# Francis Creek Annual Suspended Sediment Yield

## Turbidity Threshold Sampling Summary Report

## Hydrologic Year 2017

**Site FRC – 1099 Van Ness Avenue Ferndale, California**

**A collaborative project between**

**Humboldt County Resource Conservation District**
**County of Humboldt**
**City of Ferndale**
**State Coastal Conservancy**
**Ducks Unlimited**
**California Department of Water Resources**
**National Marine Fisheries Service**
**Natural Resources Conservation Service**
**California Department of Fish and Wildlife**
**Wildlife Conservation Board**
**U.S. Fish and Wildlife Service**

## For the

## Salt River Ecosystem Restoration Project

**By Clark Fenton**
**8-2-17 final**

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# 1. Introduction

The goal of the Salt River Ecosystem Restoration Project is to improve riparian and fish habitat, reduce flooding, enhance sediment routing and lessen sewer plant impacts on Francis Creek and the Salt River. Suspended sediment yields from the Francis Creek watershed will continue to be quantified to provide planning data for future dredging downstream. The EIR and current progress may be viewed on the HCRCD's web site http://www.humboldtrcd.org, Salt River Restoration Project tab or at the Salt River Watershed Council website http://saltriverwatershed.org/.

Figas Construction was given the contract this year to dredge to restore the connection from the Salt River to the lower portion of Francis Creek. Phase 2B will involve work around the City of Ferndale sewer treatment plant. The HCRCD has plans to help improve Williams Creek next.

Annual rainfall for the City of Ferndale for Water Year 2017 was **163%** of normal. This somewhat welcome upturn in the annual rainfall certainly increased suspended sediment transport in Francis Creek. Francis Creek transported a 10 year high of **146 million pounds** in suspended sediment past the Site FRC in Water Year 2017. The term atmospheric river of water was a phrase we all heard this year.

The largest WY 2017 storm event in Francis Creek starting on January 17$^{th}$, 2017 transported **13,788 cubic yards** of suspended sediment and was **21%** of the WY 2017 annual total of **65,787 cubic yards**. Since starting operation in 2007 the Francis Creek Turbidity Threshold Sampling station has measured almost **300,000 cubic yards** of suspended sediment passing the station.

Annual suspended sediment yields from the Francis Creek Watershed since 2007 have ranged from 378 tons / square mile / year to a 10 year high of **22,922** tons / square mile / year this year. This variation is due in part to annual rainfall totals, storm intensities, landslides and large storm event durations. This 3.2 square mile watershed is still contributing large amounts of suspended sediment into the Salt River, the Eel River and the Pacific Ocean.

The turbidity threshold sampling software developed by USFS Pacific Southwest Research Station, Arcata - Redwood Sciences Lab triggered **192** ISCO pump sample bottles this year. Francis Creek sample bottle suspended sediment concentrations peaked at **34,000 mg/l.**

HCRCD and GMA ran suspended sediment % sand fraction analysis on various ISCO bottle samples collected for HY 2017. A range of low to high suspended sediment concentration samples were taken. The % sand fraction of our 15 Francis Creek storm event suspended sediment samples for Water Year 2017 range from 3% sand at low flows to **34 % sand** at the highest flow sampled of 269 cfs at a 6 foot staff plate / 4 foot water stage on 2-9-17.

Site FRC stream channel elevation cross sections were taken with a transit in 2007, 2009 and 2017. Comparing Francis Creek streambed elevations reveals **streambed aggradation of about 1.7 feet** and terrace deposition of about 2 feet since 2007. The Van Ness Avenue box culvert has lost about 18% of it's existing area cross section since 2007 due to streambed aggradation of bedload gravel.

Clark Fenton continues to maintain the Turbidity Threshold Sampling (TTS) Station on Francis Creek in Ferndale California as an independent contractor. Hydrologic Year 2017 was the tenth full year of TTS monitoring on Francis Creek. Sarah Wilson continues to analyze and report the annual suspended sediment yields.

**The Salt River** is a tributary of the Eel River that heads in the Wildcat Mountains above Ferndale, flows across the Eel River Delta, and enters the Eel River within one mile of the Pacific Ocean. The watershed is part of the Franciscan Complex and mainly underlain by Quaternary mudstones, siltstones and sandstones of the Wildcat formation (McLaughlin, R.J. and others. 2000). Habitats and land uses that characterize the Salt / Eel River delta include the fourth largest estuary in California, salt-, brackish-, and freshwater marshes, riverine wetlands, riparian wetlands, agricultural lands dominated by dairy farms and irrigated pastures, and small communities. (USDA, 1993)

Sedimentation in the Salt River Channel has resulted in problems associated with flooding and drainage, including:

Decreased agricultural production and land values;
Degradation of the estuary and its habitats as excess nutrients are transported from flooded dairy lands downstream, Loss of a once navigable waterway; and
Increased health hazards posed by water quality degradation. (USDA, 1993)

Photo #1. 2014 aerial view of mouth of the Eel River and Salt River looking west.

The excavated Francis Creek channel is on the right side of photo.

