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Northwest Florida Water Management District
c/o Mr. Tony Countryman
via electronic correspondence

December 14, 2017

Re: Discrete Interval Water Quality Sampling – Memorandum Report of Logging and Analysis Results

Dear Mr. Countryman:

As requested, Jim Stidham & Associates (JSA) has contracted with Trinity Analysis & Development Corp. (Trinity) to provide Professional services for the task of Discrete Interval Water Quality Sampling. The purpose of this research has been to evaluate the current position of the saltwater interface along the coast of Santa Rosa, Okaloosa, and Walton Counties. The Northwest Florida Water Management District identified eleven wells, ranging in depth from 521 to 1,371 feet, as targets for investigation **(See Map: Discrete Interval Sampling Locations with Interpreted Depths to the Potable Interface)**. The results are provided in the **Table 1** of this Memo Report. Additional details are provided in **Table 2** of the attached files from Trinity. The associated tasks are summarized briefly here:

Tasks

Well Logging

- Measurement of the static water level from an established point prior to logging.
- Vertical geophysical logging of the open-hole interval of the well for fluid conductivity profiling to identify a potential saltwater interface.
- In cooperation with the NWFWMD, the results of the logging profiles were distributed for the consideration of sample collection based on the conditions encountered.

Discrete Sampling

- If no interface was suspected, then a single sample was collected based on specific conductance or fluid conductivity response as directed by the District.
- If an interface was suspected, then two samples were collected. One sample was collected from above and the second sample collected from below the interface at the District's direction.
- A YSI 556 multi-meter was utilized to determine pH and specific conductance of the collected samples in the field. Laboratory analysis was performed to determine the concentrations of sodium (Na), chloride (Cl-), and Total Dissolved Solids (TDS).
- Details of methodology are provided in the attached supporting documents provided by Trinity.

Reporting

- Field and lab results have been tabulated and summarized in this memo report.
- Total dissolved solids (TDS), chloride and sodium, by analysis, were utilized to interpret the presence of a saltwater interface (based on potable water standards FAC 62-550).
- A more detailed tabulation of results is provided in Table 2 of the attached documents.
- Geophysical logs, WellCAD, and Laboratory Analysis Reports data files are being provided electronically.

JSA sub-contracted the field work portion of this investigation to Trinity Analysis & Development Corp. Trinity has provided a description of their methodology in the attachments. JSA has managed the NWFWMD contract, as well as, coordinated with the field personnel for scheduling activities and confirmation of target sample intervals. Trinity has provided the data, field notes, processed logs and laboratory reports for compilation and delivery in this memo report.

Defining the Saltwater Interface

A saltwater interface is a zone of transition between freshwater and saltwater within an aquifer. The U.S. Geological Survey defines "freshwater" as having less than 1000 mg/L of dissolved solids. For the purpose of potable drinking water standards, 500 mg/L is the acceptable limit. The interpretation of the presence of a saltwater interface in this report has been based on the direct analysis of Total Dissolved Solids, Sodium and Chloride in the samples collected in comparison to primary and secondary potable drinking water standards of FAC 62-550. Specifically, the results have been compared to the standards of 500 mg/L TDS, 160 mg/L sodium, and/or 250 mg/L chloride for potable quality.

Summary of Results

During the course of the field activity, all of the eleven (11) study wells were visited. However, an obstruction within well 7767, at a depth just below the well case, prevented that well from being logged further and no sample was collected there. The remaining ten (10) wells were all successfully logged. Due to time and access constraints, well 3209, located within the Eglin Air Force Base, was not sampled. Ultimately, nine (9) wells were fully logged and had at least one sample collected from the open-hole portion. Conditions at each well are discussed briefly below.

NWF ID 1376 – NWFWMD West Hewett (Upper Floridan):

10/25/2017 Logs indicated water quality was fairly uniform throughout the open-hole interval. The water quality probe was fouled upon tagging bottom of the borehole at 707 feet below land surface (bls); 18 feet shallower than originally reported. The up-run verification was questionable. Logs from a previous examination in 2015 were compared to the current run and confirmed the uniform nature of the water quality within the borehole. Logs did not suggest an interface or significant transition zone within the open borehole. One sample was collected at 690 feet bls, within the depth interval of highest fluid conductivity per sampling criteria.

