from the borrow source immediately west of the pond. The borrow soils based on the Atterberg Limits cited in Table 1 are more plastic. This indicates a greater cohesive strength and higher swelling potential than the fine grained foundation soils of the bottom half of the liner. The increased strength and swelling capacity of the upper lift of soil liner would aid in both minimizing seepage induced cracking and in the healing of any cracks that did develop. It is the DSO's belief that these properties of the upper lift of compacted soil liner explain why the pond managed to function satisfactorily for 12 years.

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[7] The term heal refers to the ability of the sidewalls of the eroding channel to swell (in clayey soils) or collapse into the void (sands) thereby slowing and finally stopping further soil loss out the pathway. Note seepage may still be conducted particularly in the case of sands, but the rate of flow is slow enough that soil particles are not sluiced away.

Ultimately, failure required that an open pathway had to develop through the soil liner and any underlying foundation to the interior of the cedar field drain. There must have been at least a 12 inch vertical clearance between the top of the soil liner and the lid of the cedar field drain. Without such a clearance the drain likely would have been hooked by the farm equipment in scarifying the base of the excavation for the bottom lift of the soil liner. The maximum vertical distance between the top of the soil liner and the drain lid likely would not have exceeded 2 to 3 feet. Evidence for this comes from Mr. Yasamiishi's April 20th interview of Jason Bartelheimer. Mr. Bartelheimer recalled observing quick fine sand in the base of the excavation during construction. Presumably he was describing isolated areas of the pond bottom rather than the surface as a whole. That observation suggests that the pond floor lies close to the contact with the underlying sand stratum.

The foregoing assertion is also consistent with what little the DSO knows of the elevation of the cedar field drain. The top of the cedar drain lid was measured at elevation 9.6 feet[8] in the first test pit dug on April 21st. That test pit was situated about 200 feet northwest of the interior pond toe and 800 from French Slough. The top of the pond's soil liner is estimated to have been at elevation 10.4 feet[9]. Presumably, the cedar drain would have a gradual drop moving southeast to its outfall in French Slough. That drop could easily provide the few tenths of a foot drop in elevation to get the necessary 12 inch clearance between the drain lid and the top of the compacted soil liner across the pond bottom.

Possible mechanisms that could open a pathway to the field drain include:

- Fine grained soil could have been eroded into the drain through too wide of a gap between adjacent boards of the drain sidewalls or lid or a poorly configured concrete pipe to cedar drain repair. The resulting void could have propagated upward through the soil liner.

- A length of the sand floor could have been sluiced into the drain interior leaving a void at the base of the fine grain stratum. Such a void would remove support for the overlying fine grain soil which would respond by shifting and cracking. Again, that crack could propagate upwards through the liner.

- A section of the cedar drain could have collapsed in upon itself. That would have deprived the overlying fine grained soils of support and could have led to a shift and cracking of the soil liner in the same manner as the previous mechanism.

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[8] Elevations cited are those of April 21st NRCS survey.
[9] Adding 1.1 feet to the as-built floor elevation to match the elevations of the April 21st NRCS survey

- Alternatively, cracks may have developed along the outside of the drain, running parallel to the drain. Those cracks could have resulted from the difference in the way the wooden drain shifted from that of the encapsulating fine grained soil as the foundation settled under the weight of the embankment.

Cedar Field Drain– Whatever mechanism opened a direct hydraulic connection between the pond and the cedar drain, it took that mechanism 12 years for it to precipitate a blow out of the downstream plug. This contrasts dramatically with the remaining two sections of the pathway. The 70-year-old cedar drain has always provided a conduit with a cross-sectional area of about a square foot. That conduit extended underneath the full footprint of the pond and well out into the abutting field to the northwest and southeast.

Upward Exit through the Soil Mantle at the Outside Embankment Toe – The DSO believes that fluid pressures in the interior of the cedar drain immediately prior to the failure were driven by the fluid level in the pond. Maximum fluid pressures in the drain would have equaled the difference in elevation between the fluid surface in the pond and the field drain multiplied by the unit weight of the fluid - roughly that of water. The DSO calculated that with the fluid in the pond at or above the normal high pool level, the pressure acting in the cedar drain below the outside dike toe would have been sufficient to force open a pathway to the ground surface. The DSO believes that pathway could have been opened by hydraulic fracturing of the soil column. Hydraulic fracturing is a technique employed by, among others, the oil industry to boost yields from oil bearing strata. The fluid pressure in a sealed off section of the vertical well is increased to the point it opens fractures in the rock. Those fractures allow increased oil flow from the surrounding formation to the collection well. In the French Slough case, rotate the concept 90 degrees. The horizontal cedar field drain is the analog for the vertical boring. The pond fluid pressure in the cedar drain is equivalent to the drill rig pressurizing the encapsulating soil. The resulting cracking of the surrounding formation would have opened an exit pathway up through the fine grained soil mantle to the ground surface.

It is the DSO's opinion that hydraulic fracturing of the mantle would occur when the fluid pressure at the base of the soil column exceeded the lateral confining stress in the soil. The lateral confining stress acting in the soil was estimated as the sum of a frictional component and a cohesion component of the strength of the soil. The component due to friction was approximated by multiplying the wet unit weight of the soil column times the at-rest lateral earth pressure coefficient. The component due to cohesion was estimated using published relationships that relate cohesion to a soil's Atterberg Limits.

The reasonableness of the strength parameters used in predicting the lateral confining stress was investigated by conducting slope stability analyses of the interior pond sideslope for the end-of-construction case. The results of such an analysis would be controlled by the strength of the fine grained soil mantle. That mantle would not have had time to undergo a significant strength gain as the mantle consolidated under the weight of the embankment. Thus the soil properties calculated for the mantle would be still representative of the mantle outside the dike footprint. Soil strengths were adjusted so as to obtain factors of safety against a slope failure of 1.3. As is cited in Table 2 when such a minimum factor of safety is calculated, case histories show slope failures rarely occur. After demonstrating the reasonableness of estimated soil properties for the mantle, those properties were used to improve the DSO's estimate of lateral confining stress in the soil.

Table 2 – Factor of Safety Correlation with Observed Slope Behavior[10]

Factor of Safety - FS	**Event**
FS< about 1.07	Failures are common
1.07 < **FS** < 1.25	Failures do occur
FS > 1.25	Failures almost never occur

Considering normal variance in the DSO's estimates of the lateral confining pressure in the mantle and a fluid pressure for a normal high pool level, the DSO calculated a ratio of confining stress to fluid pressure of 0.95 to 1.1. A ratio of 1 or less indicates failure; a ratio of 1.1 provides too small a cushion to feel confident of stability given the uncertainty inherent in the analysis.

The cohesive strengths assigned to the mantle soil in the foregoing analyses are relative low compared to those cited in the NRCS Soil Mechanics report[4] for soils from the borrow pit for the embankment fill. This deserves justification. The DSO analyses were done without knowledge of the NRCS soil testing. Having now reviewed that NRCS soil testing, it is the opinion of the DSO that those samples were not representative of the mantle soils that failed. The DSO bases this opinion on the fact that the exit pathway likely passed up through the backfill of the cedar drain. The DSO assumes that this backfill consisted of mixture of Puget Silty Clay Loam, Sultan Silt Loam, and limited amounts of the underlying silty sand[11]. Mixing of soil units likely would have occurred when the soils were originally excavated with a dragline, dumped in temporary stockpiles, and finally replaced in backfilling the trench with the dragline. The assumed mixing and dumping could account for the weaker soil strengths the DSO calculated for the backfill of fine grained soils at the blow out exit site.

The NRCS investigation took a different approach to evaluating the stability of the soil mantle at the blow out site. Their analyses looked at the ratio of the buoyant unit weight of the soil column

[10] Bowles, Joseph E., Physical and Geotechnical Properties of Soils, 1979, pg. 448.