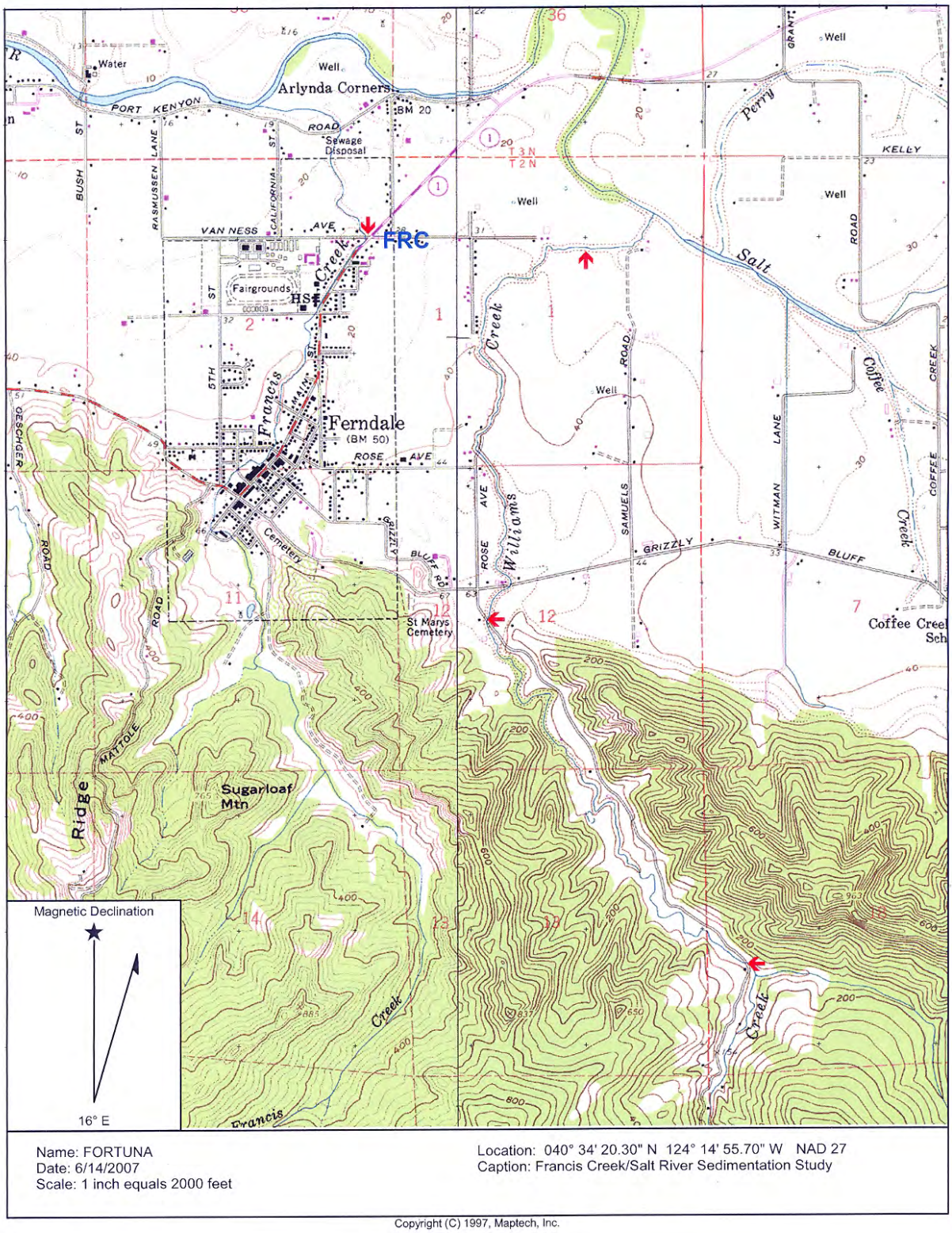


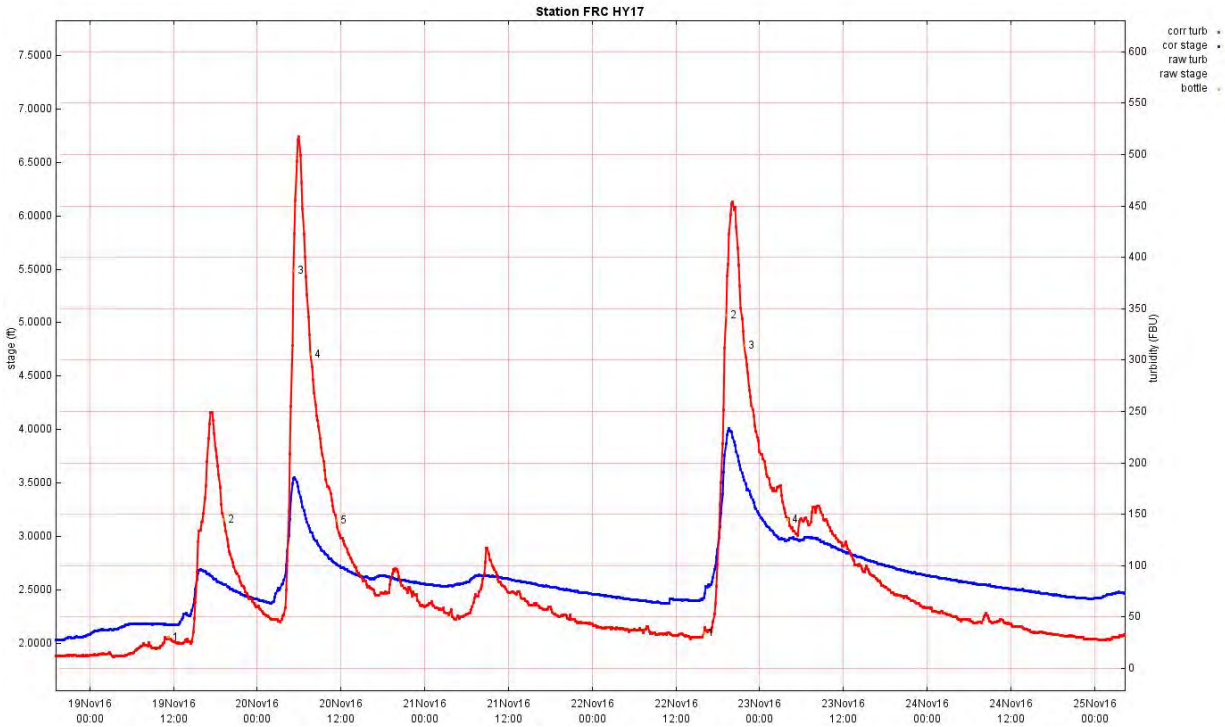

Figure # 1 Francis and Williams Creek monitoring locations

# Turbidity Threshold Sampling (TTS)

Jack Lewis and Rand Eads at the USFS Pacific Southwest Research Station, Arcata -Redwood Sciences Lab developed turbidity Threshold Sampling over 15 years ago (Lewis, Eads, 2002). RSL is a research station located above Humboldt State University for the USFS and deploys a network of these stations on Caspar Creek to monitor long-term sediment transport in the Jackson State Forest and other locations across Northern California. Redwood Sciences Lab provides all information and software for TTS sampling for free on their website. Implementation files, sampling software and TTS literature should be found at http://www.fs.fed.us/psw/topics/water/tts/.

TTS is used to calculate suspended sediment loads using turbidity measurements every 10 minutes as a surrogate for suspended sediment measurements every 10 minutes. A Druck 1830 pressure transducer and an in-stream OBS-3+ turbidimeter are installed in conjunction with an ISCO pump sampler to take water samples at direction from TTS sampling software. An algorithm is used to trigger an ISCO pump sampler to take water samples at rising and falling turbidity thresholds. The final 10-minute data file is called a flo file and displays raw and corrected stage and turbidity data side by side for easy comparison. The flo files for Site FRC 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016 and 2017 are included in Appendix 5. **On-line real time plotting should be available on the HSU website.**
http://fs-server.humboldt.edu/RTMC/FrancisCreek_DetailView.gif

TTS water samples for HY 2017 were sent to the EPA Region 9 Laboratory for suspended sediment concentration determination by subtracting filtering (SSC / Sand Fraction - ASTM D3977 -02). A regression is developed for OBS-3+ turbidity versus suspended sediment concentration. The 10-minute turbidity data is converted to 10 minute calculated suspended sediment concentration. A discharge-rating curve is developed so flow is known for the every 10 min stage data. By multiplying flow / cfs and suspended sediment concentration, pounds of sediment passing by the station are calculated. TTS Adjuster software is used to do data correction and R Sed software is used to calculate suspended sediment loads. The best equation fit for the turbidity vs. suspended sediment concentration from **bottles sampled from each storm is used to calculate loads for each storm** and the loads are summed up for the year.