The field conductivity value recorded at the sample depth was 869 µS/cm. The laboratory analyses of TDS, sodium and chloride were 478 mg/l, 142 mg/L, and 171 mg/L respectively. None of these results exceed potable drinking water standards. Given the absence of a distinct transition of fluid resistivity and no analysis results exceeding potable standards, it is interpreted that an interface at this location was not present within the open-hole interval. However, the results of the analyses, for the sample collected from near the bottom of the well, are approaching potable standards. Based on this information, the interface is interpreted to exist below the total depth of the logged open-hole interval, or, greater than 707 feet bls.

NWF ID 1696 – OCWS ISL-1 (Upper Floridan):

10/30/2017 Logs indicated a subtle transition in water quality with depth, with a trend starting at about 626 feet bls and continuing to 860 feet bls. The bottom of the open-hole interval was tagged at 860 feet bls; 30 feet shallower than originally reported. Per the sampling criteria, one sample was collected above the transition at 580 feet bls and below the transition at 840 feet bls (near the bottom of the open-hole interval).

The field conductivity value recorded at the upper sample depth was 531 µS/cm. The field conductivity value recorded at the lower sample depth was 559 µS/cm. The laboratory analyses of TDS, sodium and chloride were 334 mg/l, 131 mg/L, and 63.1 mg/L respectively in the upper sample, and, 345 mg/L, 126 mg/L and 62.7 mg/L, respectively in the lower sample. None of these results exceed potable drinking water standards and no sudden decrease in fluid resistivity was observed. Based on this information, the interface is interpreted to exist below the total depth of the logged open-hole interval, or, greater than 860 feet bls.

NWF ID 3209 – EAFB Field #4 Supply Well #2 (Upper Floridan):
10/17/2017 Logs were run but no sample was collected due to the time restriction associated with site access. The fluid resistivity log indicated results that were uniform throughout the open-hole interval. The bottom of the open-hole interval was tagged at 578 feet bls; 12 feet shallower than originally reported.

Given the uniform level of resistivity throughout the open-hole portion of the well, and, the relatively low conductivity value of 260 µS/cm to 270 µS/cm, it is interpreted that the entire interval of the open hole is fresh water. Therefore, the saltwater interface is anticipated to exist below the total depth of the logged open-hole interval, or, greater than 578 feet bls.

NWF ID 3210 – EAFB Field #4 Lower Floridan Monitor Well:
10/16/2017 & 10/17/2017 Due to an obstruction, the logging tool was unable to advance below 955 feet bls. The remaining open-hole interval was not logged. A review of logs and video run in 2015 showed the borehole diameter reduces from 8-inch to a well-gaged 4-inch between 955-960 feet bls and the borehole is off-center. The logs from 2015 also showed that the water quality was fairly uniform throughout the open-hole interval. Trinity was directed to collect two samples, if possible, to verify the uniformity observed in the 2015 log. Trinity was able to lower the sampler past the restriction and the bottom of the open-hole interval was tagged by the sampler at 1,130 feet bls; 241 feet shallower than originally reported. A sample was collected near the bottom of the borehole at 1,125 feet bls. Another sample was collected at 950 feet bls, just below the bottom of the casing depth of 935 feet bls.

The field conductivity value recorded at the upper sample depth was 2,345 µS/cm. The field conductivity value recorded at the lower sample depth was 2,196 µS/cm. The laboratory analyses of TDS, sodium and chloride were 1,240 mg/l, 466 mg/L, and 626 mg/L respectively in the upper sample, and, 1,240 mg/L, 478 mg/L and 622 mg/L, respectively in the lower sample. The analysis results from both sample points exceed potable drinking water standards. Because the upper sample was collected from just below the casing depth of the well and the analysis values exceed those for potable standards, as well as fresh water limits, the interface is interpreted to exist above the cased depth of the well. That depth at this location is 935 feet bls or less.

NWF ID 7174 – DWU MO#2 (Lower Floridan):
10/27/2017 Logs indicated a subtle transition in water quality with depth, with a trend starting at about 970 feet bls and continuing to 1,083 feet bls. The bottom of the open-hole interval was tagged at 1,083 feet bls. Per the sampling criteria, one sample was collected above the transition at 955 feet bls (below the bottom of the casing at 920 feet) and below the transition at 1,070 feet bls (near the bottom of the open-hole interval).

