Fifteenmile Creek Sediment Analysis National Water Quality Initiative Report

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DEQ is a leader in restoring, maintaining and enhancing the quality of Oregon's air, land and water.

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Executive Summary

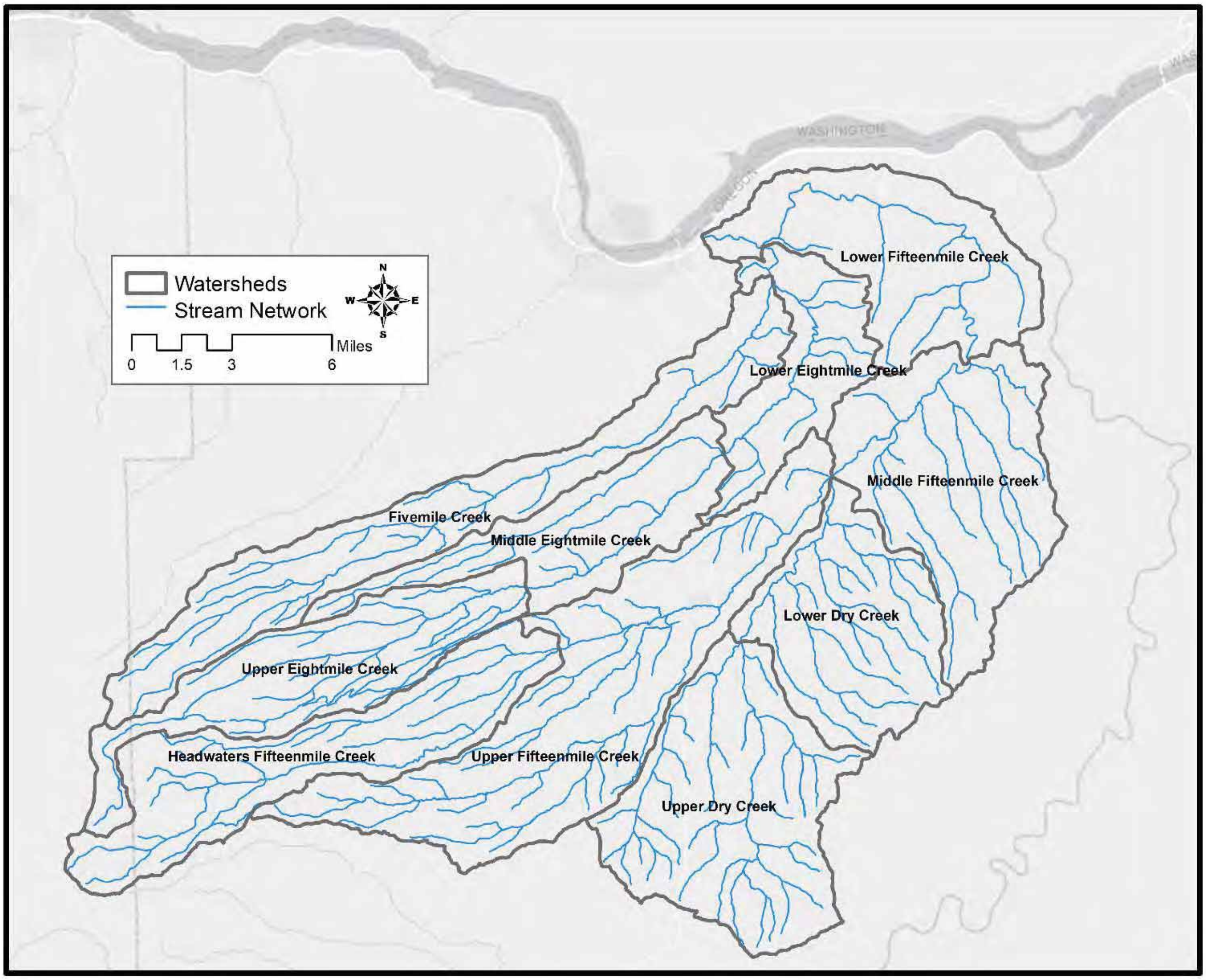
Fifteenmile Creek Watershed is on the State of Oregon 303(d) list of water quality-limited waterbodies for sediment and temperature impairments. Sediment refers to fine sediments that clog spawning gravels and make the stream less suitable for salmonid spawning. Many agencies, stakeholders and organizations have worked together for decades to restore sediment conditions in this watershed. The Oregon Department of Environmental Quality (DEQ) identified 319 funds for one of Oregon's National Water Quality Initiative (NWQI) projects to determine whether the conversion to conservation tillage on agricultural lands has resulted in improvements to in-stream sediment conditions. The DEQ worked with Tetra Tech consultants to answer study design questions, develop monitoring plans and analyze monitoring data. This report summarizes Tetra Tech and DEQ findings as well as provides recommendation for future sediment monitoring studies in the Fifteenmile Watershed.

Study Questions

1. Have improvements in sediment conditions been detected?
2. How should future monitoring and data analysis proceed in order to detect change?

Background

The Fifteenmile Watershed includes all the lands that drain to Fifteenmile Creek and its tributaries, including Eightmile Creek, Fivemile Creek, Ramsey Creek and Dry Creek (Fig. 1). Fifteenmile Watershed is located in the northern part of Wasco County, Oregon and covers 373 square miles (238,720 acres). The headwaters are located around an elevation of 4,500 feet on the east slopes Mount Hood within National Forest land. Fifteenmile Creek runs eastward and then northward to the Columbia River downstream of The Dalles Dam and upstream of the City of The Dalles.



Fifteenmile Watershed is mostly covered by coniferous forests at elevations above 2,000 feet, giving way gradually to oak forests and then to grasslands at lower elevations. Land cover at any given location is determined principally by precipitation, which varies from more than 40 inches per year at the headwaters, to as little as 10 inches per year near the mouth and along the eastern edge of the watershed. Land use tracks closely with the precipitation gradient. Forestry is the dominant land use near the headwaters and dryland crop production is the dominant land use in the lower watershed. Many of the floodplains are irrigated from the creek to grow hay. Minor land uses include urban development and fruit orchards. The City of Dufur covers 800 acres on Fifteenmile Creek near river mile 22.

Fifteenmile Watershed is home to wild steelhead, Pacific lamprey, chinook and coho salmon, cutthroat and redband trout. Excessive fine sediments harm salmonids by clogging interstitial spaces between cobbles and boulders that provide cover and food for juvenile fish (Moore 1997). Fine sediments cover spawning gravels, limiting spawning habitat and preventing the emergence of fry from redds. Suspended sediment in the water column also causes turbidity, which affects the feeding ability of juvenile salmon, steelhead and trout. In 2007, the Fifteenmile Watershed Council determined that the major sources of fine sediment to streams were poorly maintained roads (particularly on steep slopes within 200 feet of a stream), erosion of crop, range and forest lands and streambank erosion during high flow events.

Major Restoration Actions

Local stakeholders, state and federal agencies have worked together for decades to apply a whole watershed approach to restoring water quality in Fifteenmile. A variety of conservation approaches have been used that work together to reduce soil loss from upland areas and decrease sedimentation in streams that could adversely affect aquatic species. Restoration projects include:

Streamside Buffers: Since the late 1980's landowners have established vegetative buffers along 90% of perennial stream miles on privately-owned land within the watershed. This work was funded by multiple agencies, including the Bonneville Power Administration, the Oregon Department of Fish and Wildlife, the Oregon Watershed Enhancement Board and others. These streamside vegetative areas have rebounded to provide shade, water quality functions, and other resource benefits to protect the water and keep it healthy. Additionally, a majority of the perennial streams in the Fifteenmile Creek Watershed have streamside vegetative buffers enrolled in the Farm Service Agency's Conservation Reserve Enhancement Program (CREP). This is a voluntary program that restores and protects environmentally-sensitive land along streams by targeting high-priority conservation areas identified by local, state, or tribal governments or non-governmental organizations. In exchange for removing environmentally sensitive land from production and introducing conservation practices, landowners are paid an annual rental rate. A study by the Wasco County Soil and Water Conservation District showed that after these buffers have been in place for five years, they display a clear improvement in streamside conditions.

Riparian Fencing: As a part of the Fifteenmile Creek Habitat Enhancement Project, funded by BPA from 1986 to present, over 111 miles of stream have been protected through the construction of riparian corridor fence. This fencing was installed to protect instream structures and existing bank integrity from livestock and to allow natural rehabilitation of the riparian and instream fish habitat. In addition, some of Fifteenmile Creek is not fenced, but livestock grazing is excluded under lease agreements with landowners.

Forest Improvements: The United States Forest Service has conducted many restoration projects in the headwaters of Fifteenmile Creek within the Mt. Hood National Forest. Projects such as decommissioning heavily-eroded roads near streams; improving fish passage; mitigating fish entrainment into water conveyance systems; re-vegetation and reforestation of degraded areas; protecting and improving riparian vegetation; and treating dense forested stands of timber to reduce the risk of uncharacteristically severe wildfire.

Temperature Stabilization: In the summer of 2009 an unusually hot and dry stretch caused flows to plummet and instream temperature to climb into the lethal range, killing thousands of juvenile fish, including steelhead, an ESA listed threatened species. This prompted local farmers, state agencies, nonprofits and the Fifteenmile Watershed Council to explore options for improving water quality and quantity, while still keeping irrigated farmland productive. As a result, the Fifteenmile Action to Stabilize Temperature (FAST) plan was developed by the Oregon Department of Fish & Wildlife, the Oregon Water Resources Department, the Oregon Watershed Enhancement Board and The Freshwater Trust. FAST uses a predictive model that combines climate and streamflow information to forecast water temperatures at five sites throughout the watershed. When the model predicts persistent stream temperatures that are lethal to steelhead an alert is sent to irrigators, notifying them of a need to reduce diversions and keep more water instream. Irrigators then voluntarily cut back on water use to help fish survive on critically hot days in exchange for payments. In addition to the FAST plan, The Freshwater Trust has been leasing and transferring water eights from irrigators on Fifteenmile Creek for over 15 years.

Conservation Agriculture: Dryland agricultural acreage peaked soon after World War II, when most lands were tilled using moldboard ploughs. This method leads to clearly visible and measurable gullies in the field, which are highly erosive. Concentrated flow or gully erosion is erosion caused by flowing water collected in streams in a vulnerable field. Gully erosion has been substantially addressed over the years by conservation practices because it is so visible and disruptive to farm operations. In the Fifteenmile Watershed, nearly 100% of the agricultural lands were converted to “minimum till”, and 16,000 acres were enrolled in the Conservation Reserve Program between 1985 and 1990. The USDA Natural Resource Conservation Service (NRCS) reports that since 1996, 90% (76,686 acres) of the remaining cropland in the Fifteenmile Watershed has been converted from “minimum till” to “no-till” or “direct seed” farming techniques. Conservation tillage practices reduce erosion by up to 90% compared to conventional tillage.