[11] Mica flakes presumably are present in the silty sand underlying the fine grained soil mantle. The last soils removed from the trench would have been the silty sand and would have capped the stockpiles. This surmise is consistent with Dale Bartelheimer's recollection as a child of having asked if the stockpile glittering (mica flakes) was due to gold.

to the upward seepage force acting on that column. This analysis is most appropriate for non-cohesive soils that derive their strength entirely through friction between soil particles. Their analysis predicted a factor of safety lower than 1. The NRCS analysis also predicted failure.

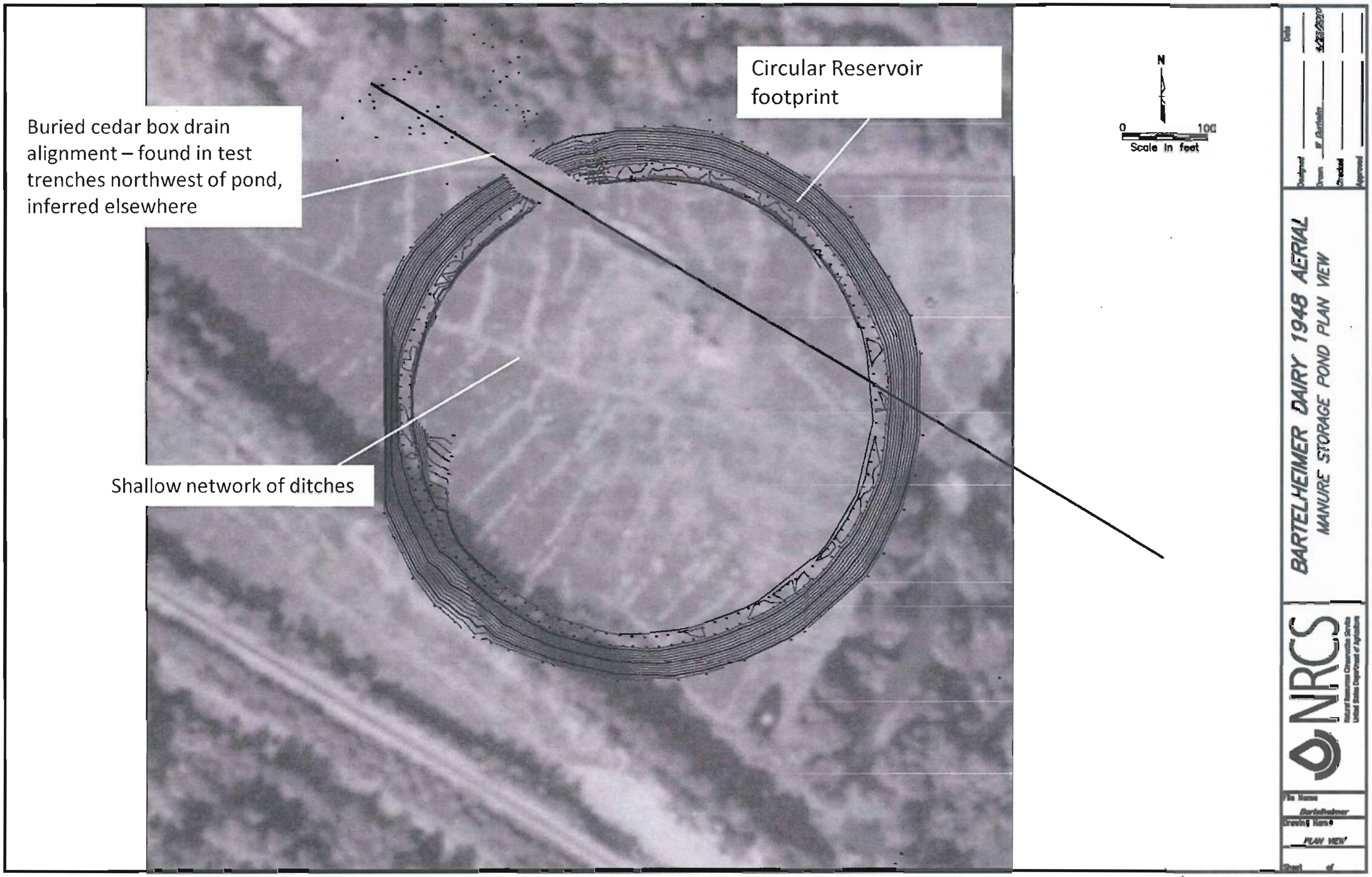
Conclusion about the cause of the Bartelheimer Lagoon failure

The seeds of the failure were laid when the decades old cedar field drain was not removed from within the pond footprint during construction.

The fact that the waste pond functioned satisfactorily for 12 years is a testament to the integrity of the compacted fine grained soil liner.

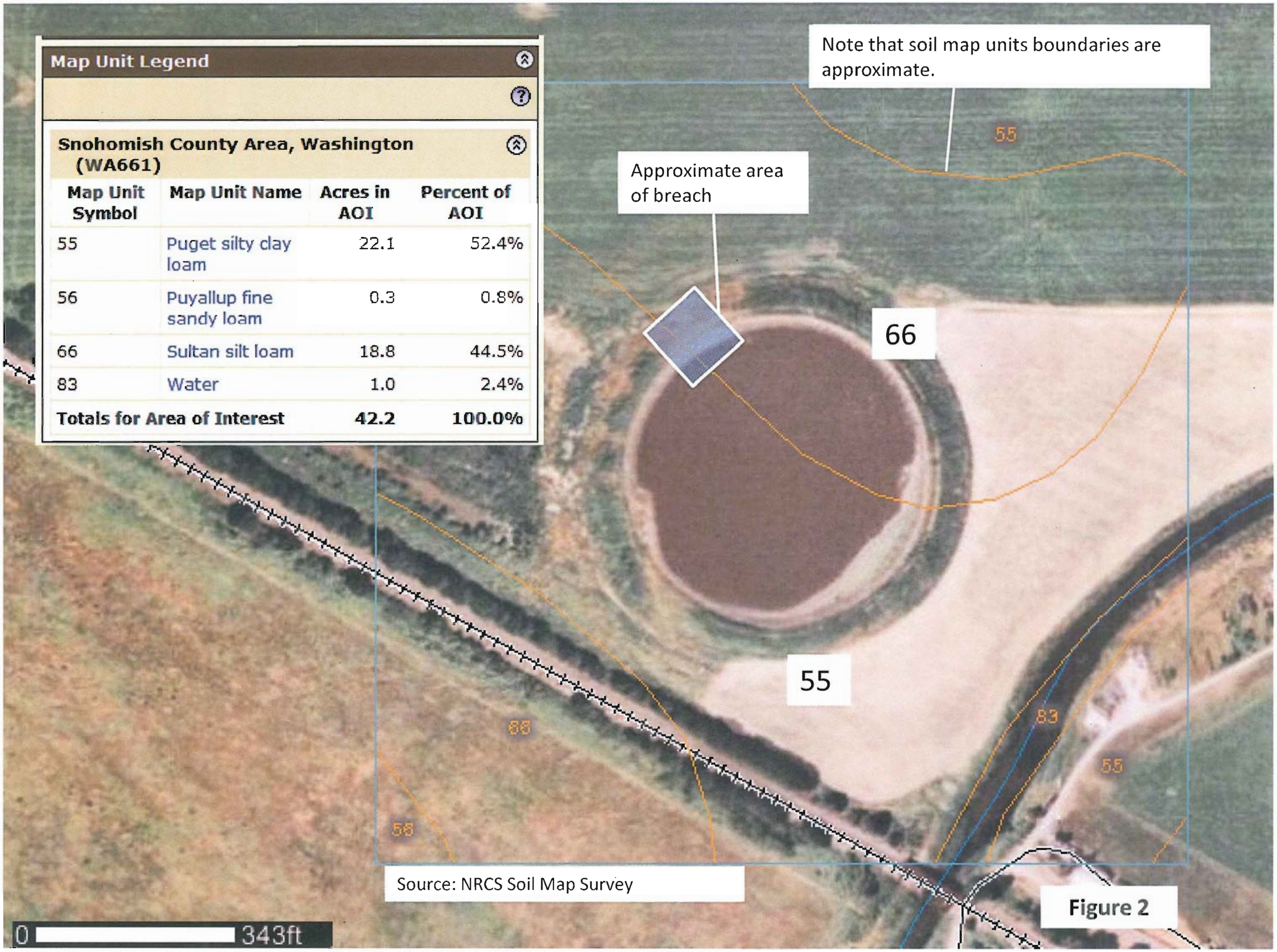
Fluid pressures acting in the cedar drain equal to the difference in the elevation of the normal high pool level and the drain times the unit weight of water were sufficient to precipitate the blow out. Consequently, one cannot directly attribute the triggering of the failure to operating the pond with a fluid level a few feet above the normal high pool level. Arguably, that action may have accelerated the process leading to failure. But, it is the opinion of the DSO that failure still would have occurred at some future date even if the pond had been operated in strict compliance with the farm plan. Ultimately the cause of failure has to be attributed to failing to remove the cedar field drain beneath the pond during construction.

