BLOEDE DAM

ALTERNATIVES ANALYSIS

JUNE 15, 2012

Submitted to:
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1 Executive Summary

Inter-Fluve is contracted by American Rivers to complete an alternatives analysis on behalf of the Project Management team[1] to consider and evaluate the pros and cons of either removing or retaining the Bloede Dam on the Patapsco River in Ilchester, Maryland. This evaluation will weigh each option against its ability to achieve the overarching goals for the Patapsco River of restoration of fish and aquatic organism passage, improvement of public safety and consideration of historic, cultural and recreational values.

To date, American Rivers and their partners, including the Maryland Department of Natural Resources (DNR), the National Oceanic and Atmospheric Administration (NOAA), and Friends of the Patapsco Valley State Park, have focused their efforts on restoring upstream segments of the Patapsco River through the removal of the Union and Simkins dams. However, the fish ladder at Bloede Dam has proven ineffective and most aquatic species are not able to migrate upstream. The Bloede Dam is the lowermost dam on the Patapsco, and thus passage for the entire system hinges upon removal of this obstruction. It is the last major fish passage barrier in the lower Patapsco, and would free up more than 64 miles of free-flowing river for herring and eel passage.

Removal of the Bloede Dam has been the focal point of previous studies, and three principle documents, Century (1980), Synergics (1989) and Gannett Fleming (2012), were extensively reviewed during this evaluation of options for addressing the fisheries and safety goals at the Bloede Dam. This document is intended to provide a synthesis of these previous studies, along with data collected during the Union and Simkins dam removal projects and recent Bloede Dam and impoundment data, and serve as an informative evaluation tool to allow stakeholders to fully understand project drivers, alternatives evaluated and the nature of the work proposed under the preferred alternative.

The alternatives evaluated herein include the following:

- No Action
- Repair of the dam and fish ladder
- Dam removal with active sediment management
- Dam removal with passive sediment management

Taking into account overarching project goals and solutions that have been tried to date, the recommended alternative is removal of the dam using passive sediment management. Specifically, the recommendation for the Bloede Dam removal approach considers fish passage goals, existing fish ladder

[1] The Project Management consists of an interdisciplinary team from the Maryland Department of Natural Resources, National Oceanic and Atmospheric Administration, and American Rivers.

maintenance issues, site safety goals, recreational impacts, ecological impacts, cultural impacts and a cost comparison with attainable benefits. Evaluations of past studies were included in the decision making, and the recommendations are in agreement with most of the recommendations in the previous Gannett Fleming alternatives analysis. We believe that the scientific evidence strongly supports dam removal as a cost-effective method of relieving concerns for public safety, achieving fish passage goals, improving recreation opportunities, and the best way to restore this segment of the Patapsco River and reasonably attain most project goals.

The decision to pursue a passive sediment management approach was based on review of sediment transport model data and by comparing channel response and sediment monitoring data collected as part of the post-removal evaluation of the Simkins and Union Dam removals. It also takes into consideration the impact of the selected approach for Maryland Park Service and the average Park user. Short-term impacts include sand deposition in the channel, overbank sediment deposition and temporary trail impacts, short-term disturbance of River Road during construction and ecological impacts to low gradient reaches lasting 5-20 years depending on river flows. Long-term benefits include fish passage restoration, improved fish and wildlife habitat, elimination of dam failure risk, improved park safety, improved kayak and canoe passage, new fishing opportunities and the uncovering of a picturesque boulder and cobble step pool channel with bedrock outcrops. It was concluded that these long-term benefits outweigh the short-term impacts to the system. The preliminary cost estimates for the alternatives discussed are given in the table below.

Table 1. Preliminary cost estimate

Alternative	Engineering	Permitting	Construction	Total*
No Action	Minimum costs for Maryland Park Service staff to fence and provide supervision at the Bloede site are $25,000 per year. These costs do not include expenses incurred by the State for maintaining and repairing the fish ladder and dam repairs to prevent failure. These costs could vary from thousands to tens of thousands per year.			
Dam and fish ladder repair	$65,000	$15,000	$800,000	**$880,000**
Removal with passive sediment management	$400,000	$35,000	$700,000	**$1,335,000**
Removal with active sediment management	$400,000	$35,000	$1,800,000	**$2,235,000**

**Costs are +/- 50% and do not include funds for adaptive management and monitoring*

2 Introduction

The Bloede Dam is located within the Patapsco Valley State Park approximately 11 miles upstream of Chesapeake Bay (Hanover Street) and 0.51 miles downstream of the Ilchester Road bridge in Ilchester, Maryland. Inter-Fluve is contracted by American Rivers to complete an alternatives analysis on behalf of the Project Management team[2] to consider and evaluate the pros and cons of either removing or retaining the Bloede Dam. This document is intended to provide a synthesis of previous studies, along with data collected during the Union and Simkins dam removal projects and recent Bloede Dam and impoundment data, and serve as an informative evaluation tool to allow stakeholders to fully understand project drivers, alternatives evaluated and the nature of the work proposed under the preferred alternative.

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2.1 Site description

The Bloede dam is a hollow-core slab and buttress dam built in 1907 by the Ambursen Hydraulic Construction Company of Boston, Massachusetts. The spillway is 34-feet high and 160-feet long, with a 40-foot wide base and adjacent concrete abutments that span a total distance of 220 feet across the river valley. The turbines, which were once housed inside the dam, have been removed, and the current structure is filling with sand. The dam drains an area of approximately 304 square miles and impounds roughly ten acres. Synergics (1989) estimated the maximum storage capacity of the dam to be 600 acre-feet, with sediment accumulation in 1989 resulting in only 150 acre-feet of water storage, but the Simkins sediment has filled the impoundment, reducing remaining storage capacity to near zero. The

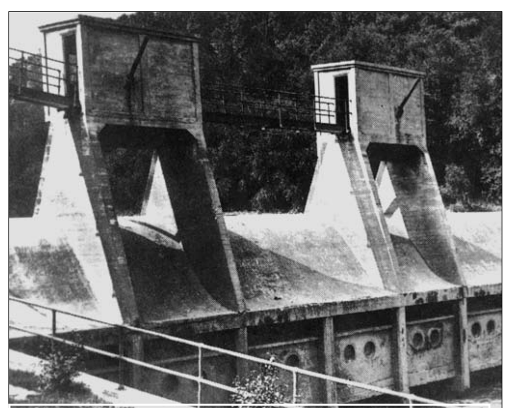

Figure 1. Gate works from an early photo of the Bloede Dam.

[2] The Project Management consists of an interdisciplinary team from the Maryland Department of Natural Resources, National Oceanic and Atmospheric Administration, and American Rivers.

original structure included several large abutment structures that held gate works for manipulation of flow and water diversion into a right bank fish ladder, but these were removed following the damage caused by Tropical Storm Agnes in 1972 (Figure 1). The design of the Bloede dam was unique, featuring water intakes below the crest that fed internal turbines. This design was also the reason for the dam's dysfunction, as large amounts of sediment deposited upstream of the dam and clogged the intake pipes. Dredging in the early 1920s temporarily restored power generation to the dam, but subsequent flooding brought more sediment. Hydropower generation was finally discontinued in March 1932 (Figure 2). Since that time, the dam has functioned only as a run-of-river dam. The Maryland DNR installed a fish ladder on the right bank in 1992. Several people have been killed at the Bloede Dam site, and the dam and abutments are defined as an attractive nuisance and a significant safety hazard. The dam has been inspected thoroughly numerous times, including Century (1980), Synergics (1989), Wheelock (1993), and Gannett Fleming (2010). These were either dam inspection reports or engineering analysis related to fish passage, repairs or demolition.

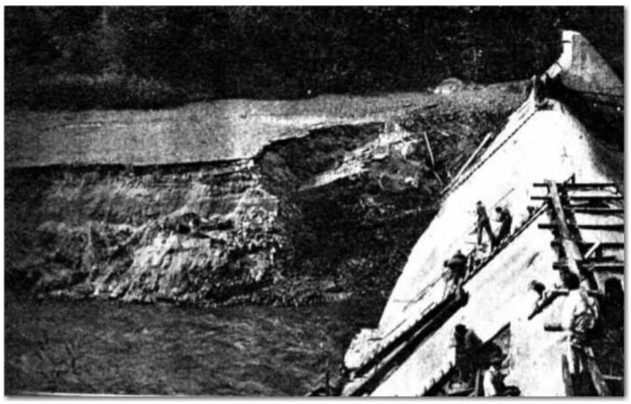

Figure 2. Flushing of accumulated sediment upstream of Bloede (ca 1920).

