Upper Owyhee Watershed Assessment

IX. Sediment Sources

Contents

The Oregon governor's strategic initiative for ensuring sustainable water resources for Oregon's future, Headwaters 2 Ocean, considers all water resources from the ridge tops to the Pacific Ocean. The completion of the assessment of the upper Owyhee subbasin is consistent with the governor's initiative. The upper Owyhee subbasin contains the headwaters of the Owyhee River and two of its principal tributaries, the South Fork Owyhee River and the Little Owyhee River.

IX. Sediment sources

Sediment enters rivers from water runoff from the basin that is being drained. The greatest movement of sediment to the rivers is dependent upon extreme weather events that create substantial surface runoff. This section considers runoff as well as the resulting sediment loss, or erosion, principally from rangelands. As a precursor, soils are discussed. The composition and amount of the sediment that enters streams and rivers is influenced by the types of soils found within the drainage basin and the vegetation that covers the soil.

A. Soils

1. Basics of soil

Soil can be defined as the product of weathering processes. Physical weathering breaks rock down into minerals, but does not change the composition of the original rock. The amount of physical weathering generally affects the grain size. Since chemical weathering alters the mineral composition of rocks, it slowly removes the least stable minerals.

The make-up of soil is controlled by six factors: the original bedrock, time, vegetation, slope, precipitation, and human action. The minerals that make up the soil begin with those which were in the **bedrock**. The bedrock breaks into smaller particles with weathering. **Time** is also a factor in soil development; the longer a soil has been exposed to the surface the more weathering can occur. **Precipitation** serves as a basic control on the amount of chemical weathering that goes on in the soil by providing water to carry away dissolved minerals and help facilitate soil development. The **vegetation** growing on any spot of soil can change the soil chemistry by taking up nutrients, by providing organic matter from fallen leaves and dead plant parts, by rain leaching nutrients from the plants into the soil, and by the root structure helping secure the soil in place. The **slope** of the land surface determines in part the stability of the soil surface. Steep slopes that are prone to landslides will have little chance for soil development as the slides remove developing soils. On a smaller scale, any hill slope will experience erosion while flat areas have greater opportunity to hold onto soil. **Human action** can change soils by adding organic matter, removing vegetation and adding mulch. Human action is most pronounced in areas with long term agriculture, road development, or urbanization, for example some soils in Europe have experienced so many years of mulching that their present composition is greatly influenced by human action. The development of a soil, also known as **pedogenesis,** is controlled by these six factors.

Soils are described on the basis of a **soil profile**, a description of the physical and chemical characteristics of the soil from the surface to the bedrock.[18] Researchers dig multiple holes across the landscape to map out a soil type and its variations. To describe soil, scientists designate **horizons**, or layers that have consistent physical and chemical characteristics. The combination of horizons found in a single hole allows a researcher to classify the type of soil they have found. In addition the soil scientist uses principles of geology to understand the distribution of soils because different parent materials and different land forms, like hills, slopes, and flood plains will have different types of soil.

2. Desert soils

"The climatic regime of arid lands can be expressed as one in which potential evaporation greatly exceeds precipitation during most of the year, and no or little water percolates through the soil. This implies of course a slow rate of chemical weathering and other water based chemical transformations, a low rate of biological activity because of water stress on plants of all kinds, and a consequent reduction of plant cover."[9:16] While semiarid climates, like the upper Owyhee subbasin, have a slightly higher quantity of precipitation than arid climates, chemical weathering is less rapid than physical weathering. One of the results of less chemical weathering is that, "soils inherit many of their characteristics from the parent material"[9:17] With physical weathering, the bedrock is broken down into smaller and smaller pieces, but it is not transformed chemically into another type of mineral.[19] Physical weathering in the form of extreme rainfall is recognized as one factor driving erosion and creating differing soils on slopes and flood plains.[54]

The other defining characteristic of soils in arid and semiarid environments is that regular precipitation events do very little leaching of minerals from the soils. This can leave layers within the soil with high concentrations of salts. "The most striking feature of desert soils is the presence of layers of accumulation of calcium carbonate [or lime], gypsum, sodium chloride or other salts."[9:17] At times these salt layers become so cemented that they inhibit the growth of plant roots. In arid and semiarid environments the development of salt concentrations is normally a factor of soil age.[9] Layers of sodium chloride and calcium carbonate (know locally as caliche) are commonplace in deeper soils. After rainfall, the water percolates through the soil to a depth determined by the amount of precipitation. In deep soils with semiarid climate, the water stops percolating before moving through all the soil. In lower low lying parts of the Owyhee drainage that were converted to irrigated agriculture, especially flood plains, caliche and salt layers had to be broken and dispersed by deep plowing to allow crop production. Many desert soils not suited to agriculture also have layers of caliche. Examples include deep soils of the YP desert and on Tuscarora's alluvial fans. Where caliche exists, rain and snow melt water can not enter deep aquifers.

a. Factors in desert soil formation

Soil formation does not occur in isolation from other ecosystem processes. Climate, vegetation and geology all influence soil. And, soil in turn influences the growth of vegetation and the break down of bedrock.

"The scarcity of vegetation limits the amount of residue available for soil organic matter production in arid climates. Since nitrogen is carried in soil organic matter, it is low in desert soils."[19:40] In addition, temperature controls the rate of decomposition of organic matter. In warm, moist climates, organic matter decomposition takes place year round, in colder climates decomposition only occurs in the warmer months. In semiarid climates decomposition only occurs during brief periods of warm and wet soil conditions. The cycling of organic material is dependent upon microorganisms in the soil that break leaf litter and branches into their component parts.[15,19]

In deserts most rain "falls rapidly. Soil washing, erosion and runoff are intense. The high runoff rate further reduces the rain's effectiveness for plant growth except along stream channels, arroyos, and valleys were water accumulates. Shrubs and trees grow more densely along these water drainageways, and soils show the effect of more organic matter."[19:40] "The consequences of the high-intensity rain are rapid runoff and accelerated erosion."[15:208] Low topographic areas accumulate soil while the high plateaus and slopes lose soil to erosion.[50]

While erosion of desert soils is often high, topography, vegetation, and storms play into how erosion actually works. Soil loss is greater when either the steepness or length of a slope increases. "Longer slopes are more susceptible to erosion on the lower end because more water accumulates on long than on short slopes. Vegetation directly affects the erosion hazard in two ways: (1) plant canopies and residues reduce the impact of raindrops on the soils surface; and (2) anchored vegetation slows water movement across the land"[15:208] Another aspect of erosion is the duration of rainfall; the longer the duration the more likely that the soil's maximum water infiltration rate will be exceeded. It is when infiltration rates are exceeded that water runs across the surface of the ground because it can not be absorbed. This is more likely if the rain is very intense or lasts for a long time.[15,38]

Soil moisture is controlled by infiltration rates (the rate at which soil can absorb rainfall) and the soil water holding capacity. The water holding capacity of a soil is based on the type and quantity of pores it has and its depth. "Rain in the arid regions tends to come in high-intensity storms in which the rainfall rate greatly exceeds the infiltration rate."[15:208] After rainfall, the water held within the soil will be depleted as atmospheric evaporation and plant transpiration use the water. "Water storage is greatest when the initial evaporation rate is high and a dry surface soil is formed rapidly."[15:211] This means that the flow of water between pores in the soil does not continue to bring deeper water to the surface where it will be evaporated. A study on water retention in semiarid soils of New Mexico showed that "moisture conditions most favorable for plants occurred in areas where: (1) the landscape was level or nearly level, with little or no evidence of erosion; (2) there was a thin coarse-textured surface horizon to permit maximum infiltration of moisture; and (3) the subsoil was fine textured and/or indurated [had a hardened layer] to prevent deep moisture movement. A coarse-textured surface soil not only permits rapid infiltration of water but also [the surface] dries rapidly and protects subsoil water from evaporation losses."[15:212]

b. Soil nutrients

Certain types of desert vegetation alter the soil in which they live by accumulating soluble minerals, normally salts. "The soil located under and in close proximity to these plants may take on a wholly different physical character."[19:40-41]

The availability of soil nutrients to plant life is dependent upon the organic material produced by vegetation growing on the soil which is subsequently deposited as litter from leaves, seeds and wood.[50] Plants need nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients.[18] Normally these nutrients become available for plant uptake from chemical weathering of the soil such that it is broken into component minerals. Because chemical weathering rates are reduced in desert soils, there are less nutrients available for plant use. Additionally, plants need a certain balance between nitrogen, phosphorus, potassium, and other nutrients. In desert soils, generally nitrogen and phosphorous levels are often insufficient for maximum growth.[18]

Desert soils are also known for their spotty distribution of nutrients. The areas around shrubs where organic litter is greatest generally have higher quantities of phosphorus, potassium and nitrogen.[40,41] This patchy distribution of nutrients is very good for the shrubs, but can have long lasting effects on fertility even after shrublands have been turned to grass.[41] The processes that lead to the development of shrub patches with high quantities of nutrients are still unknown.[41] Schlesinger and Pilmanis suggest that the formation of these islands of fertility may be due, in part, to the collection of a soil mound around the base of the shrubs, the sediment coming from wind erosion of the open spaces between shrubs.[40] The formation of nutrient rich zones around desert shrubs allows for the continuation of shrub vegetation. And, the replacement of grassy deserts with shrub deserts generates an increase in the amount of dust, and hence the patchy nature of the soil.[40]

3. Soil classification system

The United States has developed a classification system to describe all soils. The classification has orders, suborders, great groups, subgroups, families and series. Each stage of the classification process describes the soil profile in greater detail.[314,388]

The United States Geological Service (USGS) surveys show that most soils in the upper Owyhee subbasin fall into the orders of Aridisols, Entisols, or Mollisols.

"Aridisols are mineral soils of the arid regions. They have a low organic-matter content. During most of the time when temperature range is favorable for plant growth, the soils are dry or salty, with consequent restrictions on growth. During the warm season, there is no period of three months or more when soil moisture is continually available to plants, except in places where a water table is close to the surface."[15:42] Common aspects of aridisols are a layer of pebbles on the surface of the ground and a subsurface zone where salts have accumulated to form a hard or cemented layer. However, for soils to form distinctive layers throughout their depth they must be on relatively stable landforms, where erosion is minimal. On some desert tablelands with resistant geological layers, such as basalt, clay rich soils will form when the tableland is "isolated for tens or hundreds of thousands of years."[15:49]

Entisols have no development of layers within the soil that show distinctive physical or chemical modification to the parent material and, as such, are lacking layers referred to by soil scientists as pedogenic horizons. "Entisols are mineral soils showing little or no development of pedogenic horizons. . . . Pedogenic horizons have not formed because, primarily, the soils are too young due to recent deposition of fresh material or to [the natural] eroding away of the previous surface."[15:43] An example of an entisol would be a sand dune, where the is no differentiation between sand at the top where plants are growing and the mineral sand that formed the dune. Other entisols occur in areas of recent deposition such as flood plains and areas of ongoing erosion such as hill slopes.[15] Shallow stony soils over bedrock also fall in this category, including some soils of the basalt landscape of the upper Owyhee subbasin.

Mollisols are soils that generally develop under grasslands and steppe vegetation. They have a high content of organic matter that darkens the color of the soil and they are relatively fertile. The climate regimes where they develop vary from semiarid to semi-humid. Common parent materials are loess, sand, and limestone. The majority of the world's mollisols are used for agriculture.[6,52] In semiarid areas there is a subgroup of mollisols (xerolls) that develop on sites that are generally dry. "Those occurring in the United states have native vegetation of bunchgrass (e.g., *Festuca*, *Agropyron*, and *Pseudoroegnera* spp.) and shrubs (e.g., *Artemisia* spp. and *Purshia*), or savannas of grass with scattered trees. The xerolls are extensive in the Palouse loess region of Washington, Idaho, and Oregon and are widely scattered throughout the states west of the continental divide."[7:327]

4. Data on soils in the upper Owyhee subbasin

Soils in the upper Owyhee subbasin in Idaho and Nevada have been surveyed. The soil survey includes maps that break down every field into specific named soil series. The soil series are based upon physical and chemical characteristics and subsequently each series is divided by soil texture and slope. This detail can be overwhelming, but is very useful for planning purposes such as choosing appropriate locations for road construction or the installation of waste treatment facilities.[5,6,14,20]

Soils vary significantly across landscape features so that the soils found on flood plains, plateaus, and in the mountains are different. Generally areas where agriculture is productive have soils that are deeper, with less rock, and greater quantities of nutrients. Some of the soils found in the upper Owyhee subbasin are described below (Figure 9.1).

a. Agricultural soils

i. Around Riddle

The agricultural soils around Riddle are found in bottom lands and have deep deposits of fine grained sediments. The sediment derives from alluvium that has been transported by the creeks. The soil is classified as a mollisol.[20,48]

Properties and qualities
* Slope: 0 to 1 percent
* Depth to restrictive feature: More than 80 inches
* Drainage class: Poorly drained
* Depth to seasonally high water table: About 12 to 18 inches
* Available water capacity: High (about 11.2 inches)

Parent material: Loamy alluvium

Typical profile
* 0 to 9 inches: Loam
* 9 to 60 inches: Stratified sandy loam to silty clay loam