Figures
French Slough Failure



Cedar Field Drain Alignment

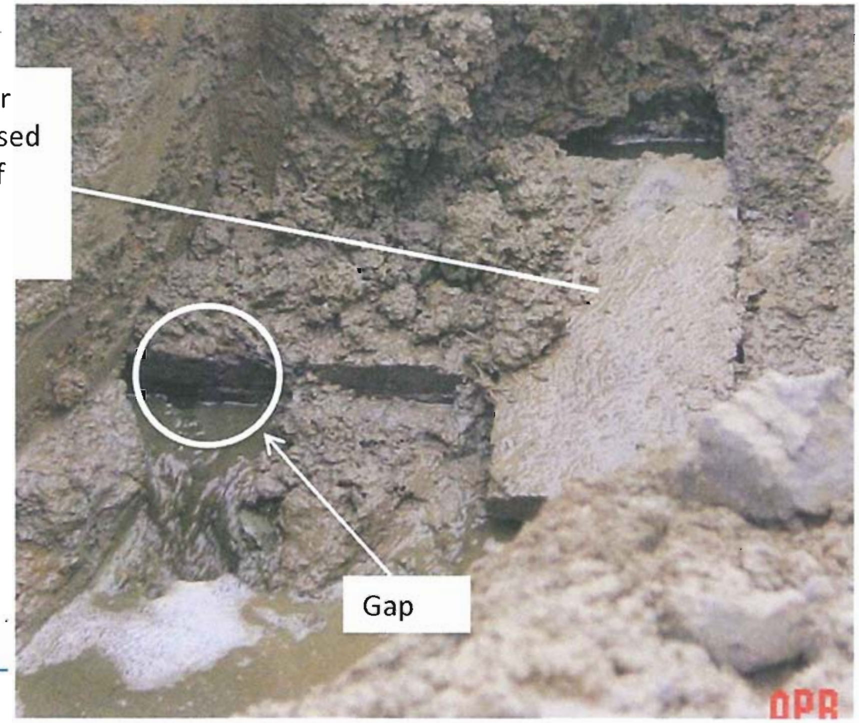
Figure 1



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
55	Puget silty clay loam	22.1	52.4%
56	Puyallup fine sandy loam	0.3	0.8%
66	Sultan silt loam	18.8	44.5%
83	Water	1.0	2.4%
Totals for Area of Interest		**42.2**	**100.0%**

Figure 2

French Slough system used 11 1/2" by 1 7/8" (actual dimension) cedar planks to construct the drain. The DSO understands that nails were used for the wall-to-lid connection from NRCS reports. However, DSO staff saw no nails projecting out of the limited sample of the population of boards ejected to the surface in the failure.



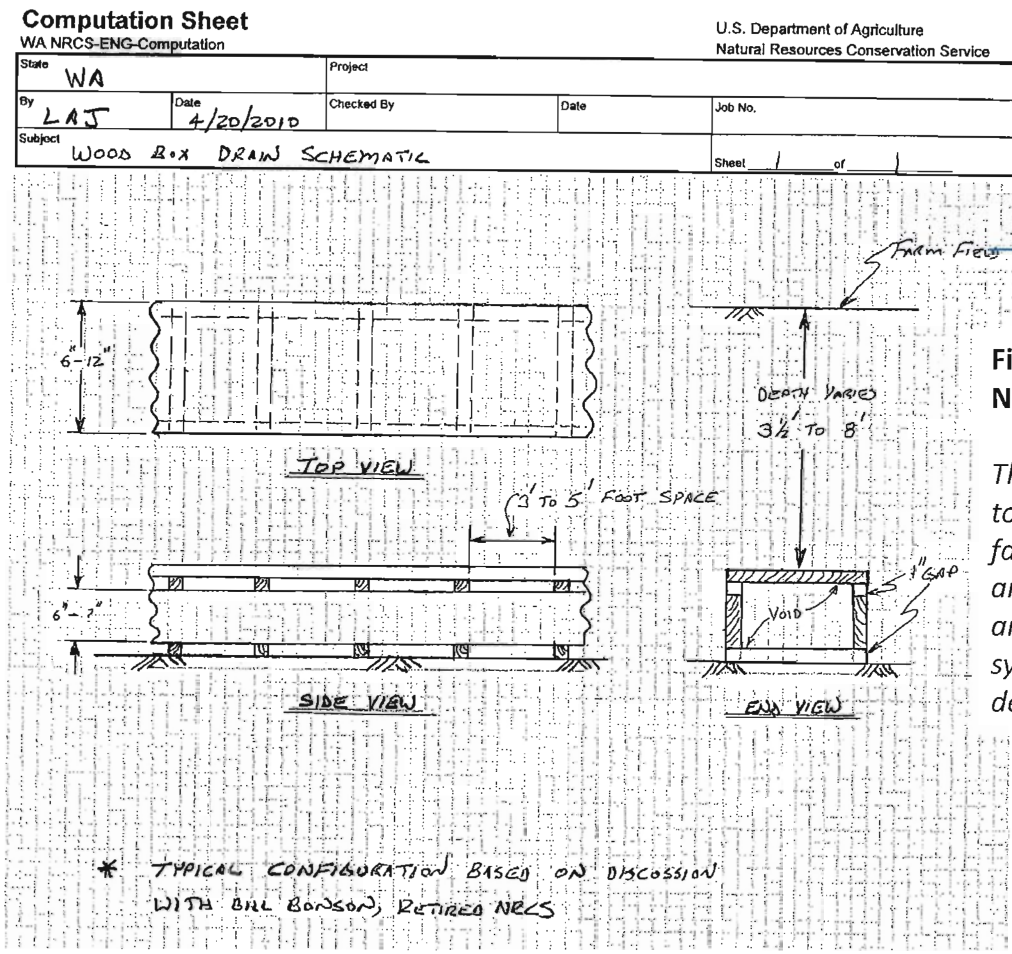
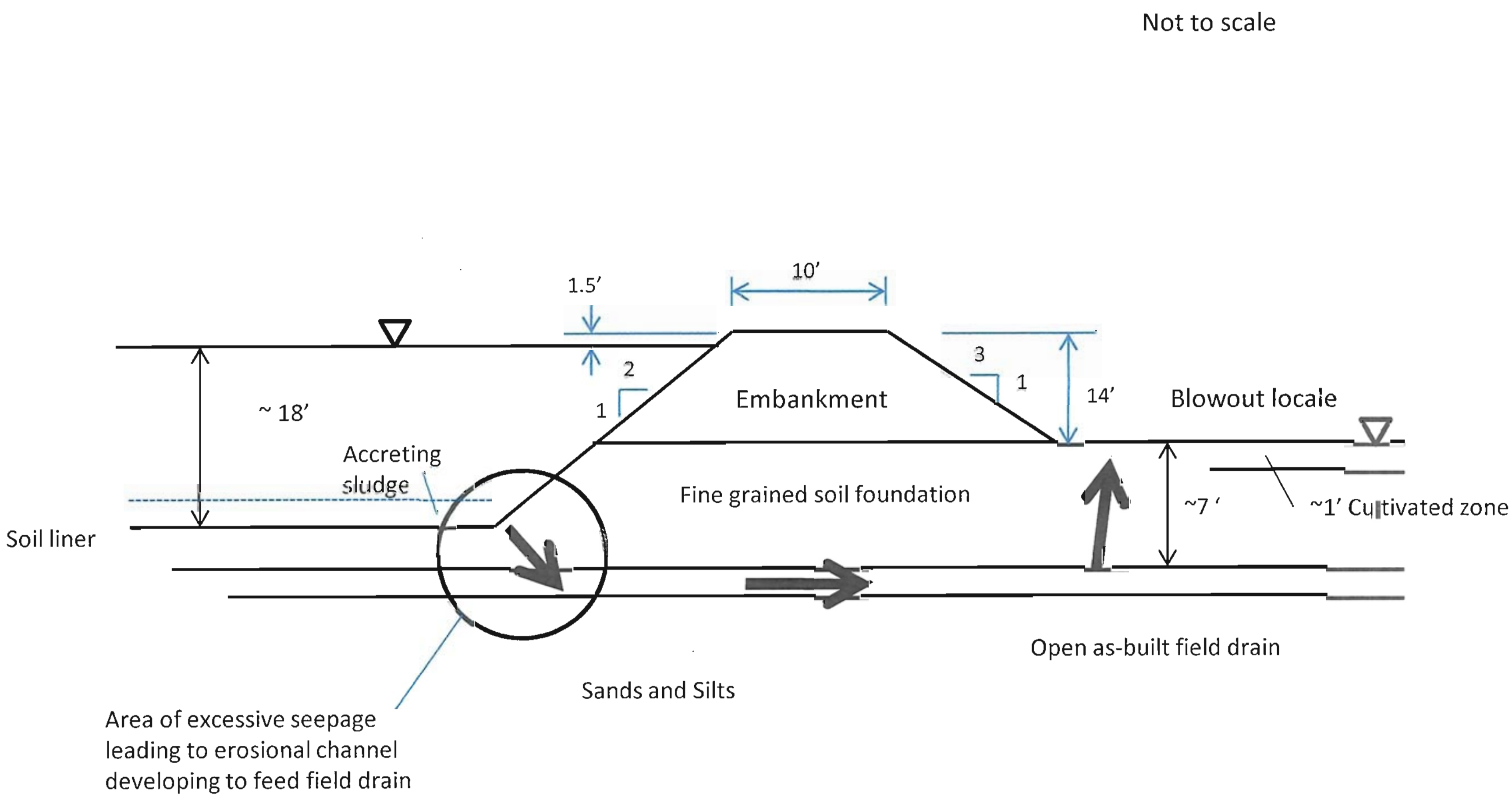