2.2 Existing river conditions summary

The Patapsco River drains the Maryland Piedmont Plateau with the Bloede site located just downstream of Ilchester Road in the Patapsco Valley State Park Avalon area. The segment of the river near Bloede separates Howard County to the south and Baltimore County to the north. The Patapsco Gorge maintains a constant slope of 0.2% from Ellicott City to Ilchester Road, but then steepens to a slope of 2.9% through the Bloede impoundment area. Just downstream of Bloede, the river begins to transition to a lower gradient stream, finally terminating in low gradient, sandy reaches as it empties into Chesapeake Bay. Throughout its length, the lower Patapsco River channel is defined by past human disturbance (gravel fill, road crossings, dams) and bears geomorphic evidence of major Tropical Storm driven events, particularly that of Tropical Storm Agnes in 1972, that moved large amounts of cobble and gravel sediment, forming permanent bar features and moving the channel dozens of feet laterally. Downstream of Bloede Dam, the channel was somewhat sediment starved prior to the Simkins removal. Inter-Fluve staff conducted a geomorphic assessment that showed some gravel and sand bars present in peripheral areas where the channel was either widened or influenced by some hydraulic backwater. These backwater areas are caused by constrictions or eddies formed by incoming tributaries. The stream transitions from cobble riffles to a gravel riffle-pool channel until the Thomas Viaduct area, where the stream transitions into a low gradient, sandy bottom river.

Upstream of the dam, there is a large point bar covered in mature trees. Tree coring of the largest sycamore trees suggest that the most recent sediment deposition occurred in the late 1960s to early 1970s, which corresponds with expected deposition and damage of any existing trees by Tropical Storm Agnes in 1972. Sediment coring and seismic data suggests a hardpan clay layer roughly 3-5 feet below the surface with sand and organic sediment (silt) deposition on top of the clay.

Figure 3. Large point bar upstream of Bloede Dam.

Previous storms in 1866, 1868 and 1972 removed or permanently damaged many of the former dams and mill sites on the Patapsco. Of the four surviving dams, Bloede, Simkins, Union and Daniels, only Bloede and Daniels remain following recent removal efforts. The Patapsco River upstream of the Simkins removal site has undergone significant changes, including coarsening of channel bottom sediment, evacuation of sands and exposure of bedrock outcrops and boulders. The bioengineered treatments at Simkins have performed according to specification, and the planted native vegetation is being actively managed. Based on monitoring data and as-built surveys post removal, the Simkins Dam has caused the release of approximately 64,000 cubic yards (CY) of coarse sand (out of a projected total of around 77-88,000 CY), over half of which is currently deposited between the Simkins dam site and the Bloede Dam.

2.3 Fish passage conditions summary

One of the primary objectives for the project is to restore passage for migratory fish including American shad (*Alosa sapidissima*), hickory shad (*A. mediocris*), blueback herring (*A.aestivalis*), alewife (*A. pseudoharengus*), American eel (*Aguilla rostrata*) and yellow perch (*Perca flavescens*), species that were once the backbone of the Chesapeake Bay economy. A fish ladder was installed at the site in 1991. Monitoring at the Bloede Dam fish ladder occurred in 1993, 1994, 1998 and 1999. These surveys revealed that a variety of fish were using the ladder but not in high numbers. Very few anadromous fish used the ladder during the April/May spawning seasons (Maryland DNR – Pers. comm.). In the early 1970s and 1990s, fisheries monitoring data indicated the presence of anadromous fish in the lower Patapsco River. Specifically, the fish community around the Bloede Dam area, including redbreasted sunfish (*Lepomis auritus*), rock bass (*Ambloplites rupestris*), American shad, gizzard shad (*Dorosoma cepedianum*), sea lamprey (*Petromyzon marinus*), white sucker (*Catostomus commersoni*), smallmouth bass (*Micropterus dolomieu*), common carp (*Cyprinus carpio*), river chub (*Nocomis micropogon*), channel catfish (*Ictalurus punctatus*), rainbow trout (*Oncorhynchus gairdneri*) and brown trout (*Salmo trutta*). In addition to these species, the South Branch Patapsco also included spottail shiner (*Notropis hudsonius*), satinfin shiner (*Cyprinella analostana*), common shiner (*Luxilus cornutus*), bluegill sunfish (*Lepomis macrochirus*), pumpkinseed sunfish (*Lepomis gibbosus*), redbreast sunfish and tessellated darter (*Etheostoma olmstedi*). The river has been stocked periodically with blueback herring, and herring have been sighted spawning in gravel riffles below Bloede Dam.

Prior to 2009, there was no consistent fisheries survey data for the Patapsco River. Sampling occurred in tributaries of the Patapsco River as part of Maryland Biological Stream Survey's (MBSS) revolving watershed survey schedule. However, the timing of these surveys varied over the years. Results from the MBSS data at 16 sampling sites below Bloede Dam found an average of 18 eels per sampling location. When data was examined at the 42 MBSS sampling sites above Bloede Dam, only four American eels were captured, or an average of 0.1 eel per sampling location. Beginning in 2009, MBSS began conducting biological monitoring in the Lower North Branch Patapsco River as part of the pre- and post-dam assessment in conjunction with the Simkins and Union dam removals. The goals of the monitoring project are to determine the potential impacts of dam removal on American eel distribution as well as on fish, benthic macroinvertebrate and freshwater mussel communities of the Patapsco River. Sampling was conducted at 21 sites in spring and summer of 2009-2011 and will continue through at least

2012 to more fully assess the changes to the aquatic community and what future restoration needs exist. While the most recent sampling data indicates that small numbers of American eel are making it into the upper portions of the watershed, the same cannot be said for the shad and herring species listed above. Spring 2011 surveys found blueback herring and hickory shad (as many as 90 in just 15 minutes of sampling) immediately downstream of Bloede Dam (Maryland DNR – Pers. comm.). In an attempt to further monitor effectiveness of the existing fish ladder, roughly 1/4 mile of river above the dam was surveyed, and a net was also placed over the upstream exit to the fish ladder. However, none of these migratory species have yet been collected upstream of the dam.

The existing fish ladder is inefficient at passing all target species and life stages. Even when operating under optimal conditions, it has been ineffective at sustaining migratory species recovery efforts identified in numerous state and federal plans. Optimal conditions include adequate attraction flow, good access and appropriate water depth at the entrance of the ladder. Achieving optimal conditions for effective operation of the fishway has proven difficult. The ladder does not allow for potential changes in hydrologic and environmental conditions up or downstream of the facility. The upstream exit of the fish ladder is chronically blocked, making it expensive and time-intensive to maintain passable flows through the ladder. Because of these inherent limitations, Bloede Dam continues to limit fish passage and hampers anadromous fish recovery efforts on the Patapsco.

3 Summary of Previous Studies

In evaluating dam removal and fish passage alternatives at the Bloede Dam, information from previous removals and previously completed analysis were also reviewed. The following paragraphs briefly summarize the most pertinent reports and analysis available.

The goals of the three pre-existing alternatives analyses differ, evolving over time as certain selected alternatives proved ineffective and new needs developed. An initial report (Century 1980), primarily concerned itself with the repair of the dam. No action was taken as a result of the Century study, which led to additional analysis performed by Synergics in 1989. In addition to once again looking at repairs to the structure, the Synergics report also took into consideration fish passage goals at the site. The Synergics recommended alternative included a Denil fish ladder, which was installed in 1991. As safety concerns continued to mount and as the ladder proved ineffective, Maryland DNR commissioned a new report conducted by Gannett Fleming completed in 2012 aimed specifically at examining river restoration and dam removal.

3.1 Century Engineering Alternatives (1980)

Century Engineering completed a preliminary study of the Bloede Dam in 1980 (Century 1980). The focus of the study was to assess the damage caused by the 1972 flood, investigate options for improving public safety and suggest measures for salvaging or preserving hydroelectric power options. The report gives cost estimates for final design and engineering of five options, including dam removal, interior repairs, exterior repairs, reestablishing hydropower and creating a watertight powerplant. Also included were recommendations for establishing a museum at the site. No action was taken outside of additional studies. Costs are summarized in the following table:

Table 2. Cost estimates for 1980 alternatives (from Century 1980)

Option	*Estimated Engineering and Construction Costs (cost adjusted to 2011 U.S. dollars)*
Dam removal	$1.48 million
Interior repairs	$164,700
Stabilize dam and exterior	$2.2 million
Reestablish hydropower	$2.04 million
Watertight powerplant	$576,000

3.2 Synergics Alternatives Analysis (1989)

In 1989, the Maryland DNR retained Synergics Inc. to conduct an analysis of potential solutions to structural deterioration and fish passage at the Bloede Dam (Synergics 1989). The goal of the study was to "develop and evaluate alternative methods of providing a cost effective way to reduce the threat of dam failure at Bloede Dam and providing fish passage from below the dam to the river above the dam." The alternatives examined were:

Alternative 1 – Removal of the dam and removal of all of the sediment impounded by the dam, resulting in reclamation of the impoundment and dam site to pre-dam conditions. The cost of this option (adjusted to 2011 dollars – U.S. Department of Labor), including engineering and construction, was estimated at $10.7 million.

Alternative 2 – Removal of the dam and stabilization of sediments following headcutting and transport of sediment. The cost of this option (adjusted to 2011 dollars), including engineering and construction, was estimated at $9.85 million.

Alternative 3 – Repair the dam and install a fish ladder for fish passage. Repairs were divided into two options, structural reinforcement of the interior and filling of the interior. The cost (adjusted to 2011 dollars) for structural repairs was estimated at $3.9 million and mass filling at an additional $4.45 million. The fish ladder was estimated at $474,000. This analysis resulted in repairs designed and built in 1991-92. See the next paragraph.