Runoff: Very slow

Hazard of erosion: Slight by water or wind

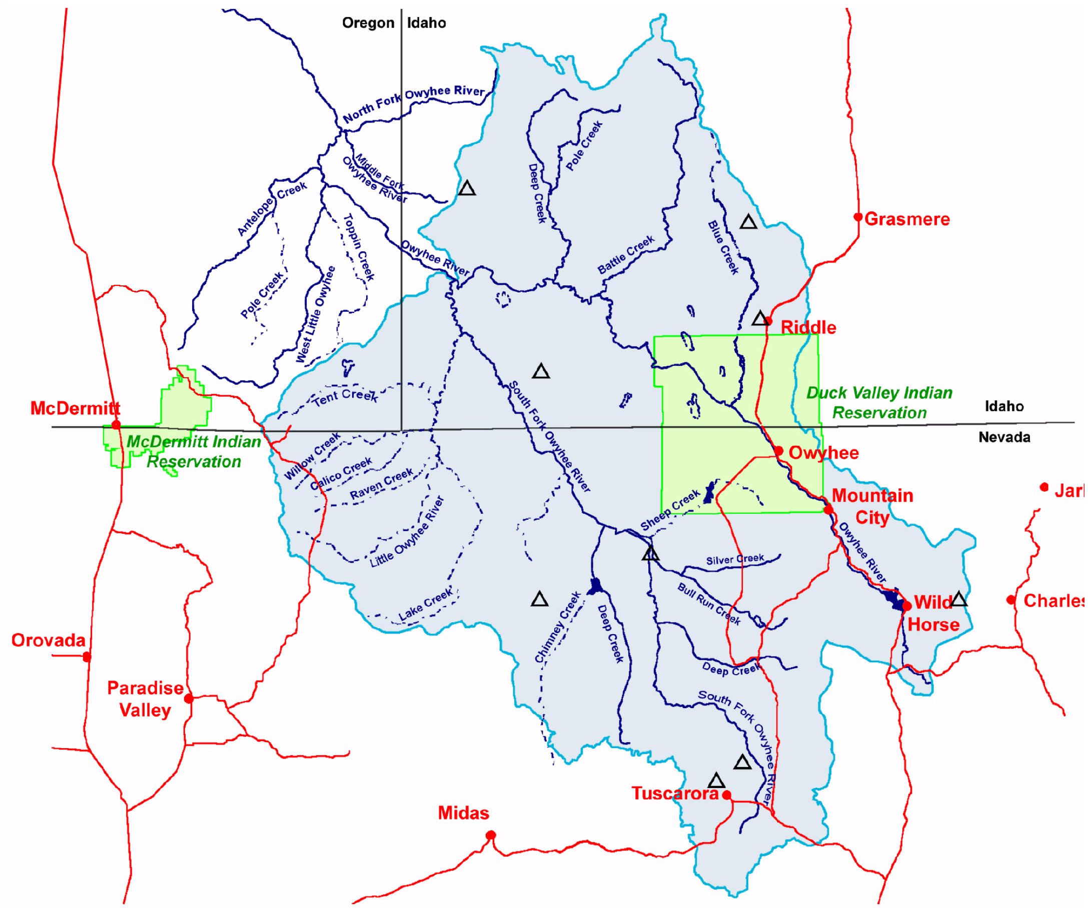

Figure 9.1. Soils from the upper Owyhee subbasin discussed below are indicated with triangles on this map.

ii. Flood plain sediments along the South Fork Owyhee River and tributaries

Along flat creek courses in wider valleys flood plains can form. The soils found along the flood plains in the upper Owyhee subbasin are very important economically. These are areas where better stands of vegetation can survive the dry summers. The flood plains with productive soils are found outside the entrenched portions of stream channels. They are generally used for hay land and pasture. Locations in the subbasin where these soils can be found include some areas along the South Fork Owyhee River, Sheep Creek, Bull Run Creek, and Silver Creek.[6,48] In technical terms these flood plain soils are classified in the mollisol order.[7]

Properties and qualities
* Slope: 2 to 4 percent
* Depth to restrictive feature: More than 60 inches
* Depth to seasonal high water table: 48 to 72 inches
* Available water capacity: 9.6 to 13 inches (high)

Parent material: Alluvium derived from mixed rocks and volcanic ash

Typical profile
* 0 to 9 inches: Loam
* 9 to 61 inches: Stratified sandy loam to silty clay loam

Runoff: Very slow
Hazard of erosion: Slight by water or wind

Another type of flood plain is that immediately adjacent to the stream channels. It is composed of the same materials as the other flood plains, but it is more frequently flooded, of more recent deposition, and at greater risk for erosion from floods. Flood plains immediately adjacent to stream channels are often considered to be riparian areas. Along the South Fork Owyhee River and tributaries these sediments are more frequently, naturally eroded and deposited. The scientific evidence for this is that these soils are of more recent deposition.

Photo 9.1. The greater availability of water and grassy vegetation on flood plains in the upper Owyhee subbasin led to the formation of soils distinct from those in surrounding uplands.

In other locations along the creek corridors where the water course is steeper or confined to a narrow channel the recent erosive and depositional events are not recorded in the soil surveys. Beaches, gravel bars, and similar unconsolidated materials that are deposited naturally along the banks of steeper stretches of creeks are not considered to be soils for the purpose of survey (they can change and move quickly).

iii. Independence Valley

The flood plains of Independence Valley have very deep, poorly drained, and slowly permeable soils.[14] The soils are composed of fine grained materials that have

Photo 9.2. Gravel bars deposited along river courses are not considered to be floodplain soils because they frequently change location.

been transported into the valley by the creeks.[5,6,48] These soils have developed with grassland cover and are classified in the mollisol order.

Properties and qualities:
* Slope: 0 to 2 percent
* Depth to restrictive feature: More than 80 inches
* Drainage class: Poorly drained
* Depth to water table: About 12 to 18 inches
* Frequency of flooding: Frequent
* Available water capacity: High (about 10.6 inches)

Parent material: Mixed alluvium
Typical profile:
* 0 to 4 inches: Silty clay loam
* 4 to 37 inches: Silty clay
* 37 to 60 inches: Silty clay loam

Runoff: Slow
Hazard of erosion: Slight by water or wind

Much of Independence Valley is used to grow hay and pasture grass.

The soils in the upper Owyhee subbasin that are currently used for agriculture and irrigated along rivers and streams are loams. The soils have a high available water capacity, are often poorly drained and are periodically flooded by the nearby creeks.

The agricultural soils are classified in the mollisol soil order. The properties of the soil that led to this classification are the result of a long time of soil formation. The soils were formed by the deposition of clay and silt sized particles during flood events. These materials originated from erosion upstream. Soil formation also included the accumulation of organic debris and nutrients from grassland/shrub vegetation cover and periodic flooding.[7]

b. Upland soils

Upland soils are found across the wide expanses of the upper Owyhee subbasin. In area covered, these are the predominate soils. Comparatively, these soils support less vegetation and hold less moisture than those used for agriculture. Below are two examples of upland soils.

i. YP Desert between Lookout Butte and the South Fork Owyhee River

Soils of the tablelands of the YP Desert are derived from volcanic ash, loess and/or welded tuff.[20,48] A sample soil profile from this area comes from between Lookout Butte and the South Fork Owyhee River. It has a duripan between 20 and 40 inches in depth and a moderate hazard of erosion. In shallow excavations, the sides of a hole will cave in as the particles are not strongly held together.

Properties and qualities
* Slope: 2 to 8 percent
* Depth to restrictive feature: 20 to 40 inches to duripan
* Depth to water table: More than 80 inches
* Available water capacity: Low (about 4.4 inches)

Parent material: Volcanic ash, loess, and/or mixed alluvium derived from welded tuff and basalt
Typical profile
* 0 to 3 inches: Silt loam
* 3 to 20 inches: Clay loam
* 20 to 30 inches: Gravelly sandy loam
* 30 to 38 inches: Cemented material
* 38 to 60 inches: Very gravelly loamy sand

Runoff: Slow or medium
Permeability: Moderately slow
Hazard of erosion: Moderate by water and wind.

ii. Between Blue Creek Reservoir and Turner Table

Soils in the upland area between Blue Creek Reservoir and Turner Table are very shallow ending in bedrock. There are many cobbles and rock fragments within the soil.[20,48]

Properties and qualities:
* Slope: 1 to 20 percent
* Depth to restrictive feature: 20 to 40 inches to lithic bedrock
* Depth to water table: More than 80 inches
* Available water capacity: Very low (about 2.4 inches)

Parent material: Volcanic ash and slope alluvium over bedrock derived from tuff breccia
Typical profile:
* 0 to 11 inches: Stony sandy loam
* 11 to 25 inches: Very cobbly sandy clay loam
* 25 to 28 inches: Extremely cobbly sandy clay loam
* 28 to 38 inches: Unweathered bedrock

Runoff: Slow to Rapid
Hazard of erosion: Water - slight to moderate, Wind - moderate

Where the bedrock is closer to the surface, 10 to 20 inches, the soil is stonier. These shallower soils are more common near hill summits.[20,48] The bed rock of volcanic origin provides all of the minerals found in the soil.

Parent material: Volcanic ash and colluvium over bedrock derived from volcanic rock
Typical profile:
* 0 to 5 inches: Stony loam
* 5 to 12 inches: Cobbly clay loam
* 12 to 19 inches: Very cobbly clay
* 19 to 29 inches: Unweathered bedrock

Photo 9.3. A stony upland soil.

Photo 9.4. The shallow soils of the uplands in the upper Owyhee subbasin are subject to more erosion where they are disturbed by unimproved roads than where they are covered by vegetation.

Across the uplands of the upper Owyhee subbasin the soils are similar to the examples above. They are typically stony and shallow. Many times the sediments are poorly held together so they can erode more easily than the agricultural soils. Where cut by road banks or excavation these soils lose the natural protection from erosion that is provided by the shallow slope of the plateaus. Plant growth is limited in these soils. The soils have bedrock or duripans close to the surface that restrict the depth to which plant roots can grow and the depth of soil that can hold useable water for plants. The soils are nutrient poor and dry for long portions of the year. They are classified in the Aridisol soil order.

c. Playa lake bed soils

Playa lake beds are unique features in the landscape of the upper Owyhee subbasin. They occupy very little of the total region but are included here because their soils are significantly different from surrounding upland regions.

Playas are locations where water accumulates and evaporates. These are the end of the line for the sediment that water is carrying. The sediment in a dry lake bed is the smallest sized particles, clays and silts, that erode easily. The modern playa lakes in the upper Owyhee subbasin are fairly small and are only flooded occasionally. As flooding is occasional, the lake beds are ranked as only fair habitats for shallow water areas and wetland wildlife.[6,48]

Properties and qualities
* Slope: 0 to 2 percent
* Depth to restrictive feature: More than 80 inches
* Drainage class: Very poorly drained (percolation is slow)
* Depth to temporary water table: About 6 to 18 inches
* Frequency of flooding: Occasional
* Available water capacity: High (about 9.1 inches)

Photo 9.5. Playa lake beds accumulate recent deposits of fine sediment with some rocks on the surface.

Parent material: Alluvium derived from mixed rocks, loess and volcanic ash
Typical profile
* 0 to 4 inches: Silt loam
* 4 to 60 inches: Clay

Photo 9.6. **The recently deposited, fine grained sediments at reservoirs are similar to those found at playa lakes and, likewise, are at risk for erosion.**

During the last glaciation the climate was wetter and lots of clay sized particles were deposited over larger areas where the lakes from that era existed. The older playa surface has rock fragments over clay.[6,48] Differences in soil for a remnant playa include:

Properties and qualities:
* Depth to water table: More than 80 inches
* Frequency of flooding: Rare
Typical profile
* 0 to 5 inches: Cobbly silt loam
* 5 to 60 inches: Clay

Soils from playa lake beds were formed out of alluvium, derived from the local rocks, that was transported in runoff from the region. They are deep deposits of fine grained sediments with no structure holding them together. The soils are classified as entisols. They are the result of recent deposition and erode easily.

Playa lake bed sediments are the product of years of the same processes that are now going on around reservoirs in the upper Owyhee subbasin. Fine grained sediments derived from the loess and volcanic rocks in the subbasin are transported by water and deposited where the water accumulates and later the soil dries. Over time the clay particles deposited at reservoirs will form thick clay soils. The recently deposited sediments of clay and loam sized particles do not have a strong soil structure and erode easily.

d. Mountain soils

Mountains by definition are high point on the landscape with steep slopes. At these high locations the soils are derived from immediately adjacent bedrock. By contrast, a flood plain will be composed of a mix of sediments derived from throughout the drainage basin above it. The steep slopes of mountains are at a greater risk of sediment erosion from rock fall and surface runoff. The hazard of erosion can be reduced by plant cover. Plant cover, however, will not stop all erosion. In some very steep mountainous regions there is no soil due to frequent rock fall and avalanche events. These areas are termed scree or talus slopes.[55]

i. Juniper Mountain

The east side of Juniper Mountain in Idaho is within the upper Owyhee subbasin. The soils are derived from the volcanic rocks prevalent in the area.

Properties and qualities
* Slope: 5 to 25 percent
* Depth to restrictive feature: 40 to 60 inches to lithic bedrock
* Depth to water table: More than 80 inches
* Available water capacity: Low (about 5.3 inches)

Parent material: Volcanic ash and colluvium over bedrock derived from basalt, tuff breccia and/or welded tuff

Typical profile
* 0 to 1 inches: Slightly decomposed plant material
* 1 to 10 inches: Stony loam
* 10 to 25 inches: Very gravelly loam
* 25 to 57 inches: Extremely gravelly sandy loam
* 57 to 67 inches: Unweathered bedrock

Runoff: Slow to moderate

Hazard of Erosion: Slight by water and wind

The mountain soils of Juniper Mountain are generally deep with a high quantity of rock. The vegetation cover is good because it contributes a layer of decomposed plant material to the soil surface, however, when the soil dries it can not hold much available water for plants.

In some of the mountainous terrain the rocks are closer to the surface and the soils are shallower. Where soils are shallower, less vegetation grows, runoff is moderate to rapid and there is a greater hazard of erosion.

ii. Wild Horse

East of Wild Horse the side of Haystack mountain has very rocky soils on steep slopes. This mountain is of the identical geological formation as the Bull Run and Independence Mountains. The soils generally end at unweathered bedrock. The suitability of these soils for wild herbaceous plants and shrubs is rated as fair and they are poorly suited to range seeding operations. Rapid runoff on these steep mountain slopes presents a high hazard of sediment erosion.[5,48]

Photo 9.7. The steep talus slope of this peak in the Independence Mountains does not support soil.

Properties and qualities
* Slope: 50 to 75 percent
* Depth to restrictive feature: 20 to 40 inches to lithic bedrock
* Drainage class: Well drained
* Depth to water table: More than 80 inches
* Available water capacity: Very low (about 2.8 inches)

Parent material: Residuum and colluvium derived from mixed rocks, loess, and volcanic ash

Typical profile
* 0 to 6 inches: Very gravelly loam
* 6 to 27 inches: Very gravelly clay loam
* 27 to 31 inches: Unweathered bedrock

Runoff: Rapid

Hazard of erosion: High by water, slight by wind

Photo 9.8. The rubble left from historic mining operations around Tuscarora is unconsolidated.

iii. Tuscarora

The hillsides around Tuscarora have been heavily impacted by mining and travel of recreationists. On aerial photos it is possible to see the scars left on the landscape. In the immediate mine areas the original soils have been completely removed. The rubble left from mining is unconsolidated, has not been reclaimed, and has few soil properties. Loose rubble has a great erosion hazard. The majority of the visible mining scars are located on the hill slopes. The characteristics of soils from the hills of Tuscarora from spots not directly impacted by mining are discussed below.[6,48]

The landscape can be divided into hill slope soils with bedrock close to the surface and soils on alluvial fans closer to the valley floor.[6,48] Characteristics of a hill slope soil follow:

Properties and qualities
* Slope: 8 to 15 percent
* Depth to restrictive feature: 14 to 20 inches to lithic bedrock
* Depth to water table: More than 80 inches
* Available water capacity: Very low (about 1.6 inches)

Parent material: Residuum derived from volcanic rocks

Typical profile
* 0 to 12 inches: Very gravelly loam
* 12 to 17 inches: Very gravelly clay
* 17 to 21 inches: Unweathered bedrock

On the hill slopes the bedrock is very close to the surface of the soil. Even under undisturbed natural conditions the sediment is not held well in place and has little water holding capacity to support vegetation.