The field conductivity value recorded at the upper sample depth was 3,495 µS/cm. The field conductivity value recorded at the lower sample depth was 11,574 µS/cm. The laboratory analyses of TDS, sodium and chloride were 1,340 mg/l, 738 mg/L, and 708 mg/L respectively in the upper sample, and, 7,700 mg/L, 5,540 mg/L and 4,240 mg/L, respectively in the lower sample. The analysis results from both sample points exceed potable drinking water standards. Because the upper sample was collected from just below the casing depth of the well and the analysis values exceed the limits for potable standards, as well as fresh water limits, the interface is interpreted to exist above the cased depth of the well. That depth at this location is 920 feet bls or less.

NWF ID 7183 – SWUC West Monitor (Upper Floridan):
10/20/2017 & 10/24/2017 Logs indicated a high-resistivity feature around 550 feet bls with an abrupt transition in water quality at the base of the feature. The bottom of the open-hole interval was tagged at 698 feet bls. Per the sampling criteria, one sample was collected above the transition at 520 feet bls (below the bottom of the casing) and below the transition at 575 feet. A third sample was collected near the bottom of the open-hole interval at 660 feet bls.

The field conductivity values recorded from the upper to the lower sample depths were 313 µS/cm, 1,345 µS/cm, and 4,342 µS/cm, respectively. The laboratory analyses of TDS, sodium and chloride were 160 mg/l, 25.6 mg/L, and 18.1 mg/L respectively in the upper sample at 520 feet bls. The middle depth (575 feet) results were 173 mg/L, 121 mg/L and 112 mg/L, respectively. The sample results from the lowest depth (660 feet) were 192 mg/L, 33 mg/L and 25.6 mg/L, respectively. None of the analysis results from any of the three sample points exceed potable drinking water standards. These results, although uniform, were not in general agreement with the predicted concentrations based on the elevated conductivity values. The reason for this is not immediately understood and the results of the bottom sample are suspect. As a note, laboratory quality assurance samples were collected during sample tasks of this well. The results, described later, showed good agreement between split sample analyses. Interference or probe signal response to an analyte which was not analyzed is a possible cause for the resistivity/conductivity values.

Although the conductivity values suggest a transition in water quality within the open hole, the analytical results did not confirm that condition. Because the deepest sample was collected near the total depth of the well and the analysis values do not exceed the limits for potable standards, the interface is interpreted to exist at a depth greater than the total depth of the logged open-hole interval, or greater than 698 feet bls.

NWF ID 7349 – SWUC East Monitor (Upper Floridan):
11/08/2017 Logs indicated a subtle transition in water quality with depth, with a trend starting at about 440 feet bls and continuing to 600 feet bls. The bottom of the open-hole interval was tagged at 600 feet bls. Per the sampling criteria, one sample was collected above the transition at 440 feet bls (below the bottom of the casing at 425 feet bls) and below the transition at 590 feet bls (near the bottom of the open-hole interval).

The field conductivity value recorded at the upper sample depth was 325 µS/cm. The field conductivity value recorded at the lower sample depth was 971 µS/cm. The laboratory analyses of TDS, sodium and chloride were 188 mg/l, 28.1 mg/L, and 24.8mg/L respectively in the upper sample, and 530 mg/L, 167mg/L and 201 mg/L, respectively, in the lower sample. The analysis results from the upper sample point do not exceed potable drinking water standards. Conversely, the results for TDS and sodium do exceed drinking water standards in the lower sample interval. For these reasons, it is interpreted that the

transition from fresh, potable water to saline conditions is at a depth within the open-hole portion of the well. Straight line interpolation was applied between sampling depths and normalized to 500 mg/L TDS to estimate the depth to the interface as follows:

Depth of interface (D_I) = $Z_2 – ((Z_2-Z_1)/(C_2-C_1)*(C_2-500\ mg/L))$
Where:
Z = depth in feet
C= concentration of TDS in mg/L
1 = designates upper sample
2 = designates lower sample

Or, D_I = 590' – ((590'- 440')/(530 mg/L-188 mg/L)*(530 mg/L-500 mg/L)) = approx. 575 feet bls.