Methods

In order to assess whether instream sediment conditions have responded to restoration actions, specifically agricultural best management practices (BMPs), a consistent sediment metric needed to be identified. The DEQ contracted Tetra Tech consultants to review available information and recommend an appropriate sediment metric to use to evaluate water quality changes. Then, given the suggested metric, to recommend an appropriate study design to use to collect additional data. Tetra Tech determined that percent sand and fines less than 2mm (SAFN) was the most appropriate sediment metric for several reasons:

1. SAFN is easily and consistently measured over time using a standard pebble count.
2. It is not sensitive to subjective interpretation and adjustments.
3. Historical and reference SAFN data exists for the Fifteenmile Watershed.
4. SAFN measures sediments that are addressed by agricultural BMPs.
5. SAFN measures sediments that are important to a wide variety of aquatic life.
6. SAFN has the advantage over suspended sediment measures, which would likely need more intensive sampling over a range of flow conditions, since total suspended solids and turbidity are negligible except during storms.

For more information on the sediment metric assessment process, see Harcum and Jessup (2015).

Monitoring

The decision to use SAFN as the primary sediment metric, as well as the existence of historic SAFN data, informed the sampling design of monitoring surveys completed in 2015 and 2016. The historic SAFN data was collected by multiple agencies using two different survey methods:

Wolman Pebble Counts: Pebble Counts require systematic random selection of 100 particles on the streambed surface along a transect or grid within the stream reach. Each particle is measured by direct measurement for larger particles and by touch for small particles. Small particles are considered silt, clay, or muck when they are not gritty when rubbed between fingers. If gritty, they are probably sand. A distribution of particle sizes yields statistics on the percent of particles less than a threshold particle size or a quantile of the distribution (e.g., the median, or D50). The D50 is the particle size diameter at which 50% of a sample's mass is comprised of smaller particles. Pebble count data can be used to calculate percent fines, percent sand and fines, and generate particle size distribution curves. Thirty-seven unique sample stations were sampled using Pebble Counts in the Fifteenmile Creek Watershed between 1994 and 2016 (Fig. 2).

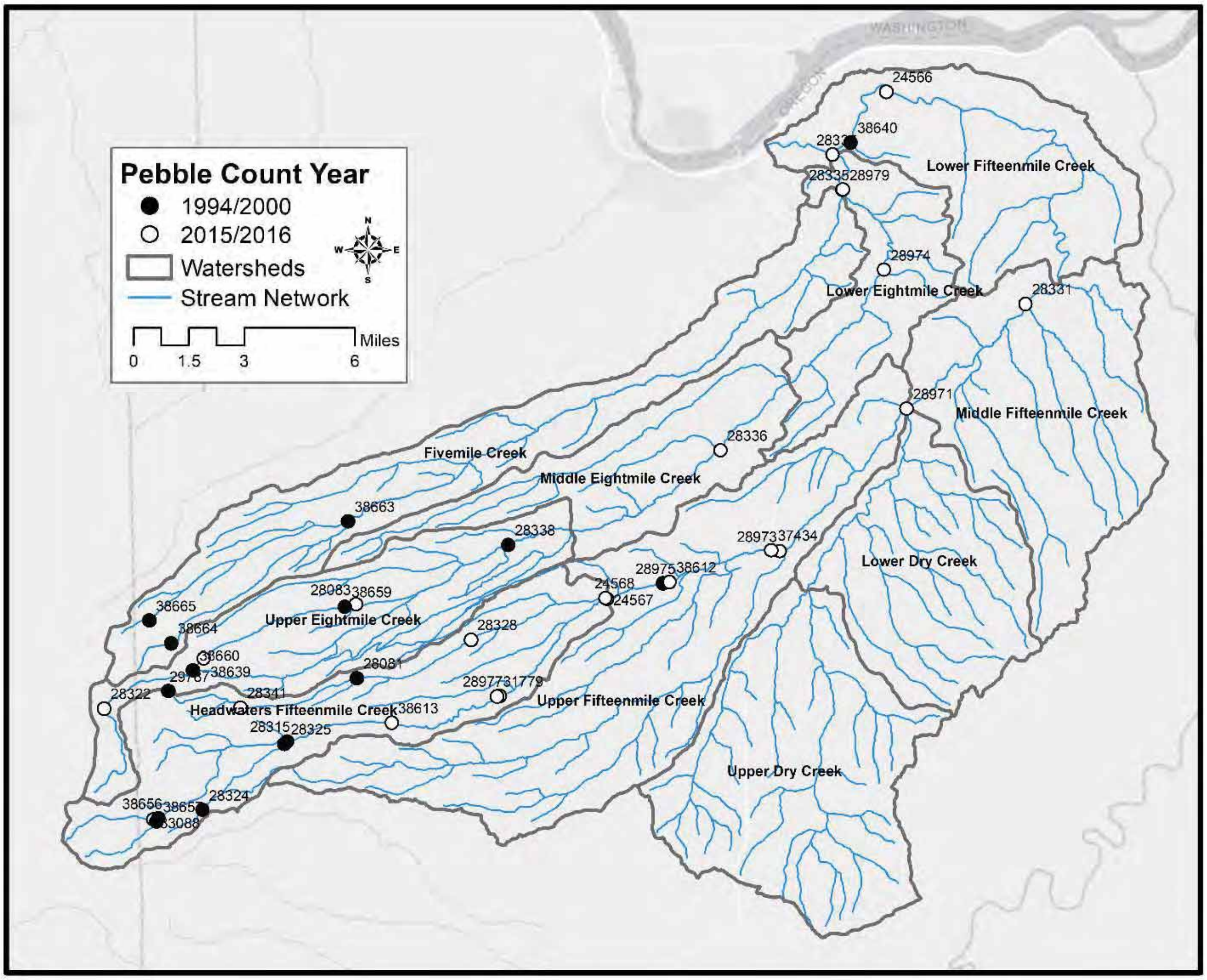


Figure 2. Map of Pebble Count locations in the Fifteenmile Creek Watershed.

Relative Bed Stability (RBS): RBS compares the observed D50 relative to the expected D50 (the calculated critical diameter of moveable particles) transformed to a logarithm. RBS is calculated from the observed D50 and additional characteristics of stream channels such as bankfull width, stream gradient, residual pool volume, and woody debris (Kaufmann et al. 2008). Bankfull width and gradient are used to calculate the volume and capacity of water moving through the channel during a channel-forming flow. Pool volume and woody debris are used to modify the capacity estimation due to channel roughness. A high RBS score indicates a coarser, more stable bed. A low RBS score indicates a relatively unstable streambed, consisting of many fine particles that could be carried away by a storm flow. Expected values of RBS are based on the statistical distribution of values observed at reference sites that are known to be relatively undisturbed. RBS values that are substantially lower than the expected range are considered to be indicators of ecological stress (Kaufmann et al. 2008). Thirty-five unique sample stations were sampled using RBS Surveys in the Fifteenmile Creek Watershed between 2005 and 2016 (Fig. 3).

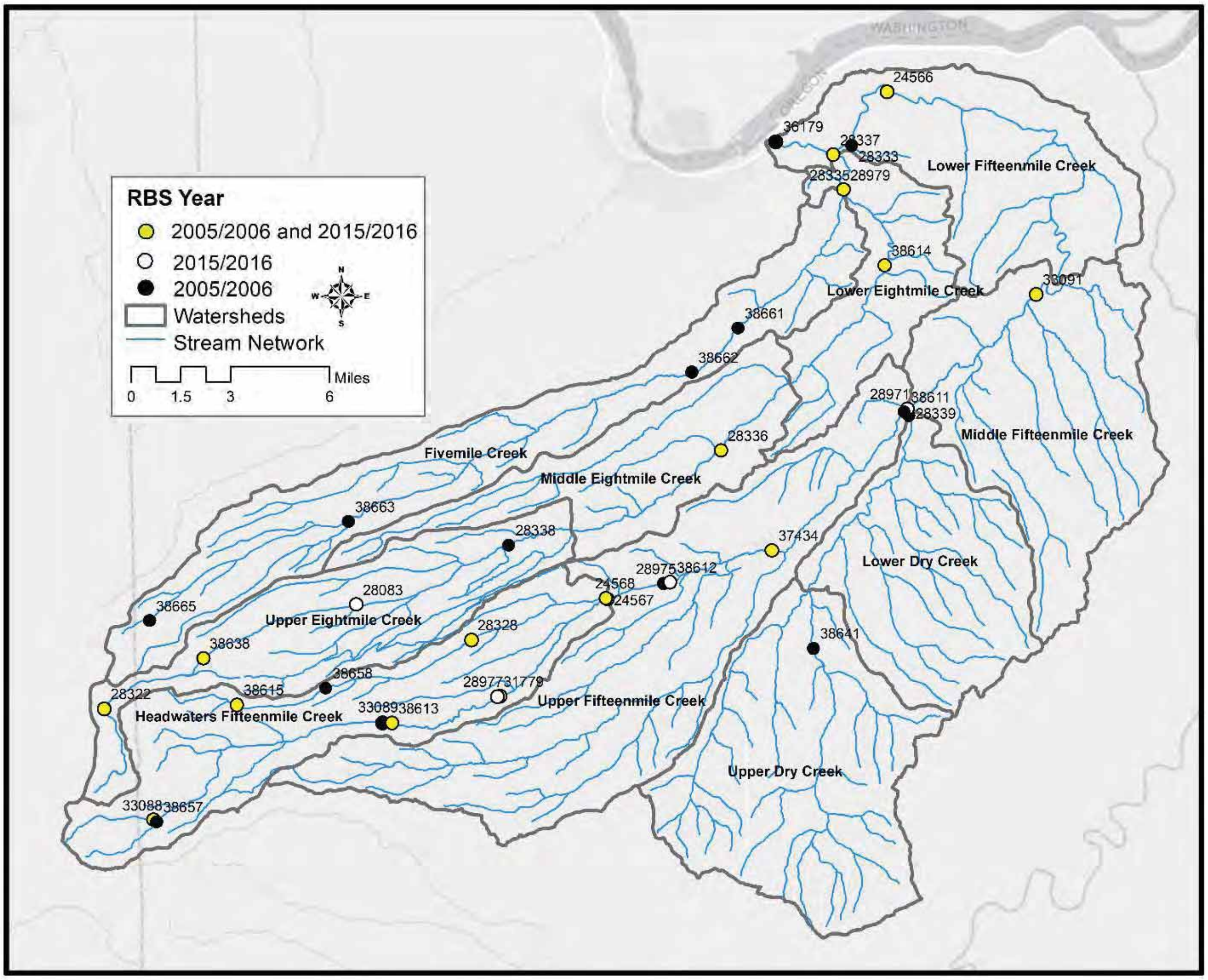


Figure 3. Map of RBS survey locations in the Fifteenmile Creek Watershed.