Plot # 1 – Water stage in blue and turbidity in red and sample bottle numbers

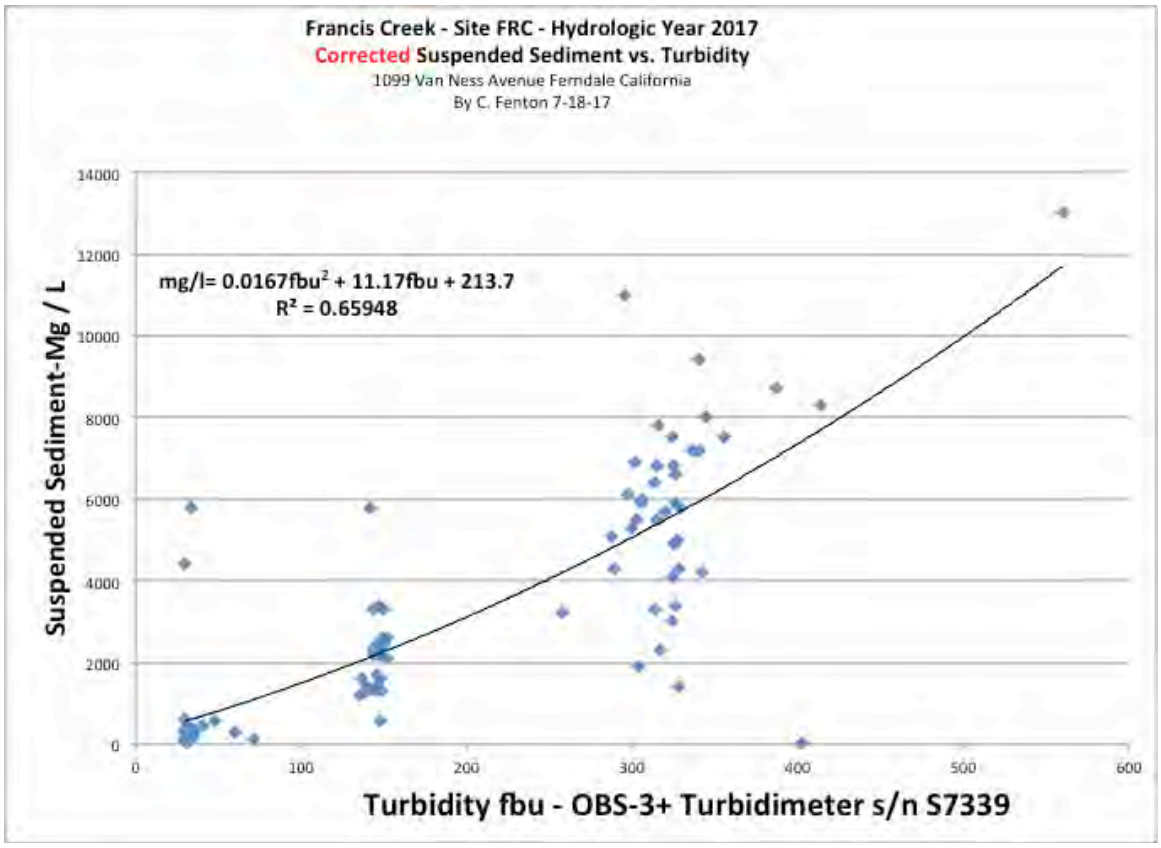
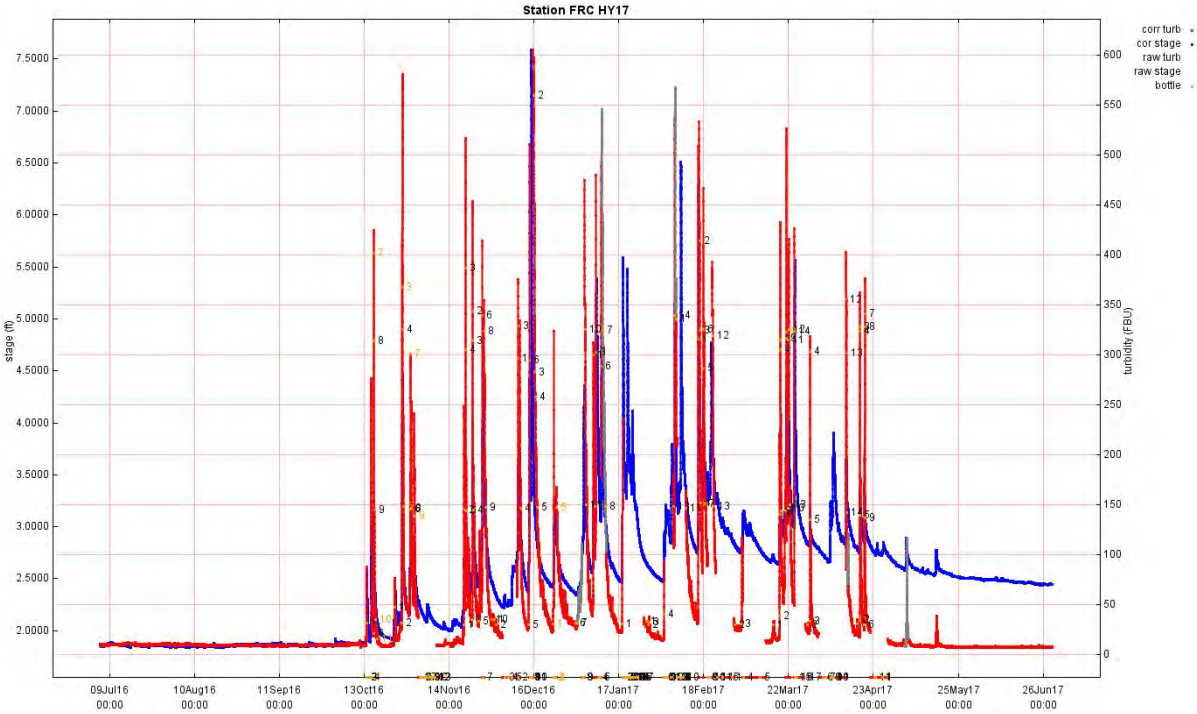
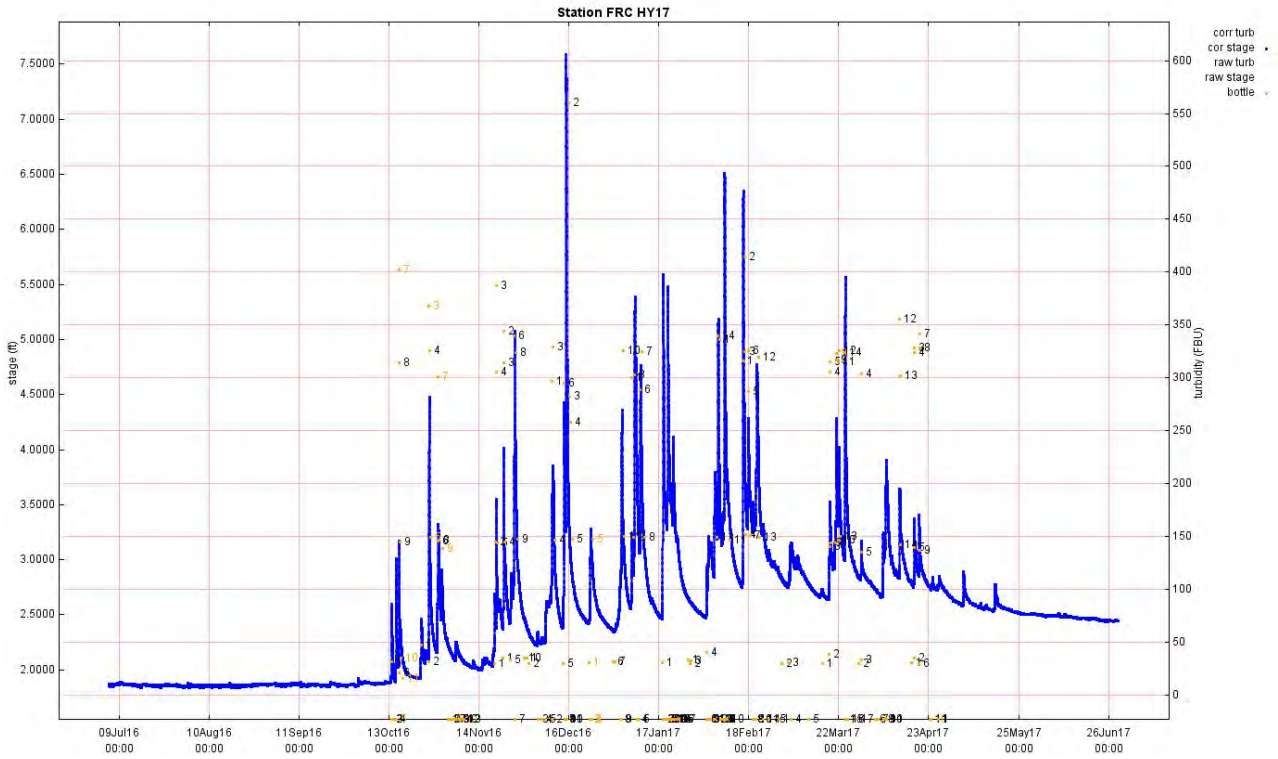