Considering the bottom sample results were just at the drinking water standard for TDS and sodium and the fluid resistivity log indicates a non-linear transition in water quality, the interface is estimated to be closer to the sampling depth based on the break in the resistivity curve (approximately 588 feet bls).

NWF ID 7686 – NWFWMD Tiger Point (Upper Floridan):
11/01/2017 & 11/02/2017 The logging tool was unable to advance below 1,228 feet bls. Trinity made several attempts to get past the unknown obstruction. The remaining open-hole interval below that depth was not logged. The total well depth of 1,306 feet was obtained during a previous log run in 2015. The current logs indicated a subtle trend in water quality starting at the top of the open-hole interval at 1,135 feet bls and continuing down to the obstruction. However, since total depth was not achieved only one sample was collected at 1,205 feet bls, near the bottom of the logged interval.

Fluid resistivity and conductivity results are fairly uniform from the bottom of the well case to the total traveled depth. The field conductivity value recorded at the sample depth was 2,647 µS/cm. The laboratory analyses of TDS, sodium and chloride were 1,210 mg/l, 593 mg/L, and 473 mg/L respectively. All of these results exceed potable drinking water standards and TDS results suggest saline conditions are present. Due to this water quality and the uniform resistivity throughout the borehole, it is concluded that this well may be cased below the depth of the saltwater interface at this location. The interface is estimated to be shallower than 1,135 feet bls.

NWF ID 7751 – Seagrove Deep (Upper Floridan):
09/28/2017 & 10/18/2017 The first attempt to log and sample this well was incomplete due to calibration issues with the logging probe. The well was re-logged and sampled on 10/18/2017. Logs did not indicate a significant transition zone within the open borehole. The bottom of the open-hole interval was tagged at 628 feet bls; 17 feet shallower than originally reported. One sample was collected at 620 feet bls, within the depth interval of highest fluid conductivity response per sampling criteria.

The field conductivity value recorded at the sample depth was 3,438 µS/cm. The laboratory analyses of TDS, sodium and chloride were 2,040 mg/l, 659 mg/L, and 1,010 mg/L respectively. All of these results exceed potable drinking water standards and TDS is greater than fresh water limits. Due to this water quality and the uniform resistivity throughout the borehole, it is concluded that this well may also be cased below the depth of the saltwater interface at this location. The interface is estimated to be shallower than 538 feet bls.

NWF ID 7767 – SWUC Burnham Road (undifferentiated Upper Floridan):
10/19/2017 An obstruction was encountered at approximately 237 feet bls (about 20 feet out of casing). After several attempts to advance the tool, we were not able to log or sample this well.

NWF ID 9137 – DWU MO#1 (Upper Floridan):
10/26/2017 Logs indicated a moderate stair-step transition in water quality from about 600 feet to 648 feet bls. The bottom of the open-hole interval was tagged at 648 feet bls; two feet shallower than originally reported. Per the sampling criteria, one sample was collected above the transition at 495 feet bls (below the bottom of the casing at 488 feet) and below the transition at 640 feet bls (near the bottom of the open-hole interval).

The field conductivity value recorded at the upper sample depth was 308 µS/cm. The field conductivity value recorded at the lower sample depth was 910 µS/cm. The laboratory analyses of TDS, sodium and chloride were 163 mg/l, 25.9 mg/L, and 8.1 mg/L respectively in the upper sample, and, 556 mg/L, 66.9 mg/L and 30.5 mg/L, respectively in the lower sample. The analysis results from upper sample point do not exceed potable drinking water standards. Conversely, the results for TDS do exceed drinking water standards in the lower sample interval. For these reasons, it is interpreted that the transition from fresh, potable water to saline conditions begins at a depth within the open-hole portion of the well. Straight line interpolation was applied between sampling depths, and normalized to 500 mg/L TDS to estimate the depth to the interface as follows:

D_I = 640' – ((640'-495')/(556 mg/L-163 mg/L)*(556 mg/L-500 mg/L)) = approx. 620 feet

Considering the bottom sample results were just at the drinking water standard for TDS and the fluid resistivity based on the log is approximately 10 ohm-m at sample depth, the interface is estimated to be deeper in the open-hole interval, or approximately 640 feet bls.