On the alluvial fans a duripan affects water movement. The duripan restricts the permeability and is restrictive to plant root growth. The soil has a hazard of erosion by water and blowing soil. Furthermore the soil is not suited for paths and trails because it erodes easily.[6] An alluvial fan soil description follows.[6,48]

Properties and qualities
* Slope: 2 to 15 percent
* Depth to restrictive feature: 20 to 36 inches to duripan
* Depth to water table: More than 80 inches
* Available water capacity: Low (about 4.9 inches)

Parent material: Alluvium derived from mixed rocks, loess and volcanic ash

Typical profile
* 0 to 10 inches: Gravelly loam
* 10 to 30 inches: Clay
* 30 to 48 inches: Indurated
* 48 to 60 inches: Stratified extremely gravelly sandy loam to gravelly sandy clay loam

Soils of both the hill slopes and fans around Tuscarora were susceptible to sediment erosion before mining. The intensive use of this area, building of trails, and piling of mining waste rock are additional human factors promoting erosion.

5. Soils summary

Most of the soils in the upper Owyhee subbasin have not been substantially modified by human occupation. Very little of the upper Owyhee subbasin has been developed. The soils in the region, as would be expected, share many characteristics with soils in other arid areas. Landform is a major component contributing to characteristics of soils, such as their depth, ability to support plant life, erodability, and particle size.

Soils in the mountains are generally shallow, support little vegetation growth, have lots of gravel, and are susceptible to erosion. The soils described above for mountainous regions of the upper Owyhee subbasin are xerolls, a subgroup in the mollisol soil order. These soils are rich in organic matter from the bunch grass and shrub vegetation that grows on them, but are dry for much of the year. Limitations to plant growth come from the semiarid climatic conditions and shallow soil depths.

Soils from the expanses of plateau are generally shallow, rocky and have a cemented layer close to the surface. These soils hold little moisture and fall within the aridisol order. Soils within the aridisol order were expected for this region because of the semiarid environment.

Soils from the flood plains and valley bottoms are classified in the mollisol order. From this we know that these areas have long been covered in organic rich grassland and/or shrub vegetation. The soil characteristics that will lead to this classification have formed over time and with specific vegetation.

On the playa lake beds the sediments are composed of very fine particles, clay and silt. These fine particles have been deposited recently. The soils are at a great hazard for erosion. Playa lake beds have soils similar to what would be expected to form at human made reservoirs that are seasonally flooded and dry.

Soils in the upper Owyhee subbasin are mostly composed of the weathering products of volcanic rocks. From particles of fine silt to cobble sized fragments in the soil derived from volcanic rock. The volcanic rock and its weathering products are of recent geological origin and the erosion products are largely fine silt.

The mineral content in soils of the upper Owyhee subbasin originates from minerals in the volcanic rocks. Predominately the minerals carried in erosion and runoff from the upper Owyhee subbasin come from the soils that came from the underlying rocks. These are not point sources. Some naturally occurring minerals of concern include mercury, antimony, uranium, and radon. The elevated concentrations of these minerals in the bedrock led and continues to lead to their natural occurrence in soils and water ways. Minerals are carried across state lines by rivers, but the non point sources are not very amenable to management solutions. There are very few point sources of mineral or chemical pollution in the upper Owyhee subbasin. Some concentrations of cyanide and mercury may be associated with abandoned, historical mining operations.[56] The pollution at mining sites could be cleaned up.

Many of the soils in the upper Owyhee subbasin can be at risk for erosion. While soils have erosion hazards or risks, the actual amount of erosion that occurs is based upon substantial rain or snow events, storms that bring heavy rainfall, and human activities that expose the sediments.

B. Erosion

The sediment load transported by a river is obvious to most observers. Crystal clear stream water is not carrying substantial amounts of sediment, while murky brown waters are a result of a large sediment load within the river. The sediments in rivers come from erosion of soil and rock. Water carrying diatoms and algae that grow in the river water will appear to be hazy from carrying sediment but the suspended particles are created by plant life. The soils within the upper Owyhee subbasin are discussed above and the rocks are discussed in the geology section of the background component of this assessment. Wind erosion contributes a very minor amount of sediment directly to the rivers.

“Erosion is an intrinsic natural process but in many places it is increased by human land use.”[51] All of the river canyons and gullies we see as scenic locations today were created by natural erosion. The goal of assessing sediment sources and erosion is not to halt the movement of sediments, but to understand, and where possible, mitigate the effects of modern human activities on soil loss.

Management of sediment losses requires an understanding of how erosion functions naturally, what creates surface runoff within the upper Owyhee subbasin, and what cultural practices are management options.

1. Forms taken by erosion

When looking at the landscape to see where erosion is happening, there are three types of soil movement.[13,37] Sheet erosion moves sediment off the surface of a large area of ground and is generally more common in flat areas. Rill erosion consists of more or less parallel erosion paths across sloping ground. Gully erosion cuts through sediments in low areas where water accumulates during runoff events, creating features we call gullies.

Identification of what type of erosion has occurred will suggest the types of actions which can be taken to prevent erosion. In nature the quantity and speed of runoff water determine the form taken by erosion, and slopes will show a progression from sheet erosion at the top where they are nearly flat, to rill erosion on the slope, and finally gully erosion along the steepest incline.[13] On furrow irrigated fields the erosion occurring is analogous to rill erosion.

Erosion at a rate which has occurred historically in areas little impacted by human activity may not be amenable to any form of management. Similarly erosion where human activity has not significantly changed the composition of the soils or the nature of vegetative cover will be difficult to alter with human intervention.

a. Management of sheet erosion

> "Sheet erosion can be prevented by maintaining plant cover and maximising infiltration of ponded water through the maintenance of soil structure and organic matter. Organic matter acts as a glue, stabilising pore spaces which transmit surface water deeper into the soil and thus reduce the volume of ponded water available for erosion."[12]

b. Management of rill erosion

> "Once runoff has been initiated, rill erosion can be prevented by either reducing flow velocity, or hardening the soil to erosion. . . . Flow velocity can be reduced by either reducing the flow volume or roughening the soil surface. Increasing surface roughness through the use of grassed waterways and grassed filter strips causes entrained soil particles to fall out of suspension. Flow volume can be reduced by not allowing sheet flow to accumulate. Techniques such as ripped mulched lines and contour drains prevent runoff building up enough volume and speed to detach and entrain soil particles. . . . Where options to reduce runoff volume or velocity are limited, surface soils may be protected from scouring by hardening the surface."[11]

c. Management of gully erosion

> "Once established, gully erosion can be difficult to control. In most cases a combination of approaches, including the use of vegetation, fencing, diversion banks and engineering structures are required. . . . Vegetation is the primary, long-term means by which gully erosion can be controlled. All gullies need to be fenced from stock and revegetated along the gully floor, sidewalls and surrounding areas. Establishing vegetation on gully sidewalls is often difficult due to moisture stress."[10]

Suggestions from Tasmania, Australia include, revegetating the gully floor with rapidly growing grasses and the sidewalls with trees, revegetating the catchment above the gully, and using irrigation hydroseeding and mulching.[10] In areas where the gully erosion can not be controlled with vegetation, "gully erosion may be able to be controlled if runoff can be diverted and safely disposed of."[10] However this requires engineering expertise and carries the, "risk of transferring instability from one area to another."[10] While we may think of Tasmania as being a world away, similar erosion problems are found in many semiarid regions of the world and their solutions are similar. At some sites the construction of upstream stock ponds can reduce runoff pressure aggravating gullies.

2. Erosion on rangelands

The effects of grazing on sediment erosion were examined in southwestern Idaho in the Reynolds Creek watershed. Reynold's Creek is close to the upper Owyhee subbasin and has similar vegetation and rainfall patterns. Expected sediment losses were calculated on the basis of observable factors such as the percentage of ground covered by leaf litter and plant canopy, soil type, slope, and rainfall. The equation used, Universal Soil Loss Equation (USLE), is widely accepted as a predictor of erosion.[57,58] Nine locations were monitored from 1972 to 1978 with ungrazed and grazed range plots. Cattle grazed at moderate (2 plots), heavy (6 plots), and severe (1 plot) intensities, meaning the utilization of, respectively, 41-60%, 61-80%, and 81-100% of key forage species. Each grazed plot of rangeland was compared to an adjacent ungrazed plot to determine effects of grazing on sediment erosion. Reduction in plant cover and leaf litter that could lead to more sediment production was observed in only two plots. Both plots were on steeper slopes and one was grazed severely and the other heavily. The remaining seven locations did not experience significant changes in cover, these included two other steep locations with a heavy grazing regime.[57] Increased sediment production on rangeland would not be predicted for areas with standard practices of grazing management.

In the study of the Reynolds Creek watershed, it was not possible for the researchers to directly measure the sediment lost from the studied plots. However four of the drainages with test plots had measurements of actual sediment yield. The actual sediment yield was only 25 percent of the soil losses calculated from the plots. The difference between actual and calculated losses indicates that less soil is eroding across the surface of the rangelands than is predicted by the standard management equation USLE.[57] The authors of this assessment also found it interesting to note that the actual soil losses in four creek drainages in southwestern Idaho were 0.22, 0.29, 0.31, and 0.43 metric tonnes / ha / year, sediment yields significantly lower than the USDA soil loss tolerance for the shallowest soils, 2.24 metric tonnes / ha / year (1 ton / acre / year).[58]

3. What increases the amount of erosion during storms and snow melt?

a. Surface erosion

Erosion is the natural process by which sediment is moved down slope. Gravity is the major force in action, as in a rock fall. But, gravity is assisted in creating erosion by water both loosening and carrying material. Two major factors contributing to how much erosion occurs are the slope of the land and type of precipitation. The greater the slope of the land, the more likely it is to undergo erosion. Steep slopes will lose more sediment than flat plains. High intensity and volumes of precipitation also increase the amount of erosion.[28] When heavy rains occur, the soil can not absorb all of the water and so some of the water starts running across the surface of the ground. Snow melt can also result in a large amount of water on the surface running across the ground, especially when the ground is still frozen. If the ground is frozen it will not absorb the water from the snow melt. If there is a large amount of surface runoff or the surface runoff is across a steep slope, this water will begin scouring the ground it is moving over and pick up sediment. Individual particles of sediment are small enough to be carried in the water and moved off of the land.[28]

Very large weather events have the power to dislodge both large particles and those which are held together firmly by forces in the soil. The influx of this sediment to the river system occurs over a short time period as the additional moving water has the force to carry these particles.[28]

Erosion is greater in areas where the landscape is in its early stages of formation. Many areas of the upper Owyhee subbasin are geologically recent (geology section of the background component of this assessment). These “new” rocks and the “new” landscape have not been smoothed from eons of erosion. Steep slopes increase erosion risks. Another implication of recent formation is that soils have only started to form, limiting the ability of the landscape to support vegetation and exposing the newly formed soils to erosion.

Soils vary in the amount of clay, silt and sand they contain. A soil composed of sand and silt particles is more likely to undergo erosion than one with a clayey surface. Soils of more recent origin have a tendency to have silt and sand particles near the surface. These particles can be dislodged more readily than clay particles. The large areas of basalt and volcanic ash in the subbasin weather to silt that is easily dislodged.

b. Stream channel erosion

Storms and snow melt can cause large runoff events.[8] This water reaches stream courses. The greatest amounts of water flowing in a creek are recorded as peak flows. In the upper Owyhee subbasin the peak river flows occur with the runoff from snowmelt (see the hydrology section of this assessment). A large quantity of fast moving water in a creek can cause scouring of the stream bed and gully erosion of the stream banks.

> “Seasonal variations in stream flow are a major determinant of the structure and seasonality of ecosystem processes in streams and rivers. Periods of high flow in small streams, for example, scour stream channels, removing or redistributing sediments, algae, and detritus. In larger rivers, high flow events may lead to predictable patterns of bank erosion and deposition.”[8:94-95]

Researchers have documented characteristics of streams that are associated with greater erosion and scouring during floods. These characteristics include flashy changes in water flow, high channel gradient, abundant coarse material in the stream bed, relatively low bank cohesion (from less structured soils and/or fewer plant roots),


Photo 9.9. The contrast between stream channels with (left) and without (right) bank erosion. On left a stream channel draining into the East Fork of the Owyhee River in Nevada. On right the East Fork of the Owyhee River above Wild Horse reservoir.

and narrow channels that enable faster deep flowing flood water.[27] Arid and semiarid streams are known for rapid changes in flow, rocks in stream beds, and less structured soils in channel banks. In the upper Owyhee subbasin, these flashy water flows can carry sediment great distances so the sediment from one state can be carried into the next state downstream.

Floods can change the shape and composition of a river. In the Colorado River, for example, “The annual cycle of scour and fill had maintained large sandbars along the river banks, prevented encroachment of vegetation onto these bars, and limited bouldery debris deposits from constricting the river at the mouths of tributaries”.[35] The increase in riparian vegetation along the Colorado River resulting from the removal of flooding after dam construction has been detrimental to aquatic life in the river.[35]

Floods are complicated from a management perspective. While they result in erosion and scouring, the effects of erosion and scouring can increase aquatic species diversity and the diversity of aquatic habitats.[35] For example, scouring can clean fine sediment out of gravel that fish use for spawning and natural flash floods can periodically reduce exotic and lake fishes that have been introduced to the streams.[35] In free-flowing rivers with episodic high flows, the plants in the riparian area are regulated by flood scour. Scour will remove plants.[35]

4. What will decrease the amount of erosion during storms?

Two factors important to decreased erosion during storms are the soil surface cover and the permeability of the soil to water. Soil surface cover can help hold sediment in place. Greater soil infiltration allows more water to be absorbed into the soil before it begins running across the surface of the ground.