3.3 Structural repair analysis and design (1991-92)

In the early 1990s, Synergics completed analysis and designs for structural stabilization of the Bloede Dam and construction of a Denil Fishway on the right (south) abutment. Inter-Fluve reviewed the Design Criteria Manual and associated plans and specifications for the design, completed in 1991. These documents include hydrology and hydraulics, material strength specifications, design plans, River Road improvement specifications, quantities and engineer's opinion of probable cost. Also included are construction logs and inspection reports, Wheelock (1993), for work completed.

3.4 Gannett Fleming (2012)

In 2010, the Maryland DNR retained Gannett Fleming to complete an alternatives evaluation of the four major aspects of dam removal at the Bloede site (Gannett Fleming 2012). These included access, bypass, sediment removal and channel restoration. Demolition of the dam was a common work activity and was not included as an alternative. The various alternatives were combined into a matrix of over 50 possible combinations. Criteria were evaluated on a point scale and scored through several metrics including feasibility, constructability, environmental impact, permitting, public safety improvement and cost.

Three access routes were examined, including River Road, Ilchester Road and the bike trail. Of the water routing options examined, both the inverted siphon and the sequential demolition scored equally. Note that wet excavation was not considered. Three options for sediment removal examined included dredging, in-channel mechanical excavation and in-channel release by natural transport. For each case, on-site versus off-site disposal was evaluated. Two options for channel restoration were identified, including construction of a controlled cataract design and passive sediment management approach. The matrix evaluation resulted in the preferred options being River Road Access, with in-channel release of accumulated sediment. No preferred bypass or dewatering option was clearly identified. It should be noted that a No-Action alternative or maintaining the dam in place was not evaluated using the scoring criteria, and this evaluation assumed dam removal.

3.5 Studies Associated with the Simkins and Union Removals

A large amount of data has been collected and analyzed as part of the already completed Simkins and Union dam removals upstream of Bloede. At both sites, extensive pre and post-removal topographic and bathymetric surveying was completed to characterize the river channel, calculate cut and fill volumes for construction and determine sediment volumes. This included probing of sediment depths and coring for analysis of grain size and possible contaminants. Computer modeling of hydrology and hydraulics was completed, as was modeling of sediment transport following removal. The project partners have funded post-construction sediment surveys to determine the fate of transported sediment versus the model predictions and have so far found the model work to be reasonably accurate at predicting sand migration downstream. As mentioned earlier in the document, the MBSS is currently monitoring fish and macroinvertebrate populations upstream and downstream of Bloede dam. All of this information is being evaluated and is an integral part of the design process for the Bloede removal.

4 Bloede Dam Alternatives

Although there have been previous inspections, analysis and alternatives analysis completed, the previous studies focused on repair of the dam with some analysis of dam removal. This analysis supports the work done by Gannett Fleming and develops dam removal alternatives in more detail.

4.1 No Action

No Action maintains the existing conditions at the site, as well as upstream and downstream of the dam structure. Evaluation of the No Action alternative, or leaving the dam in place, must include a detailed discussion of the negative impacts and costs associated with the dam. This segment will review conditions prior to dam construction and will summarize the impacts, both positive and negative, of the dam on river morphology, ecology, infrastructure, public use and safety and cost to maintain.

River morphology – The most obvious impact that the Bloede Dam has had on the Patapsco River is the trapping of sediment and burying of the natural river morphology upstream of the dam. Although the impoundment is now full and sediment does transport over the dam, we know from analysis of channel bed slopes upstream and downstream of the dam, and from recent coring of the impoundment sediments, that the pre-dam channel in the impoundment area was likely a steep, boulder, cobble and bedrock bottomed channel with step pools and cascades. Recent seismic profiling by the Maryland Geological Survey (MGS) revealed no hidden waterfalls in the impoundment (Ortt 2012). Rivers continually transport sediment, and steep boulder and cobble channels normally transport through any sediment that is gravel sized or smaller. In some situations, river segments downstream of dams become “sediment starved” or deficient in smaller grain sizes, which can result in channel widening and armoring. This effect is not significant in the Patapsco downstream of Bloede. The Bloede impoundment filled with sediment very shortly after construction, and despite flushing operations in the early 20th century, the impoundment filled nearly to capacity prior to the Simkins removal. Since the Simkins removal, additional sediment has accumulated upstream of the dam. Prior to the Simkins removal, the Bloede impoundment had approximately 10,000 cubic yards of void storage area, all of which is now filled with sand. According to the sediment transport model completed prior to the Simkins project, much of this newly deposited sediment will flush out to roughly the pre-Simkins removal profile, but the impoundment will still be nearly filled with historic sand and cobble.

Ecology - The following paragraphs briefly review the effects of small dams on river ecology specific to the Patapsco River. The general ecological effects of dams are well documented (Baxter 1977, Ward and Stanford 1979, 1983; Armitage 1984; Petts 1984). Dams cause dramatic changes in the riverine environment, the most pronounced occurring within the impoundment and downstream where flow regimes, natural transport of sediments and nutrients and temperatures are altered. In general, habitat characteristics within the impoundment shift from a free-flowing stream, which favors lotic, or riverine, plants and animals, to a lake for which those species are not adapted. The "river continuum" concept stresses the important physical, chemical and biological relationships along a river system from its headwaters to its mouth (Cummins 1979). The Bloede Dam severs this connectivity and is a significant disturbance to how the lower Patapsco processes inputs of sediment, nutrients and toxins. No Action retains this discontinuity.

Section 4.3.1. (below) delves further into the volume, grain size and quality of the sediment behind the Bloede Dam. However, the sediment found behind this structure consists predominantly of coarse material, not material to which phosphate and ammonium bind. Further research into nutrients (specifically NO3 and NO2) in the Lower Patapsco watershed reveals that nutrient contributions to the Chesapeake Bay from the Lower Patapsco watershed are not significant, particularly when compared to other Maryland watersheds (Maryland Department of Natural Resources 2005). While all efforts should be pursued to continue to reduce nutrient loads in the Patapsco River, there is no evidence to suggest that the Bloede Dam has or will contribute to that reduction. As mentioned above, the Bloede Dam does reduce the ability of the Patapsco River to transport beneficial material. Algae, aquatic plants, insects and fish depend on important nutrients and also depend on river gravel, cobble and boulder substrates (i.e. the historic channel bottom at Bloede) for attachment sites, hiding places and stable nest material. Sand deposition upstream of the Patapsco dams changes streambed substrate particle size and composition, covers gravel and cobbles and fills interstitial spaces between substrate particles (Waters 1995). The covering of the stream bottom by a thick layer of sediment reduces habitat diversity or heterogeneity and represents a loss of functional living space for *benthic*, or bottom-dwelling, organisms. Overall reduction in habitat diversity within the impoundment results in the loss of species diversity and a greater abundance of those organisms tolerant of altered conditions (Allen 1995). Stream invertebrates and fishes are replaced by more tolerant or adaptable species typically associated with reservoir or lake environments (Cole 1983, Kanehl et al., 1997). No action will cause this degraded condition to persist.

Fish habitat - The fish species that have historically inhabited the Patapsco River include smaller forage fish, fallfish, green sunfish, perch, white sucker, and creek chub, as well as anadromous American shad, hickory shad, blueback herring, alewife and catadromous American eel. All of these species are impacted by the dam. A diverse fish assemblage requires a diversity of complex habitats including shelter, interstitial spaces in rocks, gravel for spawning, riffles and pool habitat. Sediment accumulations behind small dams cover course substrates, eliminating fish habitat and fish spawning areas. Sediment upstream of the dam has filled pools, covered woody debris and simplified formerly complex habitats. No Action will maintain this degraded condition.

Macroinvertebrate habitat - The Patapsco dams accumulated large amounts of mostly sand sediment upstream, a process that fills in habitats and simplifies channel complexity. Because benthic macroinvertebrate abundance is correlated with substrate complexity and populations are more abundant in gravel and cobble matrices, deposition of sand can be detrimental to invertebrates such as insects and mussels (Cordone and Kelly 1961, Minshall 1984). With sediment aggradation behind dams, abundances of mussels and less tolerant aquatic insects like mayflies, stoneflies and caddisflies decline, while more tolerant midges, blackflies, amphipods, snails, and worms increase in density (Benke et al. 1984, Tiemann et al 2007, Hughes and Parmalee 1999, Waters 1995). Mussel larvae, or *glochidia*, develop in the gills of certain fish species particular to each mussel group. Dams are barriers to the passage of these host fish. No action will maintain the degraded stream condition and limit the diversity and species richness of invertebrates and mussels.

Fish passage - Negative impacts of dams on riverine fishes in North America have been well documented and have been related to the conversion of flowing to standing waters, modification of downstream flows, and habitat, or blockage of fish movements (e.g., Winston et al. 1991, Martinez et al. 1994, ISG 1996). Fish migrate for a variety of reasons, doing so either daily or seasonally to find food, locate spawning areas or defend territory. The physical structure of the Bloede dam directly impacts fish production by preventing access to upstream spawning grounds or downstream feeding areas. This is of particular concern for American eel and herring species whose life cycle depends on free movement between freshwater and ocean habitats.