Table 1. Water Quality and Estimated Interface Depth Summary

NWF_ID	Bottom Tagged (feet)	Casing Depth Logger (feet)	Visit Date	DTW BLS (feet)	Interface Depth(ft)	Sample Depth(s)	Cond. uS/cm	Lab Results (mg/L)		
								TDS	Na^+	Cl^-
1376	707	548	10/25	23.87	>707	690	869	478	142	171
1696	860	536	10/30	64.40	>860	580	531	334	131	63.1
						840	559	345	126	62.7
3209	578	442	10/17	115.20	>578	No Sample Collected				
3210	1130	935	10/16	113.86	<935	950	2345	1240	466	626
						1125	2196	1240	478	622
7174	1083	920	10/27	31.30	<920	955	3495	1340	738	708
						1070	11574	7700	2540	4240
7183*	698	499	10/20	42.20	>698	520	313	160	25.6	18.1
						575	1345	173	121	112
						660	4342	192	33	25.6

Table 1 (cont.). Water Quality and Estimated Interface Depth Summary

NWF_ID	Bottom Tagged (feet)	Casing Depth Logger (feet)	Visit Date	DTW BLS (feet)	Interface Depth(ft)	Sample Depth(s)	Cond. uS/cm	Lab Results (mg/L)		
								TDS	Na^+	Cl^-
7349	600	425	11/8	18.58	~588	440	325	188	28.1	24.8
						590	971	530	167	201
7686	1228	1135	11/1	22.14	<1135	1205	2647	1210	593	473
7751	628	538	10/18	30.00	<538	620	3438	2040	659	1010
7767	237	220	10/19	34.47	NA	Obstruction at 237' BLS				
9137	648	488	10/26	46.71	~640	495	308	163	25.9	8.1
						640	910	556	66.9	30.5

*QAQC Duplicates and Equipment blanks were performed at this location.
 Based on the measured conductivity values throughout the borehole.
> Indicates that the interface exists at a depth that is greater than the total depth of the logged open-hole interval.
< Indicates that the interface exists at a depth that is shallower than the bottom of the well casing.

Quality Assurance and Quality Controls

In compliance with FDEP Standards of Quality assurance, duplicate samples were collected as splits for confirmation of laboratory results. The sample from well NWF ID 7183 at a depth of 575' generated the duplicate samples. An equipment blank was collected between sample events at this well. The QA/QC results are summarized in Table 2 below.

Table 2. Quality Assurance for Laboratory Analysis Results

Analyte	**7183-575**	**7183-575 DUP**	**RPD %**	**Equipment Blank**
TDS (mg/L)	173	165	4.6	<5
Sodium (mg/L)	121	122	0.8	<0.5
Chloride (mg/L)	112	112	0	<2.5

< Indicates that the analysis result was less than the reported method detection limit.
RPD – relative percent difference

The results of duplicate analysis indicate good agreement, within acceptable reproducible accuracy, between pairs. The results of internal laboratory standards and controls are available in the attachments. The results of analysis from the equipment blank indicate that washing and decontamination procedures were sufficiently performed to avoid contamination between samples.

Daily calibration was performed on the logging equipment. Continuing calibrations were performed prior to and after each logging run against a National Institute of Standards and Technology (NIST) traceable standard of 1413 µS/cm. As reported in Table 2 of the attached files from Trinity, the RPD average was 2.8% with a 2.2 % standard deviation (after replacing the original probe on 9/28 at NWF ID 7751).