The amount of erosion which occurs is largely controlled by the vegetative cover and type of soil. Vegetation and plant litter hold soils in place.[13,38] Soil that is being held in place is much harder to erode and will only be influenced by much more intense storm events. Soils covered in rock fragments also produce less sediment from rain based erosion.[45] Rocky cover leaves less sediment available for transport by runoff and slows the speed and power of run off water.

"Infiltration is the term applied to the process of water entry into the soil. The rate of this process, relative to the rate of water supply determines how much water will enter the root zone, and how much, if any, will run off. Hence, the rate of infiltration affects . . . the amount of surface runoff and the attendant danger of erosion."[38:382] Soils high in clay or covered in rocks do not absorb water quickly and can produce more surface run off in rapid downpours. Soils with a predominance of sand or coarser particles tend to absorb water very quickly.[8] The more water that is absorbed by the soil, the less water will become surface run off.

Revegetation of stream banks is the general management practice utilized to mitigate the effects of scouring and gully erosion during high water events.[10,35] This practice is necessary where human modification of the environment has been extreme. However, vegetation can only hold stream banks together up to the point where the floods have the power to remove the plants.[35]

Not all erosion can be controlled. The portion that management practices can address is the portion that is related to cultural practices.

5. Cultural practices related to soil losses

Erosion on rangeland has not been scientifically studied in the upper Owyhee subbasin. However, erosion can be observed by those who use the same areas year after year. People downstream can observe the muddied waters of rivers carrying sediment from upstream erosion. Large sediment loads delivered to the rivers are the result of either extreme storms or other problems.

a. Sources of problems and concerns

Human land use, particularly related to vehicle travel is seen as a major source of sediment being delivered to waterways in the upper Owyhee subbasin.

i. Unimproved roads

Unimproved roads through rangelands create problems with erosion. Often the placement of dirt roads has developed as a matter of convenience, with no planning to minimize their effects on soil loss. Unimproved roads can erode more than improved roads. Improved roads will have runoff ditches along the sides which funnel water off the road and onto the range.

Unimproved roads erode in the tire tracks, collecting water running off the landscape and acting as sediment sources.[39] This happens because once water is in the wheel ruts, it can not escape. Water often flows within the wheel ruts for great distances, eroding deeper and deeper gullies into the land. Over time the erosion along one set of wheel tracks will lead drivers to move off of the existing road to drive on adjacent land. Those who use the range on a frequent basis notice that this problem becomes more pronounced with the steepness of the slope. Steep slopes have greater need of cuts designed to direct water off of the road at regular intervals.

Photo 9.10. Erosion in the tire tracks of an unimproved road across the plateau in the upper Owyhee subbasin.

Simple gutter improvements creating ways for water to escape from the wheel ruts of unimproved roads will decrease erosion.[39] Extensive descriptions for rural home owners, ranchers and rangeland managers on how to care for and improve rural roads are provided in the online publication "A Ditch in Time".[39] Many of the unimproved dirt roads in the upper Owyhee subbasin are already acting as gullies and will likely continue to do so even without vehicle traffic because the gullies will not magically grow plants to hold the soil in place.

ii. ATV tracks and off road recreation

Off road recreation by both small 4 wheelers and large 4x4 vehicles disturbs the surface of the soil. Repeated use of an area or paths for off road recreation kills vegetation. Soil compaction, which results from vehicles driving over the soil, greatly increases the chance of precipitation flowing across the surface of the land.[13] These factors leave areas used for off road recreation extremely susceptible to erosion from rainstorms or snow melt. Areas which have been used repeatedly for off road recreation contribute disproportionately larger amounts of sediment to the rivers.

iii. Stream bank erosion

Steam bank scouring can be a natural process. This scouring can also be aggravated by excessive animal pressure on riparian vegetation, leaving stream banks excessively vulnerable to erosion.

iv. Irrigation-induced erosion

There is very little irrigation in the upper Owyhee subbasin, so there is little runoff from irrigation. The concern with irrigation water is that runoff will be returned to the river. This runoff can carry sediment, nutrients, and animal wastes. Cattle are fed over winter on some pastures in the upper Owyhee subbasin and flood irrigation can carry material from these pastures.

v. Confined animal feeding operations

In some regions, concern has been expressed that sediments at confined animal feeding operations are extremely susceptible to erosion and that during storm events the sediment might be lost into the rivers, carrying with it a high concentration of animal wastes. This is not a widespread concern in the upper Owyhee subbasin.

vi. Urban areas

Urban areas can significantly increase the amount of runoff water. Urban areas have less soil area to absorb rain water. Large amounts of fine sediment are produced in construction areas.[32] The upper Owyhee subbasin has few urban areas so this is not expected to contribute much sediment to the waterways.

vii. Timber harvest

Timber harvest is associated with the addition of fine sediments to streams.[32] Large scale timber harvesting is uncommon in the upper Owyhee subbasin.

6. Erosion in the upper Owyhee subbasin.

There have been few evaluations of erosion in the upper Owyhee subbasin. The Idaho Association of Soil Conservation Districts and the Idaho Soil Conservation Commission conducted stream channel inventories on privately owned land in the upper Owyhee subbasin. The conclusion was that areas upland from the stream channel contributed little excessive erosion or deposition to the stream channels. The primary sources of erosion for the stream channel came from the stream channel and riparian areas themselves.[23]

a. Possible solutions to current problems

i. Unimproved roads

Unimproved roads through rangelands eventually need to be repaired or replaced. Simply prohibiting vehicle traffic will not halt erosion which is already carrying sediment off the road. As replacement and repairs are necessary, minimal design considerations can be implemented to divert water strategically from the roadway at reasonable intervals. In some places, routes can be chosen with less erosive potential.

ii. ATV tracks and off road recreation

Education of ATV and other off road vehicle users needs to be both more energetic and effective.

iii. Stream bank protection

Where stream banks are accessible to animals and people, maintenance of good riparian cover can diminish erosion. In many places in the upper Owyhee subbasin, the streams run in deep canyons with little livestock access and all erosion along the streams is natural.

iv. Irrigation-induced erosion

It is not known how much sediment or animal wastes are lost from irrigated fields and pastures in the upper Owyhee subbasin.

In the upper Owyhee subbasin, most irrigation is of hayfields and pasture. The traditional method of irrigating hayfields has been surface flood irrigation. This irrigation method is usually inefficient in water use for the crop. In some areas, central pivot irrigation systems have been adopted. Central pivot irrigation systems use water more efficiently.[Section XI, Agriculture, this document]

More efficient water use means less runoff. Efficient water use practices are being adopted and further adoption will result in less sediment loss from fields. Possibly the best way to deal with concerns with runoff water from agricultural fields is to eliminate the runoff altogether. This can be done with controlled water application. If all of the irrigation water applied to a field stays on the field, there will be no run-off and no worry of accompanying sediment, nutrients, and bacteria entering creeks.[47] Both sprinkler irrigation and drip irrigation systems can be designed to eliminate runoff from agricultural fields.[26,42,43,44] For hayfields and pasture, sprinkler irrigation is more cost effective than drip irrigation systems.

Other improvements to limit sediment losses include leveling and settling ponds. Leveling makes fields flatter, and flatter fields are less subject to erosion because the water in furrows is moving slowly. Slower water has less power to pick up and move sediment. An additional method to eliminate most sediment and water returning to the rivers is through the use of settling ponds in constructed wetlands or catchment ponds with pump-back systems. Settling ponds allow the sediment to fall out of suspension in the water and gather on the bottom of the pond.[44] After sediment has settled, water is returned clean to tail ditches and creeks.

7. Questions that need to be answered about soil losses

How much vegetation is needed on the rangeland to avoid erosion related to thunderstorm events? Do different types of vegetation have different amounts of sediment losses? Is the amount of vegetation needed possible within the constraints of semiarid environmental conditions?

What is the difference in sediment loss between rangeland on a flat plain and that on the slope of a hill? How does grazing affect sediment losses?

How is the amount of soil erosion changing with invasive weeds? With expanding juniper cover?

How much vegetation is needed along a stream bank for stabilization? What species of vegetation that are adapted to local environmental conditions would grow in these places? How often is this vegetation lost to natural scour?

To what extent are there soil loss problems following wildfires and controlled burning of rangeland?

There is no survey of locations with active erosion within the upper Owyhee subbasin to document the erosion rate and study whether the current rate is what would be expected to occur naturally or is being aggravated by human activities. Only the latter would be amenable to remediation. Naturally occurring erosion has been substantial and is responsible for much of the beauty and incredible landscape of the upper Owyhee subbasin.

To what extent has legacy historic overgrazing on upper Owyhee subbasin rangelands altered soil properties that influence modern sediment production? (Changes to surface cover, infiltration rates, and sediment production have been documented in other arid historically overgrazed areas.[38]) To what extent has the past legacy of overgrazing been overcome by range management practices during the last half century?

C. Sediments in waterways

One of the TMDL concerns about erosion is that increased amounts of sediment are entering the river systems. A background on how sediment enters waterways, how it is measured, and how sediment is transported by creeks and streams is presented below. This is followed by a general discussion of stream biota, the fish and macroinvertebrates that live in the water ways and may be affected by sediment in the water. The data on sediments in the water ways of the upper Owyhee subbasin and data gaps close the section.

1. Sources of runoff water

The sources of water entering the rivers in the upper Owyhee subbasin have not been delineated. The water flow in the subbasin depends upon the flow of the various perennial, intermittent and ephemeral streams. In addition, the amount of sediment carried by runoff and streams varies based upon the source. This is a data gap.

Sediments entering streams can be discussed in terms of their origin: that coming from springs and seeps, that originating in storm events, that from urban areas, and that being transported in return water from irrigation.

Water from underground aquifers, such as springs and seeps will carry little to no sediments. However this water may carry mineral concentrations picked up from the natural elements in the rocks the water has passed through.

Thunderstorms and rapid snow melt can produce massive surface runoff. This runoff will likely carry sediment from the area it passes over. The floods that may result in narrow stream channels also have the potential to scour sediments from the banks of the channels. Storms are natural and some erosion will always accompany them. Human management of sediment entering streams from storm events can only address man made sources of loose sediments.

Agricultural lands that are barren during rain storms may have greater sediment erosion.[32] In addition, these lands are deliberately irrigated. Irrigation tail ditches will carry sediments from the fields that the irrigation water ran across. This is of concern to water quality since the soil may contain high quantities of phosphorus, nitrogen, bacteria, and pesticides.

2. Sediment transport in rivers

Limiting human provoked soil losses can limit the sediment entering a river system. However not all sediment comes from human actions. The amount and types of sediment within river systems in the past are poorly known.

Erosion is a natural process by which sediments are added to the streams and rivers, and likewise rivers are the natural way that these sediments are transported to lakes and seas. While river systems carry eroded sediments, they “can also be depositional, accumulating sediment within channels and floodplains.”[31:129] How river systems transport and deposit sediment is dependent upon a number of factors including sediment supply, the river gradient, total river discharge, bed sediment size, and seasonal variations in flow.[31,36]

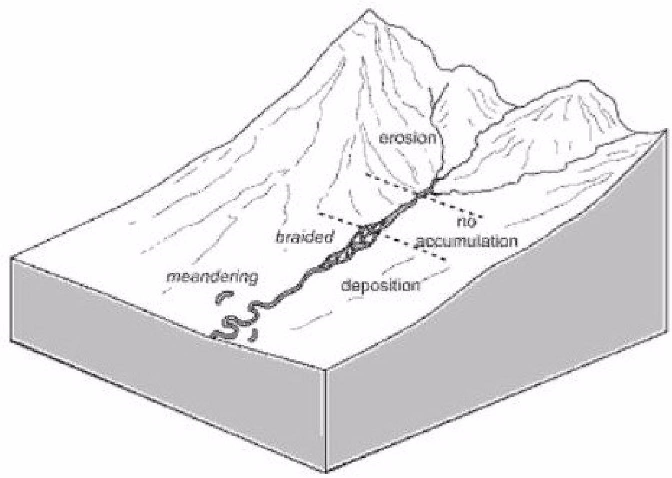

Figure 9.2. Schematic locations of erosional, transfer, and depositional zones. Adapted from 31, Figure 9.1

Gradient will determine if a portion of a river system is within the erosional, transfer, or depositional zone (Figure 9.2). "In the erosional zone the streams are actively downcutting, removing bedrock from the valley floor and from the valley sides via downslope movement of material into the stream bed. In the transfer zone the gradient is lower, streams and rivers are not actively eroding, but nor is this a site of deposition. The lower part of the system is the depositional zone, where sediment is deposited in the river channels and on the floodplains."[31:129] When looking at a river system within a landscape, the more mountainous portions will undergo erosion while rivers running across flat lands will be subject to deposition of sediments.

The gradient and water flow are related to **bed sediment size**. Bed sediments can range is size from boulders to fine silts. The size of sediment found in a given location is based upon ease of transport. Smaller particles are more easily moved by water. The sediments that a creek or river can carry within the water are termed the suspended load.[31] Those particles that can be moved along the bed of a creek by rolling are termed bed load. The suspended sediment load that water can carry is based upon its power. A greater suspended load can be carried by a creek with a steeper gradient and thus greater power of the flowing water. The greater the sediment load that can be carried in the water the more fine sediments will be preferentially removed. Creeks with more gravel in the beds tend to have higher gradients where water is moving quickly. Creeks with lower gradients and where water is moving more slowly will have finer sediments in the bed.[31] As water slows down, the sediment load it can carry is less and fine sediments settle out of suspension. For example, when the suspended load carries both silt and clay sized particles, the heavier silt particles will settle out before and upstream of where the clay is deposited. Creeks are dynamic systems with many different types of beds that are not necessarily all rock or all fine sediment.

Photo 9.11. The Jack Creek canyon shows how gradient changes from erosional slopes to transitional zones near the valley bottom.

Many physical characteristics in a river system alter sediment transport and bed sediment size, some examples are the erosion of parent material, the confluence of tributaries, and dams.[36] Rock can be introduced anywhere along a stream where the local rock deposits are breaking up. Rock introduced locally will be more angular as the transport of rocks by the stream tends to round off the edges. Where tributaries join a major channel there is an increase in the volume of water that is moving. This increased power can move more sediment and stream beds will have larger particle sizes.[36] Dams alter sediment transport as the water slows down and loses sediment that it has been carrying. The bed sediment in reservoirs and upstream of the reservoir where the water has already slowed is often fine.