Figure provided by Larry Johnson State Conservation Engineer NRCS with the following comment:

The depth of these types of structure varies ranging from 3.5 feet to 8 feet. The depth is dependent on the distance the drained farm field is to the outlet. Fields that are drained are low and wet and constructing the drain sometimes required passing through areas that are not low. In order to maintain a free draining system and to maintain a positive drainage grade the excavation depth through dry areas was typically greater.

Typical Detail Buried Drain System Scheme from Period

Figure 3



Blow Out Pathway

Figure 4

APPENDIX A

Excerpts from NRCS documents provided in Freedom of Information Act request on information related to the French Slough Dairy Lagoon failure.

Identification of Items of Note in reviewing the submittal:

Design Report, dated 6/6/1995:

> Pg. 2, "*There are possibly as many as three subsurface drainage tilelines that may be within the pond area. The location of the tileline outlets, which exit into French Creek, are known. However, the exact location of the tilelines within the pond area is not known and will not be determined until construction. The tilelines will be relocated at least 25 feet outside of the pond area.*"
>
> Pg. 4, "The seasonal high water table was determined to be at an elevation of 7.8 feet (NGVD). The average excavation depth is 5.4 feet. The pond is to be excavated to an elevation of 7.8 feet and then have a compacted soil liner installed. The soil liner shall have a minimum compacted thickness of 1.0 feet." .... "The finished pond bottom grade, after liner, is 8.8 feet."

Construction Records, Testing\Quality Assurance:

> **Cooperator Notes: Dale Bartelheimer**, 9/18/96 (Ryan) "*Marty and I identified the location of the proposed waste transfer line and the outlet end of the two underground tile lines that will be removed.*"
>
> **Conservation Assistance Notes Continuation, 9/21/96**, (HK) "*Dale Bart. call ask if drain tile needed to be removed under pond ???? also. I told him yes. All tile shall be removed within 25' of outside toe per design.*"
>
> **Conservation Assistance Notes Continuation, 9/24/96**, (HK) "*On site excavation down to above liner depth. Soil is gritty, wet & heavy (?) mottling. Talk w/contractor Greg & we decide to ask Joe if we could raise bottom 6" due to soil wetness. Call Joe, he agree.*"

Conservation Assistance Notes Continuation, 9/27/1996, (HK) "*Concrete tile expose (water flow) on R.R. side of pond ADS pipe to replace on-site will be done next wk.*"

ECI Daily Field Report 9/27/96, "*At time of visit the contractor was excavating soil from what is going to be an organic waste lagoon. The excavated soil was being placed in approx. 1' – 2' thick loose lifts. The soil was only being wheel-rolled by equipment, the contractor stated a roller was on the way and he would compact all new fill with it before placing more fill. 2 density were conducted at two locations picked by the contractor.*"

Results showed initial compaction method inadequate and soil moisture contents that appear well over optimum. December 2, 1996 DSO letter objected to low densities obtained in filling operation (shut down for the winter). DSO comments passed on to French Slough Partners on December 20th & contractor in NRCS May 21, 1997 letter. Letter directed contractor to demonstrate satisfactory compaction prior to placing any additional fill.

Conservation Assistance Notes Continuation, 9/30/96, (HK) "*Approx. 80 (%) excavation to bottom of pond completed, digging down to 0.5' below proposed pond bottom, disking by farmer & smooth roller compaction. The 8 inch lift compacted to 6"* rest of text cut off and undecipherable. Ideally, two such lifts were constructed to total the 12 inch constructed thickness – NRCS asked to provide unreadable test.

Cooperator Notes: Dale Bartelheimer, 10/7/96 (Ryan) "*We did not see pieces of concrete tile that should have been removed, so I asked Herb to double-check to make sure they were taken out. I will also ask Dale if anyone at the farm saw it being removed.*" No statement found that cited Dale's response or noted a stockpile of unsuitable concrete tile.

Conservation Assistance Notes Continuation, July 23, 1997, (HK) "*Proctor tests were modified & not standard which will raise proctor test above 95 & meet. Good.*"

Appendix B - French Slough Failure

Jerald LaVassar & John Blacklaw

April 2010

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
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MEMORANDUM

April 23, 2010

To: File

FROM: Jerald LaVassar & John Blacklaw, DSO

SUBJECT: April 13th Site Visit to Failed French Slough Wastewater Pond; SN07-0651

This memorandum is divided into two parts: 1) An informational pre-site visit meeting, and 2) the site visit. The second part describes our observations of field conditions, cites preliminary factors that appear to have contributed to the breach, and outlines future steps to narrow the likely causes that led to the failure. As is common in earthen failures, the breaching process washes away much of the critical evidence that would aid in identifying the actual failure mechanism.

MORNING MEETING

We arrived at the offices of the Snohomish Conservation District (SCD) at 10:00 AM. The meeting commenced shortly thereafter. An attendees list is attached as Appendix C.

The gathering was told that the facility was visited by one of the Bartelheimer brothers (the farm's operators) on April 11th around 11:00 AM. The impoundment was functional at that time. Around 11:00 AM on the 12th, Jason Bartelheimer received a call from a third party alerting him to foam exiting a buried tile drain outlet. The Bartelheimers notified the National Resource Conservation Service (NRCS) and the SCD staff of the failure. Representatives of the NRCS were on-site that afternoon. Erica Fifer was one of that party and she estimated the impoundment breach released some 15 million gallons. An unknown fraction of that release entered French Creek through an existing system of field drains that pass through the footprint of the creek dike.