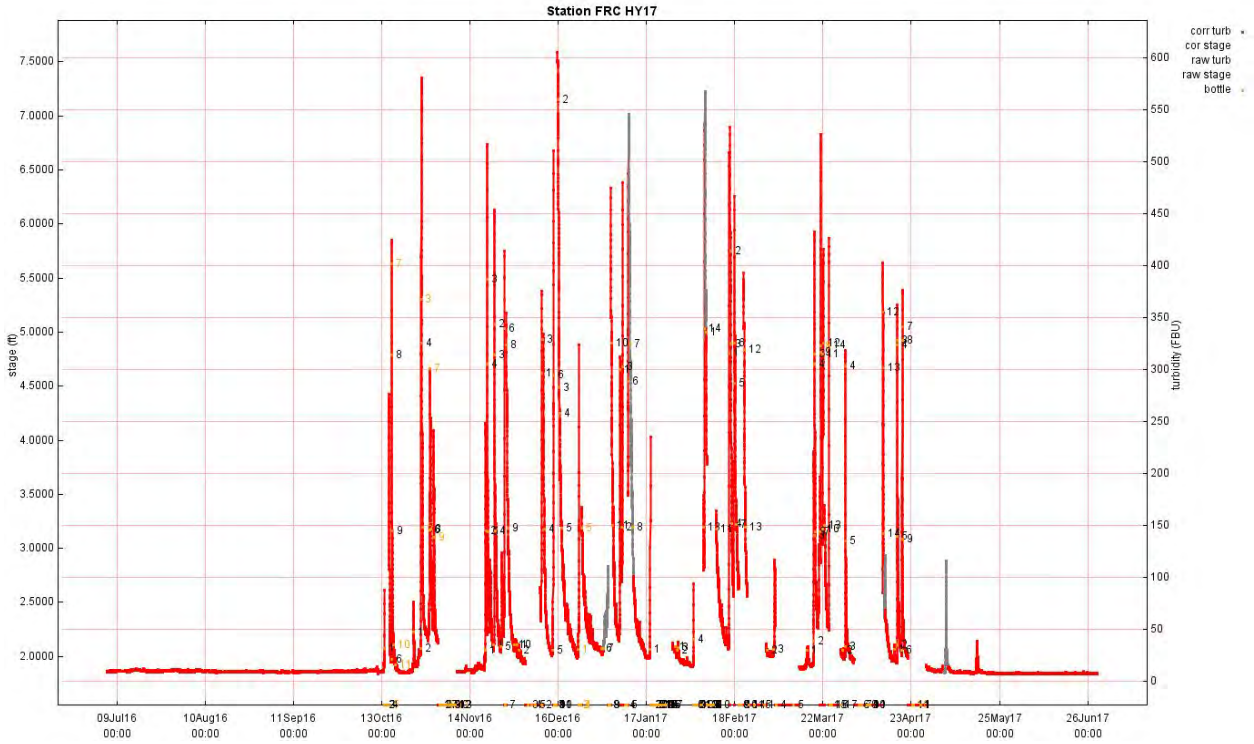

Chart # 1 Turbidity vs. Suspended Sediment Concentration




Plot # 2 Stage / turbidity / bottles plot of HY 2017 at Site FRC on Francis Creek.




Plot # 3 Stage plot of HY 2017. Max storm stage 12-15-16 in blue was 7.59 feet @ 326 cfs.




Plot # 4 Turbidity (fbu) and bottles sampled plot of the HY 2017 water year at Site FRC

# 2. Francis Creek 2017 Suspended Sediment Load

The Francis Creek TTS Station (Site FRC) is located at the intersection of State Hwy 211 and Van Ness Avenue in Ferndale, California. Francis Creek is the second largest tributary to the Salt River watershed at 3.2 square miles (Buffleben, 2007). The Williams Creek watershed is the largest at 5.7 square miles. TTS Monitoring commenced at Site FRC on Francis Creek on 1-23-07.

| Hydrologic Year | Total Suspended Sediment Lbs. | Total Suspended Sediment Kg | Total Suspended Sediment Cubic Yards | Highest Single Storm Sediment Kg | Highest Single Storm Flow CFS | Annual Susp. Sed. Yield Tons/ Sq. Mile |
|---|---|---|---|---|---|---|
| **2008** | 41,739,922 | 18,932,910 | 18,187 | 4,511,312 | 274 | 6,521 |
| **2009** | 12,578,664 | 5,705,593 | 5,480 | 1,351,049 | 135 | 1,965 |
| **2010** | 38,979,924 | 17,685,991 | 16,985 | 4,270,058 | 215 | 6,091 |
| **2011** | 70,342,760 | 31,915,953 | 30,650 | 17,045,608 | 268 | 10,991 |
| **2012** | 65,859,288 | 29,881,710 | 28,696 | 12,563,530 | 230 | 10,291 |
| **2013** | 139,352,629 | 63,209,938 | 60,720 | 28,228,313 | 462 | 21,774 |
| **2014** | 2,419,062 | 1,097,578 | 1,054 | 355,314 | 46 | 378 |
| **2015** | 84,450,445 | 38,316,899 | 36,798 | 20,380,963 | 488 | 13,195 |
| **2016** | 77,129,899 | 34,995,417 | 33,608 | 10,855,762 | 335 | 12,052 |
| **2017** | **146,698,718** | **66,560,217** | **63,921** | **14,357,492** | **326** | **22,922** |
| **Totals** | **683,779,722** | **310,244,883** | **297,943** | | | **Avg. 10,617** |

Table # 1 – Francis Creek Annual suspended sediment load summaries

The purpose of this TTS monitoring station is to provide guidance on how much suspended sediment can be expected to enter the Salt River dredge or detention areas over time from the Francis Creek watershed. A bulk specific gravity of 85 lbs. per cubic foot was used to calculate cubic yards of fresh flood deposit sediment. (USDA, 93)

The Ferndale Enterprise reported on 6-22-17 that rainfall for Ferndale for "The weather year to date from 7-1-16 to 6-18-17 was **163%** of average at **66.60** inches. The Weather Year average from 1971, July 1st to 6-18-17 **is 40.77** inches rainfall. Rainfall **last year** from 7-1-16 to 6-18-17 was **50.47** inches." This is the main reason Francis Creek transported so much suspended sediment this year.

The annual suspended sediment load / yield from the Francis Creek watershed above Site FRC for Hydrologic Year **2017** from 7-5-16-15 to 6-29-17 was **146,698,718 pounds** / **66,560,217 kg** / **66,921 cubic yards** or a annual yield of **22,922 tons per square mile per year** of suspended sediment. This is about 5 times the annual tons per square mile yield from the Eel River and possibly 10 times the annual yield per square mile from local watersheds such as Elk River, Freshwater Creek and Jacoby Creek.

The TTS station at the Van Ness Culvert on Francis Creek has measured a total of almost 300,000 cubic yards since 2007.

The largest suspended sediment estimation period of HY 2017 was storm period 8, the 1-17-17 storm event, yielded **31.6 million pounds** passing the Francis Creek TTS station or 21 % of the HY 17 suspended sediment annual yield.

The annual suspended sediment yield from the Francis Creek watershed above Site FRC for **Hydrologic Year 2016** from 7-2-15 to 7-5-16 was **77,129,899 pounds** / **34,995,417 kg** / **33,608 cubic yards** or **12,052 tons per square mile per year** of suspended sediment. This was presumably after 4 years of drought in Northern California.

Due to the turbidity sensor boom being pushed up out of the water at high flows and losing turbidity data, a discharge versus suspended sediment concentration regression was used to calculate storm suspended sediment loads.

The **Eel River at Scotia** carries an almost incredible **4,330 tons of suspended sediment every year from every square mile** of its drainage basin. On average, 4 to 8 inches of soil is washing is washing off the slopes every hundred years. That is the highest regional rate of erosion ever measured in the United States, more than 13 times the national average. Most of that phenomenal load goes down the river in about 6 days of the largest discharges during the winter floods. (Roadside Geology of Northern and Central California – D. Alt / D. Hyndman – 2000)

The average annual suspended yield for the **Mad River** is about 1,751,500 tons, or about **3,600 tons /sq. mi/yr.** for Qss. (Klein, R. 2007, Personal Communication.)

## Summary of individual storm suspended sediment estimates:

The table below is from the Sarah Wilson suspended sediment report for FRC **HY 2017**. Her complete report is in Appendix 1. The hydrologic year was broken up into storm-by-storm time periods and the suspended sediment load was calculated for each period. Ms. Wilson has done this same analysis for Redwood Sciences Lab

By Sarah Wilson

The quality of the estimate for each period depends on the following categories:
Number of bottles within the period and the coverage of the bottles over the entire period.
The strength of the relationship between the surrogate variable (stage or turbidity and sample ssc as measured by CV and r2.
The complexity and number of models and objects used to calculate the estimate of each period.
The quality of the surrogate variable data (usually stage which is converted to discharge).
An estimate cannot receive a high grade if the quality of the underlying data is questionable.

| Period | Dates and Times | Dump: Bottles | Sediment Load (kg) | % of Total Load | Grade |
|---|---|---|---|---|---|
| 01 | 160605,1030,161015,1300 | 4:1-5 | 39,008 | 0.06% | poor |
| 02 | 161015,1310,161102,0000 | 4:6-9, 5:1-8 | 701,755 | 1.05% | poor |
| 03 | 161102,0010,161119,0000 | 6:1-13 | 5,580 | 0.01% | good |
| 04 | 161119,0010,161125,0000 | 7:1-5, 8:1-4 | 780,293 | 1.17% | good |
| 05 | 161125,0010,161213,1700 | 8:5-9,9:1-3 | 3,326,050 | 5.00% | good |
| 06 | 161213,1710,170101,0000 | 9:5-11, 10:1-5 | 4,442,376 | 6.67% | fair to good |
| 07 | 170101,0010,170117,0000 | 12:7-11, 13:1-8 | 8,659,097 | 13.01% | good |
| 08 | 170117,0010,170202,0000 | 14:1-17, 15:1-3 | 14,357,492 | 21.57% | fair |
| 09 | 170202,0010,170215,1200 | 15:4-14, 16:1-11 | 12,674,342 | 19.04% | very good |
| 10 | 170215,1210,170303,0000 | 17:1-15, 18:1-2 | 9,525,227 | 14.31% | good to ver |
| 11 | 170303,0010,170328,0000 | 18:3-5, 19:1-16 | 8,377,961 | 12.59% | fair to good |
| 12 | 170328,0010,170411,0000 | 19:17, 20:1-11 | 1,919,777 | 2.88% | fair |
| 13 | 170411,0010,170428,1140 | 20:12-14, 21:1-11 | 1,248,507 | 1.88% | fair |
| 14 | 170428,1150,170629,1010 | none | 502,752 | 0.76% | poor |
| | | | | | |
| | | **Total Load (kg)** | **66,560,217** | | |

Table # 2 – HY 2017 Storm Period Suspended Sediment loads

Sarah Wilson continues to do suspended sediment load analysis with Redwood Sciences Lab TTS Adjuster and R Sed analysis software. Sarah Wilson received her Bachelors of Science in Biology from San Jose State University and a Master's of Science in Watershed Management from Humboldt State University. Her husband is an active duty member of the US Coast Guard.