Macroinvertebrate sampling

Aquatic macroinvertebrate species were sampled in 2016 by DEQ staff. Due to their high taxonomic diversity, central position in stream ecosystem food-webs, and varied feeding strategies, macroinvertebrates are widely used indicators of stream biological condition (Hubler et al. 2016). Macroinvertebrate response to fine sediment is often taxon-specific, with effects observed on survival, burial, egg hatching success, growth, feeding, and relative abundance and richness. Analyzing taxon-specific response to fine sediments allows for the creation of a diagnostic index to identify for a specific cause of impairment; the Biologic Sediment Tolerance Index (BSTI) (Hubler et al. 2016). The macroinvertebrate species assemblage observed relative to the expected assemblage (O/E) at a sample station is a common indicator of disturbance from natural conditions. Samples were collected using kick nets. Fifteen stations were sampled for macroinvertebrates between September 19th and 22nd in 2016 (Fig. 4).

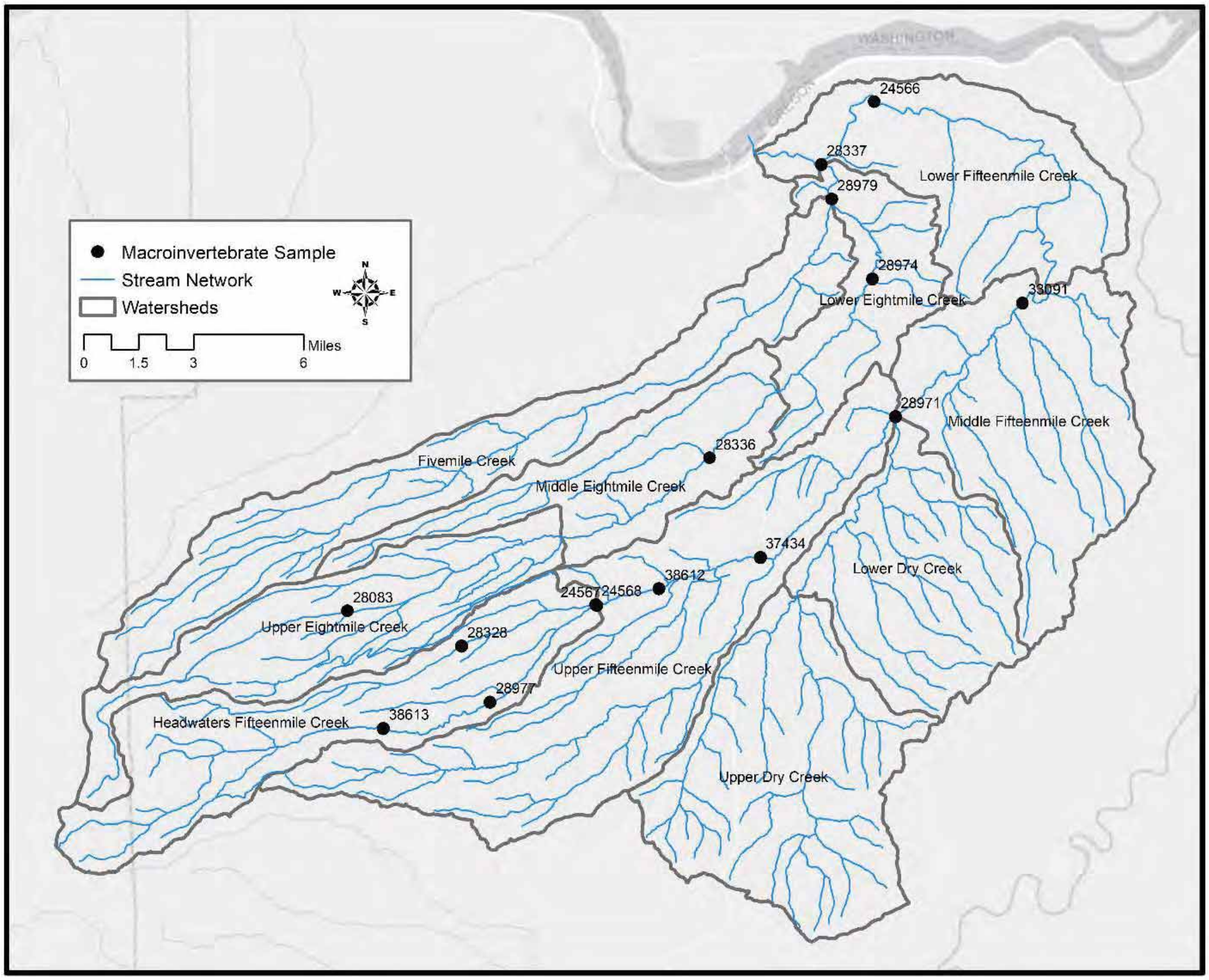


Figure 4. Map of macroinvertebrate samples collected in 2016 in the Fifteenmile Creek Watershed.

A timeline of Pebble Counts and RBS surveys is presented in Table 1. Even though both monitoring methods provide SAFN data, differences in methodology limit the comparison of SAFN measures from different survey methods. The USFS conducted Pebble Counts in riffles and pool-tails, concentrating on productive macroinvertebrate habitat and suitable salmonid spawning locations, while the RBS surveys were completed in all habitats of the entire stream reach. Given these differences, SAFN is expected to be higher in the RBS datas than the USFS Pebble Count data (Harcum and Jessup 2015). The different habitat types sampled for the RBS surveys and Pebble Counts reduces the validity of a direct comparison between the two data sets.

Table 1. Timeline of sediment sampling in the Fifteenmile Watershed.

Year	Agency	Sampling Method	Notes
1994	USFS	Wolman Pebble Counts	Only forested upper watershed and riffle and pool-tail habitats sampled
2000	USFS	Wolman Pebble Counts	Only forested upper watershed and riffle and pool-tail habitats sampled
2005	ODA, DEQ	Relative Bed Stability	All habitats sampled
2006	ODA, DEQ	Relative Bed Stability	All habitats sampled
2015	DEQ	Wolman Pebble Counts & Relative Bed Stability	All habitats sampled
2016	DEQ	Wolman Pebble Counts & Relative Bed Stability	All habitats sampled

Data Analysis

Tetra Tech Analysis

Prior to this study, Tetra Tech was contracted to provide analysis and interpretation of stream sediment monitoring data in relation to agricultural BMP effectiveness. Although SAFN was identified as the primary metric, three additional sediment metrics were analyzed; percent gravel and fines less than 6mm, the median particle size (D50), and log of Relative Bed Stability (LRBS). These measures are useful for assessment because they affect habitat suitability or are standards used in habitat comparisons (Jessup 2016). Particles less than 6mm are important components of salmonid spawning gravels and were the standard used for assessment by the USFS. The D50 is a standard particle statistic that is also used in RBS calculations. Decreased sand and fine sediment would indicate less fine sediments in the system and substrate condition improvements. Increased D50 would also indicate substrate condition improvements because the larger median sediment size suggests more stream bed stability. An RBS value approaching one (or an LRBS value approaching zero) is also in an indication of improving stream bed stability.

Sites were matched among time periods so that analyses could consider paired comparisons. When multiple samples were available within a time period (sites sampled in both 2005 and 2006 or in both 2015 and 2016), then only the most recent sample was used. Typical comparisons included visual inspection of box-plots and bi-plots of substrate measures by time period as well as two-way paired t-tests. In t-tests, significance was generally assessed at a p level of 0.05. Comparisons were only made between data collected with the same method, Pebble Counts or RBS Surveys.

Pebble Count Analysis: Three time periods were compared for pebble count measures; 1994, 2000, and 2015-16. ODEQ provided data for 39 pebble count sampling events. For the paired comparisons, 23 valid pebble count comparisons were used. Because the focus of the comparisons was related to effects of agricultural BMPs and those were only applicable in the non-forested sites sampled after 1994, the focus of comparisons for the pebble count data in later time periods included 17 sites (34 samples).

RBS Analysis: Two time periods were compared for two substrate measures; 2005/06 and 2015/16. ODEQ provided data for 63 RBS sampling events (Fig. 3). For the paired comparisons, 18 valid RBS comparisons (36 samples) were used. The measures were SAFN and the log of Relative Bed Stability (LRBS). The LRBS incorporates particle size distribution statistics and stream channel characteristics in an index of observed particle sizes in relation to expected particle sizes. When the observed median particle size is much smaller than the expected median particle size calculated from channel dimensions and roughness, then the channel substrates are less stable than expected.

DEQ Analysis

The Oregon DEQ worked with natural resource agency partners (Oregon Department of Agriculture, Oregon Watershed Enhancement Board, Oregon Department of Fish and Wildlife, and the USDA Natural Resource Conservation Service) through the Conservation Effectiveness Partnership (CEP) to develop and execute additional sediment data analysis methods. The Oregon Department of Fish and Wildlife provided SAFN threshold recommendations based on literature values and watershed specific aquatic species requirements. These were used to interpret SAFN changes over time. The Oregon DEQ plotted particle size distribution curves for each site and visually inspected them for changes over time relative to threshold SAFN values. Decreases in the smaller particle size classes indicate more stable streambed substrate.

Macroinvertebrate Analysis: DEQ staff used two different models to assess biological and sediment conditions based on macroinvertebrate species assemblages sampled in 2016. The PREDATOR model is a River Invertebrate Prediction and Classification System (RIVPACS) type model that predicts the expected occurrence of macroinvertebrates at a sample location. This is done by developing a list of insect species that commonly occur at least disturbed, or reference, locations that have similar natural characteristics to the sample locations. The list of species generated from the reference locations is known as the “Expected” taxa list or “E”. This list is compared to the captured aquatic insects or, “Observed” taxa (“O”), at an assessment site. The predictive model output is the observed to expected (O/E) taxa ratio. Scores less than one have fewer taxa at a site than were predicted by the model. Scores greater than one are either equivalent to the reference location or may have an enhanced insect community as a result of some type of enrichment. The PREDATOR model is regionally specific for assessing the biological integrity of wadable streams across Oregon (Hubler 2008).

The second model is a weighted averaging inference model that assigns stressor scores to a sample location based on the tolerance of the observed macroinvertebrate species to a stressor. The Biologic Sediment Tolerance Index (BSTI) is the stressor score used to infer fine sediment conditions from macroinvertebrate species assemblages (Hubler et al. 2016). BSTI ranges from 0-30, with high BSTI indicating more stressful sediment conditions.

Results

Tetra Tech Analysis

Pebble Counts: For the comparisons between 1994 and other periods, all sample sites were in the western forested regions of the watershed. All substrate measures improved in

comparison to the 1994 forested site conditions (Table 2, Table 3). In comparisons between 2000 and 2015/16, there was no improvement in any of the substrate measures (p>0.05, Table 3). In this later period, there was a mix of forested and agriculturally dominated sites. Even when the data were limited to agricultural sites only, there was no improvement between 2000 and
2015/16. Comparison patterns were similar for percent sand and fines less than 2mm and percent gravel and fines less than 6mm. For the median particle size (D50), the difference in particle size between 1994 and other time periods was only marginally significant (p=0.10) (Table 2).

Table 2. Mean Wolman pebble count substrate measures within three time periods for all samples, regardless of comparability among time periods.