The NRCS staff outlined the steps the Bartelheimers have taken to notify the agencies involved in public health protection. This included notifying the Department of Health and the Water Quality (WQ) Office of Ecology. The NRCS understands that Ecology's WQ Dave Garland had agreed to inform the appropriate people at the Department of Fish & Wildlife. Water quality downstream was being monitored for pollutant levels that could impact public health, fisheries, and the shellfish beds at the mouth of the river.

The question was raised as to what additional steps could be taken to minimize any further releases of animal waste into French Creek. Erica stated that the animal waste stream normally entering the impoundment had already been diverted to another animal waste storage facility. Land application of effluent had been shifted to areas that do not drain towards the Creek dikes. Further discussions as to what measures could be taken by the NRCS and the SCD were tabled until the party could tour the site and observe conditions first hand.

Information presented by the NRCS and or shown on the plans included the following:

1) The impoundment design was developed by the NRCS. The design was submitted to the Department of Ecology Dam Safety Office (DSO) and approved by the DSO in May 1996. Construction commenced in 1996 and was completed in 1997.

2) One of the principal sources of borrow to construct the embankment came from the area a short distance to the west of the impoundment extending near to the Burlington Northern Santa Fe Railway embankment. That depressed area is now receiving waste that apparently is feeding one of the "tilelines" that discharges to French Creek.

3) Plan Sheets 2 & 3 (see Figure A1 of Appendix A) show existing "tilelines" that passed through the dike footprint in the northeast and southwest arcs of the circular embankment (well away from the breach area). Note 8, Plan Sheet 2 (see Appendix B) stated, "Any existing tilelines extending into the proposed pond area shall be removed at least 25 feet outside of the proposed pond area ….".

4) NRCS personnel observed elements of the construction along with two site visits by Ecology's Dam Safety Office staff.

5) Following the breach NRCS's preliminary review of construction records found a reference to the discovery and removal of a drain(s?) from the dike perimeter. It was our sense that the NRCS believed this drain(s) was found well away from the actual breach site. As of the 11^{th} the NRCS stated that it was their understanding that this drain had not been found on the opposite side of the embankment footprint. Again, it was our sense that NRCS staff felt that the "opposite side" of the embankment could have included the section that breached. The above records were not made available to us due to NRCS protocols at this early stage in the investigative process.

6) The drain of Note 5 above was considered important to understanding the failure as dimensioned lumber was found strewn in the debris field of the breach, see Appendix A Figure A2. Again we were not given particulars as to their source, but NRCS staff

believe that a buried wooden underdrain system was constructed in the immediate area in the 1940s, see Figure A3 for a depiction of such an installation typical of the period.

7) The breach occurred a few tens of feet counter-clockwise from the Spillway, see attachment French Creek Plan Sheet 3. This Plan Sheet shows no buried "tilelines" running anywhere near the breach site, see Figure A1.

Following the briefing, the parties drove to the farm to observe firsthand the failure.

SITE VISIT

We arrived at the edge of the farm property around noon; the weather was cold and rainy. We hiked in through foot high grasses. Muck left by the failure was visible at the base of the grasses within a few hundred feet of the end of the access road. The muck thickened and shallow pools of standing fluid were encountered as we traversed the remaining ¼ mile to the impoundment breach. The Bartelheimers had set a pump system to move liquids reaching the depressed borrow site. It appeared that a light duty dozer was pushing up a low dike to channel surface flows moving towards the borrow area to the pump. The liquids were pumped a few hundred feet where they spilled onto the ground. Grade in the discharge area was such that it conducted flow to the north northeast away from the borrow area. The discharge area was marked by a large mound of foam.

At the embankment we observed local areas on the downstream face and crest where burrowing animals have been active, see Figure A4. The mouths of the larger observed animal runs were on the order of 0.2 foot in diameter. Extensive reaches of the crest and portions of the downstream face showed evidence of having supported a dense growth of blackberries. The vines appeared to have been cut down and chopped up in the recent past and left where they fell.

The high effluent level in the pond appeared to have exceeded the invert elevation of the emergency spillway in the not too distant past. This opinion was based on the solids deposited out of the flow as much as some 2 inches above the invert elevation of the spillway at the control section, see Figure A5. Assuming the plan details were accurate, the distance between the control section of the spillway and the crest was some 15 to 16 inches. Accordingly, visual evidence indicates the maximum pool level was probably within 12 inches of the dike crest here. Locally, the crest showed evidence of having had shallow surface flow across its surface at a few spots typically on the north to northeasterly section. It was our opinion that this flow represented wind driven waves splashing up on to local, slightly depressed reaches of the crest. A visual inspection of the high pool mark around the pond was consistent with such an elevated pool. Further, while complicated by the presence of grasses and the remnants of vines, it appeared the dike crest elevation was relatively uniform. That could reflect minimal settlement since construction or relatively uniform settlement. This assessment will be checked once the embankment is surveyed.

The breach was visually estimated to be some 60 ft. wide at the crest level and some 20 ft. wide at the mud line see Figure A6. The right breach sidewall (looking out of the pond) was near vertical with a free standing height of some 14 ft, Figure A7. The exposed cross-section showed a cap of dark organic matter on the upstream face some 12 inches thick. A separate compacted soil liner facing, separate and distinct from the remainder of the embankment could not be visually discerned on the interior 2H on 1V sideslope above the mud line. One could distinguish a few lift lines within the embankment. Animal runs were not observed on this face.

On the left side of the breach Figure A8, the original breach wall had likely been near vertical. However, at some point there was a secondary failure of a roughly 10 ft. thick slab of the cross-section into the breach. That secondary slab failure appeared to have occurred with the base dropping and moving towards the right side into a scour hole that likely developed during the course of the dam breach flood. We were able to get closer to the backside of the secondary block failure and as a consequence we were able to discern what appear to be lift contacts more definitively. The secondary failure block exhibited near vertical cracks likely induced in the process of moving and coming to rest.

The soils exposed on the breach sidewalls were gray and brown fine grained soil composed of silt and clay. These soils were judged to possess medium plasticity although we did not do any field index testing while on site. The fill had local inclusions of mottled, cobble sized fragments of more plastic fine grained soils. We did not observe any pervious sandy seams embedded within the fine grained fill. Occasional well rounded gravels were observed encapsulated within the fine grained soil matrix. Even with the embedded gravels, the soil matrix was judged to have a suitably low permeability to minimize seepage losses.

The debris field limits covered a wide area. The debris field surface was littered with pieces (we observed at least 15) of dimensioned lumber 11½" deep by $1^7/_8$" thick, Figure A2. The lengths of lumber fell into two classes, those some 2 feet in length and those 10 to 20 feet in length. The roughly 2 ft. lengths of wood seemed to be spread over the greatest distances. The thickness of the dimensioned lumber suggests the wood was milled decades ago. Yet, the wood was typically judged to be in a sound condition even though wet. This suggests the lumber comes from a depth below the seasonal fluctuations in the ground water surface. Constant submergence can dramatically decrease the rate at which wood deteriorates.

This lumber was partly embedded within relatively uniform, clean fine sand, Figure A2. Visually, that sand was starkly different from the soils (clay and silt) and muck of the majority of the breach. All five of the Test Pits, Figure A9, excavated in developing the impoundment plans encountered silty SAND (SM) at depths variously a foot or two above the elevation of the base of the pond to depths typically less than 4 ft below the pond base. The surface of the silty SAND equates to a minimum depth of 3 feet to a more typical 7 foot depth below field grade, Figure A10. Jason Bartelheimer related a story his father told him of being 8 and seeing mounds of sand produced in excavating for the underdrains back in the 1940s. Jason's father reportedly described the sands as seeming to sparkle in the sun which had prompted him to ask if there might be gold in the piles. Aside from the sand exposed in the debris field, we observed no surface exposures of such sands. The observed lumber and associated sand again suggest the possibility that a blow out of the impoundment occurred with at least a portion of its length down the wooden underdrain system that dates back to the 1940s. Conversely, we could not come up with a plausible alternative explanation that would account for the observed sound, wet, aging lumber's presence in the debris field.