A concrete Denil fish ladder was constructed on the right abutment in 1991. Spring 2011 surveys found blueback herring and hickory shad immediately downstream of Bloede Dam; however, none of these migratory species have yet been collected upstream of the dam. The existing fish ladder is inefficient, at best, in passing all target species and life stages. Even when operating under optimal conditions, it has proven ineffective at species recovery efforts. Since the ladder's installation, the upstream end has been chronically clogged with debris from high flows, and difficult maintenance requires a large amount of volunteer hand labor (Figure 2). The Maryland DNR has had to conduct yearly cleanouts since construction, and some of the baffles are missing, reducing the effectiveness of the fishway even further. The No Action alternative results in the continued fragmentation of aquatic habitat and an inability to meet state fish passage goals.

Wildlife impacts - As part of the river ecosystem, birds, reptiles, amphibians and mammals are all susceptible to the effects of dams. Bird and mammal species dependent on riparian habitat or certain fish food species can be negatively impacted. The Bloede dam is 34-feet high, and so inundates a large riparian area. No action will maintain the current condition with the vegetated riparian zone slightly narrower and higher in elevation than would be without the dam. This current condition includes the concrete abutments and fish ladder that further limit riparian habitat near the dam. The dam also limits upstream and downstream passage of reptiles and amphibians along the near bank region. Riparian corridors in urban areas are critical habitat areas for birds and mammals, allowing them to migrate from watershed to watershed. The No Action alternative results in continued fragmentation of riparian connectivity.

Temperature - Small dams often elevate water temperatures by stagnating flows and increasing the exposure area and time of solar heating (Horne 2001, Poole and Berman 2001, Walks et al 2000). Temperature increases depend on the surface area and depth of the impoundment, and its water retention time. Elevated water temperatures may directly impact biota by exceeding the organism's physiological tolerance or indirectly by decreasing concentrations of dissolved oxygen, a problem that intensifies during the summer months when air temperature is warmest and flows are low (Walks et al. 2000, Ward and Stanford 1989). The No Action alternative results in increased solar exposure over other alternatives.

Recreation – The Patapsco River has an active paddling community, but kayak passage is currently blocked at the Bloede Dam. During smaller rain events when water levels are high enough to support boating, there are typically 20-30 kayakers using the river. The Bloede dam is a significant danger to paddlers, involving a takeout at the dam site. The 2-4% slope channel buried by impoundment sand is the best potential kayaking water on the Patapsco River. The Bloede area is also an access point for groups looking to tube or float down the river and is frequently used by park visitors interested in meeting or playing in and around the riffle area below the dam. The No Action alternative will result in continued danger to paddlers and other park users, as well as continued degradation of potentially attractive kayaking reaches.

Fishing – Anglers currently fish in the marginal pools and riffles at the upper end of the impoundment, the pool just upstream of the dam, and also in the plunge pool downstream of the dam. Fishing pressure is heavy during the spring put and take trout stocking period, largely concentrated downstream of the dam. Fishing pressure is generally light for the remainder of the year. If the dam is not removed, it will take a longer time to evacuate the additional Simkins Dam sediment from the impoundment area, and fishing in the pools and riffles immediately downstream of Bloede will be impacted for a longer time. The exact time of sediment flushing is dependent on river flows, but may take several years. No Action will extend the period of sediment flushing, but will retain the existing fishing opportunities once the sediment is flushed. Flushing time will depend on precipitation and stream flows and thus is not predictable. No action will continue to deny anglers the opportunity to fish for herring and shad upstream of Bloede dam.

History – The Bloede Dam is an angled slab and buttress dam, a design that was used extensively by the Ambursen company at the turn of the century. The project was conceived by Victor G. Bloede, a well-known scientist and founder of the Patapsco Electric Manufacturing Company, and is the first known instance of a submerged hydroelectric generating plant. According to power company historical documents, the dam was built on an undeveloped site and was used to generate power annually from 1907 to 1931. The dam was run by Patapsco Electric and Manufacturing Co. and then was completely bought out by the Consolidated Gas Electric and Power Company in 1928 after the City of Baltimore denied Bloede the right to expand nearby infrastructure. The dam was purchased in 1938 by the State Board of Forestry with the provision that no further electrical development would be conducted at the site. The dam is currently owned by the State of Maryland. The power generating equipment has been removed, and significant concrete work has been completed on the interior of the dam. Interpretive signage along the Grist Mill Trail describes the dam and its construction. Based on a historical documentation package assembled by Paula Reed & Associates, in February 2011, the Maryland DNR determined that the dam was eligible for the National Register of Historic Places and sought concurrence from the Maryland Historic Trust (MHT). In April 2011, MHT agreed with the DNR findings that the structure is eligible for listing in the register under Criteria A, B and C for its specialized engineering, innovative design and association with early electrification. No Action at the site will temporarily preserve the dam remnants, although the interior has been altered and all of the mechanical and electrical works have been removed.

Aesthetics – People are attracted to the sound and imposing appearance of dams, often associating them with natural waterfalls. The Bloede dam spans several generations, and many people have known the dam their entire lives. Park users walk, run and bike along the Grist Mill Trail and River Road and

Figure 4. Example of potential viewscape following removal.

thus encounter the dam every day. Aesthetics, however, are personal, and for every person that sees the dam as an amenity, there are likely people who view the dam as an intrusion into the natural aesthetic of the park. The dam currently blocks 3,000 feet of steep boulder and cobble channel in what would be the deepest part of the Patapsco gorge. Bedrock outcrops throughout the impoundment reach are currently hidden from view. The concrete abutments and fish ladder are in contrast with the natural setting of the park. The No Action alternative would maintain the current sound and viewscapes.

Safety – The Bloede dam, like many other dams around the country, is an attractive nuisance. People are attracted to the structure and the sound, and often congregate below the dam, wading in the pools and playing on the rocks. The abutments, sewer pipe and spillway offer a challenging climbing experience that attracts people ignorant of the inherent risks. Despite warning signs posted on both abutments, swimmers, including children, routinely slide down the spillway and jump into the pool below the dam (Figure 5). This pool is small however, and footing on the dam crest is dangerous. In just the period from 2005 to 2011, three people have been killed and numerous others injured at the dam. If no action is taken, these incidents are likely to continue.

Figure 5. Children sliding off of the Bloede Dam spillway (ca 1980).

Dam failure – All dams, regardless of their design or construction, have the potential to fail during large storm events. In the United States, dams fail every year, and the number is increasing as dams age. In the late 1980s and early 1990s, the State of Maryland took measures to protect the Park and surrounding communities from dam failure. Structural analysis by Synergics (1989) revealed stability problems and identified potential solutions. The State then repaired the dam in 1992 and subsequent inspections have called for only monitoring or minor repairs (Gannett Fleming 2012). The Bloede Dam was historically listed as a significant hazard dam. In a letter to the Maryland DNR dated 5/4/2011, Maryland Department of the Environment (MDE) dam safety engineers reviewed dam break modeling results and recognized that, because Bloede Dam is a run-of-river structure almost filled with sediment and the fact that the watershed area to the dam is very large (>300 square miles), failure of the dam shows insignificant increases in downstream flooding. They recommended reclassifying the dam from a significant to a low hazard structure. However, it should be noted that concrete has a typical design life of 30-75 years. The original concrete used in the dam's construction is well over 100 years old and has exceeded the normal design life. Dams only degrade over time, and if no action is taken, the dam will eventually need to be replaced. In the meantime, there will be a need for continual maintenance, inspection, design and repair costs.

4.2 Repair of the dam and fish ladder

4.2.1 Repair of the dam

The 1991-1992 repair work stabilized the dam and addressed structural integrity issues reported after the 1972 Tropical Storm had damaged the dam and subsequent studies highlighted the need to stabilize the interior deck to withstand added pressure from sediment deposition. It is not known how long these repairs will last or when additional repairs will need to be made. Structural concrete has a typical design life varying from 30 to 75 years, and any structure in flowing water is subject to added stress that can shorten the design life. It is likely that the next major repair will be repair or partial replacement of the spillway cap. This could cost between $200,000 and $1,500,000 depending on the work performed.

The Maryland DNR uses crews of 5-10 people to clean out the fish ladder annually. This effort could be made easier by improvement of the access road to allow for heavy equipment to reach the upstream side of the right abutment. A working platform could be installed on the upstream side to facilitate cleanout by small scale heavy equipment. The cost for design and construction of road improvements and fish ladder access would fall in the $80,000 to $200,000 range depending on the work performed.

4.2.2 Repair of the fish ladder

Recent evaluation of the fish ladder was conducted by the Maryland DNR and the U.S. Fish and Wildlife Service (Dick Quinn). Field observation suggests that fish were getting confused at the first turn, and that this turn could be modified to reduce the angle. It is not known whether or not changing the fishway corner would be effective in improving passage. The dam would also need to be retrofitted to pass American eel elvers. Maryland DNR fisheries report an annual need to replace and repair safety grating and fencing, as well as baffles. The current maintenance budget for the Bloede Dam is not adequate to conduct annual repairs and is also not adequate to hire the necessary heavy equipment needed to safely remove large blockages of debris from the upstream side of the dam.