Floods change sediment transport in rivers. The increase in water flow increases the power of the creek or river. With greater flow and power, more and larger particles can be moved as suspended and bed load. Sediment transport as suspended load increases during a flood. Visually this can be seen as murkier water. Floods also have the power to move larger material as part of the bed load. The rolling of rocks during a flood is the movement of bed load that, over time, leads to rounded cobbles and rounded gravel. Greater transport of sediments by flood waters is natural.[31] The greater water flow during flooding also carries the suspended sediments further downstream, sometimes for great distances.

Less pronounced seasonal variations in water flow will also change the ability of a creek to transport sediment. The lowest sediment transport can be predicted for times of the year with the lowest flows. Meanwhile the peak flows during spring snow melt would likely correspond with high levels of sediment transport.

The highest flows may account for almost all sediment movement in creeks. Singh and Durgunoglu state that, "80-90% of the sediment load is carried during the highest 10-15% of the flows."[59:199]

3. Measuring sediment in water

To the naked eye water that has suspended sediment looks murky. The haziness results from very small particles that remain suspended in the water. Suspended sediment is frequently measured in terms of this haziness, or turbidity.[53] While it is easiest to see the sediment transported in suspension, creeks and rivers also move sediment as part of the bed load. These particles move by tumbling along in the bed. They are pushed along but are too heavy to be held within the water.

a. Suspended sediment

Suspended sediment is measured based on how clear the water is (turbidity) or the amount of sediment found within the water (suspended sediment concentration).

Turbidity is related to how much light will pass through the murky water. One rough estimate can be made from recording the depth at which a black and white disk can no longer be seen. The common laboratory measure of turbidity is based on the scattering of light in water. The Nephelometric Turbidity Unit (NTU) is higher for murky water and lower for water with no particulate matter (Figure 9.3). The treated drinking water in your home is not permitted by the EPA to exceed 1 NTU.[16] "A turbidity of 3000

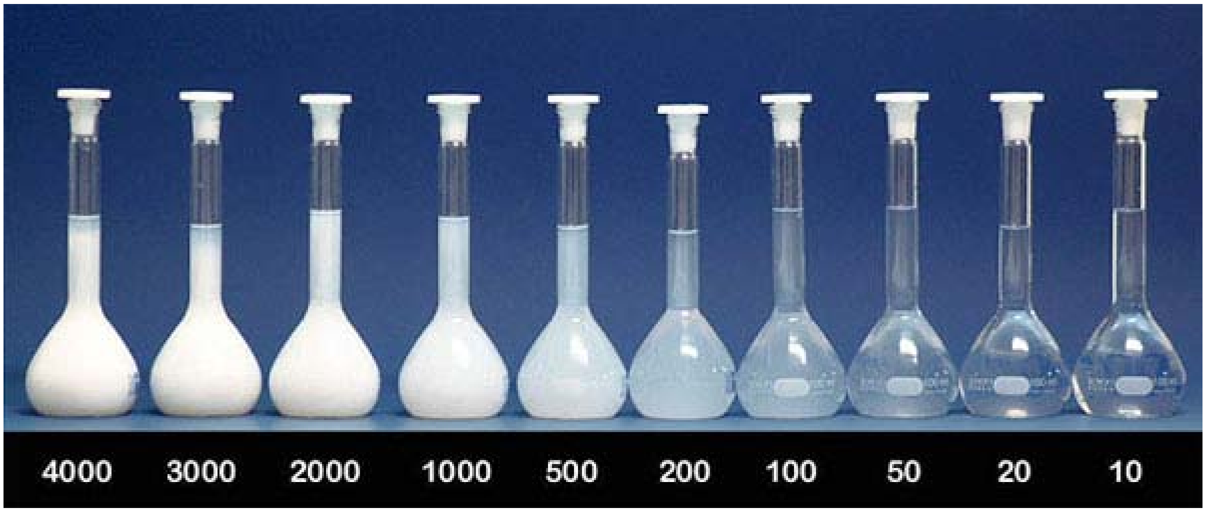

Figure 9.3. Examples of water turbidity measured in NTU.[33]

NTU typically corresponds to a suspended sediment concentration of 3 g/l but this will vary depending on the characteristics of the particles in suspension."[25:14] When a water sample is taken to measure turbidity it must be analyzed in a timely manner.

Turbidity is measured on the basis of all particles in water. Sediment, while often a major factor in high turbidity, is not the only source of haziness in water. Turbidity "is caused by the presence of suspended and dissolved matter, such as clay, silt, finely divided organic matter, plankton and other microscopic organisms, organic acids, and dye."[49:TBY-3] Turbidity measurements also are effected by particle size, "for a given sediment concentration a reduction in particle size results in an increase in turbidity."[25:14]

Manual water sampling is the oldest method of obtaining measurements of suspended sediment concentration. "Manual sediment sampling is highly time-consuming and cumbersome but is reliable and accurate and remains a reference (and so used for calibration of other methods) as it is the most widely and often used and allows the determination of the size distribution. The sampling can be done manually (grab sample) or using a pump."[25:1] Sediment is then separated from water and weighed. The total suspended sediment measured in this manner is generally expressed in the units milligrams per liter (mg/l). The Federal Interagency Sedimentation Project provides information on sampling methodologies.[17]

When examining the sediment carried by streams and rivers, the scale of measurement is important. The flux of sediment is more variable in smaller watersheds than in larger ones due to localized, short duration events like landslides or flash floods. "Larger watersheds integrate the stochastic pulses of sediment occurring within their smaller subcatchments and thus dampen the variability of sediment fluxes through reaches that drain large areas."[32:2748] Measurements of turbidity and suspended sediment load naturally vary between creeks, between years, and between seasons. Large fluctuations are expected in smaller creeks due to local events.

There are very few turbidity measurements for streams and rivers in the upper Owyhee subbasin. There are very few measurements of suspended sediment concentration. Measurements have not been collected systematically (such as by week) to provide data on seasonal river changes. These are a data gaps. The contributions of algae and diatoms to the turbidity of upper Owyhee subbasin water is unknown, another data gap.

b. Bed load

The sediment and gravel that move along the bottom of a creek is the bed load. The amount of material that is moved along will be based on the power of the water flowing in a creek and the creek gradient. This means that more of these materials will move during high flow events and far less during low flows. During high flow events the large scale movement of bed sediments can cause scouring.

> "Bed-load transport is even more difficult to estimate in alluvial streams than suspended sediment and poses a particular problem in high-energy bedrock rivers. So far, no sediment-monitoring agencies have been able to devise a standard sampler that can be used without elaborate field calibration or that can be used under a wide range of bedload conditions. The samplers used are giving quite different results depending on river characteristics so a combination of sampling methods should be used."[25:2-3]

The most widespread method for measuring bed load is with traps for the materials that are moving. Portable bed load traps can be installed at riffles to measure the movement of particles larger than 4 mm size.[25] Particles of this size are small gravel. The traps would not measure movement of sediment that is a major concern in discussions of stream characteristics.

Photo 9.12. The stream bed of this intermittent creek in the upper Owyhee subbasin is covered with sediment. This creek would only move sediment in its bed load.

Measurements of sediment and gravel moved as bed load are not available for the upper Owyhee subbasin. This is a data gap.

The suspended and bed loads of creeks are moving continually downstream and inevitably cross state boundaries.

4. Sediments and stream biota

Streams are home to many organisms. The complexity of stream habitats has a positive influence on the diversity of macroinvertebrates and fish that inhabit them.[36,46] Complex habitats have many different types of cover, slow and fast moving water, different stream beds, variation in water temperatures, and variation in aquatic vegetation.

a. Macroinvertebrates

Macroinvertebrate fauna are known to respond to the physical characteristics of streams.[36] The aquatic insects found on stream bottoms are benthic macroinvertebrates. They are important in water quality assessments because they have short life cycles, are generally sedentary, are a primary source of food for fish, and are easy to sample.[21]

Where stream flows change and the type of stream beds are diverse more types of macroinvertebrates can be found. “Species diversity is generally higher in heterogeneous environments, and positive relationships between sediment sorting and taxa diversity have been reported.”[36:831] Within a stream the macroinvertebrate populations will vary based upon the location they are sampled. Variation can occur on a small scale. “Species diversity is likely to decline downlink and increase at significant LSSs [Lateral Sediment Sources]”[36:831] The influx of more water and sediment at a tributary, for example, will increase local macroinvertebrate species diversity.

Some macroinvertebrate populations are intolerant of sediment in the creek bed. “Macroinvertebrates (Plecoptera) intolerant to sediment are mostly found where substrate cover is less than 30% (<6mm). More sediment tolerant macroinvertebrates (Plecoptera) are found where the substrate cover is greater than 30% (<6mm).”[22:48] The specific populations that prefer different bed sediment sizes are used in some assessments of aquatic habitat to indicate the type of creek bed.

i. Stream Macroinvertebrate Index

Since sediment can impair creek bed habitat for macroinvertebrates, samples of these populations are used to classify the stream habitats. The stream macroinvertebrate index (SMI) is a measure commonly used in assessments of water quality. The index includes measures of the macroinvertebrate population that are predicted to increase or decrease with increasing perturbation. Measures include richness, composition, pollution tolerance, diversity, feeding group, and habit.[21]

According to the Idaho Department of Environmental Quality (DEQ), “The SMI is a direct biological measure of cold water aquatic life.”[21:6-4] The index is based upon measures of the macroinvertebrate populations in streams that are ‘unimpaired’ within a bioregion. The distribution of index scores, calculated ‘unimpaired’ macroinvertebrate populations in a given bioregion, is determined. From this distribution, if a population falls below the 10th percentile of the reference collection (the ‘unimpaired’ macroinvertebrate populations) then it is given a condition rating of 1, and if it falls between the 10th and 25th percentile the rating is 2. Above this the rating of 3 is assigned. According to the Idaho DEQ, this distribution accurately assigned approximately 85% of ‘impaired’ streams to rating 1 and 90-97% of ‘impaired’ streams to rating 2.[21]

Unimpaired streams should receive a condition rating of 3, the best. However, the authors of this assessment would like to point out that the way the rating system has been constructed, approximately 25% of the ‘unimpaired’ reference streams would fall into the condition ratings of 1 and 2. The SMI values for some ‘unimpaired’ streams, those below the 25th percentile, overlap numerically with the SMI values of ‘impaired’ streams. Caution must be exercised in the interpretation of the SMI index given that there is a substantial overlap between values for the ‘unimpaired’ and ‘impaired’ streams that were used to establish the condition ratings.

The stream macroinvertebrate index is based upon populations within a specific bioregion.[21] This means that there are various SMI bioregions for Idaho, including the ‘Snake River Basin’ bioregion.

The SMI is used in some assessments to determine if sediment is impairing existing beneficial uses of a creek for fish.[22]

Local baseline data on macroinvertebrate populations in the upper Owyhee subbasin are needed since the SMI is based upon macroinvertebrate populations in healthy local streams. The macroinvertebrate populations in the Owyhee River drainage may be distinct from those in the larger Snake River Basin bioregion. Filling this data gap is imperative if the SMI index is going to be used to classify the health of stream systems. Designation of a stream as ‘impaired’ must be based on a large body of scientific knowledge and accurate assumptions about the natural temperature regimes of streams.

b. Fish

Fish communities are part of complex aquatic ecosystems. The complexity of these systems makes management decisions very complicated. Some elements of these ecosystems include creek structure, cover, temperature, nutrients, suspended sediment, seasonality, depth, velocity, geographic region, other species present, amount of available habitat, temperature refugia, and the life stage of the fish.[46] One major goal in the management of fish habitats is to maintain the productive capacity of these habitats, a goal that requires knowledge of the productive capacity prior to development.[46] This knowledge is a data gap for the upper Owyhee subbasin.

i. Fish known to be in the upper Owyhee subbasin in Idaho

In 1974 a fishery survey was conducted of Big Blue Reservoir on Blue Creek, Little Blue Reservoir on Little Blue Creek, Paine Creek Reservoir on Paine Creek, Juniper Basin Reservoir on Juniper Creek, Squaw Creek Reservoir on Squaw Creek, and Bybee Reservoir on Shoo-fly Creek. The survey was conducted to evaluate the potential of the reservoirs for stocking with game fish. In Big Blue Reservoir they collected suckers, shiners, and squawfish. Upstream they also found sculpins. In Little Blue Reservoir suckers and shiners were gathered. Paine Creek Reservoir had shiners but “was apparently stocked in the 40s and early 50s and produced large trout up to 4 to 6 pounds.” The fish populations of Juniper Basin, Squaw Creek and Bybee Reservoirs were “unknown”.[34]

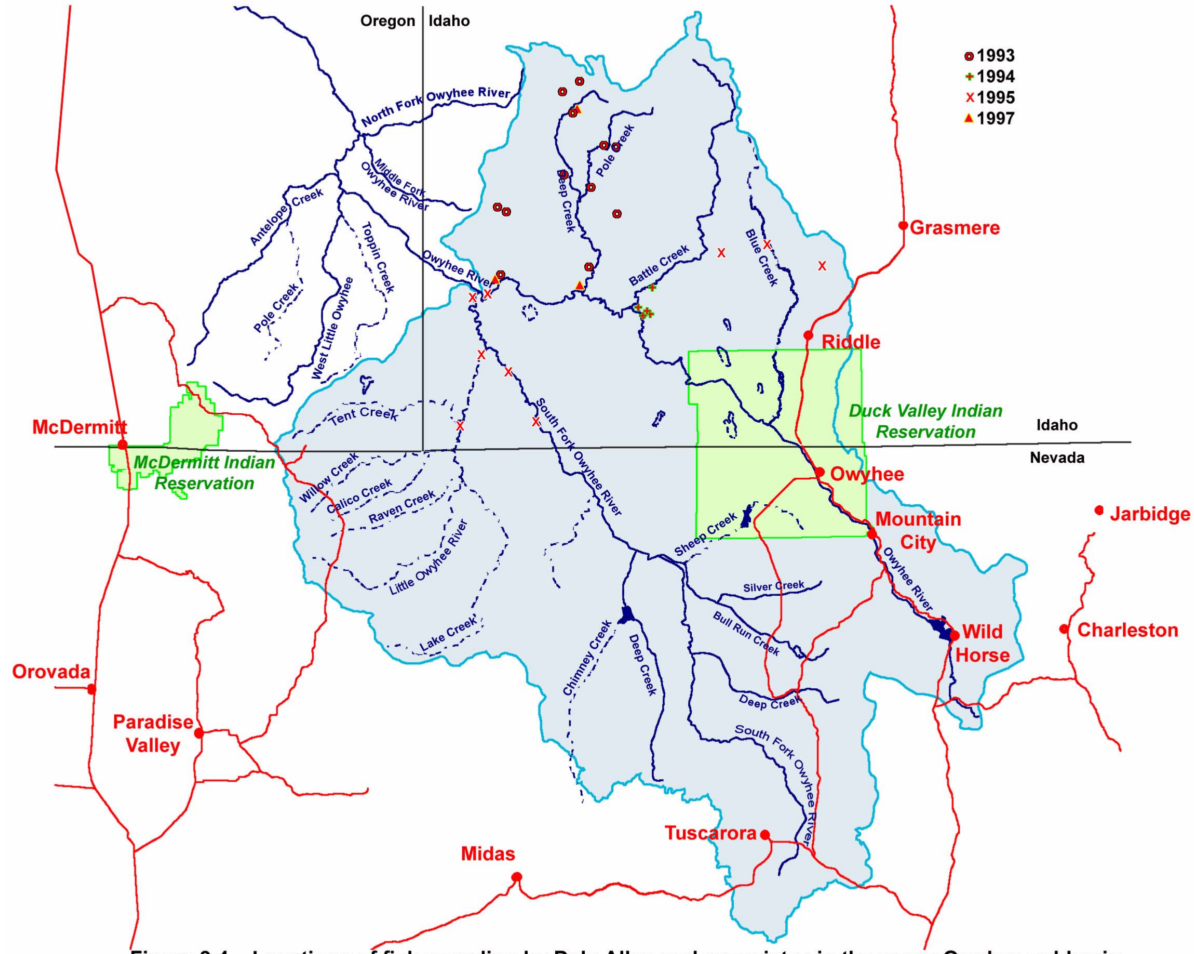

Figure 9.4. Locations of fish sampling by Dale Allen and associates in the upper Owyhee subbasin in Idaho