Substrate measure	Time period		
	1994	2000	2015-16
% < 2mm	27.02	18.76	22.63
% < 6mm	35.10	26.07	29.82
D50	16.33	23.03	27.48

Table 3. Comparison statistics for three Wolman pebble count substrate measures among three time periods, showing results of t-tests and conclusions regarding substrate condition improvements.

Comparison	t-test	Conclusion
% < 2mm		
1994 - 2000	t = 3.50, df = 11, p = 0.005	Less % SAFN in 2000
2000 – 2015/16	t = -1.46, df = 16, p = 0.16	No improvement
1994 – 2015/16	t = 4.24, df = 4, p = 0.01	Less % SAFN in 2015/16
% < 6mm		
1994 - 2000	t = 3.51, df = 11, p = 0.005	Less % FNGR in 2000
2000 – 2015/16	t = -0.73, df = 16, p = 0.47	No improvement
1994 – 2015/16	t = 3.23, df = 4, p = 0.03	Less % FNGR in 2015/16
D50		
1994 - 2000	t = -1.80, df = 11, p = 0.10	Larger in 2000, marginal significance.
2000 – 2015/16	t = -0.69, df = 16, p = 0.50	No improvement
1994 – 2015/16	t = -2.12, df = 4, p = 0.10	Larger in 2015/16, marginal significance.

RBS: RBS data were collected in 2005/06 and again in 2015/16. In this time period, no improvement was indicated from the LRBS or SAFN measurements ($p>0.05$) (Table 4, Fig. 4).

Table 4. Comparison statistics for two RBS substrate measures among two time periods, showing results of t-tests and conclusions regarding substrate condition improvements.

Comparison	t-test	Conclusion
LRBS		
2005/06 – 2015/16	t = 0.38, df = 15, p = 0.71	No change in substrate condition
pSAFN		
2005/06 – 2015/16	t = -0.79, df = 15, p = 0.44	No change in substrate condition

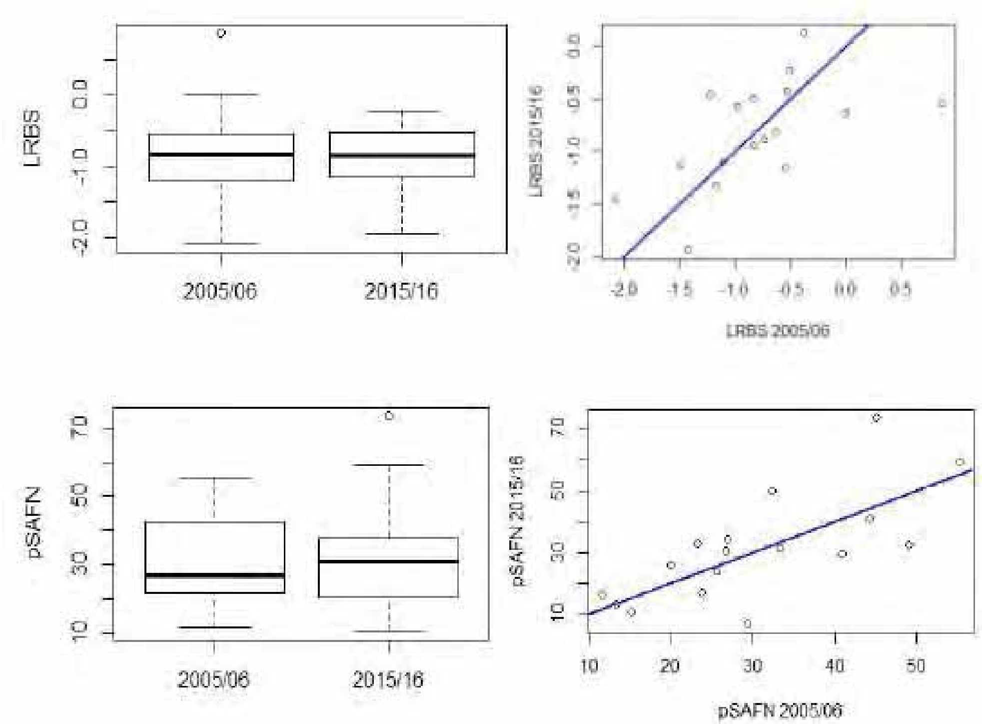
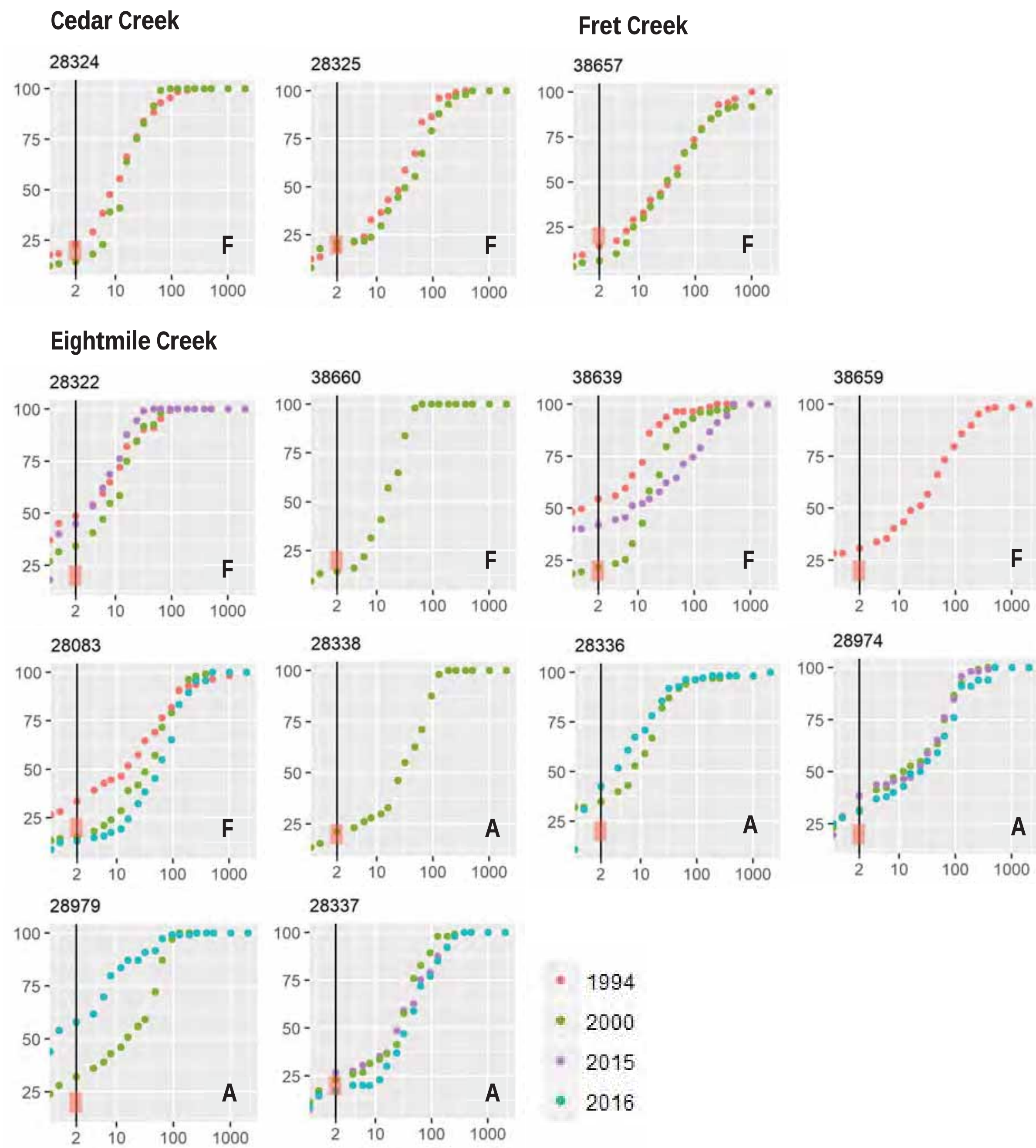


Figure 5. Distribution of RBS substrate measures in comparable sites among time periods, showing box plots with medians, quartiles and extremes on the left and comparisons in 'pre' and 'post' periods with the 1:1 line on the right.

DEQ Analysis

Particle size distributions were plotted for each station and compared to sediment benchmarks in order to assess whether streambed sediments have changed over time. Kondolf et al. (2008) used SAFN to assess the physical quality of spawning habitat and determined that 15% is the maximum level of SAFN allowing for 50% survival to emergence. Fifteen percent is also within the range of the Oregon Department of Fish and Wildlife’s benchmarks for spawning habitat, which states that less than 12% SAFN is desirable and more than 25% SAFN is undesirable.

In Cedar Creek and Fret Creek, tributaries to the headwaters of Fifteenmile Creek, all stations displayed satisfactory SAFN conditions in 1994 and 2000 (Fig. 6). Eightmile Creek, on the other hand, displayed some of the poorest SAFN conditions in the watershed. In 1994, 2015 and 2016 the two highest SAFN values were recorded in Eightmile Creek and fifteen out of twenty-two samples, across all years, exceeded the ODFW sediment benchmark (Fig. 6). Two stations (28083 and 28337) satisfied the ODFW sediment benchmark in 2016 as well as displayed a decrease in SAFN over time (Fig. 6). Station 28083 is adjacent to forest land and Station 28337 is adjacent to agricultural land.



Sediment Size

Figure 6. Particle size distributions for Pebble Counts in Cedar Creek and Eightmile Creek. Plots are ordered from upstream (left) to downstream (right). The number above each plot is the LASAR station identification. The vertical line indicates percent sand and fines less than 2mm (SAFN). The red box represents SAFN benchmarks used by ODFW to assess habitat suitability for steelhead spawning; less than 12% SAFN is ideal and more than 25% SAFN is undesirable. The letter in the plot indicates land use adjacent to the sample station; A for agriculture, F for forest, R for residential.

In Fifteenmile Creek, seven out of fifteen stations had data that could be compared between the earlier (1994 & 2000) and later (2015 & 2016) sampling periods (Fig. 7). Six of these seven stations displayed a decrease in SAFN over time; three of which were adjacent to agricultural land. Nine out of twenty-eight samples, across all years, exceeded the ODFW sediment benchmark. Eleven out of fourteen samples collected in 2015 or 2016 met the ODFW sediment benchmark; six of which were adjacent to agricultural land.