Passage may be improved by replacing the existing ladder with a natural bottom fishway built partially into the bedrock and valley side slopes. Because removing the fish ladder and replacing it with a larger, natural bottom fishway would cost well over $2 million, we do not recommend this course of action. We also do not recommend changes to the existing concrete structure, as the benefit is unpredictable and the cost high. It may be beneficial to clean out the intake and also maintain the existing ladder until funds can be generated to remove the dam.

Under a dam repair or repair of the fish ladder scenario, the existing conditions listed above for river morphology, ecology, habitat, temperature, recreation, safety, historical and archeological and fishing would remain the same as under the No Action alternative. If the fish ladder is modified or improved, fish passage may be slightly improved over the existing conditions. It should be noted, however, that fish ladders have not been found to be effective at passing all species and life stages of fish. They require regular maintenance to function properly, and their efficiency varies widely. Effectiveness depends on a variety of factors, including slope, head drops, resting pools, light, substrate and attraction at the entrance. Research is being conducted into the effectiveness of various designs, but no fish ladder has yet been devised that effectively passes all species and life stages of fish.

Under a dam repair scenario, there would be some improvement of public safety by reducing the risk of dam failure.

4.3 Removal with Passive Sediment Management

This alternative examines full removal of the Bloede Dam using natural sediment transport as the primary means of removing the accumulated sediment from behind the dam. The first few paragraphs below summarize the basic elements involved with access, demolition, water routing and restoration. Following that is a summary of the positive and negative impacts of this method of dam removal.

4.3.1 Construction Impacts

Typically, designing engineers do not dictate means and methods for construction projects. This stifles creativity on the part of the contractor and can potentially block reasonable solutions. In the case of dam removal in general, and this dam in particular, it is important to at least discuss potential means and methods so that the stakeholders understand what is involved and construction impacts are minimized.

This exercise is more for the elimination of certain methods that are not in the best interests of the Patapsco Valley State Park, the public at large or the project partners. The actual means and methods used to achieve the desired outcome may differ, but eliminated options will likely not be reinstated. It is important to remember that construction related impacts will be on the order of days or weeks as compared to the months or years used when counting the impacts of existing dams or sediment transport associated with dam removal.

Water Routing – Removal of the dam will require water routing or diversion of flow to allow for demolition activities to be performed partially in the dry or at least out of the active flow of the river. Full coffer dam installation and either gravity or pump dewatering is not necessary to remove the dam or as erosion control. With either passive or active removal of sediment, there will be some sediment transport downstream as part of the design, so working partly in wet or flowing conditions is a reasonable approach with considerable cost savings. Full dewatering of the lower Patapsco, even during low flow, would cost between $200,000 and $300,000. The Patapsco is a very flashy system, and even moderate rainfall events can result in damaging floods that could overwhelm and/or damage any dewatering setup, as was the case with the Union Dam removal.

The river could be temporarily diverted away from one abutment using sand bags (e.g., Super Sacks), sheetpile or sheeting, concrete barriers or some other suitable means to allow construction of a water routing notch. Alternatively, if stream flow is low, the river could be passed through the fish ladder to allow construction of the notch. A notch could be cut into the spillway at the north spillway abutment. The door-sized openings in each of the buttress walls on either side of the notch would first be blocked off to prevent water from filling the interior portions of the dam. The downstream spillway slab and downstream vertical wall would be removed from the spillway crest down to the concrete floor slab (a vertical dimension of 21 feet, 6 inches). The concrete would be removed from the inside face of one buttress to the inside face of the adjacent buttress (a horizontal dimension of 8 feet, 6 inches). The notch would be formed by removing an 8-foot, 6-inch wide portion of the inclined upstream slab between the two buttresses. The base flow rate of the Patapsco River is reported to be approximately 120 cubic feet per second (cfs) in the Synergics (1989) report. A single notch, 8.5-feet wide by 5-feet deep, can pass approximately 270 cfs. The above procedure would be repeated four or five times by cutting the notch down another 5 feet until the dam has been removed to the stream bed elevation.

Sewer Pipe Protection – The gravity sewer main must remain in service throughout the construction period. Therefore, the main must be protected from damage due to the construction activities associated with the demolition and removal of concrete and movement of equipment. The bedrock and concrete are both rigid materials which will readily transmit vibrations with little attenuation.

Vibration generated by the demolition activities will be transmitted to the sewer pipe. In accordance with Baltimore County standards, the sewer pipe will be equipped with vibration monitoring devices and a Vibration Monitoring Plan developed and implemented similar to Simkins Dam. During construction, production monitoring will be performed. Maximum allowable particle velocities should be developed based on Baltimore County Standards (Peak Particle Velocity of 0.50 inches/second for frequencies less than 40 Hz). If recorded vibrations exceed established threshold levels, construction activities would be stopped and reviewed and new construction procedures implemented to minimize vibration levels. Coordination with Baltimore County Public Works will be ongoing throughout the project planning and implementation to ensure their concurrence with the final removal plans around the sewer line and the monitoring and protections put in place.

Dam Stability – Demolition of the dam will require removal of portions or sections of concrete. The location, dimension and orientation of these sections should be planned out so that the remaining portions of the dam are stable for the anticipated loads. The inclined upstream slab and downstream spillway chute slabs should be removed first. The vertical cut lines should be as close to the face of the buttress as possible leaving little to no concrete cantilevering off the buttress. The buttress sections should be the last to be removed. The bottom elevation of any section to be removed should not be lower than the diversion notch.

Method of Demolition – Typical methods of reinforced concrete demolition include blasting, hydraulic hammering, and saw cutting. The slab and buttress design of Bloede Dam with steel reinforcing will make effective blasting difficult. For this and public safety reasons we have eliminated blasting as a viable demolition method and will prohibit this method in the contract documents.

Hydraulic hammering utilizes a hydraulic excavator equipped with hydraulic impact hammer or hoe ram. Demolition rates can be relatively slow using this technique, depending on the density of steel reinforcing or the type of equipment used. Once sections are demolished, hydraulic excavators and/or front end loaders will be required, working at the toe, to load the debris onto trucks. The contractor may be required to salvage the reinforcing steel for recycling or disposal.

Saw cutting using a diamond wire saw is well-suited to demolition of sections of the reinforced concrete spillway and abutments. This method will allow cutting and removing of well-defined sections of concrete. The area to be cut and removed would need to be exposed. Removal of sections of the upstream inclined slab would require excavation of the sediment impounded just behind the slab. Holes would be drilled at the corners of the cut area in order to insert the saw bands. The diamond wire saw band is then threaded through the holes and attached to the saw. The saw consists of a hydraulic/electric drive unit and a series of pulleys designed to apply tension to and guide the diamond wire. The pulleys, guides, and wire are relatively light and can be set up by hand or lifted into place by a small machine. The cuts would be made to well-defined sections of concrete and the section removed.

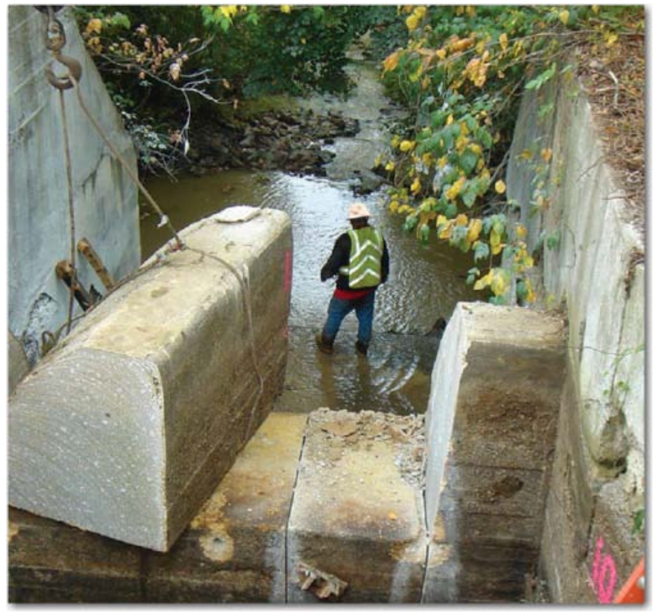

Figure 6. Sawcutting requires crane removal of large cut pieces.

A crane would be required to remove and load the cut sections onto trucks (Figure 6). There would be virtually no harmful vibrations or dust associated with saw cutting. Multiple methods could be used. Hammering is the most efficient way to breach the spillway. To minimize impact to the sanitary sewer, diamond wire cutting and concrete removal by crane is best suited for demolition of the north abutments and sections of the dam located between the sewer main and Grist Mill Trail. The wire saw can be set up by hand and the crane can be set up in the stream channel and reach over the sewer main to remove segments of concrete.

Access and Staging – Based on site analysis, data from previous studies and interviews with the major stakeholders on site, we have concluded that the best access route will be along the existing River Road downstream of the dam. The dam is 2.7 miles from the Gun Road crossing and 4.0 miles from the main park entrance at South Street. The existing road embankment is stable, and the road is wide enough for truck traffic directly to the dam site. There will undoubtedly be damage to the road caused by heavy truck traffic, and the road will need to be repaved upon project completion. There will need to be some road improvement and widening of the staging area downstream of the dam, but removal of the fish ladder will greatly increase the available staging space. Preferred staging is directly adjacent to the dam near the fish ladder area.