As previously noted the interior pond slope is relatively steep, 2H on 1V. Even so, the slope did not exhibit visual evidence that sliding of the surface extended below the accumulated organic waste on the surface. We asked Erica to check on the interior pond slope stability in her site visits over the coming days. A delayed slope failure could occur as the embankment soils undergo a stress change as pore water pressures readjust to the drop in the pool.

In driving back to the Olympia, we drafted a list of follow-up steps to hopefully improve our understanding of what is the likely cause of the failure. The list included the following:

1) Survey the crest to understand the pattern of relative crest settlements and all that implies as to the likelihood of embankment cracking.

2) Identify the maximum elevation of the pool as judged from the debris in the spillway and the observed high water ring around the interior slope.

3) Excavate a series of test pits near the mouth of the breach to assess foundation conditions and to see if there is indeed a buried underdrain in the vicinity of the breach.

A PowerPoint file is attached illustrating observations and comments cited above.

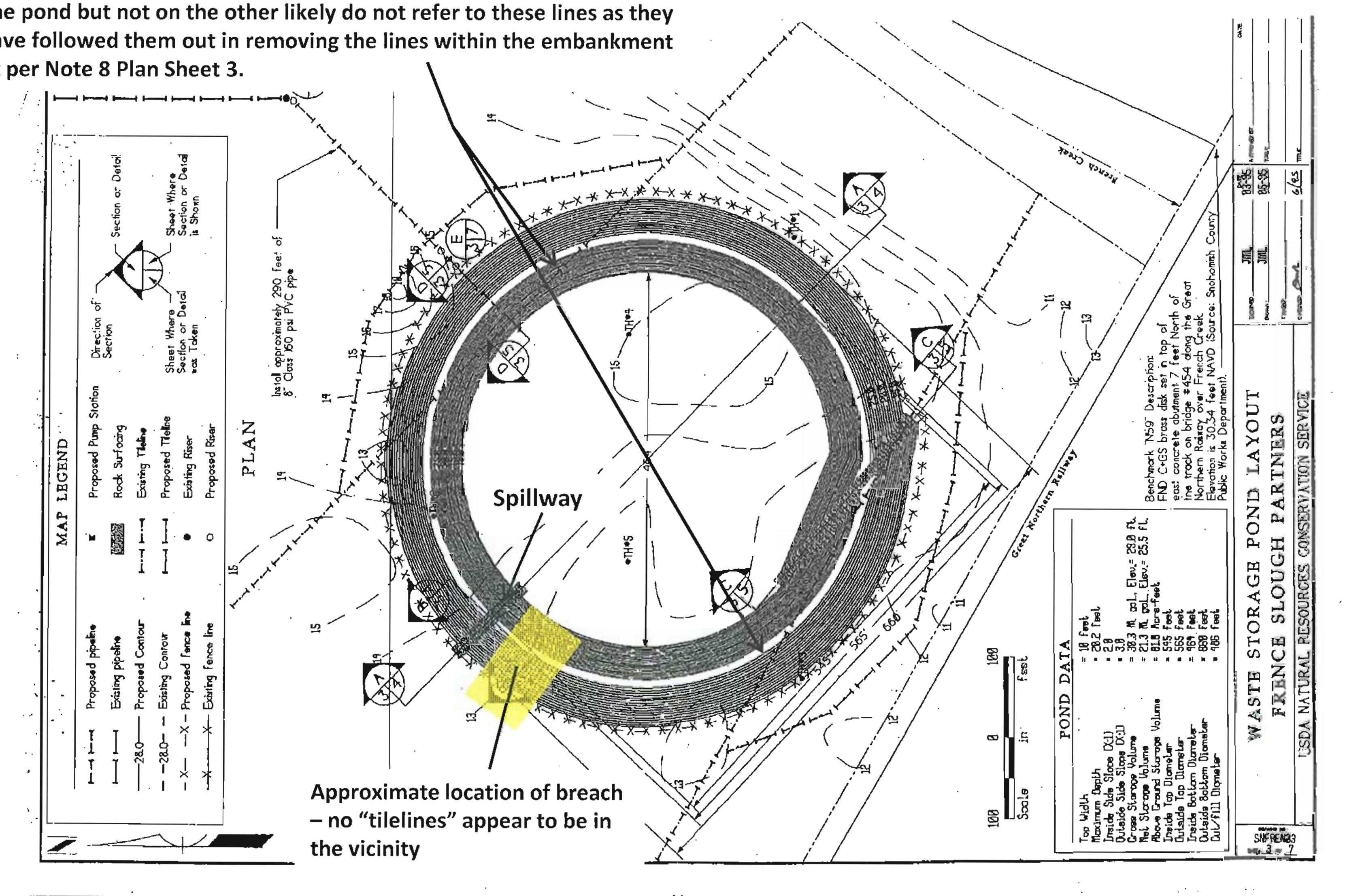
Attachments: Appendix A- French Slough Failure.pptx
Appendix B – DSO's copy of the As-built plans
Appendix C - Attendees list

Appendix A - French Slough Failure

Jerald LaVassar & John Blacklaw

April 2010

The plans call for removal and rerouting of the "tilelines" around the impoundment. The comments LaVassar heard about finding the drains on one side of the pond but not on the other likely do not refer to these lines as they would have followed them out in removing the lines within the embankment footprint per Note 8 Plan Sheet 3.



Source: As-built Plans NRCS Sheet 3 Plan View.

Plan View Showing "Tilelines" & Breach Area

Figure A1

Exposed lumber presumably from drain

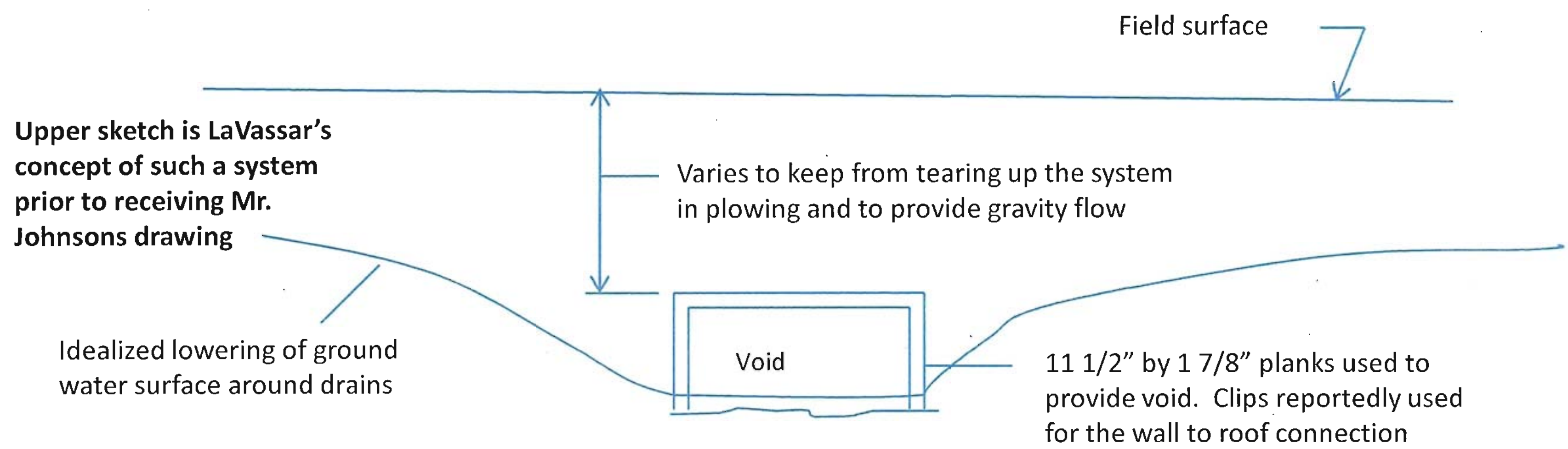
Deposits of fine uniform sand and exposures of fine to coarse rounded gravels adjacent to the buried lumber

