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To: Subcommittee on Water and Wildlife
Committee on Environment and Public Works
United States Senate
Hearing on:

The Impacts of Mountaintop Removal Coal Mining on Water Quality in Appalachia

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Good afternoon Chairman Cardin and members of the Committee. I am Margaret Palmer and I thank you for inviting me to discuss scientific evidence of the environmental impacts of surrounding mountaintop removal coal mining, and the likelihood these can be mitigated using current restoration practices.

By way of background: I am an environmental scientist with expertise on stream ecosystems and restoration ecology. I have been conducting research and publishing books and articles for more than 25 years, have served as a scientific advisor for the National Science Foundation, the National Center for Ecological Analysis & Synthesis, the National Center for Earth Surface Dynamics, as well as both international and regional scientific programs. While I am a Professor at the University of Maryland and spend most of my time in that great state, I also have a home in West Virginia. My ties to the Appalachian mountains go way back since my family is from western North Carolina, where I spent much of my childhood.

Everything I am presenting today is based on current science from published peer-reviewed scientific literature. I have provided, along with this statement, a paper by myself and Professor E.S. Bernhardt from Duke University that not only includes more detail, than what is in this testimony but provides the citations to the scientific literature upon which my comments are based. My comments fall into two main categories:

Part I - Environmental Impacts on Natural Resources
- I.1. Magnitude and irreversibility of impacts;
- I.2. Consequences of losing headwater streams;
- I.3. Significance of cumulative impacts:
- I.4. Extent of downstream water quality impacts

Part II: Scientific Feasibility of Mitigation
- II.1 Methods used to assess impacts and calculate required mitigation actions:
- II.2 Types of mitigation proposed

Summary and Closing

Part I. Environmental Impacts on Natural Resources

I.1. Magnitude and irreversibility of environmental impacts

The impacts of mountaintop removal with valley fills (MTVF) are immense and irreversible, and there are no scientifically credible plans for mitigating these impacts. The process involves complete deforestation of a mountain summit, followed by blasting it with explosives to remove hundreds of meters of the mountain that cover the coal seam. The rocks and other ‘overburden’ are then pushed into valleys surrounding the site where they fill small streams. The valley fill which now sits on top of once forested streams is graded into a series of ‘stair steps’; water that was once absorbed by the mountain soils and associated vegetation, now runs rapidly into the fill and exits at its base into larger streams.

The removal of vegetation from mined watersheds, and the alteration of valley contours on mined sites fundamentally alters the patterns of water flow through impacted valleys and changes how water is delivered to streams that are below the valley fill. It is important to understand that how water reaches a stream, and what that water has encountered as it moved toward the stream determine the quality of that water. Before they are destroyed by mountaintop mining, the steep, small streams receive most of their water from belowground (i.e., as groundwater) unless there has just been a heavy rain. This water arrives at the stream after infiltrating the ground around lush vegetation, soaking into the soil, and then moving laterally toward the stream (Fig. 1). As it moves through the soil, the water is purified and simultaneously enriched with nutrients that are necessary for the stream food web. Mining however removes hundreds of feet of soil, rock, and dead and living plant material. Even if the surface soils are stored and returned to the summit, the paths along which groundwater previously flowed to streams have been obliterated – the summit and its organic-rich layers of soils which harbor ecologically important communities of bacteria, fungi, and burrowing insects are no longer intact stratigraphically. In fact, water reaching the streams that are left at the bottom of valley fills comes from the fill itself which, as I describe later, is so polluted that entire groups of organisms can no longer live in it.