Surveys for redband trout (*Oncorhynchus mykiss gairdneri*), the only salmonid in the upper Owyhee subbasin, have been conducted by Dale B. Allen and associates on different stream reaches in the upper Owyhee subbasin in Idaho (Figure 9.4). In 1993 stream segments at least 200 feet long were sampled in the Red Canyon Creek and Deep Creek drainages. Redband trout were found in three of the four reaches sampled in the Red Creek drainage. Eight of the nine stream segments in the Deep Creek drainage had no redband trout. The section sampled on Nip and Tuck Creek had a high density of redband compared to other sections sampled both in these drainages and in the Jordan Creek drainage outside the upper Owyhee subbasin. Other fish species collected during the 1993 surveys were longnose dace (*Rhinichthys cataractae*), leopard dace (*Rhinichthys falcatus*), speckled dace (*Rhinichthys osculas*), redside shiner (*Richarsoniuis balteatus*), mountain sucker (*Catostomus platyrhynchus*), chiselmouth (*Acrocheilus alutaceus*), northern squawfish (Ptychocheilus oregonensis), smallmouth bass (*Micropterus dolomieui*), and sculpin species (*Cottus* spp.).[4]

In 1994 surveys were conducted on reaches of Battle Creek and Owyhee River. No redband trout were found in either of these watercourses. Other fish identified in at least one of the sampled stream segments were smallmouth bass, redside shiner, speckled dace, bridgelip sucker (*Ptychocheilus oregonensis*), longnose dace, mottled sculpin (*Cottus bairdi*), chiselmouth, mountain whitefish (*Prosopium williamsoni*) and northern squawfish.[1]

The 1995 fish surveys were conducted on stream reaches of Little Owyhee River, South Fork Owyhee River, Owyhee River, Blue Creek, Little Blue Creek, and Shoofly Creek. The survey for redband trout found no redband in the Little Owyhee River, the South Fork Owyhee River, or the three creeks. In a segment of the Owyhee River just above Crutchers Crossing four redband were found by electrofishing. Other nongame species collected on South Fork Owyhee River and Owyhee River were small mouth bass, bridgelip sucker, longnose dace, northern squawfish, sculpin species and

Photo 9.13. Fish observed at Wiley Ranch along the East Fork of the Owyhee River, July 2010.

largescaled sucker (*Catostomus macrocheilus*). No fish were found in the Little Owyhee River or Shoofly Creek as they were dry.[2]

In 1997 a survey was conducted of the redband trout population at two sites on Deep Creek and one site on Red Canyon Creek. There were no redband at either of the Deep Creek sampling sites. The Red Canyon site contained a low density of redband trout. Other fish species present at the sampling sites were bridgelip sucker, chiselmouth, longnose dace, redside shiner, sculpin species, smallmouth bass, speckled dace, and sucker species.[3]

During July 1997, five biologists floated the Owyhee River for a week. During that time only one redband was collected by angling the river; it was caught just below the confluence with Deep Creek. Redband were observed but not caught or sampled near the mouth of Red Canyon Creek. No other redband were observed. The conclusion of the participants was that "redband trout were almost entirely absent in these reaches of the Owyhee River." The angling catch consisted of smallmouth bass and northern squawfish.[3]

On the South Fork Owyhee River a study in 1995 found no redband trout. Electrofishing at the 45 Ranch on the South Fork Owyhee in 1999 also found no redband but located smallmouth bass, northern squawfish (pikeminnow), mottled sculpin, and largescaled sucker.[24]

Within the Upper Owyhee HUC, spawning of salmonid species has not been documented. Thus the 2003 TMDL for this area of the upper Owyhee subbasin does not designate spawning as a beneficial use for any water body.[23]

ii. Redband trout in the Snake River and Owyhee River drainages

Meyer and colleagues studied the occurrence of redband trout in waterways of the Snake and Owyhee River drainages.[29] Their work examined the occurrence of redband trout (*Oncorhynchus mykiss gairdneri*) in relationship to environmental factors and stream characteristics at sample locations. They do not provide data on the specific sample locations. This means that the creeks in the Owyhee River drainage are not singled out. The major division in Meyer and colleagues' study was between desert and montane streams. Data from sites in the upper Owyhee subbasin are included in the group of samples from desert streams south of the Snake River. The majority of studied desert streams sites are in the Owyhee River, Bruneau River, and Salmon Falls Creek drainages. By contrast the montane streams are from north of the Snake River in the drainages of the Boise River, Payette River, Big Wood River, and Weiser River.

The locations sampled for this study were randomly chosen. However, when these locations were visited between late June and early October, samples were only taken if the stream had enough water to support fish life, was less than 25 meters wide (114 ft), and averaged less than 0.7 meters (27 inches) deep.

Redband trout were found in greater densities in desert streams:

> "Of the 615 sites that contained [enough water to support] at least one species of fish, redband trout were found at 384 (62%) of the sites, including 176 (65%) of the 273 study sites in desert streams and 208

> (61%) of the 342 study sites in montane streams. For sites that contained redband trout, mean density was 21 redband trout · 100 m^{-2} (95% CI 17–26) for desert streams and 11 redband trout · 100 m^{-2} (95% CI 10–13) for montane streams."[29:82]

Using the map published with Meyer's study, the authors of this assessment counted at least 20 sample locations on streams within the upper Owyhee subbasin. It is not known if trout were encountered in these locations or not (97 of the surveyed desert creek sites had no trout).

Meyer and colleagues statistically analyzed their large data set. Some of the environmental and stream characteristics of the sampled areas are related to the occurrence of redband trout. In desert streams redband trout were found where there was a greater percent of cobble-boulder stream bed, a lower percentage of fine sediment stream bed, greater amounts of stream shading, lower populations of pikeminnow and smallmouth bass, and greater stream gradient. In montane streams redband trout were found in streams at lower elevations, where there was more stream bed in cobble/boulder sized particles, and in lower gradient steams. Variables that did not contribute statistically to explaining redband trout occurrence in either desert or montane streams included the percent unstable stream banks, density of nonnative trout (not including the hatchery rainbow trout numbers as they were eliminated from analysis), stream width, water conductivity, and the percent gravel sized particles in the stream beds.[29]

Further analysis was conducted to better understand the population density of redband trout where there were redband trout. For desert streams these models can account for 43% of the variation in density based on stream order (smaller streams have more fish), stream shading (more fish in streams with more shading), percentage of cobble/boulder substrate (more fish where there are more cobbles), and either unstable banks (more fish where the banks were less stable) or width:depth ratio of the stream (deeper, narrower creeks have more trout). The best models for montane creeks only explained 17% of the variation in the density of redband trout. This means that the environmental variables and stream characteristics analyzed do not describe why the densities of redband trout vary in mountain creeks.[29]

Water temperature data was recorded at 51 arbitrarily selected study sites over the summer (June-August). In the montane streams, the mean summer water temperatures (<18°C, 64°F) had no relationship to redband trout density. In the desert streams, the mean water temperatures varied between approximately 11 and 22°C (52-72°F) and streams with higher temperatures had lower redband trout population densities.[29] The high maximum water temperatures did not mean there were no trout. Meyer and colleagues "captured redband trout at 6 sites with maximum water temperatures >28 °C and at 2 sites with >30 °C. These results concur with Zoellick's (1999) finding of redband trout in stream reaches with maximum stream temperatures of 29 °C. These temperatures exceed the thermal tolerance reported for other native salmonids that occupy arid climates in the western United States"[29:86] Meyer and colleagues suggest that with higher stream temperatures, some of the trout may move to cooler streams or find pockets of cooler water.

The study "results suggest that, in general, environmental conditions were more suitable for redband trout in desert streams than in montane streams."[29:87] Limiting factors to the range and density of redband trout populations in arid streams include summer stream temperatures and the presence of piscivorous fish. In the case of the latter, it is unknown if the of piscivorous fish (pikeminnow and smallmouth bass) prefer different habitats or if they prey on redband trout.

Meyer and colleagues' work highlights the complex relationships between fish and their environment. Redband trout do not live in all of the desert streams and characteristics of their preferred environments have been given as the factors associated with their occurrence. The authors of this assessment would like to highlight that factors that are related to the occurrence and density of redband trout in desert streams are predominantly natural environmental characteristics. Stream gradient, creek depth to width ratio, percent cobble/boulder substrate, percent fine sediment substrate, and occurrence of native pikeminnow are related to the local geography, type of bed rock under the stream, type of rock being weathered upstream, and native fish species. Meanwhile, the occurrence of smallmouth bass is a product of sport fishing. The other element that enters into preferred habitat locations is stream shading which is a product of the local vegetation and frequency of stream scour.

Meyer and colleagues' study demonstrates that redband trout prefer to live in specific types of natural stream environments and, in their preferred desert stream locations, the population densities are higher than in mountain streams. Whether streams in the upper Owyhee subbasin sampled in the study contained redband trout is unknown.

iii. Stream beds

Stream beds generally have a mix of material of different sizes from fine sediments, like silt, up to boulders. Different fish have different habitat preferences.

Stream bed structure is a factor in the fish that use a creek system. For example:

> "Salmonids have been shown to have a preference for larger and varied substrates, and to avoid sand or other fine substrates. On the other hand, some species, such as prairie river cyprinids or the Eastern sand darter (*Ammocrypta pellucida*), may be most abundant over fine substrates, avoiding gravel and large rocky substrate. Substrate composition has been implicated as a factor in fish growth, varying by species."[46:21]

While the species mentioned in the above quote are not found in the upper Owyhee subbasin, it is important to note that there is no one perfect type of stream bed for all fish. In the upper Owyhee HUC some of the fish species preferences are as follows:

> "The small mouth bass species (*Micropeterus dolomieui*), found throughout the Upper Owyhee River Watershed, require adequate substrate for nest building. This substrate could be sand or gravel. The sucker species found in the area (*Catostomus macrohelus*) prefers gravel

to rocky substrate. Northern pikeminnow (*Ptychocheilus oregonensis*) uses streams and rivers for spawning activity, but is more of a broadcast spawner than nest builder. Sculpin (*Cottus baird*) are also known to inhabit waters in the Upper Owyhee Watershed. Sculpin prefer clean water and clean gravel for habitat."[22:48-49]

Different fish live, spawn and feed in different types of stream beds.

- *Sediments on stream beds as a pollutant*

Erosion adds sediments to the rivers. The addition of fine sediments to a stream by human induced erosion can fill in pools and the spaces between cobbles. This changes the stream bed.

The addition of fine sediment to stream beds is seen as a pollutant because of its detrimental effects to fish populations. "Bedload sediment can disturb habitat for macroinvertebrates, fill in interstitial spaces required for spawning and rearing areas, and fill in pools needed for refuge."[22:48]

Sediment in stream beds has been identified as a deterrent to spawning and as a possible limiting factor to populations of salmonids. "Sedimentation has been identified as one possible agent degrading freshwater ecosystems and limiting the persistence and recovery of salmonid populations. High levels of fine sediment (<2 mm diameter) in spawning gravels are correlated with low survival of salmonid eggs and alevins*."[32:2740-2741]

Gravel is discussed as the best stream bed type in many habitat restoration projects and management reports, in large part due to the desire to increase fish spawning habitat:

> "Many valued fish species use gravel for spawning, and therefore the restoration of spawning gravel has frequently been an objective of habitat enhancement projects where gravel is assumed to be limiting. Placement of instream structures may trap gravel and improve spawning habitat, and the addition of large cobble and boulder habitat can increase localized densities of salmon and trout but the effect may be temporary if fines inundate interstitial spaces over time. Demonstration of increased spawning activity in newly created spawning habitat does not necessarily translate to an increase in total egg deposition or adult abundance.[46:22]

Gravels in creeks and rocky areas in lakes are both used more frequently as spawning areas. However this does not necessarily change the population numbers. The creation of new rock areas in lakes, while attracting more fish, shows no apparent change in fish productivity or biomass.[46]

Stream beds low in sediment and high in gravel are necessary for the spawning of some fish species. It is not known what portion of a stream needs to have a gravel bed for fish to spawn in the stream. It is not known whether human activity has

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* Alevins are tiny fish carrying a food supply (a sac of egg yolk) attached to their bellies.

increased or decreased the amount of fine sediment in the rivers and streams of the upper Owyhee subbasin.

iv. Suspended sediments in fish habitat

Sediment is considered to be a pollutant because of the haziness that it introduces to the water where fish live. “Suspended sediment can impair sight feeding fish by reducing their capability to find food. It may also aggravate gills and reduce oxygen intake.”[22:48] “Most studies have demonstrated that turbidity levels exceeding 25-30 NTUs will impair aquatic life use by causing reduced fish growth, reduced survival, reduced abundance, respiratory stress, and increased ventilation. Avoidance, reduced energy intake and displacement can occur at turbidity levels of 22 to greater than 200 NTUs.”[22:48] It is not known if human activity in the upper Owyhee subbasin has increased or decreased the NTU of waterways.