There is a bridge that crosses the Patapsco River on Gun Road leading to River Road. The last bridge inspection was performed in 2010. The 2010 bridge inspection report lists the design load for the Gun Road Bridge as HS20 with a Gross Vehicle Weight of 36 tons. The right abutment affords access to both the toe and top of the dam. There appears to be ample room to stage and store equipment and materials to assist in the demolition and removal of debris. The grade of River Road Trail is sufficiently flat for loaded trucks to traverse. A secondary road could easily be constructed, also at a reasonable grade of 12% or flatter, extending from River Road Trail to the downstream toe. Accessing the upstream side of the dam is a little more difficult due to heavy tree growth and steep slopes. However, with some selective tree removal and constructing an access road, the contractor should be able to mobilize hydraulic excavators to the upstream side.

The other two alternatives, the Grist Mill Trail and the abandoned and damaged River Road segment upstream of the dam, are eliminated as potential access routes. The Grist Mill Trail would need to be rebuilt and also would be closed during construction. This trail is heavily used by many hikers and runners. In addition, access from the north side would require crossing the sanitary sewer pipe. This project design will attempt to remove the dam without crossing the sewer pipe. The Synergics report recommended repair of River Road upstream of the dam and access from Ilchester Road. The River Road segment upstream is privately owned, and the project stakeholders do not wish to pursue easement agreements or rebuild the road. Use of this route would also be extremely costly, in excess of $300,000. Stabilization of the road would require setting pilings into concrete and construction of a stone or concrete wall to support the road embankment.

Removal and Disposal of Construction Debris – As discussed in the Access section above, the site lends itself to constructing an access road from River Road Trail down to the toe of the dam, including using crushed dam debris in repavement of existing roads within the park. The methods used to collect and load the debris will depend on the method of demolition. Hydraulic hammering will result in a range of debris sized from large pieces a cubic yard or larger, down to gravel size. Excavation of the debris would most likely be accomplished using a hydraulic excavator and either live loading onto off-road trucks or using a front end loader to load 10-wheeled dump trucks. The contractor may be required to salvage the reinforcing steel for recycling or disposal. Sawcutting would result in large pieces of debris most easily handled by a crane and loaded into 10-wheeled dump trucks.

The total volume of concrete in the dam has been estimated to be approximately 2,400 cubic yards. If hauled off-site, 10-12 cubic yard dump trucks could roughly keep pace with demolition, and removal of debris would take approximately 12-20 days depending on the number of trucks used and the haul distance. Hauling is expensive, could be damaging to park roads and would require traffic control and added safety measures. If a disposal area can be identified near the dam, the construction cost can be further reduced. Our investigation and that completed by Gannett Fleming (2012) eliminated the use of the abandoned segment of River Road upstream of the dam. Concrete could, however, be hauled east along River Road. Rather than haul the material fully off-site, it is possible to reuse the concrete to rebuild segments of River Road within the park. A rock crusher could be imported to the dam site and could process broken concrete into road base gravel to be loaded directly onto trucks. Assuming one-foot thick layer of crushed concrete road base, the entire demolished dam and fish ladder volume could be wasted on a 3,500-foot segment of road base without ever leaving the park and thus reducing the need to repave longer segments of park access roads. The roadway would also need to be paved or graded with crushed compactable gravel. The demolition and removal of rubble, as well as the stabilization of the channel following removal will take 30-60 days, but will depend on weather, necessary drawdown strategies and interceptor pipe stabilization.

The concrete debris could be taken off-site and beneficially reused to construct oyster habitat in the Chesapeake Bay, as was done for the Simkins Dam removal project. Disposal of construction debris would typically be left up to the contractor unless the owner had a specific location identified, in which case the disposal area would be dictated to the contractor in the specifications.

Restoration – Restoration of the impoundment will be predominantly passive. Sediment evacuation time will vary, and bank areas will be exposed over varying times depending on river flows. The Maryland Geological Survey collected subsurface data at 11 locations in the impoundment and near the dam site. Sediment cores were taken in the impoundment and adjacent floodplain areas, and both Ground Penetrating Radar and Seismic sounding investigations were conducted, including a seismic profile of the channel centerline and cross-sections (Ortt 2012). Initial results indicate that the dam was constructed adjacent to bedrock outcrops on river right and left but that bedrock in the channel center is some 30 feet below the base of the dam. Based on the initial coring data and extrapolation of slope data from upstream and downstream of the Bloede impoundment, the resulting channel slope following sediment evacuation will be approximately 3% through the impoundment. Seismic data indicates no significant bedrock falls or grade drops along the existing channel center. Judging from the cross-section data generated from the seismic survey, bedrock contact along the toe of the right bank and left bank areas on either end of the impoundment will be consistent throughout the impoundment area. This steep bank is vegetated along the current shoreline, and significant revegetation may not be possible given the steep slope and rocky terrain. The resulting bank may simply be large outcrops with patches of soil conducive to planting. Revegetation and soil stabilization along this bank will not involve extensive bioengineering, but will focus on simple grading and shaping followed by seeding and perhaps blanket placement in selected areas.

Coring and Seismic survey results indicate bedrock just below the surface at the upstream and downstream ends of the large floodplain or “point” bar on the north side (river left) of the impoundment. Additional coring data is needed to confirm, but preliminary GPR and coring data suggests that the floodplain area on river left is a clay surface over bedrock. This clay layer is encountered between 3 and 5 feet below the surface, and is covered with more recent fine silt and sand. Much of this upper soil layer and possibly some of the clay layer may have been deposited during Tropical Storm Agnes in 1972. Tree cores from large sycamore trees in this area suggest a surface roughly 30-40 years old, but photos taken following the 1972 storm indicate that some of the largest trees were present prior to the storm. Coring on the downstream side of the dam near the fish ladder showed bedrock roughly 5-10 feet below the ground surface, corresponding to seismic data. Clay soils on bedrock would allow for the construction of steeper banks on this side of the river, but until the dam is removed and the water drawn down at least partially, the exact soil profile of the entire area will not be known. An adaptive management strategy is important in dam removals. This allows for flexibility and field engineering decisions that can save large amounts of money in the long run. Additional borings are planned for the floodplain areas and thalweg upstream of the dam.

Historical and Existing Sediment **-** The Bloede impoundment has been filled with sediment since the 1930s. The impoundment filled with sediment within a few years of its construction and had to be regularly flushed or dredged in order to maintain inflow to the turbines (Figure 2). For the Simkins removal, passive sediment management was used rather than active excavation of the accumulated sediment. Roughly 60,000 cubic yards of accumulated sand upstream of the dam was allowed to transport downstream following removal, some of which has migrated into the Bloede impoundment and downstream of the Bloede dam, as predicted. Prior to removal of Simkins, the Bloede impoundment had the capacity for roughly 10,000 cubic yards of sediment storage (Stillwater 2010). Since the removal, sediment from the Simkins Dam has completely filled the remaining void space and is now transporting over the Bloede Dam. Some overbank sediment deposition is noted downstream of Bloede Dam on the adjacent banks, and the channel bottom is showing evidence of sand transport as predicted. Bathymetry in the former Simkins Dam Impoundment and the Bloede Impoundment was recorded on three occasions to date. The original estimate of the amount of sediment to be released following the removal of the Simkins Dam is 88,000 to 104,000 cubic yards (Interfluve, 2008). Based on recent surveying and comparison of pre and post-survey data, the quantity of sediment determined to have been excavated from the Simkins Impoundment, as well as deposited in the Bloede impoundment following the removal of the Simkins Dam, is estimated (Table 3). These values do not include material already existing in the Bloede Impoundment prior to the removal of the Simkins Dam.

Table 3. Sediment volumes

Digital Elevation Model Area	Net Cut/Fill yd^3 (Pre-Removal to April, 2011)	Net Cut/Fill yd^3 (Pre-Removal to December, 2011)
Simkins Impoundment	-41,799	-63,080
Bloede Impoundment	24,980	24,771

In the period from before the Simkins removal to December 2011, the amount of sediment deposited in the Bloede Impoundment was observed to decrease when compared to the same value prior to dam removal through April 2011. This is a factor of hydraulic conditions that are capable both of transporting material over the dam and of mobilizing existing material in the impoundment. It is safe to assume that similar patterns are occurring in areas where the DEM does not extend. We expect similar conditions to exist into the future (assuming the maintenance of present conditions) and that the Simkins sediment will pass through the Bloede impoundment into the downstream reaches as predicted in the DREAM-1 model.