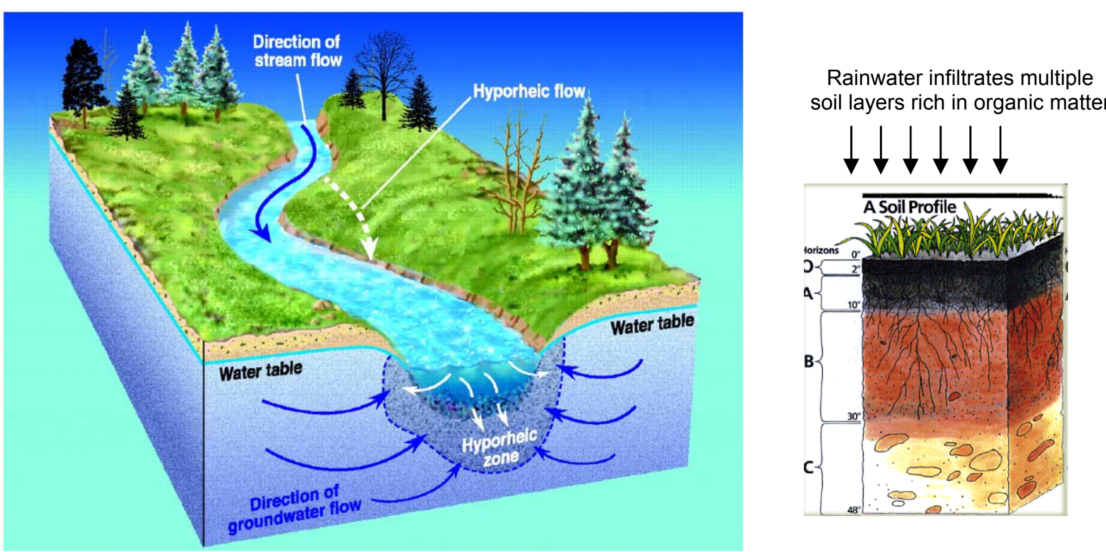


Fig. 1 Groundwater moves into healthy streams after passing through vegetation and rich soil layers.

There are now a number of peer-reviewed scientific studies documenting the fact that the hydrologic “regime” (source, timing, and amount of water flow) below mined sites is fundamentally altered. Since the flow regime is one of the key variables determining what types of fish, insects, and other aquatic organisms can live in a stream, even if the water coming out of valley fills could be purified before entering streams, the biological community will never be the same. Further, wildlife that were residents of the mined site are displaced or die and biota in the stream that was buried are killed.

I.2. Consequences of losing headwater streams

The streams that are buried by the valley fill are called headwater streams – they are those regions “where rivers are born” because their flow and associated biota, sediment, and dissolved constituents feed downstream waters – without headwaters, larger streams and rivers below lose the nourishment and source of clean water that fuels them.

Fig. 2 West Virginia streams.

In their healthy state, many headwater streams have visible surface flow only part of the year, but ecological processes important to the entire watershed occur within them year-round; when surface water is not visible, many of the biota including salamanders, insects and crustaceans reside below the streambed surface or in small pools under rocks that retain water. In fact, headwater streams are among the most diverse streams in the world in part because they can harbor some species that are unique (*i.e.*, the only place in a river network these species occur is in the headwaters). Headwaters also provide a refuge from predators and changes in temperature for some species, and are important spawning and nursery grounds for some others.

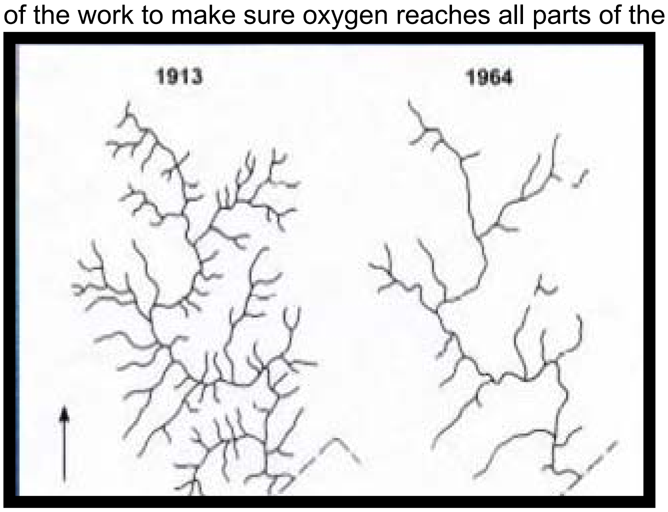
In addition to being biodiversity hotspots, there is abundant scientific evidence that headwater streams play roles disproportionate to their size in watersheds. They are critical to nutrient cycling, water purification, and organic matter processing that fuel downstream food webs. The small ephemeral and intermittent streams within the river networks are conduits that transport water, sediments and dissolved materials from mountain tops to large river ecosystems. Shallow headwater streams have high contact between water and sediments, and thus exceptionally high rates of nutrient and organic matter storage and processing. The biological communities in headwater streams import hard-to-digest plant material from forest products (leaves and sticks) and convert that material into high-quality fats and proteins (insects and salamanders) that are exported to downstream food webs.