# 3. Francis Creek 2017 Large Storm Events

The largest sediment producing storm event of Hydrologic Year 2017 was storm period 8 occurring on January 17th to February 2nd 2017 producing 14 million pounds of suspended sediment.

The highest stage of the year, a 7.6 foot peak / 326 cfs on 12-15-17, had 120,000 pounds / **52 cubic yards** of suspended sediment was flowing past the Francis Creek TTS Station **every 10 minutes**. That's comparable to **5 10-yard dump trucks** full of sediment driving by every 10 minutes. That's using the second best equation ssc = 3953.08(stage)^0.45.

| | | |
|---|---|---|
| # 1 | Storm Period # 8 - 21.57 % | 14,357,492 pounds 1-17-17 to 2-2-17 |
| # 2 | Storm Period # 9 – 19.04 % | 12,674,342 pounds 2-2-17 to 2-15-17 |
| # 3 | Storm Period # 10 – 14.31 % | 9,525,227 pounds 2-15-17 to 3-3-17 |

The top 3 storm events / periods contributed over 50 % of the annual suspended sediment load out of 14 storm periods.


Photo # 2. Instrument Shed TTS Station FRC

# 4. Suspended Sediment % Sand Fraction Analysis HY 2017

HCRCD and GMA determined % sand fraction analysis on various ISCO bottle samples collected for HY 2017. A range of low to high suspended sediment concentration samples were taken.

The % sand fraction of the 15 Francis Creek storm event suspended sediment samples for Water Year 2017 range from **3% sand at 12 cfs low flow to 34 % sand at the highest flow sampled of 269 cfs** at a 6 foot staff plate / 4 foot water depth on 2-9-17.

The only other sediment gradation results found at the present is a stream bank flood deposit sample taken in 2007 from the river left bank below the Port Kenyon Road Bridge above Francis Creek after a major storm event. That sample with mechanical analysis yielded a result of 30 % sand, 54 % silt and 16% clay.

There are now several active slides in the upper watershed and recent samples probably reflect those sites. Bed load aggradation looks to be about what we expected. Very little, if any of the gravel is generated by the landslide. Qls parent material is predominantly silt, fine sand and clay (mid to upper Rio Dell fm). The gravel source is higher in the section (downstream of the Qls) in the upper Scotia Bluffs, Carlotta, and Hookton formations. (Tom Stephens, personal communication, 2017)

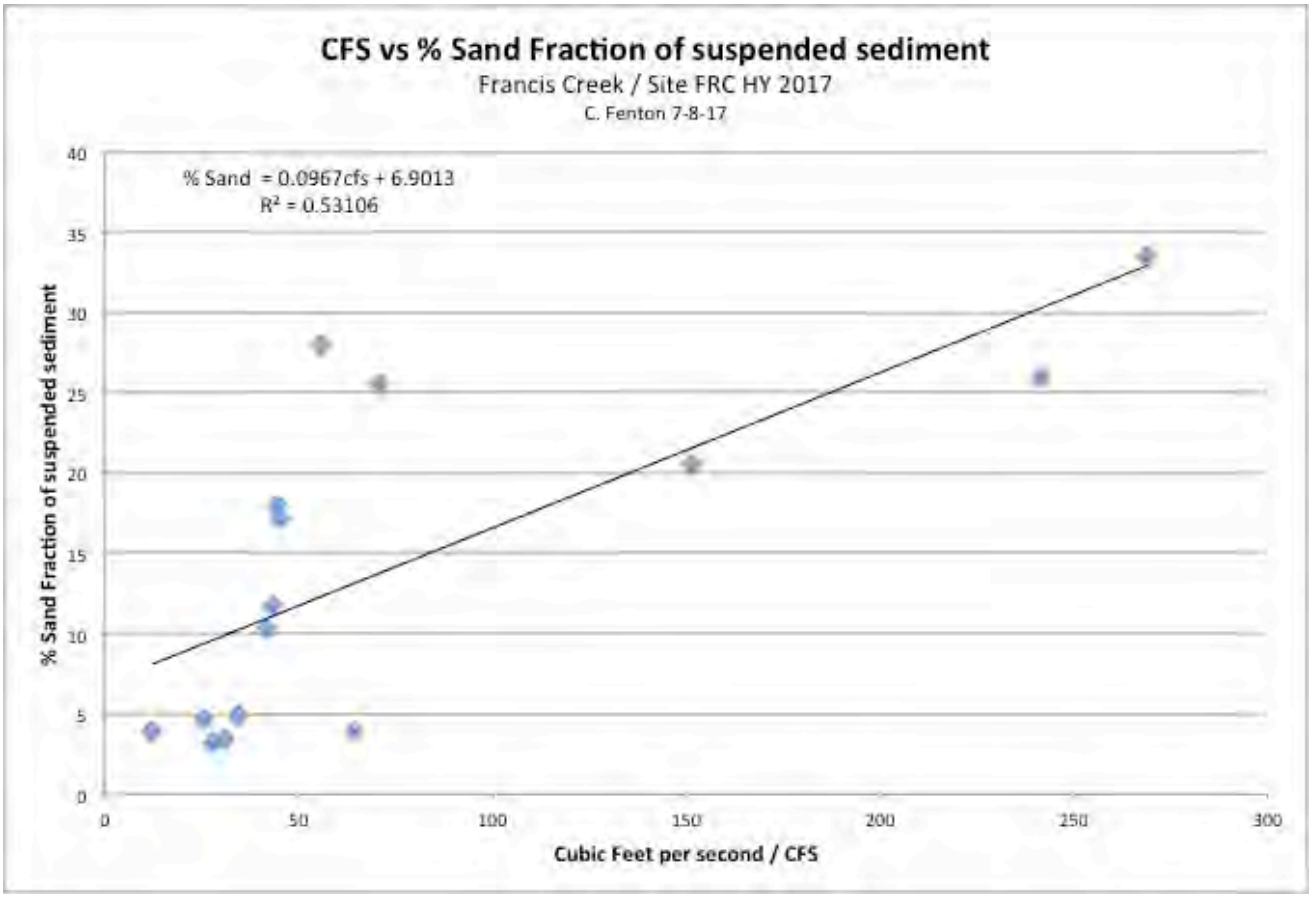



Chart # 2 CFS vs % sand fraction of Francis Creek suspended sediment.