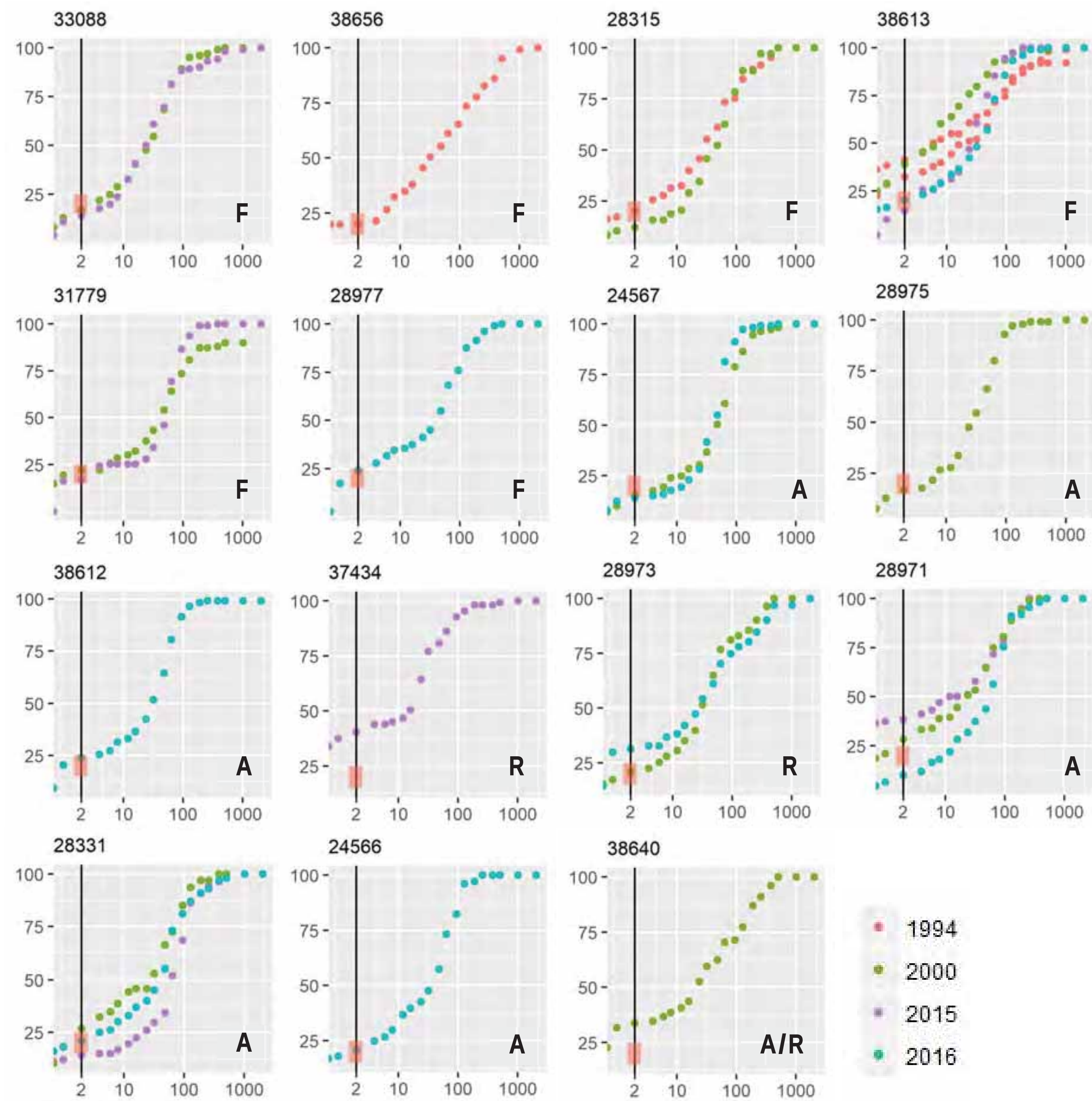


Figure 7. Particle size distributions for Pebble Counts in Fifteenmile Creek. Plots are ordered from upstream (left) to downstream (right). The number above each plot is the LASAR station identification. The vertical line indicates percent sand and fines less than 2mm (SAFN). The red box represents SAFN benchmarks used by ODFW to assess habitat suitability for steelhead spawning; less than 12% SAFN is ideal and more than 25% SAFN is undesirable. The letter in the plot indicates land use adjacent to the sample station; A for agriculture, F for forest, R for residential.

One out of six stations in Fivemile Creek and its tributaries (Middle Fork Fivemile and South Fork Fivemile) exceeded the ODFW sediment benchmark; however, sediment conditions improved at this station (38663) over time and in 2000 the benchmark was met. One station in Fivemile Creek (28335) was located adjacent to agricultural land and met sediment benchmarks in both 2000 and 2016; however, sediment conditions degraded over time. In Ramsey Creek, a tributary to upper Fifteenmile Creek, six out of thirteen samples, across all years, exceeded ODFW sediment benchmark criteria. Four out of five samples collected in Ramsey Creek in 2015 or 2016 met the ODFW sediment benchmark. All samples were collected in forested stream reaches.

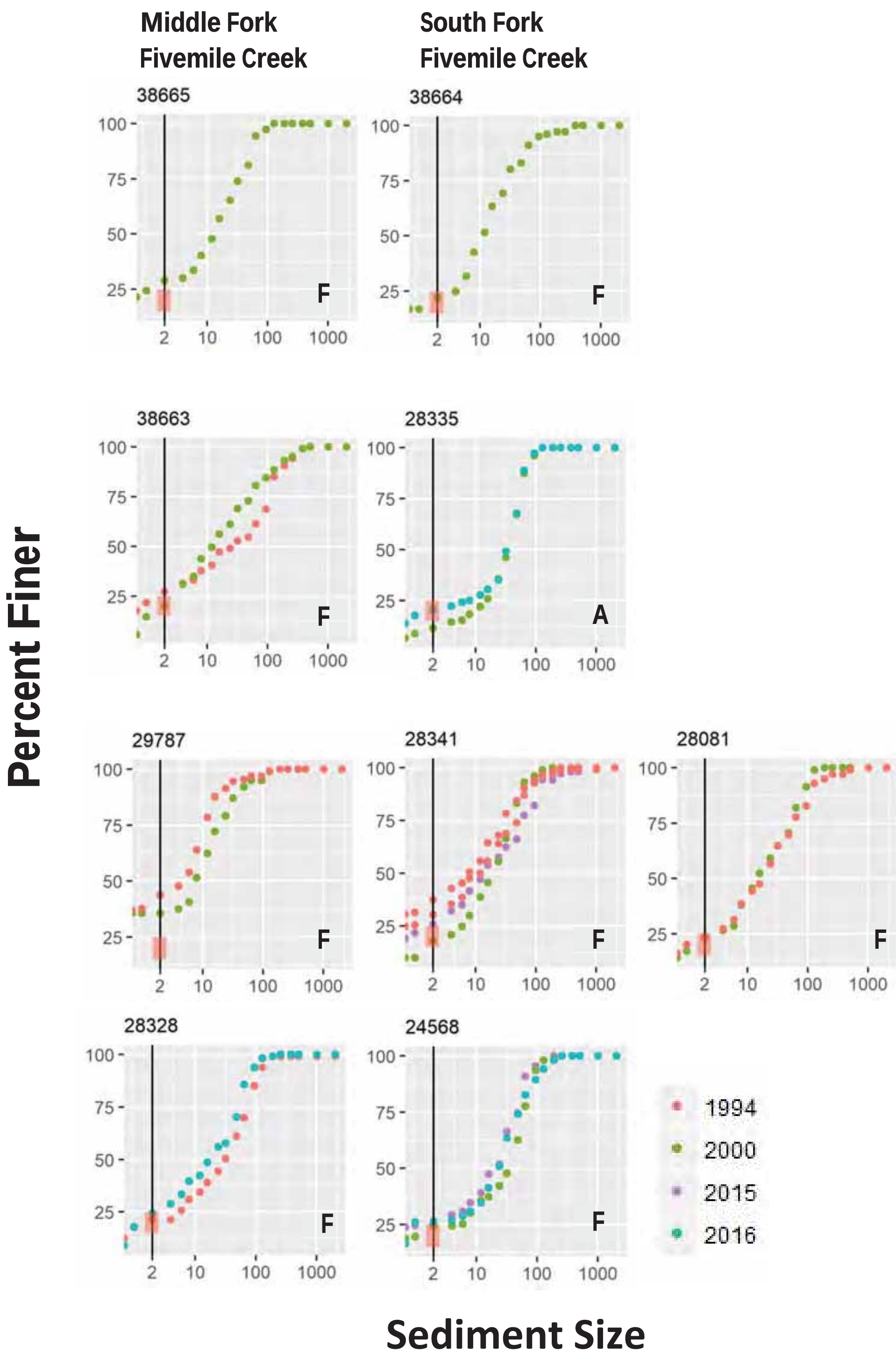


Figure 8. Particle size distributions for Pebble Counts in Middle Fork Fivemile Creek, South Fork Fivemile Creek, Fret Creek, Fivemile Creek and Ramsey Creek. For each stream, plots are ordered from upstream (left) to downstream (right). The number above each plot is the LASAR station identification. The vertical line indicates percent sand and fines less than 2mm (SAFN). The red box represents SAFN benchmarks used by ODFW to assess habitat suitability for steelhead spawning; less than 12% SAFN is ideal and more than 25% SAFN is undesirable. The letter in the plot indicates land use adjacent to the sample station; A for agriculture, F for forest, R for residential.

Results from the macroinvertebrate biological condition and stressor models generally tracked sediment condition associated with percent SAFN derived from 2016 Pebble Counts (Table 5). Station 28979, near the mouth of Eightmile Creek, had the worst BSTI score (29) and the highest SAFN (54.13%). Station 28336, in Middle Eightmile Creek, had the worst O/E ratio (.64) as well as the second highest SAFN (30.91%). The lowest SAFN, indicating best sediment condition, was 6.36% at Station 28971, however this station had the second worst O/E ratio and the third worst BSTI score. This could be because the 2016 Pebble Count was completed in November, while every other station was sampled in September. In winter, we would expect higher stream flows and more turbidity than in the summer, which would result in less fine sediments settling onto the stream bed. This station was sampled in September of 2015 and SAFN was 37.25%, indicating poor sediment conditions.

Station 24568 had the best O/E score (1.23) and a SAFN value of 25.96%, which is only slightly above the 25% benchmark identified by ODFW as undesirable for steelhead. The rest of the least disturbed stations had desirable SAFN conditions relative to the ODFW benchmark. Based on O/E condition, the least disturbed stations were located in the upper watershed and the moderately and most disturbed stations were distributed throughout the lower watershed (Fig. 9).

Stations with the lowest BSTI scores (less than 10), indicating macroinvertebrate species assemblages that are less tolerant of fine sediments, had SAFN values within the desirable range of the ODFW sediment benchmark and were identified as least disturbed by the O/E ratio. The BSTI data displays generally degrading trends in sediment condition from upstream to downstream (Fig. 10). This corroborates trends in SAFN condition based on ODFW sediment thresholds.

Table 5. Biological condition and stressor model results based on macroinvertebrate data collected in 2016. O/E is the ratio of observed to expected macroinvertebrate taxa based on reference site assemblages in Oregon. BSTI is the Biologic Sediment Tolerance Index that measures the tolerance of macroinvertebrate taxa to fine sediments. SAFN is the percent of sand and fine sediment less than 2 mm in diameter derived from Pebble Counts in 2016.