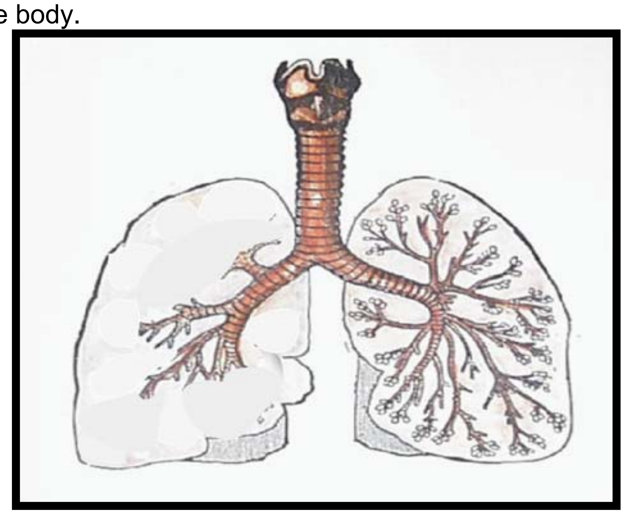
I.3. Significance of cumulative impacts

It might seem intuitive to assume that because headwater streams are small, with only a few are filled each time a new mine is dug, that the overall impacts are not that significant. This is not the case. First, because the ecological importance of headwater streams is disproportionate to their size, they are critical to the health of watersheds.   Second, it is important to understand that in the central Appalachian Plateau, the most significant changes in land use and land cover are related to surface mining of bituminous coal. This change is the single largest driver of land use change in this region today. To give you an example: in the Laurel Creek watershed in West Virginia more than 25% of the watershed by area is covered by surface mine permits, and 37% of the headwater streams (by length) intersect mines or valley fills. When you think about the fact that many counties across the U.S. are trying to limit land use change for development to 10 – 12% because water quality is so degraded beyond that point, it is hard to imagine those numbers for Laurel Creek – particularly because mountain top mining is far more destructive to the landscape than a new home or even a cluster of homes.

A useful way to think about the loss of headwater channels is to consider how analogous they are to the small passageways in the human lung. The capillaries accomplish most of the important work in exchanging gases between the respiratory and circulatory system; without them you would die. Indeed, when a person gets emphysema (like my mother), they begin to lose use of the small passageways and slowly suffocate. Small intermittent and ephemeral headwater channels function similarly in watersheds – they do much of the processing of source materials for delivery to sustain downstream ecosystems and ensure productive rivers. Remove too many of them and the system slowly dies (Fig. 3).

Fig 3. Watersheds have complex stream networks – the smallest branches called headwaters are responsible for a disproportionate amount of stream functions carrying nutrients and organic matter to larger streams and rivers. Similarly the capillaries surrounding the smallest branches of the lungs (alveoli) do most of the work to make sure oxygen reaches all parts of the body.





I.4. Extent of downstream water quality impacts

The fragmentation and exposure of mined rock to air and water results in high rates of rock weathering, which leads to increased concentrations of a number of chemical constituents in the stream water below fills. Some of these cause acute toxicity in aquatic life, but many of them cause chronic low level stress to organisms. The chronic stress from many chemicals adds up to serious problems for organisms. The high level of impairment found in streams below mining valley fills is because the additive impact of all this stress is simply too much for many species. Thus, it is the cumulative impact of elevated concentrations of multiple stressors that leads to biological impairment in these streams. By analogy, consider a person that smokes just a few cigarettes a day but is 75 pounds overweight and has very low level diabetes --- none of the stressors alone necessarily lead to death but together, the levels of physiological stress on this person are extreme and will shorten their lifespan.