Determining the exact amount of sediment currently stored in the Bloede impoundment will depend on the analysis of seismic profiles and coring completed by MGS in the winter of 2011/2012.The MGS used manual coring and vibracoring to collect nine cores in the Bloede impoundment and floodplain area. One additional core was taken upstream of the main impoundment area, and another downstream of the dam. As mentioned above, initial analysis indicates that there are no bedrock contacts within 10 meters of the surface that would create a natural fish passage barrier upon removal of the dam. All cores indicate that the impounded sediment is roughly 75% fine to medium sands, 20-25% gravel and between 1-5% fine sediment. Gravel and cobble were encountered at maximum depth (Ortt 2012). MGS was only able to penetrate 3.5 feet of sediment in the area 150 feet upstream of the Cable Stay Bridge, encountering cobble and boulder material at this location. This indicates that the Bloede impoundment area is shorter than originally expected and that estimates of stored sediment may need to be reduced in final design.

Prior to final design, accurate estimates of sediment stored between Bloede and Simkins will be generated. The Synergics (1989) report included minimal borings but did give estimates of 52,000 CY stored within the channel and 51,000 CY stored in the point bar on the left bank. The report does not reveal the methods used in this estimate. Assuming fines and coarse sand, the observed recent input of 25,000 CY added to the Synergics in-channel estimate yields a value of 77,000 CY available for transport following the removal of the Bloede Dam. This value is within the range of transport predicted in the DREAM-1 model of between 77,000 – 88,000 CY. This does not include the material stored within the point bar.

DREAM-1 Model - Prior to the removal of the Simkins Dam, Inter-Fluve and Stillwater Sciences developed a sediment transport model in an attempt to predict the fate of sediment released during the removal. Preliminary data analysis indicates that the DREAM-1 Model is fairly accurately predicting sediment dynamics both upstream and downstream when examined in profile. The first year of the model run varies based on three different potential hydrographs from a wet year (2004), an average year (1983) and a dry year (1965) (Stillwater Sciences, 2010). In all cases and at all monitoring sections, the model is either slightly under-predicting both sediment deposition and erosion or has accurately predicted erosion and deposition except in the case of the dry year. Based on the observed discharges following the removal of the dam, local hydrology is following the pattern of an average to wet year, indicating that the model is accurately predicting sediment deposition in the area. Because the DREAM-1 model results for the Simkins Dam appear to be consistent with monitoring data, the previously run DREAM-1 model for the Bloede Dam removal without modification will be used for final design.

Contamination – The sediment in the Bloede impoundment is predominantly sand. Sediment of this size and larger typically does not retain contaminants. As part of the Synergics (1989) study, Wapora examined 5 cores in the impoundment, each varying in depth between zero and 25 feet and containing mostly sand with some fines. The cores were tested for metals including mercury and arsenic, but none of the samples exceeded RCRA thresholds for risk to public health.

In late 2011, the MGS used manual coring and vibracoring to collected seven cores in the Bloede impoundment and floodplain area. One additional core was taken upstream of the main impoundment area, and another downstream of the dam. Of the cores, only one revealed contaminant concentrations above the Threshold Exposure Level, a biological impact threshold. The detected chemicals were polyaromatic hydrocarbons (PAHs). None of the chemical concentrations in the sample exceeded the Probable Effects Concentration for PAHs established by the USEPA. However, when the archived sample was retested, it showed no contamination. Additional samples of the area also showed no contamination (Ortt 2012).

4.3.2 Infrastructure summary

Existing and Historical Condition Assessment – As previously referenced, Bloede Dam is a flat slab buttress dam, also known as an Ambursen Dam. A buttress dam is a reinforced concrete structure characterized by an inclined flat slab upstream face supported by vertical buttresses. The Bloede Dam was constructed in 1906 and used to generate power for roughly two decades. As part of the original construction, a timber fish ladder was constructed on the right side of the spillway. This is not the current fish ladder, which was constructed much later in 1992. The original structure had three seven-foot diameter steel penstocks routing water to turbines, but only two were ever used. In 1912-13, the intakes were replaced with gates operated from two motor houses on top of the spillway, and a sluice gate was added to one of the turbine bays. In 1972, Tropical Storm Agnes resulted in extensive damage, causing the No. 1 and No. 2 motor houses to fall apart and wash downstream. The old timber fish ladder was similarly damaged, and major portions of River Road were wiped out. Subsequent inspections in the late 1970s recommended reinforcement of the dam's interior. The dam was rehabilitated in 1991 when concrete was added to the buttresses and upstream slab to improve weathering resistance and strengthen the dam to resist the added loads caused by silt accumulation. A concrete Denil-type fish ladder was also installed on the right abutment.

The layout of the dam consists of a central overflow spillway 168 feet wide with non-overflow sections on each side transitioning into the natural abutments. The overall length of the dam is 220 feet, the base is 40 feet wide, and height is 34 feet. Typical design and construction practice for a buttress dam, as well as obvious rock outcrops on both abutments, indicates that the dam is founded on bedrock.

Additional and structural cores are not required for the structural assessment of the dam. The Synergics (1989) report contained a structural evaluation that included core sampling of the original concrete. Testing included compressive strength, unit weight, and petrographic examination. The petrographic examination did not indicate any adverse reaction between the aggregates and hydration by-products. The 1989 stability analysis indicated that the dam met criteria for sliding and overturning under the assumed loading conditions. The stress analysis indicated that the upstream inclined slab and portions of the buttresses were overstressed due to the accumulation of silt. The cracks and spalls that were observed during the 1989 inspection were consistent with the results of the stress analysis.

Sanitary Sewer- A 42-inch diameter gravity sewer main extends along the north side of the river channel and penetrates the dam on the left side at the foundation contact. The pipe slope downstream of the dam is 0.28% and the pipe is exposed downstream of the dam and upstream of the impoundment, passing under the point bar area near the base of the walking trail embankment. Downstream of the dam, the pipe runs along mounted concrete supports mounted on bedrock outcrops at the toe of the left valley wall (Figure 7). Upstream of the Bloede Dam, near the upper end of the impoundment, the interceptor is exposed along the left bank. Information regarding the material properties of the sewer pipe is limited. There is no available information regarding pipe wall thickness. Based on typical pipe products sold by the Lock Joint Company at the time of installation, the pipe is probably spiral wound steel with a mortar coating. Any changes in channel bed elevation must consider impacts to the sewer. Project design of any kind must consider pipe support, changes in pipe support due to sediment loss, vibration during construction and countermeasures to avoid damage to the pipe.

Figure 7. The sanitary sewer pipe and pylons make two steep drops just downstream of the Bloede Dam.

Upstream - Additional infrastructure exists upstream of the dam. The upstream suspension bridge abutments were built in the early to mid 1800s as part of the original railroad bed, and have withstood numerous large Tropical Storm events for over 150 years. The railroad bridge will also be examined, but the abutments do no contact the channel. It is assumed that actions at Bloede will not affect the railroad stability. The main tributary channel in the Bloede impoundment is the Bonnie Branch, discharging just downstream of the suspension bridge near the upper end of the impoundment. Base level change translated through the reach could cause headcutting at the Bonnie Branch confluence and subsequent undermining and failure of the outlet structure. Removal of the Bloede Dam will result in a drop in the real channel bed elevation through the impoundment. In any dam removal, it is important to assess the potential impact of channel bed elevation drop on tributaries. Another important part of the design process will be to examine potential scour effects on the central pier of the Ilchester Road crossing. It is assumed that the bridge piers and abutments are founded on bedrock, and this assumption will be verified by further analyzing as-built plans and site conditions during final design.

Downstream - Downstream of the dam, in the Avalon Park area, there is currently a turnaround parking lot area at the Swinging Bridge and a well-used parking lot/picnic area at Gun Road. The effect of sediment deposition on these areas is a consideration in the design process. Along the left (north) bank of the river, a paved path is maintained by the State Park and is used by hikers, runners and bikers. Deposition of sand and silt on the trail during floods is being considered. Along the right (south) bank up to Bloede Dam, a paved road allows for park user access to the Swinging Bridge area and maintenance access up to Bloede Dam. Gabion walls support portions of River Road downstream of the Swinging Bridge area. The road upstream of Bloede was damaged during Tropical Storm Agnes and is currently impassable. Park users and employees access the Avalon picnic area, Swinging Bridge and Bloede areas via the Gun Road crossing. The effect of sand deposition at this crossing will be an important component to design and monitor. Built in 1835, the Thomas Viaduct is the world's oldest multiple arched stone railroad bridge and is still in use today. Sand transported from dam removals upstream will deposit in the Thomas Viaduct area, and the effects of channel aggradation in this area will be examined.

4.3.3 Dam Removal Impacts

The No Action alternative above is essentially a summary of the effects of dams on the riverine environment and public safety. Thus, either dam removal alternative results in the eventual reversal of many of the impacts listed in the No Action alternative regarding river morphology, ecology, infrastructure, public use and safety.