STATION	STREAM	O/E	O/E CONDITION	BSTI	SAFN
24568	Ramsey	1.23	Least disturbed	13	25.96
28083	Eightmile	1.17	Least disturbed	8	12.17
28977	Fifteenmile	1.1	Least disturbed	8	17.31
28328	Ramsey	1.1	Least disturbed	12	18.02
38612	Fifteenmile	0.96	Least disturbed	12	20.34
24567	Fifteenmile	0.93	Least disturbed	10	12.39
38613	Fifteenmile	0.93	Least disturbed	9	16.35
28337	Eightmile	0.84	Moderately disturbed	21	15.00
28974	Eightmile	0.8	Moderately disturbed	13	28.00
33091	Fifteenmile	0.8	Moderately disturbed	22	NA
37434	Fifteenmile	0.8	Moderately disturbed	28	NA
28979	Eightmile	0.74	Most disturbed	29	54.13
24566	Fifteenmile	0.72	Most disturbed	18	17.82
28971	Fifteenmile	0.72	Most disturbed	27	6.36*
28336	Eightmile	0.64	Most disturbed	24	30.91

**Only station sampled in November of 2016.*

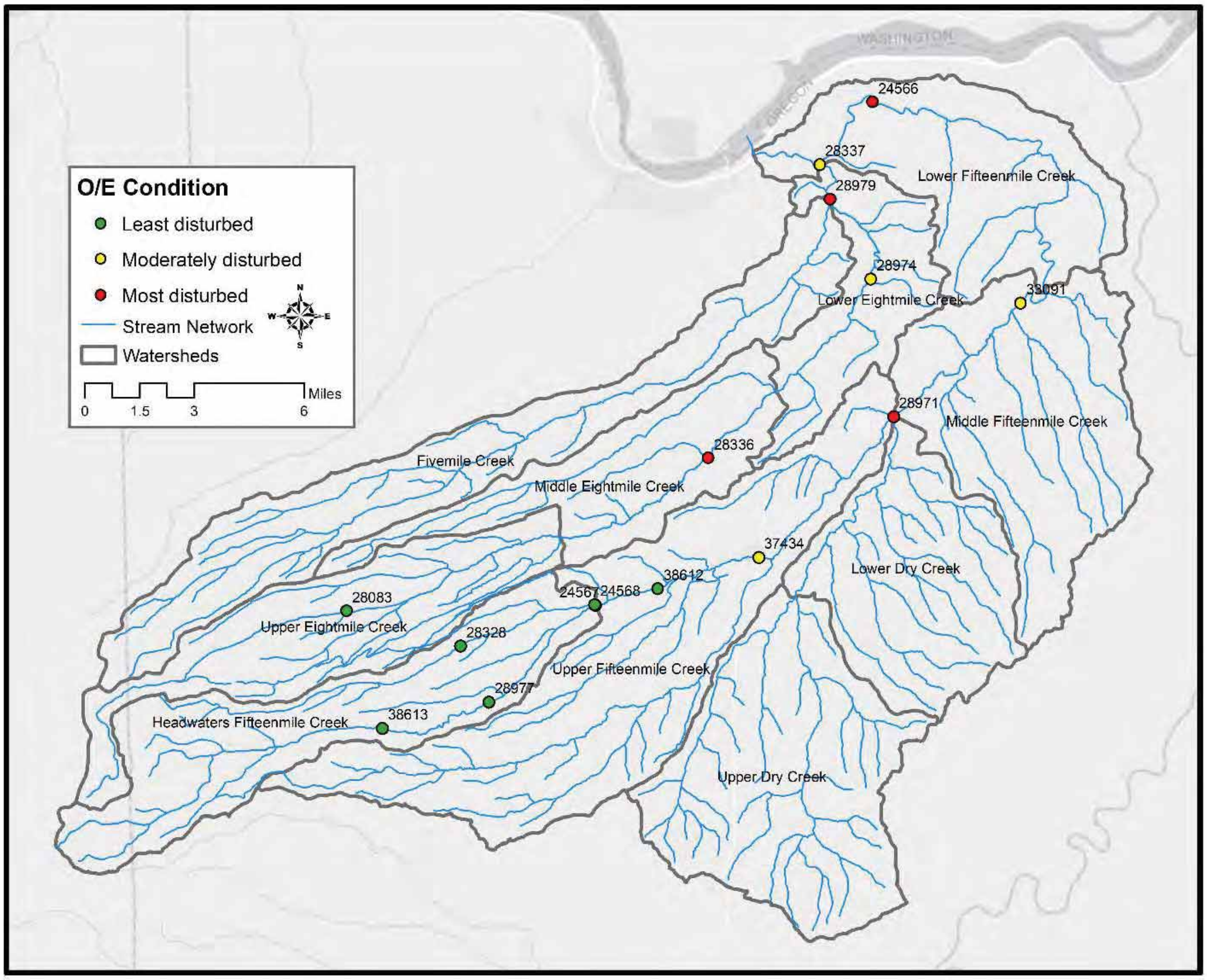


Figure 9. Map of O/E condition of macroinvertebrate species observed at each sample location in 2016. The LASAR station ID of each sample site is labeled on the map.

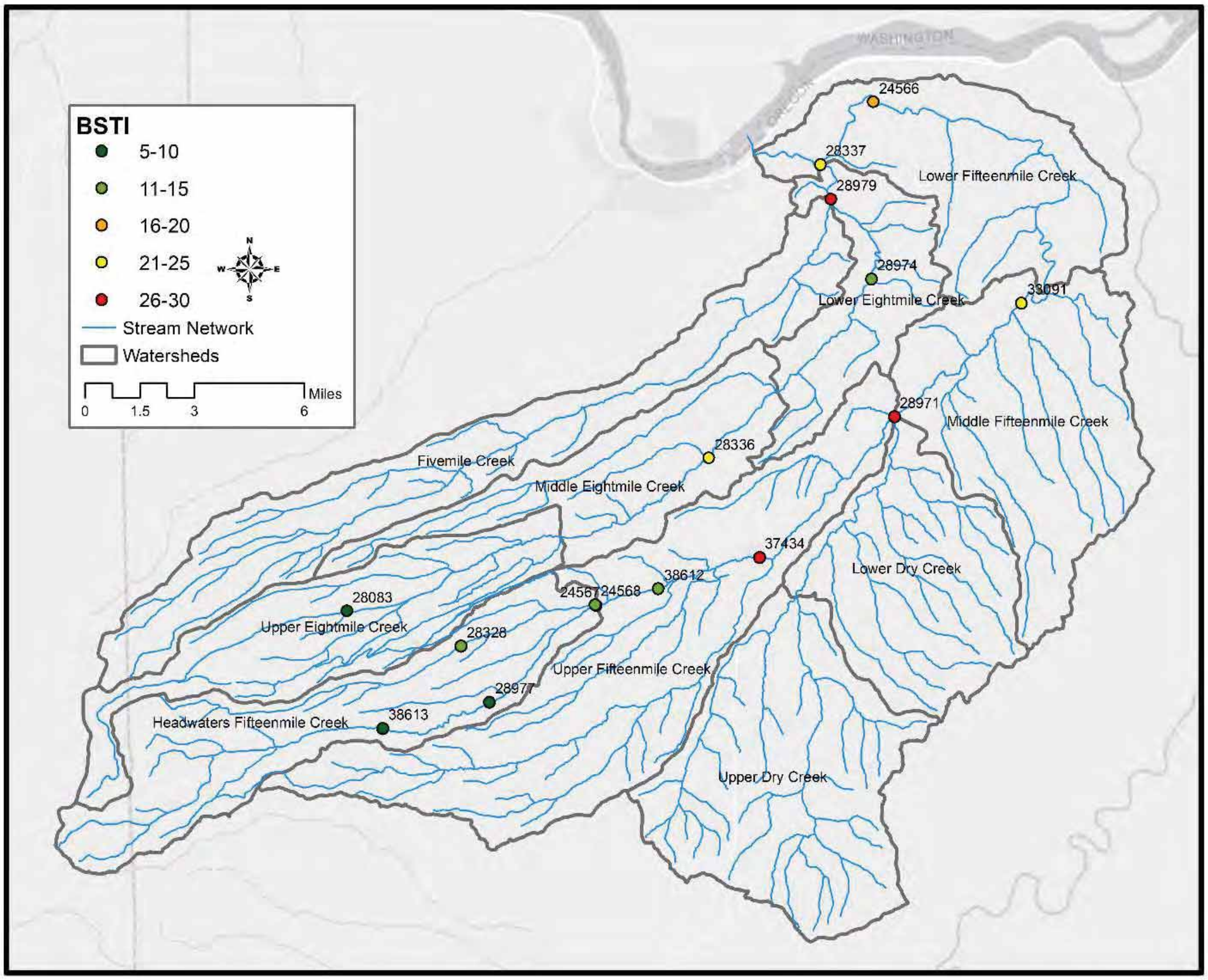


Figure 10. Map of BSTI scores indicating the fine sediment tolerance of macroinvertebrate species observed at each sample location in 2016. The LASAR station ID of each sample site is labeled on the map.

Discussion

Have improvements in sediment conditions been detected?

No. Currently available data do not indicate that substrate conditions have improved in the Fifteenmile Creek Watershed in response to agricultural BMP implementation. However, anecdotal evidence suggests that conditions have improved. Farmers and agency hydrologists that have worked in the basin for decades agree that there is visibly less gully, wind, and sheet flow erosion from fields that have transitioned from conventional tillage practices to conservation tillage and direct seed practices. Additionally, erosion rates calculated by local NRCS Soil Conservationists using the Revised Universal Soil Loss Equation 2 (RUSLE2) demonstrate drastic reductions in sediment transport to streams over time (NRCS 2015). The Oregon Department of Fish and Wildlife captured before and after images of riparian restoration projects adjacent to agricultural fields that have undoubtedly provided bank stabilization and reduced sediment deposition to the stream (Fig. 11, Fig. 12). These observations are contradictory to the results of this report, which begs two questions: If substrate conditions have improved in Fifteenmile Watershed, why don't the data tell this story? And, if substrate conditions have not improved, why not?

Figure 11. Fifteenmile Creek U 2 riparian corridor protection site at river mile 36.5 (ODFW 2013).

Figure 12. Fifteenmile Creek Brew 5 riparian corridor protection site at river mile 20.0 (ODFW 2013).

Data Limitations

A possible explanation for why this analysis does not demonstrate improvements in sediment conditions is that the existing data does not capture pre-treatment conditions relative to tillage BMP implementation. The Pebble Counts completed by USFS in 1994 and 2000 only surveyed the upper, forested portion of the watershed, which is not representative of agricultural land management. The 2005/06 and 2015/16 sampling events surveyed locations adjacent and downstream of agricultural lands, but the 2005/06 data cannot be considered baseline since the majority of the watershed had already been converted to conservation tillage practices by then
(Jessup 2016).

Another explanation is that some years of the existing data could not be compared due to the differences between sampling methods used to survey substrate conditions. The USFS conducted pebble counts in riffles and tails of pools, concentrating on productive macroinvertebrate habitat and suitable salmonid spawning locations, while all other surveys were collected in all habitat types. The difference in habitat types between survey years reduces the validity of a direct comparison between the two data sets. Given the differences in the methodologies, SAFN from all habitats is expected to be higher than SAFN from pool tails and riffles. As a result, these two data sets cannot be meaningfully compared to each other (Harcum and Jessup 2015).