Conclusion and Recommendations

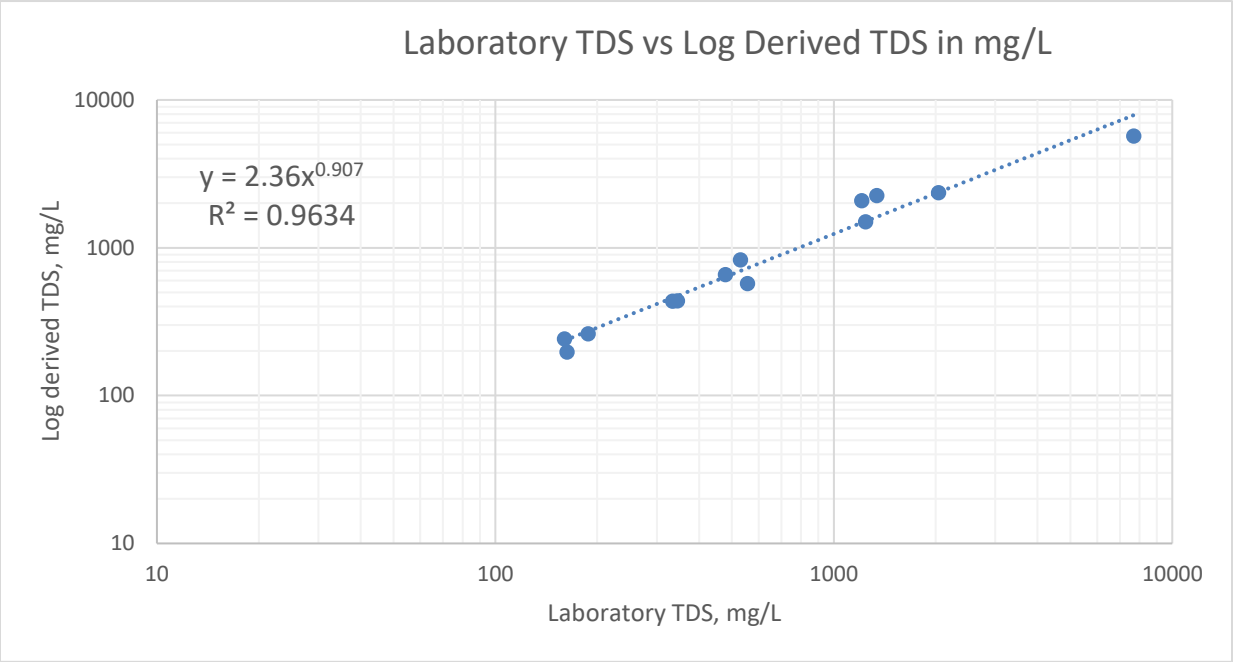

Figure 1. Linear Regression Relationship Between Log Estimated and Lab Analyzed TDS Values

The chart above was generated for the purpose of considering the general agreement of analytical results compared to the results predicted from conventional calculations of TDS from conductivity (Temperature corrected conductivity multiplied by 0.65). Because the intent was to predict the likelihood of an interface within the borehole using the geophysical log, the conductivity results from the log were used compared to analytical results of TDS. NOTE: As reported above, the results from well NWF ID 7183 were a significant outlier and have been removed from this chart. They are included in the full Excel (.xls) spreadsheet of analytical reporting in the attachments. From this chart we conclude that, generally, conductivity is a good prediction tool for TDS values.

Travel speed for the logging and sampling equipment was limited to 10 to 12 feet per minute. The intent was to limit mixing within the well by the submerged tools. In this study, duplicate analysis was performed on splits collected from the sampler vessel. We recommend expanding duplicate sampling to include separate sampling passes to the same depth for comparison of reproducible results at the same position in future events.

Professional Certification

This document was based upon information made available to, or gathered by, Jim Stidham & Associates, Inc. (JSA). The scope of work, methodology, results, conclusions, and recommendations were based upon discussions with sub-contracted agents and regulatory agency personnel.

JSA has conducted this investigation in a manner consistent with sound practices and that level of care and skill normally exercised by members of the profession operating under similar circumstances. JSA does not assume responsibility for conditions which did not come to its actual knowledge or for conditions not recognized as environmentally unacceptable at the time this document was prepared. If conditions are discovered or determined to exist that differ from those described, the undersigned geologist should be notified to evaluate the effects of any additional information on the assessment and recommendations in this document.

The undersigned professional has prepared this report on behalf and as an employee of JSA. This document was prepared to provide a Memo Report for Discrete Interval Water Sampling for the Northwest Florida Water Management District. It should not be construed to apply to any other site.

Prepared by:

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Jim Stidham & Associates, Inc.
Date: 12-14-2017

Discrete Interval Sampling Locations with Interpreted Depths to the Potable Interface

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Sampling locations (well number)
County/State roads
Eglin AFB
County boundary

Depth is in units of feet.

> Indicates that the interface is predicted to be at a depth greater than the total depth of the well.

< Indicates that the interface is predicted to be at a depth less than the depth of the well casing.

NA Insufficient data was available for determination of the interface depth.