5. Sediment data for the upper Owyhee subbasin

TMDL studies of streams and rivers in parts of the upper Owyhee subbasin have identified sediment as a pollutant in some streams and reservoirs within the upper Owyhee subbasin. Sediment measurements have been taken during these studies and these data are summarized below.

a. South Fork Owyhee River

In 1999 a TMDL study was carried out for the South Fork Owyhee River. “Turbidity/suspended sediment samples were taken at eight sites during the May reconnaissance trip. Except for the two sites in Nevada, all turbidity results were below 25 Nephelometric Turbidity Units (NTUs). Suspended sediments results varied from 50 to 77 mg/l in Idaho, to 24 to 75 mg/l in Nevada.”[24:27]

Turbidity measurements below 25 NTUs are favorable because these levels do not impair aquatic life. Yet with less than 10 samples for the South Fork Owyhee River, there is a great data gap:

> “Turbidity information is limited. During a five day monitoring trip on the South Fork Owyhee River, turbidity samples were collected at sites in Nevada and in Idaho. However, due to the limited holding time for turbidity samples, all samples collected exceeded the recommended holding time for submittal to the laboratory. The data is still important, but may be more of an indicator of inorganic material than organic material. The information obtained in May is also important to determine water quality conditions originating from Nevada.”[24:30]
>
> “Obtaining “background” turbidity information may even pose a larger problem. Without long term temporal information, the background levels needed to compare to State of Idaho standards may not be obtainable.”[24:30]

Macroinvertebrate populations were measured in 1999 in the upper Owyhee subbasin at the El Paso Pipeline Crossing and 45 Ranch. Measurements taken in July and August at both locations indicate the abundance and expected species for the type of river.[24] In fact, the El Paso Pipeline Crossing sample from July received the maximum possible score, 23, using the Idaho River Index for macroinvertebrates.

The riparian areas of the South Fork Owyhee River on the 45 Ranch allotment have been assessed. Alongside this, the river channel has been documented. “The upstream segment [of the South Fork] had a greater percentage of channel bottom covered with coarse material (cobbles and gravel) than the lower segment. This may reflect sediment input from the Little Owyhee system that would tend to dump sand and silt into the South Fork during flash floods.”[30:10] In discussing the South Fork, Moseley states, “it appears to me that the erosional and depositional processes are in balance. The terraces are actively being degraded to a moderate degree and contribute to the sediment load of the river, including both bed load and suspended load. Bed load deposits are being laterally accreted (minimal vertical accretion) in the deeply entrenched floodplain and are colonized by the sandbar willow communities. Some of the suspended load settles out within the channel below bankfull stage. If it’s deposited in slack water or eddies, it creates the fine-textured substrates colonized by the sharp bulrush community. Cattle have virtually no effect on these processes on the 45 Allotment.”[30:14-15]

b. Upper Owyhee HUC

According to a 1998 Idaho DEQ report five streams and two reservoirs in the Upper Owyhee HUC within Idaho were polluted by sediment (Table 9.1).[22]

Table 9.1. 1998 DEQ listed water quality limited segments (§303(d) listed streams) in the Upper Owyhee HUC, Idaho. (CWAL = cold water aquatic life, SS = salmonid spawning, PCR = primary contact recreation).[22]

Stream	**Pollutants of Concern**	**Stream Miles**	**Impaired Uses**
Blue Creek Reservoir	Sediment	185 Acres	CWAL, SS
Juniper Basin Reservoir	Sediment	750 Acres	CWAL, SS
Deep Creek	Sediment, Temperature	46.1	CWAL, SS
Pole Creek	Sediment, Temperature, Flow Alteration	24.0	CWAL, SS
Castle Creek	Sediment, Temperature	11.5	CWAL, SS
Battle Creek	Bacteria	62.3	PCR
Shoofly Creek	Bacteria	22.9	PCR
Red Canyon Creek	Sediment, Temperature, Flow Alteration	5.2	CWAL, SS
Nickel Creek	Sediment	2.8	CWAL, SS

These water bodies have been described in the 2003 *Upper Owyhee Watershed Subbasin Assessment and Total Maximum Daily Load Owyhee County, Idaho* and the 2004 *Upper Owyhee Watershed TMDL Implementation Plan for Agriculture.*[22,23]

While Sediment has been identified as a pollutant in some creeks, the quantity of sediment in the waters of Deep Creek, Pole Creek, Castle Creek, Red Canyon Creek, and Nickel Creek is not known. It is not known if monitoring of these creeks for the TMDL report included sampling for sediment.

In the following discussion it is important to note that there is a difference between ‘designated beneficial uses’ and ‘existing uses’.

i. Reservoirs

The two reservoirs discussed in the reports have single measurements of sediments. It is not known if measurements were made when livestock were grazing in the allotment. Livestock watering or substantial runoff events can increase the amount of sediment suspended in water.

- *Blue Creek Reservoir*

The Blue Creek Reservoir is used to store irrigation water. "The listed pollutant of concern is sediment. Biological monitoring conducted in 2001 indicated sediment is impairing the biological communities."[22:xviii] The major biological community within the reservoir is stocked fish. "In 2000, the Idaho Department of Fish and Game introduced domestic Kamloops trout in the reservoir. With the stocking of the Kamloops, the reservoir has been determined to have cold water aquatic life as an existing use and criteria to support this existing use therefore applies."[22:xviii] Prior to the introduction of Kamloops trout the designated beneficial uses of the reservoir were listed as water supply, aesthetics, and wildlife habitat. "There is no indication that these uses are impaired."[22:32]

There is one measurement of sediment within Blue Creek Reservoir. On July 7, 2001 the turbidity was measured at 67 NTUs at the reservoir surface (0.5 meters) and 64 NTUs at the reservoir bottom (3.2 meters).[22] At the same time the total suspended solids were measured at 23 mg/l at the surface and 25 mg/l at the bottom. Representative sediment and NTU data is a data gap for this water body.

- *Juniper Basin Reservoir*

"Juniper Basin Reservoir constructed in 1923, was designed as a storage reservoir for irrigation water. It has since fallen into disrepair. The reservoir is mainly used for livestock watering."[22:11] The reservoir has a depth of 2 meters below the outlet (6.5 feet) and 5 meters (16 feet) at full capacity. The sediment on the bottom of the reservoir is fine grained. At present the only agricultural use may be livestock watering as it is unknown if the reservoir release valve is capable of functioning.

"Juniper Basin Reservoir does not have designated beneficial uses except for water supply, aesthetics and wildlife habitat (IDAPA§ 58.01.02140.04.). There is no indication that these uses are impaired. Existing uses include PCR [Primary Contact Recreation] or SCR [Secondary Contact Recreation]. The listed pollutant is sediment. It is not clear how Juniper Basin Reservoir was placed on the 1998 §303(d) list."[22:32]

There is one measurement of sediment within Juniper Basin Reservoir. On July 6, 2001 turbidity was measured at 72 NTUs at the reservoir surface (0.5 meters) and bottom (1.2 meters).[22] Total suspended solids for the same day were 11 mg/l at the surface and 14 mg/l at the bottom of the reservoir.

Although the Idaho DEQ did not find the reservoir in 2003 to have impaired uses, the authors of this assessment noticed that the use of Juniper Basin Reservoir for watering of cattle had resulted in an extreme concentration of cattle around the reservoir in 2010 at the expense of the aesthetic appearance and all other uses.

Photo 9.14. Cattle using the Juniper Basin Reservoir as a water source in July 2010.

ii. Creeks

Sediment has been identified as a pollutant in five creeks within the Upper Owyhee HUC. The suspended sediment concentration and turbidity in these creeks have not been directly measured. The Stream Macroinvertebrate Index was used as an indirect measure of sediment pollution. The SMI rates the health of a creek's macroinvertebrate community in comparison to reference collections from 'unimpaired' creeks. The SMI scores used to designate sediment as a pollutant in these creeks are given in Table 9.2. The dates of the sample collections are not known.

Table 9.2. Stream Macroinvertebrate Index scores for five creeks in the Upper Owyhee HUC between 1995 and 1999. Higher numbers indicate better health of the macroinvertebrate population.[22:34]

Creek	1995	1996	1997	1998	1999
Deep Creek (location 1)	22.33, 24.33	65.82	50.73	60.57	
Deep Creek (location 2)	45.55, 41.78	48.5	46.48	51.46	62.17
Pole Creek					50.55
Castle Creek		34.49, 21.58			
Red Canyon Creek					63.36
Nickel Creek	9.97				

* >58 Condition Rating 3 (best); 49-57 Condition Rating 2; 31-48 Condition Rating 1; <31 Minimum Threshold

The creeks were revisited in 2000 and 2001 for the 2003 Idaho DEQ assessment, "macroinvertebrates and periphyton* samples were collected on those systems listed as being impaired by sediment. Two sets of samples were collected in 2000 and two sets in 2001."[22:49] SMI scores were not calculated. No comparison was made with the macroinvertebrate population data from previous years. Instead, the presence and absence of species known to be tolerant or intolerant to sediment was used as an indirect measure of sediment pollution. In addition a siltation index was calculated. Of the five creeks where sediment was listed as a pollutant, three did not show sediment pollution in the 2000 and 2001 samples. Sediment was not a limiting factor to fish populations in Pole Creek, Red Canyon Creek, or Nickel Creek. Castle Creek and the upper course of Deep Creek were impaired by sediment.[22] While Nickel

* Periphyton is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems.

Creek did not show signs of sediment pollution, the general lack of macroinvertebrate and periphyton species in the creek (maybe due to metal toxicity), put sediment back on the pollutant list. Data and recommendations from the 2003 assessment were set aside in the subsequent summary report with no explanation. Both Pole Creek and Red Canyon Creek are listed as polluted with sediment in the 2004 report.[23]

iii. Feasibility of addressing the Upper Owyhee HUC TMDL

Resolving the sediment pollution in suspended and bed load of creeks is one goal of the TMDL. Flooding, or high water flow episodes are a major contributor to suspended sediment. During a flood there is more water moving with greater power. This results in greater turbidity and thus more sediment in the running water. Floods also move a greater amount of bed load.

Other factors that influence the amount of sediment within water vary between still and running water bodies.

- *Reservoirs*

As water in reservoirs and lakes tends to be calm, the sediment carried by a stream will settle on the bottom of reservoir or lake. This fine grained sediment can be remixed with the water due to disturbances such as higher than normal water flows, stock watering, or wind.

The Juniper Basin Reservoir is currently used for watering stock. As the majority of the reservoir is shallow the entrance of stock into the reservoir may result in significant disturbance of the lake bed and reintroduction of sediment into suspension. All riparian vegetation around the reservoir has been consumed.

Exclusion of stock from the Juniper Basin Reservoir would limit disturbance of the water and fine sediments on the reservoir bed and would allow the establishment of riparian vegetation. Stock exclusion from reservoirs is a good management practice that can be implemented by the development of off reservoir water sources for stock. Whether stock exclusion will meet the pollution requirements of the TMDL reports is unknown.

The TMDL report from 2003 stated that, “It is not clear how Blue Creek Reservoir was placed on the 1998 §303(d) list.”[22:32] However, this placement indicates that sediment was recorded for the reservoir in 1998, prior to stocking of domestic Kamloops trout in 2000.[22] These fish are considered to be at risk from this sediment. The actual sediment pollution and the factors contributing sediment pollution at Blue Creek Reservoir are unknown.

It is unknown how much new sediment is introduced to the reservoirs each year.

- *Creeks*

Some creeks have sediment exceeding that desired for salmonid fish habitat. Limiting human made sources of sediment erosion will limit additional silting in of the creek beds if it is a factor. Improvement of fords should be considered as vehicle traffic and erosion of the road bed can contribute sediment to a creek. The sediment which would occur in the absence of anthropomorphic activities is not open to amelioration.

The fine sediments that are already in creek beds will be best removed naturally by successive high flow events that scour and remove the fine sediments. The speed with which fine sediments are removed is outside of human control.

The majority of the region has not been heavily impacted by humans. Erosion of sediment off of the rangelands and erosion of the stream channels during weather events and high water flows will continue.

Direct measurements of sediment in suspension and on the creek beds are needed to understand some of the natural variation.

Future monitoring of the creeks should include observation and sampling at various locations along the stream as changes in topography and the location of tributaries impact the stream bed's properties. The health of a stream system should be assessed from multiple points of data collection. The lack of this extent of information is a data gap as is the understanding of the stream system which would result from having the information.

Whether the goals for sedimentation of the TMDL can be met is unknown. Stream bank erosion is assumed to be a major contributor of sediment to the creeks and reservoirs with sediment pollution. The TMDL sets limitations on streambank erosion rates.[22] There is no current implemented way to measure streambank erosion rates. Calculating streambank erosion requires measuring the tons of sediment lost per mile per year. Another limitation has been placed on the total sediment load in tons per year. It is unknown how much sediment is actually moving through the creeks each year so it is unknown if the sediment load allocation figures can be met.

6. Sediment standards

a. Idaho

"The state of Idaho utilizes narrative sediment criteria and numeric turbidity criteria to determine if there are violations of WQS [Water Quality Standards]".[22:47]

> "With an absence of a numeric criterion for sediment, some TMDLs in Idaho have set targets for total suspended solids (TSS), suspended sediment and/or substrate embeddedness or percent fines. Once impairment to the beneficial uses has been determined, as described in IDAPA§ 58.01.02.200.08, an interpretation or an extrapolation is made with the use of literature values. These values can either define a water column allocation, substrate targets and/or both."[22:47]

> "Section 250 of the WQS describes applicable turbidity levels. IDAPA§ 58.01.02.250.02.d. states 'Turbidity, below any applicable mixing zone set by the Department, shall not exceed background turbidity by more than fifty (50) Nephelometric Turbidity Units (NTUs) instantaneously or more than twenty-five (25) NTU for more than ten (10) consecutive days.'"[22:47]

Determining the background turbidity level for the WQS requires an area where there are no anthropogenic sources that would affect the water quality. These levels would also be creek specific. The lack of this information is a data gap.

b. TMDL of Upper Owyhee HUC

Limits for suspended sediment concentrations, turbidity, and particle size in the channel beds have been delineated by the EPA for the Idaho portion of the upper Owyhee watershed:

> "A draft Subbasin Assessment and TMDL for the Upper Owyhee Watershed was completed by IDEQ and approved by the EPA in March 2003. Pollution load allocations were included for the 303(d) listed stream segments as well as other non-listed stream segments within the Upper Owyhee Watershed and ranged as follows: 87-100 percent shading for temperature; 50 mg/L monthly average and 80 mg/L durational targets for suspended sediment; 25 NTUs target for reservoirs; 27 percent fine material reduction for channel substrate; and stream bank erosion targets ranging from 3.4 to 43.5 tons/mile/year."[23:9-10]

There are no plans for monitoring sediment in association with the limits set within the TMDL.[23:35-37] The natural background of sediment load and for channel shading are unknown data gaps.