<u>Elevated conductivity from pollution by numerous ions.</u> Water feeding larger streams emerges from the base of the valley fill and has elevated concentrations of sulfate, bicarbonate, calcium and magnesium ions, as well as often including elevated concentrations of multiple trace metals (aluminum, manganese, selenium) that are potent pollutants. The combined toxicity of multiple constituents leads to a loss of sensitive aquatic organisms even though downstream habitats are intact.

The exposure of coal seams during coal mining provides many opportunities for the leaching of sulfate (SO_4^{2-}) into surface waters. Mining-impacted streams in WV often have 30-40 fold increases in SO_4^{2-} concentrations (Brooks et al. 2002; Pond et al. 2008) with 13 streams in the 2009 WVDEP database having SO_4^{-} concentrations higher than found in seawater (>2717 mg L^{-1}). Studies have shown that sulfate concentrations continue to increase even after mining ceases. The relationship between mining activities and high sulfate concentrations is so well established that the 2008 WVDEP West Virginia Integrated Water Quality Monitoring and Assessment Report suggested that SO_4^{2-} concentrations >50 mg L^{-1} could be used as an indicator of mining activity. *Why is this a problem?* Elevated sulfate concentrations stimulate stream bacteria to produce sulfide that is directly toxic to plants and many organisms. High sulfate concentrations also interfere with nutrient cycling in streams.

Other ions that enter the streams below valley fills, including magnesium, calcium, and bicarbonate, lead to very elevated levels of suspended solids and conductivity; as noted earlier, trace elements like aluminum and selenium are also elevated and the latter is so serious that I devote an entire section to it.

The cumulative, or additive effect, of all the constituents leads to biological impairment in waters below valley fills. A group of insects well known to those who love to fly fish are the mayflies – they are considered good indicators of water quality because they are not very tolerant to pollution. The number of species of mayflies you find in streams declines as mayflies you find in streams declines as pollution increases. Since conductivity is a good indicator of water pollution below valley fills, many studies have examined mayfly diversity and abundance in valley fill streams (Fig. 4). Typical conductivity levels in West Virginia streams range from 13 – 253 µS/cm while valley fill streams can reach >2500. Recent studies by Hartman et al. (2005) and Pond et al. (2008) compared water quality between paired reference and valley fill impacted streams and found that specific conductivity in the filled sites was at least twice as high as in the reference streams.

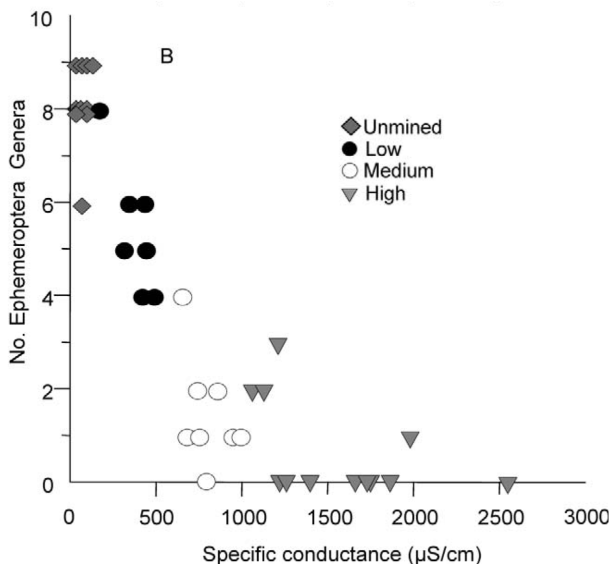


Figure 4. Number of sensitive insect (mayflies) groups (genera) as a function of stream conductivity in West Virginia streams with different levels of mining impact. Mayflies are widely recognized by the scientific and management community as indicators of water quality. From Pond et al. (2008). "Downstream effects of mountain top coal mining." Journal of the N. American Benthol. Society. 27:717-737.