These limitations mean that the only valid comparisons to make between existing data sets are between Pebble Counts from 1994 and 2000 and between RBS surveys from 2005/06 to 2015/16. The locations of 1994 and 2000 Pebble Counts did not capture pre-treatment conditions for agricultural BMP implementation, so neither of these comparisons can compare pre-treatments versus post-treatment sediment condition relative to conservation tillage practices. This means that, even if sediment conditions have improved in the Fifteenmile Watershed in response to agricultural BMP implementation, the currently available data would not be able to detect or measure improvement. Therefore, the influence of conservation tillage practices on instream sediment conditions cannot be assessed with the existing data sets.

Unchanged Sediment Conditions

It is possible that sediment conditions have not improved as much as expected in the Fifteenmile Watershed. A doctoral student at Portland State University investigated why this may be the case in her dissertation research. Dr. Melanie Malone's goal was to identify the sources of stream sediment in the study area as well as the influences of conservation management techniques on sediment sources.

Dr. Malone used historic aerial imagery analysis, LiDAR spatial analysis, cesium-137 sediment source tracking and interviews with landowners to identify what proportions of sediment in streams were from upland versus near-channel erosion and to distinguish between what erosional processes are influenced by human activity in contrast to those that occur naturally. Her findings indicate that a significant amount of sediment in streams is sourced from cultivated fields despite the adoption of conservation tillage practices throughout the majority of the watershed.

Dr. Malone argued that this is likely due to inconsistencies in how conservation tillage techniques are being implemented throughout the watershed. Her interviews with farmers, NRCS and extension agents revealed that there is a high amount of variability in the way farmers practice, and define, conservation tillage. Many farmers use the term "no-till" interchangeably with conservation tillage, even though they may not be consistently meeting the requirements of true no-till or direct seed practices, and the intensity of soil disturbance varies widely among different tillage practices (Table 5). Farmers might practice no-till in two or three of their crop rotations, then use a different form of conservation tillage due to field conditions or other environmental factors. An extension agent also told Dr. Malone that some farmers have returned at least part of their land to conventional tillage after practicing no-till due to a variety of issues related to herbicide resistance, managing crop stubble, changes in weather patterns, and loss of CRP funds.

NRCS uses tillage practices to estimate erosion rates from agricultural fields in the Fifteenmile Creek Watershed (Table 7). This means that determining exactly which type of tillage practices are in use in the watershed, and to what extent, is critical for estimating watershed wide erosion rates that reflect reality. Overestimating the amount of land converted to true "no-till" practices could be why in stream sediment conditions are poorer than expected.

Table 6. Table presented in Dr. Malone's thesis showing categories of conservation tillage and residue. Large differences between residue conserved, soil disturbance, and erosion occur due to equipment differences used for each method (Washington State University Extension Service 2017).

Classification		Primary Tool(s)	Tillage Intensity	Residue Coverage
Clean-till		Moldboard plow	High, soil inversion	<30%
Clean-till		Heavy offset disk	High	<30%
Reduced-till		Chisel plow, disk	High	<30%
Reduced-till, Minimum-till, Mulch-till	High residue farming (Conservation tillage)	Chisel plow	Moderate	>30%
Strip-till		Strip-till implement	Non-uniform, moderate-none, 6-12" deep	60-80%, bare soil in planted strip
Zone-till		Gang of coulters on planter, row cleaners	Non-uniform, moderate-none, 1-2" deep	60-80%, bare soil in planted strip
Direct seed, No-till*		Planter with row cleaners	None	60-80%, 0-80% in planted strip
Direct seed, No-till		Planter without row cleaners	None	80-100%

** Direct seeding and No-till refer to the same practice*

Table 7. Table presented in Dr. Malone's thesis showing the differences between erosion rates based on type of tillage used. Erosion rates were calculated by NRCS Soil Conservationist in Wasco County using RUSLE2 (NRCS 2015). The amount of eroded soil per year assumes that there are 81,130 acres of cultivated land in the Fifteenmile Creek Watershed.

	No-Till/ Direct Seed	Conservation Tillage (Rate for Reduced Till, Minimum Till, Mulch Till)	Conventional Tillage Rate
Erosion Rate (tons/acre/year)	0.34	4.6	8.83
Eroded Soil (tons/year)	27584	373198	716378

Future Monitoring

How should future monitoring and data analysis proceed in order to detect change?

The lack of baseline sediment condition limits our understanding of how agricultural BMPs targeting tillage practices have affected instream sediment conditions in the Fifteenmile Creek Watershed. However, future sediment monitoring can still demonstrate that meaningful changes in sediment condition have occurred relative to current conditions. Limitations encountered in this study may be avoided by ensuring that future survey methods produce data that is comparable to pre-existing data. To accomplish this, the DEQ recommends repeating Wolman Pebble Counts at stations sampled in 2015 and 2016. A summary of all pebble count surveys completed in the watershed can be found in Appendix D. Pebble Counts may be especially valuable after high flow events that flush fine sediments out of the system. Pebble Counts are recommended over RBS Surveys for monitoring changes in SAFN over time since they require less resources and are simpler.

It is also recommended to continue monitoring macroinvertebrate species assemblages at stations sampled in 2016. Changes in the sediment tolerance (BSTI) of the macroinvertebrates species observed over time may indicate when and where sediment conditions are improving in the watershed. Monitoring instream fine sediments alone may indicate improvements in habitat condition, but it is particularly useful to understand whether aquatic organisms are recovering as well. In addition, macroinvertebrate sampling is a cost effective measure of instream sediment conditions that can be used by a broad range of resource managers, from government agencies with well-developed biological monitoring programs to citizen-based monitoring organizations with relatively minimal resources and experience.

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Appendix A. Tetra Tech's pebble count results used in comparisons between 1994, 2000 and 2015/16.

Station Key	Site Name	Latitude	Longitude	% <2mm 1994	% <2mm 2000	% <2mm 2015	% <2mm 2016	% <6mm 1994	% <6mm 2000	% <6mm 2015	% <6mm 2016	D50 1994	D50 2000	D50 2015	D50 2016
28331	Fifteenmile Creek at Emerson Loop Rd (d/s Standard Hollow)	45.54571	-120.9797		18.11	12.04†	18.00		32.28	14.81†	25.0		28.89	62.32†	40.0
28315	Fifteenmile Creek d/s Cedar	45.3799	-121.3975	17.14	10.28			25.71	15.89			27.6	42.29		
33088	Fifteenmile Creek d/s Rd 2730 and Fifteenmile CG	45.35009	-121.4732		12.87	10.78			21.78	17.65			26.86	24.0	
28971	Fifteenmile Creek u/s Dry Ck	45.5056	-121.0476		20.97	37.25†	6.36		33.06	41.18†	11.82		23.0	12.0†	56.0
31779	Fifteenmile Creek u/s Dufur City intake	45.396	-121.2802		19.27	16.22			22.02	24.32			4.02	50.77	
28973	Fifteenmile Creek u/s Pine Cr.	45.45054	-121.1203		17.12		29.77		22.52		32.82		31.08		27.11
24567	**Fifteenmile Creek u/s Ramsey Ck**	45.4333	-121.2177		10.09		12.39		17.43		15.04		47.47		42.13
38613	Fifteenmile Creek u/s Rd 4421 bridge	45.3864	-121.3391	38.24	28.7	10.09†	16.35	45.1	45.37	25.69†	23.08	6.0	6.31	25.87†	35.56
28335	Fivemile Creek u/s Eightmile Creek	45.59236	-121.0807		8.65		17.59		14.42		22.22		34.91		32.8
28083	Eightmile Creek @ forest boundary	45.4333	-121.3578	28.18	14.29		12.17	39.09	18.1		14.78	14.67	34.67		56.0
28336	Eightmile Creek 300 meters u/s Endersby bridge	45.4909	-121.1522		32.0		30.91		40.0		51.82		7.4		3.6
28337	Eightmile Creek at mouth (confluence with 15mile Creek)	45.6064	-121.0856		17.31	14.29†	15.0		25.96	27.62†	20.0		28.24	25.09†	36.0
28974	Eightmile Creek d/s county bridge	45.56047	-121.0582		27.88	28.57†	28.0		41.35	43.75†	37.0		12.0	20.0†	24.0
38639	Eightmile Creek d/s Rd. 4440	45.41306	-121.4433	49.65	19.42	40.0		55.94	23.3	44.44		1.07	13.88	7.6	
28979	Eightmile Creek u/s Fivemile Creek	45.5925	-121.0803		28.0		54.13		36.0		61.47		15.2		0.59
28322	Eightmile u/s FSR 4400	45.3942	-121.4995	45.05	31.48	40.0		54.05	40.74	53.33		2.5	6.75	3.22	
28328	Ramsey Creek @ new forest boundary	45.41844	-121.294		17.7		18.02		21.24		28.83		31.43		17.5
28081	Ramsey Creek @ old forest boundary (RY2800)	45.4042	-121.3581	20.2	17.14			27.27	26.67			18.22	14.57		
29787	Ramsey Creek @ Pebbleford campground	45.4006	-121.4634	37.69	35.64			47.69	37.62			4.75	7.73		
28341	Ramsey Creek d/s Forest Rd. 4450	45.3935	-121.4235	31.3	9.9	21.7		42.61	20.79	32.08		7.83	19.6	13.71	
24568	Ramsey Creek u/s confluence with Fifteenmile Creek	45.4337	-121.2182		19.63	24.55†	25.96		24.3	29.09†	26.92		34.5	20.8†	23.2
28324	Cedar Creek d/s Rd. 2730-160	45.35349	-121.4456	18.46	13.33			29.23	18.1			9.2	13.58		
28325	Cedar Creek u/s Fifteenmile	45.3789	-121.3993	13.46	17.82			21.15	21.78			25.45	33.33		

† Results not used in comparison due to earlier year.

Appendix B. Tetra Tech's RBS survey results used in comparisons between 2005/06 and 2015/16.