Suspended Sediment Sand / Fine Results from GMA - Francis Creek 2017 cf 4-3-17

Received 3-21-17 Sand > # 230 sieve per GMA raw raw

| Bottle # | Date sampled | Time sampled | Analysis Performed | Fine Conc. | Sand Conc. | % Sand | % Fine | Flow cfs | Turbidity fbu | SSC Conc. | Unit | Lab Code | Lab Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5FRC07 | 10/30/16 | 14:00 | S/F Split | 4250 | 489 | 10 | 90 | 42 | 301 | **4,740** | mg/l | 1 | poured out? |
| 12FRC01 | 12/23/16 | 7:40 | S/F Split | 239 | 9.94 | 4 | 96 | 12 | 31 | **249** | mg/l | 1 | |
| 12FRC02 | 12/23/16 | 15:00 | S/F Split | 3930 | 133 | 3 | 97 | 28 | 369 | **4,060** | mg/l | 1 | |
| 12FRC03 | 12/23/16 | 16:00 | S/F Split | 5210 | 187 | 3 | 97 | 31 | 335 | **5,400** | mg/l | 1 | |
| 12FRC04 | 12/24/16 | 1:50 | S/F Split | 4390 | 228 | 5 | 95 | 34 | 316 | **4,620** | mg/l | 1 | |
| 12FRC05 | 12/24/16 | 14:50 | S/F Split | 1950 | 96.3 | 5 | 95 | 26 | 148 | **2,050** | mg/l | 1 | |
| 14FRC05 | 1/19/17 | 18:20 | S/F Split | 1950 | 429 | 18 | 82 | 44 | 152 | **2,380** | mg/l | 1 | |
| 14FRC06 | 1/20/17 | 2:30 | S/F Split | 4120 | 1420 | 26 | 74 | 71 | 289 | **5,540** | mg/l | 1 | 2 particles > 1 mm |
| 14FRC07 | 1/20/17 | 10:40 | S/F Split | 8610 | 1790 | 17 | 83 | 45 | 523 | **10,400** | mg/l | 1 | |
| 14FRC10 | 1/20/17 | 23:10 | S/F Split | 25610 | 1050 | 4 | 96 | 64 | 461 | **26,660** | mg/l | 1 | |
| 14FRC11 | 1/21/17 | 13:10 | S/F Split | 7690 | 3000 | 28 | 72 | 56 | 332 | **10,690** | mg/l | 1 | several large particles > 2 mm |
| 14FRC15 | 1/22/17 | 21:50 | S/F Split | 2140 | 285 | 12 | 88 | 43 | 151 | **2,430** | mg/l | 1 | |
| 16FRC06 | 2/9/17 | 10:20 | S/F Split | 18510 | 9370 | 34 | 66 | 269 | 563 | **27,880** | mg/l | 1 | aux B 5 10:10 26,000 mg/l per EPA |
| 16FRC07 | 2/9/17 | 12:30 | S/F Split | 23670 | 8330 | 26 | 74 | 242 | 501 | **32,000** | mg/l | 1 | aux sample 5 minutes after GMA DI sample |
| 16FRC09 | 2/9/17 | 16:00 | S/F Split | 16390 | 4260 | 21 | 79 | 151 | 580 | **20,650** | mg/l | 1 | aux B 8 15:50 23,000 mg/l per EPA |
| 3476Q-6005Q | 2/9/17 | 12:25 | S/F Split | 21670 | 6750 | 24 | 76 | | | **28,420** | mg/l | 1 | GMA DI sample 1 of 2 |
| 3715Q-6272Q | 2/9/17 | 12:25 | S/F Split | 21890 | 6370 | 23 | 77 | | | **28,260** | mg/l | 1 | GMA DI sample 2 of 2 |

GMA Lab Codes

1 All analysis performed in accordance with Quality Manual, dated December 28, 2012

2 The following exceptions to EPA Method 180.1 were noted:

3 Sample concentrations are below reporting limits

rising or falling limb?

Table # 3 suspended sediment % Sand Fraction data.

# 5. Stream Channel Aggradation Survey 2007 to 2016

The Francis Creek stream bed and stream bank terrace here are rising over time. Site FRC stream channel elevation cross sections were taken with a transit in 2007, 2009 and 2017. Comparing Francis Creek streambed elevations reveals streambed aggradation of about 1.7 feet and about 2 feet of suspended sediment deposit on the lawn / terrace of 1099 Van Ness Avenue since 2007. The Van Ness Avenue box culvert has lost about 18% of it's existing area cross section since 2007 due to streambed aggradation of bedload gravel.

Photo # 3. Streambed transit survey 2-5-07

**Francis Creek / Van Ness Culvert stream bed gravels aggradation / deposition:**
Crossection surveys from 3-12-09 and 12-29-16 / 7.7 years.
1.7 feet stream bed aggradation river left or 0.22 feet per year
0.7 feet stream bed aggradation river right or 0.09 feet per year
Mean stream bed aggradation 1.2 feet per 7.7 years or 0.16 feet per year

From downstream foot bridge mid plank end to stream bed surveys 2-5-07 and 12-29-16 / 9.9 years.
1.36 feet stream bed aggradation mid channel in 9.9 years
0.14 feet stream bed aggradation per year

**Suspended sediment aggradation / deposition lower terrace river right yard of 1099 Van Ness Avenue:**
Surveys 2-5-07 and 12-29-16.
2.36 feet suspended sediment aggradation in 9.9 years
0.24 feet suspended sediment aggradation per year

**Van Ness Box culvert reduction in capacity 2-5-07 to 12-29-16:**
87.96 square feet reduced to 71.64 square feet = 18.6% reduction crossectional area

Bed load aggradation looks to be about what we expected. Very little, if any of the gravel is generated by the landslide. Qls parent material is predominantly silt, fine sand and clay (mid to upper Rio Dell fm). The gravel source is higher in the section (downstream of the Qls) in the upper Scotia Bluffs, Carlotta, and Hookton formations. (Tom Stephens, personal communication, 2017)

Since bedload sampling isn't happening, can't tell how much is moving through the section. For now, the stream bedload appears to be in kind of dynamic equilibrium; what comes in passes through with a little accumulation. Aggradation of 0.16'/yr is about the diameter of a medium gravel clast.
(Tom Stephens, personal communication, 2017)