The finding that entire groups of insects – and not just mayflies -- are nearly eliminated in MTM streams is not a good finding for West Virginia water ways, particularly because the poor water quality with high conductivity and high sulfates can persist long after mining activities cease. The West Virginia Department of Environmental Protection has found that 86% of the mountain streams in their database with conductivity > 500 µS/cm were scored as impaired using the genera based GLIMPSS index.

<u>Selenium (Se) and water quality</u>. The water quality of streams below mountaintop removal mining sites is a serious issue, because when Se enters the aquatic food web it can reach levels that are toxic to fish and wildlife, such as birds. Selenium occurs naturally in coal. It is leached out from coal and overburden that fills valleys when they are exposed to air and water. Professor Dennis Lemly of Wake Forest University, who is a world expert on selenium and its ecological impacts, has completed numerous studies and a white paper he wrote on the topic was submitted as part of this hearing. I refer you to this paper for details, but describe the seriousness of the issue very briefly here. Because selenium can be bioaccumulated in the tissue of organisms, even small quantities in the water can lead to major problems for organisms: as you move up the food chain, Se is concentrated more and more and can cause severe abnormalities, death, or reproductive failure (Fig. 5).

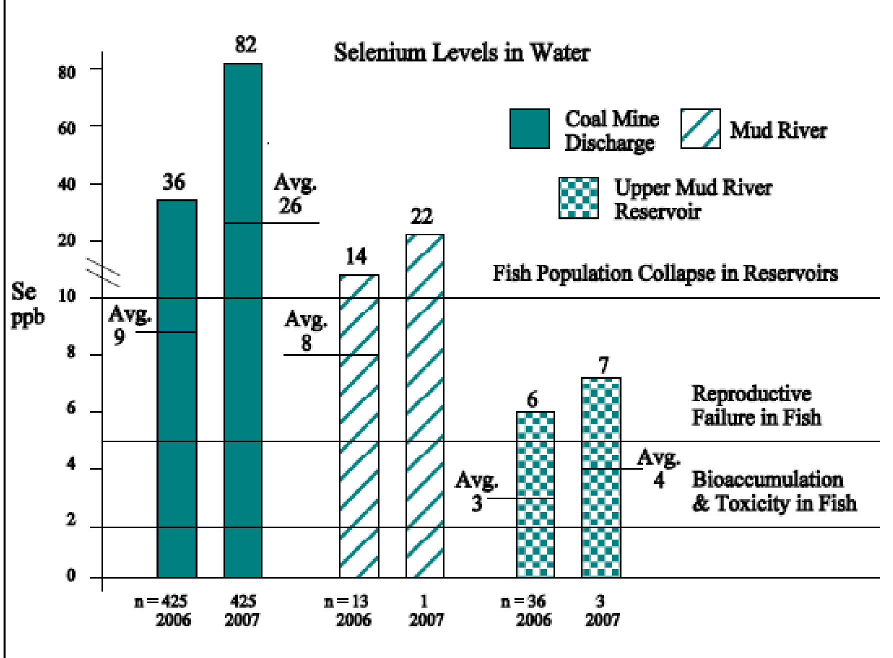
We know that this is a major problem in Appalachian streams impacted by mountaintop mining, because a major environmental impact study was completed in 2005 by four federal agencies and the West Virginia DEP (EPA 2005). Over 1200 stream segments were examined, finding that the valley fills used for waste disposal are a primary source of selenium contamination. Because of the size and placement of these fills, selenium leaching and associated pollution of downstream aquatic habitats, left untreated, will continue in perpetuity. Further, Dr. Lemly's studies since this EIS have shown that effluent from a mountaintop removal operation in West Virginia had as much as 82 ug/L selenium –

an amount that is over fifteen times the threshold for toxic bioaccumulation. Thus, selenium is a real and immediate risk for wildlife.