Presumed remnants of buried drain

Sand Deposits in the Breach Flood Path

JML April 2010

Figure A2



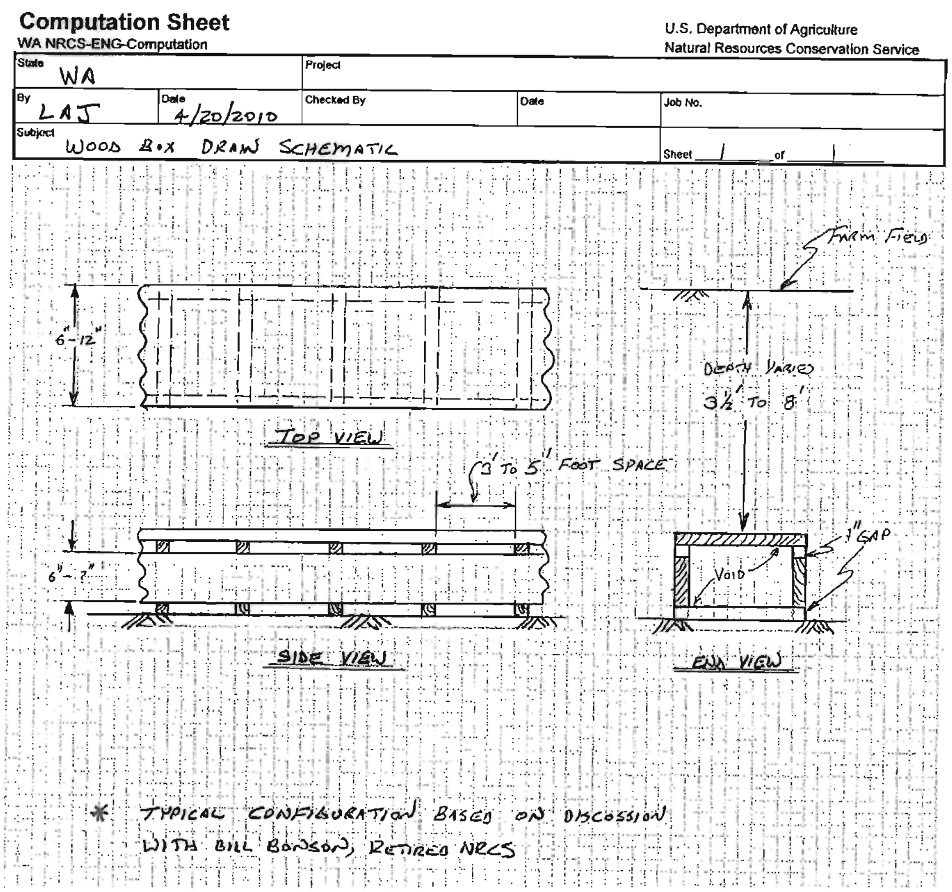


Figure provided by Larry Johnson State Conservation Engineer NRCS. He provided the following comments:

The depth of these types of structure varies ranging from 3.5 feet to 8 feet. The depth is dependent on the distance the drained farm field is to the outlet. Fields that are drained are low and wet and constructing the drain sometimes required passing through areas that are not low. In order to maintain a free draining system and to maintain a positive drainage grade the excavation depth through dry areas was typically greater.

French Slough

Typical Detail Buried Drain System Scheme from Period

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Figure A3

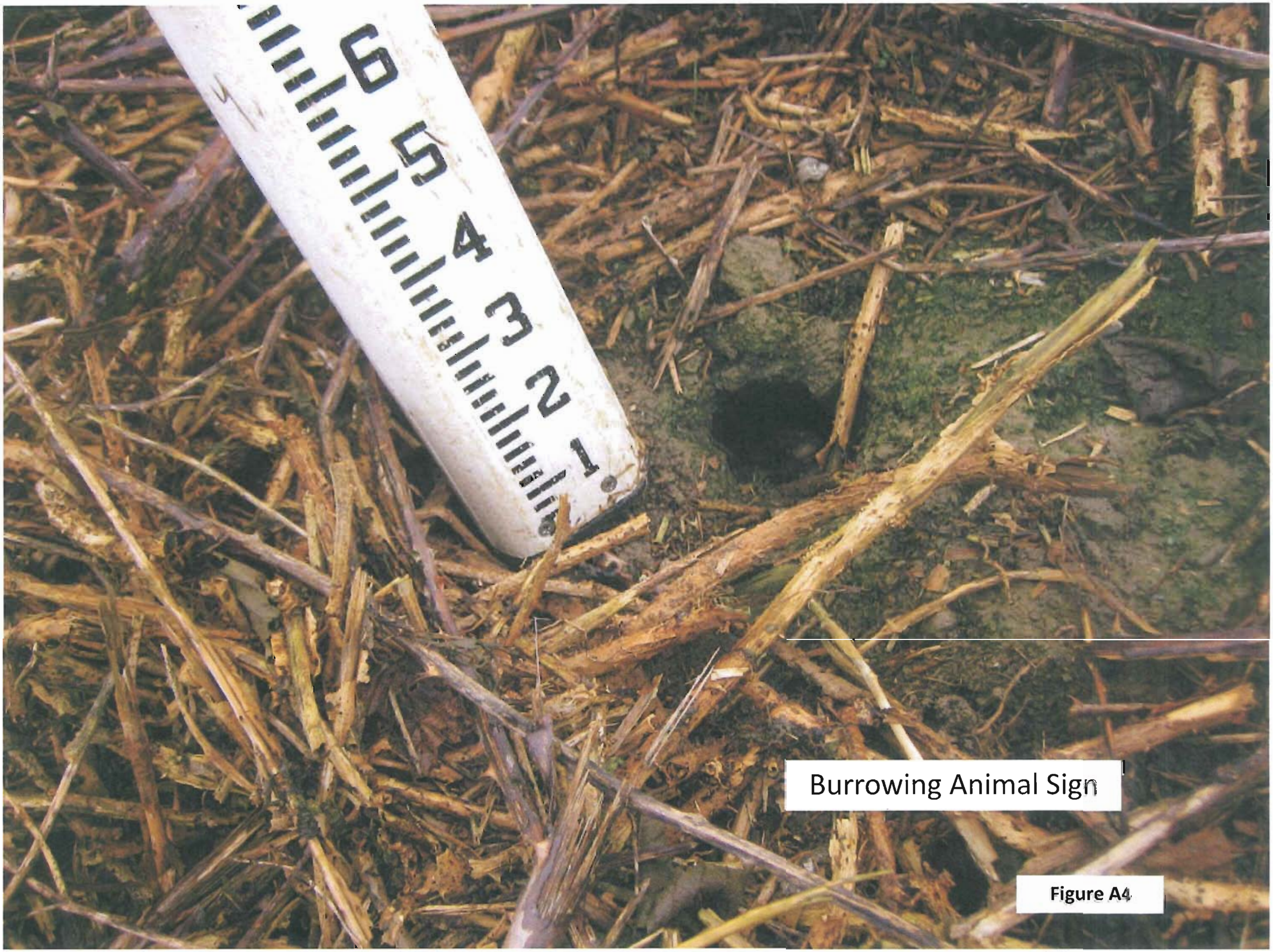
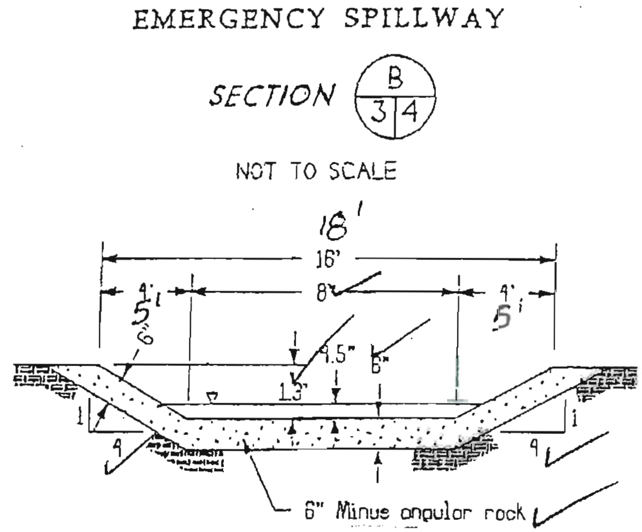


Figure A4



Source: As-built Plans NRCS Sheet 4 Section B.