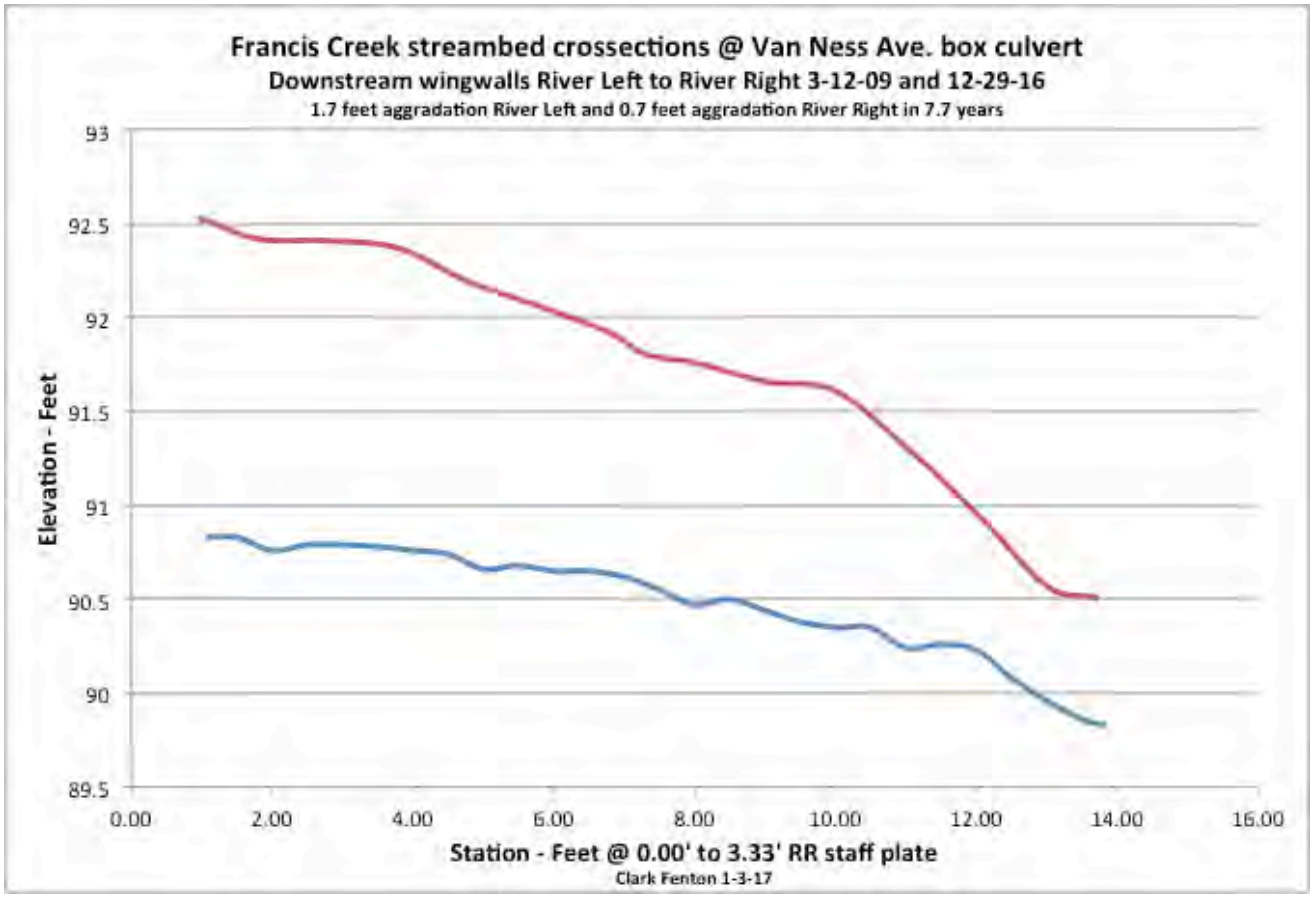



Chart # 3 Francis Creek Streambed Aggradation 2009 to 2016

# 6. Francis Creek Ranch Slide – March 2011

During a set of 5 rainfall events starting 3-23-11 and ending 4-1-11 a large debris torrent occurred approximately 3.4 river miles upstream of the station. The forester of the upstream property, Chris Carroll, estimates the slide to be roughly 100,000 cubic yards in size.

Photo # 4. Francis Creek Ranch Slide April 2011

The California Geological Survey visited the site on April 7, 2011. Details from their report by Don R. Braun dated April 18, 2011 include that a bridge was removed from its abutments by the debris. At the slide site bedrock materials "consisted predominantly of soft to moderately dark gray siltstone with minor amounts of fine sub rounded gravel. Significant precipitation in the area during the month of March may have been the main contributor to the recent failure. The debris is estimated to consist of about 50% wood or logs and about 50% dark gray silt. Information supplied by Mr. Mark Distefano of TRC suggests that the destroyed former bridge over Francis Creek was approximately 15 to 20 feet above the channel and that the current debris in the channel is about 4 to 5 feet above the height of the old bridge suggesting that the debris thickness at this location may be about 19 to 25 feet. Francis Creek will likely remain turbid with suspended sediment during future rainy seasons until a stable channel and side slopes develop." (CGS, 2011)

Using turbidity threshold sampling analysis Sarah Wilson estimated that approximately **11 million kilograms / 24 million pounds** / **10,600** cubic yards of suspended sediment presumably came from the Francis Creek Ranch Slide during this period. The suspended sediment is mainly fine sand and silt and totals do not include bed load gravel. During this slide event, the TTS station sucked over 40 water samples from Francis Creek, including 14 water samples over 35,000 milligrams/liter. Eight of those 14 bottles had over 65,000 mg/l, one bottle had 100,000 mg/l and one bottle had 180,000 mg/l.

# 7. Field and Lab Operations HY 2017

The station on Francis Creek – Site FRC – was made possible by funding from the Humboldt County Resource Conservation District, 5 Counties Salmonid Conservation Program, City of Ferndale and the Road Fund of the Humboldt County Public Works Department**.** The City of Ferndale Public Works constructed the Site FRC Equipment Enclosure Shed, and the equipment was installed in January of 2007.

Photo # 5. - Site FRC at 1099 Van Ness Avenue 2007

The TTS station uses an ISCO Model 6700 automatic pump sampler, a Campbell CR101X data logger, Druck 1830 pressure transducer, and an OBS-3+ turbidity probe. The data logger and pressure transducer were up and running on 1-18-07. The OBS-3+ in-stream turbidimeter hangs from a boom off the ceiling of the culvert and has been operational since 1-23-07. The equipment has been mostly trouble free and the turbidimeter is sent in for calibration each summer.

Field Operations still include upgrading TTS station equipment, taking discharge measurements, making TTS Station FRC data dumps / sample bottle swaps, repairing storm damage to equipment and removing sediment and debris covering the pressure transducer pipe tip and/or hanging on the turbidimeter boom. Streambed aggradation has forced raising the boom and turbidimeter housing and pressure transducer pipe every year as the streambed rises to touch the housing.

A data logger modem was also purchased so that real time stage (water level) and turbidity data could be posted on the Redwood Sciences Lab website, which could function as part of an early warning network for flooding. This real time on-line data plotting has been available since the beginning of HY 2008. http://fs-server.humboldt.edu/RTMC/FrancisCreek_DetailView.gif

The sampling / tubidity sensor boom was raised this spring due to streambed aggradation**.** The instrument boom is right where the most stream bed aggradation is occurring. The instrument shelter is being threatened by the rising elevation of the streambank terrace. Unless the shed is elevated, suspended sediment at very high flows can be expected to enter the shed soon.

## Turbidity:

Turbidity is a number derived from the amount of light suspended sediment blocks from passing through water. Turbidity is usually caused by rising water flow transporting increasing levels of suspended sediment. Chronic turbidity is the tendency for streams to remain at elevated levels of turbid water for long periods. Causes of chronic turbidity can include landslides into a stream bleeding sediment for long periods to several storms in a row hitting a watershed in close intervals and keeping flow and turbidity and suspended sediment concentrations elevated. Land use in a watershed can contribute to chronic turbidity. Elevated levels of turbidity can cause harm to aquatic species.

The OBS-3+ Turbidimeter was chosen for this application because of the expected very high turbidities. The OBS-3+ sensor consists of a high intensity infrared emitting diode, which shines out into the water flow and a detector to measure light bounced back from the suspended sediment. The more infrared light bounced back the higher the turbidity.  FBU turbidity units are used per the USGS turbidimeter nomenclature table from May 2012. The OBS-3+ has a stated range of 4000 fbu but has a practical high range of about 2900 fbu for Francis Creek Sediments, which is the highest available for an in-stream turbidimeter. Flow based suspended sediment loads will be used for turbidities above the range of the OBS-3+ Turbidimeter or where debris has pushed the turbidimeter instrument boom out of the water.

# Discharge Measurements HY 2017:

A single discharge rating curve was used for HY 17. A 3rd order polynomial discharge rating curve equation was used to try to reflect the low flows better and be conservative for the high flow calculations.

Clark Fenton collected 5 discharge measurements for Hydrologic Year 2017. The deepest wading rod measurement was at 3.93 feet @ 84.2 cubic feet per second and the baseline HY 17 wading rod measurement was 1.89 feet at 0.36 cfs. GMA / Thomas Grey took the highest flow measurement with a bridge board on 2-9-17 at 6.08 feet @ 238.2 cfs.

The highest stage for Hydrologic Year 2015 was **8.04 feet @ 488 cfs** on February 6th, 2015.

The highest stage for Hydrologic Year 2016 was **6.754 feet @ 335 cfs** on March 5th, 2016.

The highest stage for Hydrologic Year 2017 was **7.59 feet @ 326 cfs on December15, 2016.**

USFS / USGS methods were used for obtaining flow measurements. (Harrelson 1994, USGS). Low flows were measured with a Wading Rod using either a Pygmy current meter or a Price AA current meter. For higher flows an A-55 Reel, 30 lb. Columbus Weight, Price AA current meter and a bridgeboard were used. An accurate estimate of stream discharge is vital to accurate suspended sediment load calculations.