Station Key	Site Name	Latitude	Longitude	2005 LRBS	2006 LRBS	2015 LRBS	2016 LRBS	2005 SAFN	2006 SAFN	2015 SAFN	2016 SAFN
33088	Fifteenmile Cr. d/s FSR 2730 & Fifteenmile Campground	45.3501	-121.4732	-0.84		-0.49		13.33		13.46	
37434	Fifteenmile Creek @ Dufur Park	45.4511	-121.1252	-0.84	-0.58†	-0.71†	-0.95	23.81	15.53†	17.14†	25
33091	Fifteenmile Creek 1/3 mile d/s Standard Hollow	45.5494	-121.9742	-0.98	-1.51†	-0.51†	-0.58	40.95	47.57†	23.81†	29.52
24566	Fifteenmile Creek 2.5 Miles u/s Eightmile Creek	45.6307	-121.0548	-0.53			-0.43	26.67			30.48
28977	Fifteenmile Creek between chlorine building and Dufur City intake	45.396	-121.2786		-0.5		-0.22		11.7		16.19
28971 /38611	Fifteenmile Creek u/s Dry Creek	45.5056	-121.0476		-0.01	-0.63	-0.74†		20	25.71	35.24†
24567	Fifteenmile Creek u/s Ramsey Cr.	45.4333	-121.2177	-0.64			-0.82	25.71			23.81
38613	Fifteenmile Creek u/s Rd 4421 bridge	45.3864	-121.3391		-0.55	-1.08†	-1.16		23.3	29.52†	33
28975	Fifteenmile Creek u/s Underhill diversion	45.439	-121.186		-0.38	0.12‡			29.41	6.86‡	
38614	Eightmile Creek ~280 meters d/s county bridge	45.5623	-121.0582		-1.23	-1.69†	-0.46		49.02	46.53†	32.38
28336	Eightmile Creek 300 meters u/s Endersby bridge	45.4909	-121.1522		-1.43		-1.94		45.1		73.33
28337	Eightmile Creek u/s Fifteenmile Creek	45.6064	-121.0856		-1.11	-0.79†	-1.1		33.33	20.59†	31.43
28979	Eightmile Creek u/s Fivemile Creek	45.5925	-121.0803		-2.09		-1.45		55.24		59.05
28322	Eightmile Creek u/s FSR 4400	45.3942	-121.4995		-1.18	-1.33			32.38	50	
28328	Ramsey Creek @ new forest boundary	45.4184	-121.294		0.86		-0.54		26.92		34.29
24568	Ramsey Creek u/s Fifteenmile Creek	45.4337	-121.2182		-1.5	-1.37†	-1.13		44.23	40.95†	33.33
38615	Ramsey Creek u/s USFS Rd 4550	45.3948	-121.4253		-0.74	-0.89			15.24	10.58	

† Results not used in comparison due to earlier year or uncertain slope.

‡ Results measured in 2014.

Appendix C. Summary of all Relative Bed Stability surveys in the Fifteenmile Creek Watershed.

STATION	LOCATION	LAND USE	2005	2006	2015	2016	LON.	LAT.
24566	Fifteenmile Creek 2.5 miles u/s Eightmile Creek	Agricultural	Yes			Yes	-121.05480	45.63070
24567	Fifteenmile Creek u/s Ramsey Ck	Agricultural	Yes			Yes	-121.21770	45.43330
24568	Ramsey Creek @ mouth	Agricultural		Yes	Yes	Yes	-121.21820	45.43370
28083	Eightmile Creek @ forest boundary	Forest				Yes	-121.35780	45.43330
28322	Eightmile u/s FSR 4400	Forest		Yes	Yes		-121.49950	45.39420
28328	Ramsey Creek@ new forest boundary	Forest		Yes		Yes	-121.29400	45.41844
28333	Fifteenmile Creek @ Petersburg (u/s 8mile)	Agricultural/residential		Yes			-121.07510	45.60990
28335	Fivemile Creek u/s Eightmile Creek	Agricultural		Yes			-121.08069	45.59236
28336	Eightmile Creek 300 meters u/s Endersby bridge	Agricultural		Yes		Yes	-121.15220	45.49090
28337	Eightmile Creek at mouth (confluence with 15mile Creek)	Agricultural		Yes	Yes	Yes	-121.08560	45.60640
28338	Eightmile Creek @ rivermile 19	Agricultural		Yes			-121.27200	45.45550
28339	Dry Creek @ mouth	Agricultural		Yes			-121.04690	45.50300
28971	Fifteenmile Creek u/s Dry Ck	Agricultural			Yes	Yes	-121.04760	45.50560
28975	Fifteenmile Creek u/s Underhill's diversion	Agricultural		Yes			-121.18600	45.43900
28977	Fifteenmile Creek between chlorine building and Dufur City intake	Forest		Yes		Yes	-121.27860	45.39600
28979	Eightmile Creek u/s Fivemile Creek	Agricultural		Yes		Yes	-121.08030	45.59250
31779	Fifteenmile Creek u/s Dufur City intake	Forest			Yes		-121.28020	45.39600
33088	Fifteenmile Creek d/s Rd 2730 and Fifteenmile CG	Forest	Yes		Yes		-121.47322	45.35009
33089	Fifteenmile Creek 1/4 mile u/s Rd 4421 bridge	Forest	Yes				-121.34428	45.38650
33091	Fifteenmile Creek 1/3 mile downstream Standard Hollow	Agricultural	Yes		Yes	Yes	-120.97420	45.54940
36179	Fifteenmile Creek Above Seufert Falls (AKA Cushing Falls)	Agricultural/residential	Yes				-121.11760	45.61190
37434	Fifteenmile Creek at Dufur Park	Residential	Yes	Yes	Yes	Yes	-121.12523	45.45106
38611	Fifteenmile Creek ~300 meters u/s Dry Creek	Agricultural		Yes			-121.04940	45.50447
38612	Fifteenmile Creek d/s Underhill diversion	Agricultural				Yes	-121.18236	45.43950
38613	Fifteenmile Creek u/s Rd 4421 bridge	Forest		Yes	Yes	Yes	-121.33911	45.38640
38614	Eightmile Creek ~280 meters d/s county bridge	Agricultural		Yes	Yes	Yes	-121.05816	45.56231
38615	Ramsey Creek u/s Forest Rd 4450	Forest		Yes	Yes		-121.42530	45.39480
38638	Eightmile Creek u/s FSR 4440 (IS THIS 39638? Still no 2015 calculation)	Forest		Yes	Yes		-121.44360	45.41330
38641	Dry Creek above Fargher Rd. bridge near RM 8	Agricultural		Yes			-121.10320	45.41215
38657	Fret Creek u/s Rd. 2730	Forest		Yes			-121.47140	45.34930
38658	Ramsey Creek u/s old forest boundary @ end of N. South Rd (spur road off 4421 Rd)	Forest		Yes			-121.37560	45.40060
38661	Fivemile Creek ~Rivermile 5 d/s of gravel pit	Agricultural		Yes			-121.14118	45.53892
38662	Fivemile Creek d/s intersection of Pleasant Ridge Rd and Fivemile Rd., ~rivermile 7	Agricultural		Yes			-121.16752	45.52200
38663	Fivemile Creek u/s USFS boundary, below Middle/South Fork confluence	Forest		Yes			-121.36110	45.46610
38665	Middle Fork Fivemile Creek d/s 4430 crossing	Forest		Yes			-121.47320	45.42850

Appendix D. Summary of all Pebble Count surveys in the Fifteenmile Creek Watershed.

STATION	LOCATION	LAND USE	1994	2000	2015	2016	LON.	LAT.
38640	Fifteenmile Creek 240 meters u/s county bridge in Petersburg	Agricultural/residential		Yes			-121.0754	45.6110
24566	Fifteenmile 2.5 miles u/s 8mile	Agricultural				Yes	-121.05480	45.63070
28331	Fifteenmile Creek at Emerson Loop Rd (d/s Standard Hollow)	Agricultural		Yes	Yes	Yes	-120.9797	45.5457
28971	Fifteenmile u/s Dry Ck	Agricultural		Yes	Yes	Yes	-121.0476	45.5056
28973	Fifteenmile u/s Pine Cr.	Residential		Yes		Yes	-121.1203	45.4505
37434	Fifteenmile Creek at Dufur Park	Residential			Yes		-121.12523	45.45106
38612	Fifteenmile Creek d/s Underhill diversion	Agricultural				Yes	-121.1824	45.4395
28975	Fifteenmile u/s Underhill's diversion	Agricultural		Yes			-121.18600	45.43900
24567	Fifteenmile u/s Ramsey Ck	Agricultural		Yes		Yes	-121.21770	45.43330
28977	Fifteenmile Creek between chlorine building and Dufur City intake	Forest				Yes	-121.2786	45.3960
31779	Fifteenmile u/s Dufur City intake	Forest		Yes	Yes		-121.2802	45.3960
38613	Fifteenmile Creek u/s Rd 4421 bridge	Forest	Yes	Yes	Yes	Yes	-121.3391	45.3864
28315	Fifteenmile d/s Cedar	Forest	Yes	Yes			-121.39750	45.37990
28325	Cedar Creek u/s Fifteenmile	Forest	Yes	Yes			-121.39930	45.37890
28324	Cedar d/s Rd. 2730-160	Forest	Yes	Yes			-121.44560	45.35349
38656	Fifteenmile d/s Fret Creek	Forest	Yes				-121.47030	45.35060
38657	Fret Creek u/s Rd. 2730	Forest	Yes	Yes			-121.47140	45.34930
33088	Fifteenmile d/s Rd 2730 and Fifteenmile CG	Forest		Yes	Yes		-121.47322	45.35009
24568	Ramsey @ mouth	Agricultural		Yes	Yes	Yes	-121.21820	45.43370
28328	Ramsey @ new forest boundary	Forest		Yes		Yes	-121.294	45.41844
28081	Ramsey @ old forest boundary (RY2800)	Forest	Yes	Yes			-121.35810	45.40420
28341	Ramsey Creek d/s Forest Rd. 4450	Forest	Yes	Yes	Yes		-121.42350	45.39350
29787	Ramsey Creek @ Pebbleford campground	Forest	Yes	Yes			-121.46340	45.40060
28337	Eightmile Creek at mouth (confluence with 15mile Creek)	Agricultural		Yes	Yes	Yes	-121.0856	45.6064
28979	Eightmile Creek u/s Fivemile Creek	Agricultural		Yes		Yes	-121.08030	45.59250
28974	Eightmile Creek d/s county bridge	Agricultural		Yes	Yes	Yes	-121.0582	45.5605
28336	Eightmile Creek 300 meters u/s Endersby bridge	Agricultural		Yes		Yes	-121.1522	45.4909
28338	Eightmile Creek @ rivermile 19	Agricultural		Yes			-121.27200	45.45550
28083	Eightmile Creek @ forest boundary	Forest	Yes	Yes		Yes	-121.35780	45.43330
38659	Eightmile Creek 0.2 miles u/s Forest Boundary	Forest	Yes				-121.36400	45.43241
38639	Eightmile Creek d/s Rd. 4440	Forest	Yes	Yes	Yes		-121.4433	45.4131
38660	Eightmile Creek @ CG interpretive trail bridge	Forest		Yes			-121.44944	45.40861
28322	Eightmile u/s FSR 4400	Forest	Yes	Yes	Yes		-121.49950	45.39420
28335	Fivemile u/s Eightmile	Agricultural		Yes		Yes	-121.0807	45.5924
38663	Fivemile u/s USFS boundary, below Middle/South Fork confluence	Forest	Yes	Yes			-121.36110	45.46610
38664	South Fork Fivemile d/s 4430 crossing	Forest		Yes			-121.46110	45.41950
38665	Middle Fork Fivemile d/s 4430 crossing	Forest		Yes			-121.47320	45.42850