Figure 5. Selenium in discharge from a mountaintop removal coal mining operation in West Virginia polluted downstream receiving waters to levels that far exceed toxic thresholds for fish (from Lemly 2008). The maximum concentration (82 ug/L) is over fifteen times the threshold for toxic bioaccumulation. Selenium causes fish deformity and reproductive failure.

Fish larva exposed to selenium Mud River, WV June 2007

From R. Lemly 2009



Top: Abnormalities of the spine in fish exposed to selenium. Bottom: Lateral curvature of the spine caused by exposure to Se (left); Normal fish (right)

Dorsal view; Note deformed spine in “S” shape, typical of scoliosis due to selenium poisoning. This individual also has deformed pectoral fins

Side view; Note distended, fluid-filled yolk sac (edema) with delayed yolk absorption. Individual also has dorso-ventral curvature of the spine and deformed fins and eyes - both eyes on same side of head

Part II. Scientific Feasibility of Mitigation

II.1 Methods used to assess impacts and calculate required mitigation actions

In order to obtain a permit, companies proposing a new mine site must thoroughly evaluate the existing water resources, estimate the impacts quantitatively, and propose actions to mitigate for these impacts. Streams and impacts to them can be characterized in two ways: structurally and functionally. The distinction between the two characterizations is key to serious scientific concerns about current and past comprehensive mitigation plans, as well as, impact assessment requirements by the U.S. Army Corps of Engineers.

Structural measures evaluate the ecological state at a point in time while functional attributes describe how the system is performing over time. Examples of ecological structure include channel shape, habitat features, and the number of species found in one sampling trip. Functional measures describe ecological processes and rates such as the input of organic matter over time, the rate of growth of organisms, or the nutrient cycling capacity. Both types of measures are important, yet mitigation plans do not directly measure ecosystem function; instead, almost all plans are based on a single "snapshot" measure of structural traits like channel shape, water depth, and number of insects. Functional measures represent system performance; not measuring them to evaluate the health of a stream that is to be destroyed (and thus has to be mitigated for) would be like our doctor only measuring our height and weight and never taking our blood pressure or heart rate.

Those performing assessments of sites to be mined or receive permit applications have argued that measuring ecological functions is too hard, yet aquatic ecologists do it all the time. I even employ high school students to assist with this work, and we do it on many streams using a very small annual research budget. In fact, the second edition a text book is now out with a chapter devoted to each method and there are many examples in the literature of streams that have been assessed using this method. The reason that scientists are concerned about the inadequate assessments that are being completed on these sites, is that the roles these small streams play in nature is vastly underestimated without these measures. Healthy streams are living, functional systems not simple channels that can be described based on their size and shape.

Because ecologically valuable headwater streams will be permanently destroyed, all mitigation plans should address the ability of enhanced or restored streams elsewhere to replace the functions performed by the lost headwater streams, yet this is not done. Further, the Clean Water Act stipulates that all natural resource and ecological functions that are lost must be replaced. Thus, a clear emphasis has been placed on functionality.

Mitigation projects are typically monitored for 5 to 10 years after completion. The required monitoring suffers from the same short falls – failure to measure stream functions. In addition, while the burial of streams is permanent many stream enhancement projects will be of short duration. Thus, monitoring of 5-10 years will miss the temporal differences between impacts and the mitigation intended to offset them.

11.2 Types of mitigation proposed

Permits to fill "waters of the U.S." may be granted by the U.S. Army Corps of Engineers based on 'rendering the impacts non-significant', because mitigation actions are proposed to replace lost aquatic resources and ecological functions. Proposals for compensatory mitigation to replace losses when headwater streams are buried by the mining activities may occur through a variety of actions, but generally fall into two categories: stream creation and stream restoration or enhancement.

Stream creation. This is a process where attempts are made to create a stream by excavating a ditch and placing structures like boulders and rocks into the channel. These are meant to replace the headwater streams that are buried by mining overburden. These creation attempts are often undertaken on or near a valley fill and they usually rely on the fill or mined area for their waters source.