Photo # 6. Clark Fenton discharge measurements

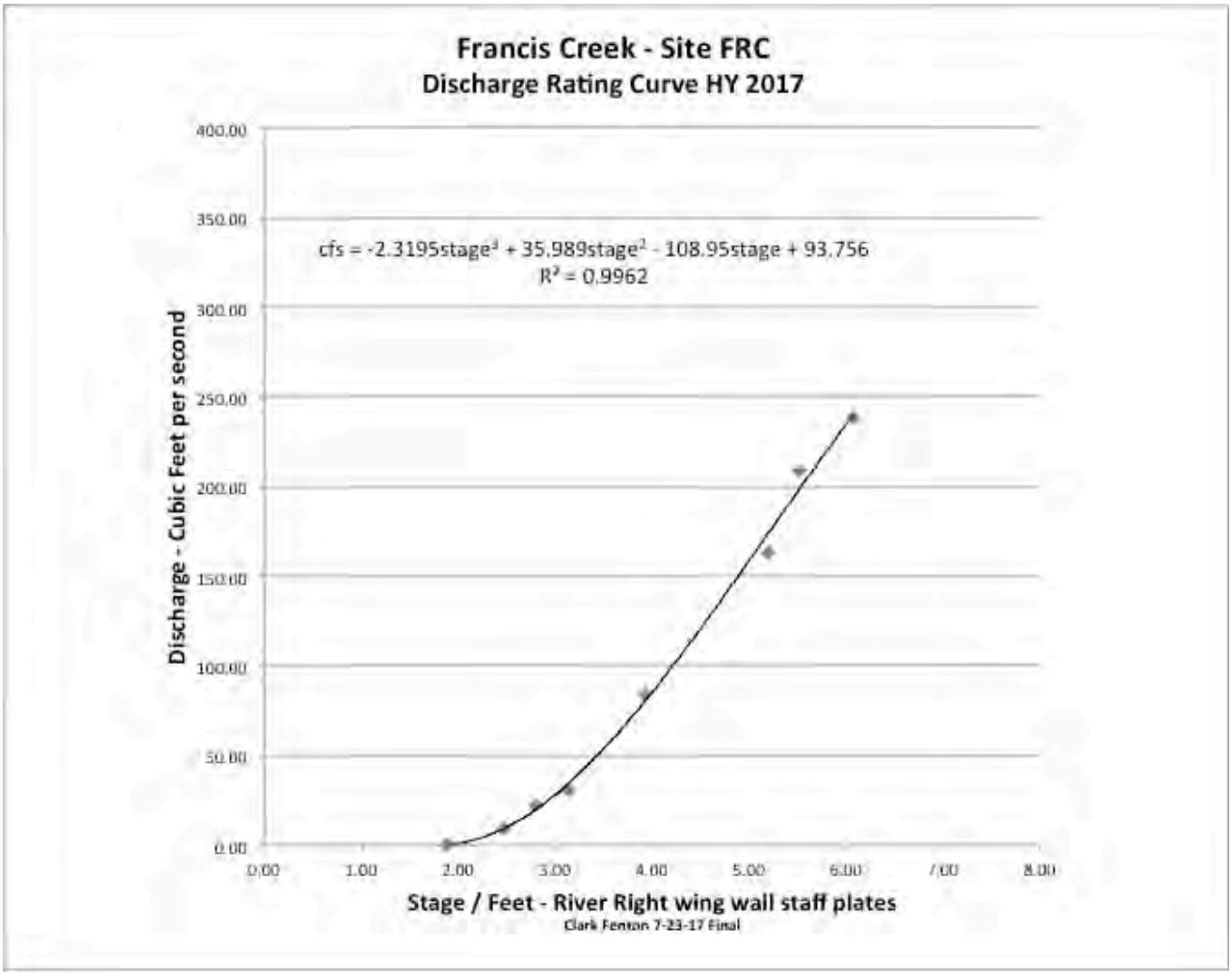



Chart # 4. Site FRC HY 2017 Discharge Rating Curve

See Appendix 3 for discharge sheets and rating curves.

Aggradation or rising of the streambed around the staff plates from bed load mobilization is still being observed. The streambed is mobile gravels and annual discharges are needed in this location to ensure representative discharge measurements. A streambed aggradation correction to stage measurements of about 2 feet is being considered. A 6 foot staff plate water depth is about a 4 foot water depth now.

# Lab Operations 2017

The United States Environmental Protection Agency – Region 9 Laboratory ran the Francis Creek suspended sediment concentration (mg/l) samples for Hydrologic Year 2014. Suspended sediment concentration determination by subtracting filtering (SSC / Sand Fraction - ASTM D3977 -02) was used.

Thanks to Valentina Cabrera-Stagno, Duane James, Lucrina Jones, Greg Nagle and Peter Husby of the United States Environmental Protection Agency – Region 9 Laboratory for running the Francis Creek suspended sediment concentration samples for Hydrologic Year 2017.

The suspended sediment concentration of each bottle is compared to the corresponding OBS-3+ Turbidity and a regression is developed for each storm period. See the FRC 2017 turbidity / suspended sediment concentration regression chart # 1 in Section 1. **If turbidity data isn't available a regression with flow vs. ssc is developed and used.**

The Francis Creek TTS sampling software triggered **192** ISCO Pump samples in HY 2017, **234** ISCO Pump samples in HY 2016, **100** ISCO Pump samples in HY 2015, **34** ISCO Pump samples in HY 2014 and **193** ISCO pump samples for HY 2013. Francis Creek 2017 sample bottle suspended sediment concentrations peaked at 34,000 mg/l.

Graham Matthews Associates got **28,340** mg/l at 12:25 2-9-17 from the average of their 2 depth-integrated sample bottles taken about 5-10 minutes before Clark Fenton triggered an ISCO point sample. The EPA Lab got a result of **32,000** mg/l, about 11% higher, on the ISCO pump sampler point sample taken.

Clark Fenton took two ISCO point samples that morning 2-9-17 at 10:10 and 10:20. The EPA Lab got **26,000** mg/l on the 10:10 sample and GMA got **27,880** mg/l on the 10:20 sample.

Clark Fenton took another two ISCO point samples on 2-9-17 at 15:50 and 16:00. The EPA Lab got **23,000** mg/l on the 15:50 sample and GMA got **20,650** mg/l on the 16:00 sample.

GMA ssc results are higher for the morning sample and lower for the afternoon sample compared to EPA results. Given the high flow turbulent conditions during sampling, the samples taken on 2-9-17 10 minutes apart are pretty close.

EPA Region 9 Laboratory 2017 reports are on file at the Humboldt County Materials Testing Lab.

# 8. Closing Summary:

The City of Ferndale cannot expect future years to be consistently dry or consistently wet. The short 10 year period of monitoring on Francis Creek shows some storms have an intense rainfall / water depth / sediment transport event or some storms are gradual events that don't transport suspended sediment. The size and location of the Francis Creek watershed along the North Coast of California ensure it will continue to experience large rapid rise and fall of water depth in sediment laden storm events.

Francis Creek is transporting an average of 30,000 cubic yards of suspended sediment each year over the last 10 years for a total of 300,000 cubic yards. It shed 65,000 cubic yards this year.

The streambed gravel bedload aggradation average is 0.17 feet per year over the last 10 years. Anecdotally I have seen most of that aggradation in the last 4 or 5 years. Any changes in the upper watershed will determine if that rate increases or not. The Francis Creek March 2011 slide has not had any major movement in awhile. Various smaller slides and mass wasting issues are occurring in the Francis Creek and Williams Creek watersheds. The Francis Creek stream channel at the Van Ness Culvert is losing it's conveyance capacity and raising the chances smaller storms to cause flooding similar to larger storms earlier.

It was a surprise to measure up to 34% suspended sediment sand fraction this season. An earlier stream bank flood deposit gradation analysis suggested the deposit was mainly silt and sand and not much clay and colloids. At higher flows we can expect the % sand fraction to be over 50%. This high % of sand may reduce sediment impacts on any anadramous fish spawning gravels in Francis Creek.

This sand, silt and clay make it down the Salt River and the mouth of the Eel River and is flushed out into the Pacific Ocean. The mouth of Humboldt Bay is 8 miles north up the coast.

The biggest equipment challenge continues to be keeping the turbidimeter sensor and housing in the water taking data as woody debris keeps snagging on it at high flows and lifting it out of the water even after 40 lbs of lead have been attached to the base of the equipment boom.

The pair of high quality 12-volt equipment batteries that HCRCD bought last year are working well and holding a charge longer than previous batteries. The datalogger and turbidimeter are 10 years old now and are still faithfully functioning well. Unfortunately Campbell Scientific no longer supports the datalogger and sampling software at the Francis Creek TTS monitoring station and a complete upgrade is needed for the next 10 years of monitoring.

A cellular modem also is needed as Redwood Sciences Lab, who hosts the on-line plotting site with HSU, is moving all their stations to cellular modems and software. This would make the Francis Creek on-line plotting more secure and easier for RSL to support.

The last 4 years on Francis Creek has seen a wide range of annual suspended sediment loads and has seen only 1 really dry year in the last 4 years of California's drought. Ferndale's unique geographic position on California's North Coast will ensure a better than average chance of large storm events transporting significant amounts of suspended sediment for the near future. Ferndale is at the mercy of the atmospheric rivers above.

Thanks to Summer Daughterty of the HCRCD for persuading the EPA to run our ssc samples again this year.

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