7. Sediment transport

A major data gap is an understanding of how sedimentation of upstream rivers and creeks affects the amount of sediment downstream.

How much of all the sediment transport is accounted for by unusually high flow events?

Will direct measurements of sediments in creeks agree with the conclusion drawn from the populations of macroinvertebrates?

How much of a stream course would naturally have a gravelly bed for fish to find desirable habitat? How do short periods of increased water turbidity (such as those associated with storm and runoff events) affect fish health? Are fish moving between stream segments over the course of the year with fluctuations is water flow, temperature, and bed habitat?

Bibliography

1. Allen, Dale B., Brian J. Flatter, and Katie Fite. 1995. Redband trout (*Oncorhynchus mykiss gairdneri*) population and habitat surveys in Jump, Reynolds and Sheep Creeks and in sections of the Owyhee County, Idaho. Retrieved 2/10/2011. inhttps://research.idfg.idaho.gov/Fisheries%20Research%20Reports/Res-Allen1994%20Redband%20Trout%20Populations%20and%20Habitat%20Surveys%20in%20Jump,%20Reynolds,%20and%20Sheep%20Creeks%20and%20Sections%20of%20Owyhee%20Co.pdf
2. Allen, Dale B., Brian J. Flatter, and Katie Fite. 1996. Redband trout (*Oncorhynchus mykiss gairdneri*) population and habitat surveys in southern Owyhee County, Idaho. Retrieved 1/9/2011. http://www.blm.gov/pgdata/etc/medialib/blm/id/publications/technical_bulletins/tb_01-2.Par.38938.File.dat/entiredoc.pdf
3. Allen, Dale B., Brian J. Flatter, Jon Nelson, and Chris Medrow. 1998. Redband trout (*Oncorhynchus mykiss gairdneri*) population and habitat surveys in northern Owyhee County and the Owyhee

River and its tributaries, 1997. Retrieved 12/1/2010. http://www.blm.gov/pgdata/etc/medialib/blm/id/publications/technical_bulletins/tb_98-14.Par.67597.File.dat/entiredoc.pdf

4. Allen, Dale B., Brian J. Flatter, Katie Fite and S.P. Yundt. 1993. Redband trout (*Oncorhynchus mykiss*) population and habitat inventory in Owyhee County, Idaho. Idaho Department of Fish and Game, Bureau of Land Management Challenge Cost Share Project, ID013-435001-25-9Z. Retrieved 2/10/2011. https://research.idfg.idaho.gov/Fisheries%20Research%20Reports/Res-Allen1993%20Redband%20Trout%20%28Oncorhynchus%20mykiss%29%20Population%20and%20Habitat%20Inventory%20in%20Owyhee.pdf
5. Blackburn, Paul W. 1997. *Soil Survey of Elko County, Nevada, Central Part*. United States Department of Agriculture, Natural Resources Conservation Service.
6. Bowerman, Terry S. 1997. *Soil Survey Northwest Elko County Area, Nevada, Parts of Elko and Eureka Counties.* United States Department of Agriculture, Natural Resources Conservation Service.
7. Buol, S.W., F.D. Hole, R.J. Cracken, and R.J. Southard. 1997. *Soil Genesis and Classification, 4th edition*. Iowa State University Press, Ames.
8. Chapin, F. Stuart, III, Pamela A. Matson, and Harold A. Mooney. 2002. *Principles of Terrestrial Ecosystem Ecology.* Springer Science+Buisness Media, New York.
9. Claridge, G.G.C. and I.B. Cambell. 1982. A comparison between hot and cold desert soils and soil processes. In *Aridic Soils and Geomorphic Processes*, edited by D.H. Yaalon, pp 1-28. Catelina Verlag, West Germany.
10. Department of Primary Industries and Water, Tasmania, Australia. 2007. Gully Erosion. Managing Natural Resources. Accessed June 19, 2007, http://www.dpiw.tas.gov.au/inter.nsf/WebPages/TPRY-5Z668U?open
11. Department of Primary Industries and Water, Tasmania, Australia. 2007. Rill Erosion. Managing Natural Resources. Accessed June 19, 2007, http://www.dpiw.tas.gov.au/inter.nsf/WebPages/TPRY-5Z6643?open
12. Department of Primary Industries and Water, Tasmania, Australia. 2007. Sheet Erosion. Managing Natural Resources. Accessed June 19, 2007, http://www.dpiw.tas.gov.au/inter.nsf/WebPages/TPRY-5Z65Y4?open
13. Department of Primary Industries and Water, Tasmania, Australia. 2007. Water Erosion. Managing Natural Resources. Accessed June 19, 2007, http://www.dpiw.tas.gov.au/inter.nsf/ThemeNodes/TPRY-5Z65JT?open
14. Dollarhide, William E. and George J. Staidle. 1980. *Soil Survey of Tuscarora Mountain Area, Nevada, Parts of Elko, Eureka and Lander Counties.* United States Department of Agriculture, Soil Conservation Service and United States Department of the Interior, Bureau of Land Management.
15. Drengne, H.E. 1976. *Soils of Arid Regions*. Developments in Soil Science 6. Elsevier Scientific Publishing Company, New York.
16. Environmental Protection Agency. 2011. Drinking Water Contaminants. Accessed January 4, 2011, http://water.epa.gov/drink/contaminants/index.cfm
17. Federal Interagency Sedimentation Project. 2011. Federal Interagency Sedimentation Project. Accessed March 5, 2011, http://fisp.wes.army.mil/
18. Fuller, W.H. 1975. *Management of Southwestern desert soils*. University of Arizona Press, Tucson, Arizona.
19. Fuller, W.H. 1975. *Soils of the Desert Southwest*. University of Arizona Press, Tucson, Arizona.
20. Harkness, Alan L. 2003. *Soil Survey of Owyhee County Area, Idaho*. United States Department of Agriculture, Natural Resources Conservation Service.
21. Idaho Department of Environmental Quality. 2002. Water Body Assessment Guidance, Second Edition - Final, January 2002. Idaho Department of Environmental Quality.

22. Idaho Department of Environmental Quality. 2003. *Upper Owyhee Watershed Subbasin Assessment and Total Maximum Daily Load: Owyhee County, Idaho*. Retrieved 1/28/2008. http://www.epa.gov/waters/tmdldocs/Upper%20Owyhee%20FINAL%2002-03-03.pdf

23. Idaho Department of Environmental Quality. 2004. Upper Owyhee Watershed TMDL Implementation Plan for Agriculture.

24. Ingham, Michael J. (principal author). 1999. South Fork Owyhee River Subbasin Assessment and Total Maximum Daily Load. Idaho Division of Environmental Quality. Retrieved 1/23/2007. http://www.deq.idaho.gov/water/data_reports/surface_water/tmdls/owyhee_river_sf/owyhee_river_sf_entire.pdf

25. International Atomic Energy Agency. 2005. *Fluvial sediment transport: Analytical techniques for measuring sediment load*. Isotope Hydrology Section, International Atomic Energy Agency, Vienna, Austria. Accessed March 5, 2011, http://www-pub.iaea.org/MTCD/publications/PDF/te_1461_web.pdf

26. Jensen, L., and C.C. Shock. 2001 Strategies for Reducing Irrigation Water Use. Oregon State University Extension Publication EM8783. July. Http://eesc.orst.edu/agcomwebfile/EdMat/html/EM/EM8783/em8783.html

27. Kochel, R. Craig. Geomorphic Impact of Large Floods: Review and New Perspectives on Magnitude and Frequency. In *Flood Geomorphology* edited by Victor R. Baker, R. Craig Kochel, and Peter C. Patton p. 169-188. Willey Interscience Publication.

28. Lewis, Jack. 2003. Turbidity-controlled sampling for suspended sediment load estimation. In: Bogen, J. Tharan Fergus and Des Walling (eds.), *Erosion and Sediment Transport Measurement in Rivers: Technological and Methodological Advances* (Proc. Oslo Workshop, 19-20 June 2002). IAHS Publ. 283: 13-20. Accessed June 19, 2007, http://www.fs.fed.us/psw/publications/lewis/lewis_redbook03.pdf

29. Meyer, Kevin A., James A. Lamansky Jr., and Daniel J. Schill. 2010. Biotic and abiotic factors related to redband trout occurrence and abundance in desert and montane streams. *North American Naturalist* 70:77-91.

30. Moseley, Robert, K., 1999. Inventory and assessment of riparian areas on the 45 Ranch Allotment. Idaho Department of Fish and Game. Prepared for: Idaho Field Office, The Nature Conservancy. Boise, Idaho

31. Nichols, Gary. 1999. *Sedimentology and stratigraphy*. Wiley-Blackwell.

32. Opperman, Jeff J., Kathleen A Lohse, Colin Brooks, N Maggi Kelly, and Adina M Merenlender. 2005. Influence of land use on fine sediment in salmonid spawning gravels within the Russian River Basin, California. *Canadian Journal of Fisheries and Aquatic Sciences* 62:2740-2751.

33. Optek. 2011. Turbidity units of measure. Accessed January 4, 2011, http://www.optek.com/Turbidity_Measurement_Units.asp

34. Pollard II, Herbert. 1974. Owyhee County Reservoir Fishery Survey: Job Completion Report, Lake and Reservoir Investigations. F-53-R-8. Job VII-b. Retrieved 1/8/2009. https://research.idfg.idaho.gov/Fisheries%20Research%20Reports/Volume%20031_Article%2054.pdf

35. Porr, N. LeRoy, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg. 1997. The Natural Flow Regime: a Paradigm for river conservation and restoration. *BioScience* 47:769-784.

36. Rice, S.P, M.T. 2001. Greenwood, and C.B. Joyce. Tributaries, sediment sources, and the longitudinal organization of macroinvertebrate fauna along river systems. *Canadian Journal of Fisheries and Aquatic Sciences* 58:824-840.

37. Ritter, Michael E. 2006. *The Physical Environment: an Introduction to Physical Geography*. Accessed June 19, 2007, http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html.

38. Rostagno, César M. 1989. Infiltration and sediment production as affected by soil surface conditions in a shrubland of Patagonia, Argentina. *Journal of Range Management* 42:382-385.

39. Russell H. Lanoie. 2007. A Ditch in Time... Gravel road maintenance and erosion control. Rural Home Technology. Accessed June 19, 2007, http://www.ruralhometech.com/fr/ditch.php

40. Schlesinger, W.H. and A.M. Pilmanis. 1998. Plant-soil interactions in deserts. *Biogeochemistry* 42:169-187.

41. Schlesinger, W.H, J.A. Raikes, A.E. Hartley, and A.F. Cross. 1996. On the spatial pattern of soil nutrients in desert ecosystems. *Ecology* 77:364-374.

42. Shock, Clint. 2006 Efficient Irrigation Scheduling. Malheur Experiment Station. Accessed June 19, 2007, http://www.cropinfo.net/irrigschedule.htm

43. Shock, C.C. 2006. Drip Irrigation: An Introduction. Oregon State University Extension Service, Corvallis. EM 8782-E (Revised October 2006) http://extension.oregonstate.edu/umatilla/mf/Misc%20Files/Drip%20Irrigation%20EM8782.pdf

44. Shock, C.C. 2007. Malheur County Best Management Practices. Accessed June 19, 2007, http://www.cropinfo.net/bestpractices/mainpagebmp.html

45. Simanton, J. R., E. Rawitz, and E. D. Shirley. 1984. Effects of rock fragments on erosion of semiarid rangeland soils. In Erosion and Productivity of Soils Containing Rock Fragments, pp 65-72. Soil Science Society of America, Madison, WI.

46. Smokorwski, K.E. and T.C. Pratt. 2007. Effect of a change in physical structure and cover on fish and fish habitat in freshwater ecosystems - a review and meta-analysis. *Environmental Reviews* 15:15-41.

47. Sullivan, D.M., B.D. Brown, C.C. Shock, D.A. Horneck, R.G. Stevens, G.Q. Pelter, and E.B.G. Feibert. 2001. Nutrient Management for Sweet Spanish Onions in the Pacific Northwest. Pacific Northwest Extension Publication PNW 546. 26p.

48. United States Department of Agriculture. 2011. Web Soil Survey. Accessed 2/15/2011, http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

49. United States Geological Survey. variously dated. National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at http://pubs.water.usgs.gov/twri9A.

50. Wallwork, J.A. 1982. *Desert Soil Fauna*. Praeger Publishers, New York, New York.

51. Wikipedia. 2007. Erosion. Accessed May 30, 2007, http://en.wikipedia.org/wiki/Erosion

52. Wikipedia. 2011. Mollisols. Accessed 2/27/2011, http://en.wikipedia.org/wiki/Mollisol

53. Wikipedia. 2011. Turbidity. Accessed January 4, 2011, http://en.wikipedia.org/wiki/Turbidity

54. Guthrie R.L. 1982. Distribution of great groups of aridisols in the United States. In *Aridic Soils and Geomorphic Processes*, edited by D.H. Yaalon, pp 29-36. Catelina Verlag, West Germany.

55. Wikipedia. 2011. Scree. Accessed March 23, 2011, http://en.wikipedia.org/wiki/Scree

56. Lincoln, Francis Church. 1923. Mining districts and mineral resources of Nevada.

57. Johnson, C.W., G.A. Schumaker, and J.P. Smith. 1980. Effects of grazing and sagebrush control on potential erosion. *Journal of Range Management* 33:451-454.

58. United States Department of Agriculture. 2011. National Soil Erosion Research Lab. Accessed 24 March 2011, http://ars.usda.gov/Research//docs.htm?docid=10626

59. Krishan P. Singh & Ali Durgunoglu. 1989. Developing accurate and reliable stream sediment yields. *Sediment and the Environment* (Proceedings of the Baltimore Symposium, May 1989), IAHS Publ. no. 184, pp. 193-199.