Spillway Detail

Figure A5

View Out Breach

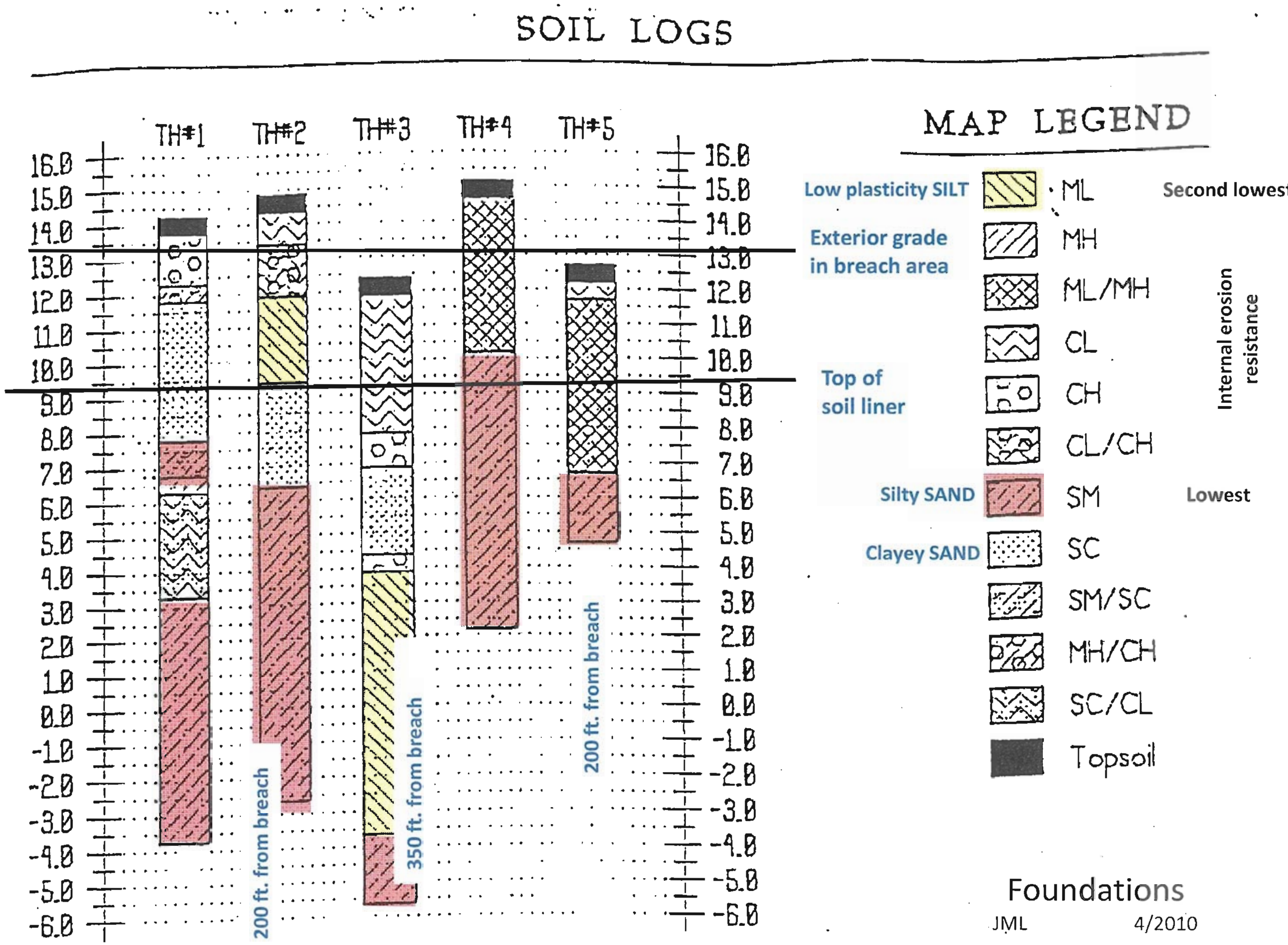
Figure A6

Right Breach Sidewall

Figure A7

Left Sidewall of Breach

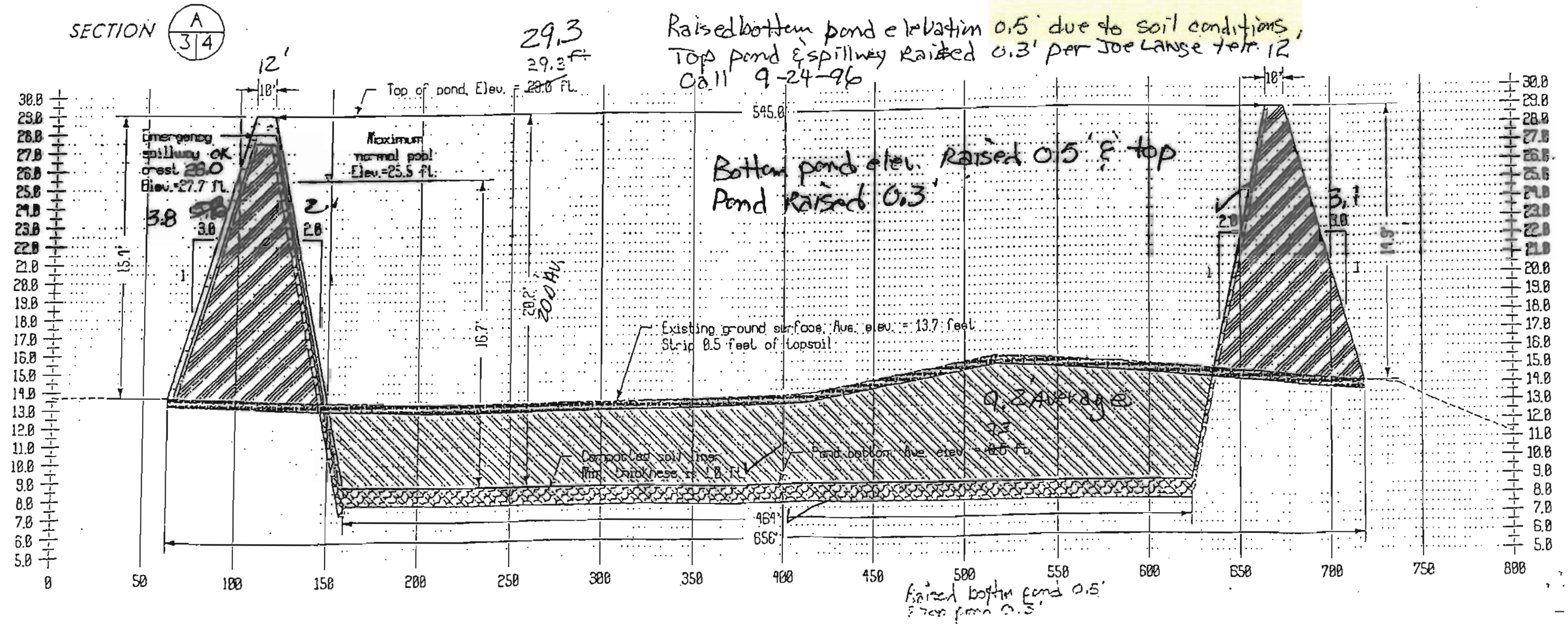
Figure A8



Source: Plan Sheet 4 As-built Plans, NRCS, dated 9/18/1997 with highlights & notes added by LaVassar

Figure A9

Source: As-built Plans NRCS Sheet 3 Section A.



Questions & Observations:

1) A hand written note states the pond bottom was raised *"0.5 ' due to soil conditions"*. Ideally, the construction record identifies what soil conditions prompted that change.

2) The compacted soil liner is shown extending up the 2H on 1V interior pond sideslopes. Compacting this facing zone would have been a challenge. We can come up with schemes to do it, but they involve variously overbuilding the zone, bringing it up coincidently with the adjacent section of the fill, yo-yoing a roller up the slope, or using a compactive plate hung off a backhoe boom. Again, ideally the construction records describe what was actually done.

As-built Cross-Section

Figure A10