Even if a channel can be constructed to convey water below a valley fill, they will not have the energetic base, thermal or flow regimes to support the native aquatic community**.** The energetic basis of the stream food web of mountainous Appalachian streams is leaf litter from the surrounding trees. For most of the year, bacteria, fungi and aquatic insects consume the leaves and wood that fall or are washed into the stream from the surrounding forest. Constructed streams on or below valley fills are in high light environments, with early vegetation consisting primarily of short-stature grasses. With abundant light, algal production is likely to be high, and with the open canopy, temperatures may reach levels that native fauna can not acclimate to. Thus, while an un-impacted mountain stream ecosystem in the Appalachian region is fueled by leaf litter from the surrounding forest, the created streams will be fueled by algal production. Without a forest canopy, water temperatures in the constructed streams will be significantly hotter in summer and significantly colder in winter than in the forested streams.

Fig. 6: left panels: an intermittent headwater streams during dry periods and after rains; right panel: a ditch associated with a mining site post reclamation.

The process of attempting to create a stream in association with a mountaintop coal mine typically involves: re-grading mined land and digging a channel with a particular shape, width, and depth that is selected from a stream channel classification system originally developed in the western U.S. This shape is not necessarily even similar to what existed prior to the mining activities; more importantly, what surrounds a new ditch and how water reaches the ditch bear no resemblance to intact headwater streams in the Appalachians. Due to the mountaintop removal and valley fill activities, all of the natural water flow paths, the landscape topography, the vegetative inputs to streams, the riparian soil and the streambed biogeochemistry are different or totally absent.

There is not a single case in which a channel built in this manner has resulted in a healthy stream with the biota and functions of un-impacted headwater streams. No study has ever produced any evidence that created streams at these sites have hydrological and ecological dynamics that are similar to the high gradient headwater streams they are meant to replace. Stream creation is simply outside the current scope of accepted science. Ditches may be built to convey water but streams are living systems – far more than rock lined ditches. Creating ecologically healthy streams in places where the natural groundwater and surface water flow paths are so altered, and the landscape and vegetation so impacted, has not ever been accomplished - yet permits are being given for this activity. Stream “creation” is certainly not considered a form of ecological restoration. Stream restoration varies along a continuum from simple projects like planting riparian trees along streams, to re-shaping channels and even sometimes re-routing a section of a channel. But that is very different from trying to make a fully-functioning, living stream some place that it did not previously occur.

<u>Stream restoration</u>. Restoration or enhancement of degraded streams in areas adjacent or contiguous to the mining site typically involves stabilizing a streambank, re-shaping a channel, or replanting riparian vegetation. Enhancement and restoration actions are typically applied to perennial streams, even if the streams that are lost due to mining are ephemeral or intermittent.

Proposals to mitigate by restoring or enhancing degraded perennial streams off-site can not mitigate for the loss of ephemeral and intermittent streams. The unique biota, distinctive high gradient profiles, and irregular flows of these small streams generate ecological conditions that can only be found on the very steep sides of intact mountain summits. In particular, the intermittent nature of flow contributes to the evolution of diversity, the support of unique species, and heightened rates of particular biogeochemical processes with watershed wide consequences.

Summary and Closing

In conclusion, Mr. Chairman and fellow Senators, mountaintop removal mining with valley fills causes permanent environmental impacts. The mountain summits that are removed to reach the coal may not have the same shape or height they previously did, the streams that are buried when rocks and dirt are dumped over the side of the mountain into the valleys below are gone forever, and there is no evidence to date that mitigation actions can compensate for the lost natural resources and ecological functions of the headwater streams that are destroyed. Further, the water quality impacts from the mining and valley fills permeate downstream such that many streams not directly touched by the mining activities are biologically impaired. Selenium levels measured in streams below valley fills are as high at levels known to cause major deformities, toxicity, or reproductive failure in fish. Conductivity levels in some streams below valley fills are like seawater. Fish in rivers and reservoirs below fills have deformities and reproductive failures due to selenium exposure. Scientific studies in well respected journals document these impacts, and there is not a single study in the peer-reviewed literature providing evidence that streams created for mitigation replace the functions and structures of natural headwater streams.

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