River morphology – Removing the obstruction created by the dam will allow the river to naturally transport incoming sediment through the reach. The DREAM-1 sediment transport model completed for the Simkins removal included three model runs with removal of the Bloede Dam following removal of the Simkins Dam. Under each model scenario, the Bloede Dam sediment is shown to completely evacuate within the first year following removal. The total amount of sediment upstream of Bloede dam was modeled as 76,000 cubic yards. This volume is similar to the volume estimated to have evacuated from the Simkins impoundment because the Bloede impoundment is much shorter and steeper than Simkins. Preliminary results show eight feet of sediment deposition directly below the dam but rapidly decreasing after removal. The reach roughly 5,000 to 30,000 feet downstream of Bloede shows up to four feet of deposition, rapidly decreasing after removal. As mentioned above, the pre-dam channel in the impoundment area was likely a steep, cascading or riffle-pool channel, possibly with small waterfalls. The impounded sediment is primarily coarse sand, as was found in the Simkins impoundment. Following breaching of the Simkins dam, this coarse sand immediately mobilized and, within one year, was nearly completely evacuated from the Simkins impoundment. Incipient motion analysis of an idealized trapezoidal channel suggests that shear stresses in the evacuated Bloede reach will exceed those needed to entrain large gravel and medium cobble (30-70mm) for a 2-year return interval event (5,000 cfs). Even at baseflow, sand in the deepest portions of the channel will be mobile.

Ecology - Removal of the Bloede Dam will cause a shift from a lentic, or lake, ecology to a lotic or riverine ecology. The physical, chemical and biological relationships that make up the river continuum will be restored. There will be a general shift in the communities of algae, aquatic plants, insects and fish from generalists to those that depend on gravel, cobble and boulder substrates for attachment sites, hiding places and stable nest material. Streambed substrate particle size will increase, and there will be a dramatic increase in channel complexity and available gravel and cobble, interstitial space for cover and functional living space for fish and macroinvertebrates. Because benthic macroinvertebrate abundance is correlated with substrate complexity and populations are more abundant in gravel and cobble matrices, removal of fines will result in higher densities of invertebrates. Decreases in fine sediment and improved passage will create better conditions for mussel populations, allowing host fish to pass unhindered to many miles of formerly inaccessible habitat.

Many fish spawn in gravel substrates, but few spawn in sand or fine silt. The conversion of the Bloede and Simkins impoundments to gravel and cobble habitat will create nearly two miles of improved spawning habitat. Sediment evacuation will uncover pools, cascades and riffles and will create the complex habitats preferred by river fish.

Short and long-term impacts - This section deals with the short-term and long-term effects of natural sediment transport following dam removal. A comprehensive review of the short and long-term impacts of dam removal was recently completed by Bednarek (2001).

Suspended sediment (TSS) concentrations can negatively impact stream biota. As with any pollutant, the impact on aquatic species depends on the concentration and exposure time, both of which can vary dramatically in a dam removal. Suspended sediment in natural, stable streams does not produce mortality in fish, and the Bloede removal is not expected to produce any more turbidity than would be produced during a flood event. No fish mortality was reported as a result of the Simkins removal. Research shows that warmwater fish are adapted to, and are tolerant of, high suspended loads, and laboratory experiments exposing fish to suspended sediment showed mortality only at extremely high concentrations (for summary, see Waters1995). The DREAM-1 model results show a spike in TSS immediately following the Bloede Dam removal but with levels dropping to near background within a few days (Stillwater 2010). The Passive Sediment alternative will result in short-term spikes in TSS but little impact to the biota.

Large pulses of sediment will move downstream following the Bloede removal and will temporarily inundate natural sediments, potentially suffocating fish eggs and macroinvertebrates, covering pool and riffle habitat, burying redds and increasing overbank deposition. These effects are similar to those caused by dams and reversed by removal, but whereas dam effects last for decades or centuries, the effect of downstream sediment deposition is temporary. Three recent dam removals, the Simkins Dam, Sandstone Dam and Merrimack Village Dam, had sand-filled impoundments prior to removal. After removal, transport occurred in nearly identical ways, with initial headcutting and entrenched channel evacuation, followed by gradual widening. In each case, sand quickly evacuated and is actively moving out of the downstream reaches (Pearson et al. 2011). The DREAM-1 model predicts that the sediment downstream of Bloede will move through the lower Patapsco 10 to 20 years, depending on the flow conditions modeled. A large flood such as a Tropical Storm event could move the sediment out of the lower Patapsco in a very short time, possibly one event. In 2011 and early 2012, sand from the Simkins removal has migrated into the lower reaches of the Patapsco between Bloede Dam and the Bay. After recent floods, some overbank deposition of sand has been observed in the near bank regions, and filling of pools has also been noted. Additional channel aggradation will be one outcome of the Bloede removal, and the channel may take on a braided appearance for several years. Eventually, this sand will move through the system and pool habitat will reform. During the Simkins removal design phase, predicted sediment deposition areas were delineated separately using field geomorphic assessment and also computer modeling (Figure 8). To date, both the DREAM-1 model and the geomorphic assessment results have accurately predicted where sediment deposition will occur. The figure below is an excerpt from the geomorphic assessment showing predicted depositional areas near the Thomas Viaduct.

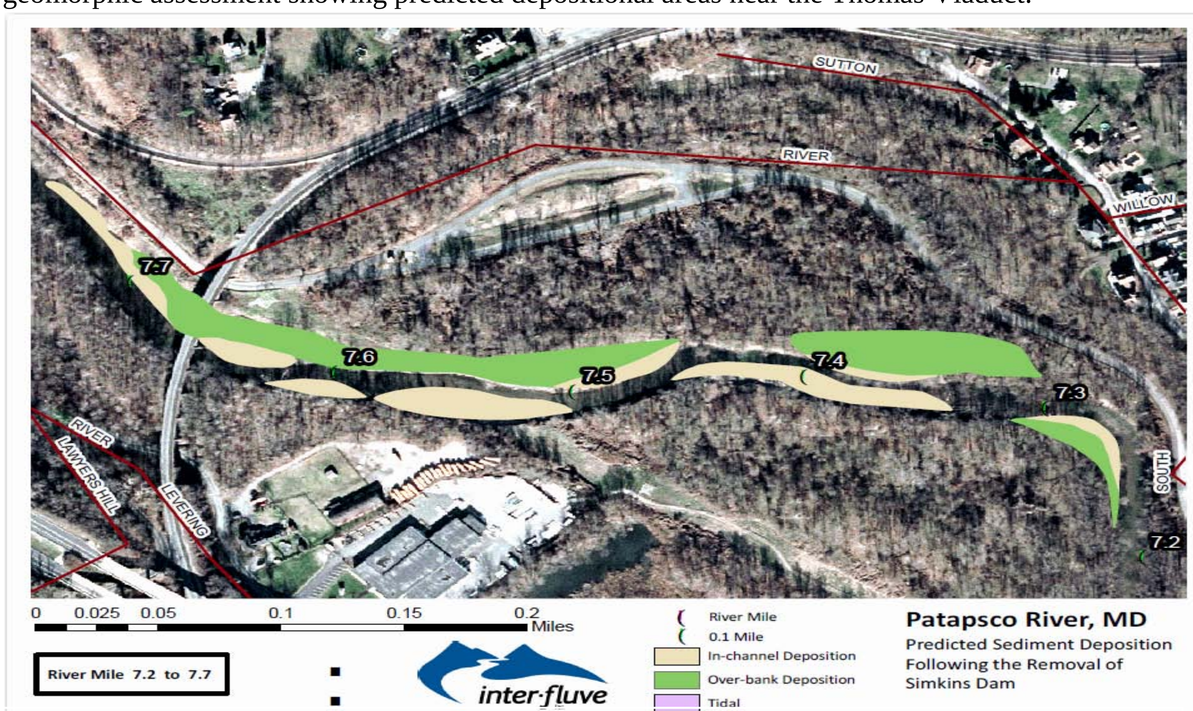

Figure 8. Geomorphic assessment results for predicted depositional areas near the Thomas Viaduct

Gray and Ward (1982) showed that macroinvertebrates and algae immediately downstream of the Dry Creek Dam were decimated within minutes of extremely rapid drawdown but that these populations were able to recover within 2-3 months and 9 months, respectively. Following dam removal, overall lotic macroinvertebrate abundance and diversity increases relative to that of impoundment communities. As the stream bottom becomes cleansed of sediment and a new channel is formed, water quality improves and more heterogeneous habitat becomes available (Bushaw-Newton et al. 2002, Calaman and Ferreri 2002). Preliminary macroinvertebrate monitoring data from the Maryland Biological Stream Survey (MBSS) showed five genera statistically more abundant before dam removal and one more abundant after removal. Monitoring will continue into 2013 and likely beyond.

While sessile communities like mussels and invertebrates can suffer significant impacts downstream of dam removals, fish are able to move upstream or downstream of the impact zone and thus avoid many of the negative impacts. Indeed, a fish's ability to pass through the dam site is one of the single most important benefits to the ecological community. Fish species can respond quickly to improved passage, increased sediment size, habitat complexity and decreasing temperature following dam removals, and populations benefit over the long term (Maclin and Sicchio 1999, Kanehl 1997). Scour holes below the dam will temporarily fill with substrate following dam removal thus eliminating areas where fish tend to congregate. In the long term however, changes in the physical habitat following dam removal should result in increased abundance and diversity of riverine fishes as newly available habitat is exploited (Born et al.1998, Stanley et al 2002).

Fish can become stranded during rapid drawdown. Mitigation possibilities include rescuing fish by either removing them prior to dam breach using electrofishing, netting or other techniques or gathering stranded fish from exposed sediments. Rescuing fish from a small dam impoundment is often not practical and uneconomical from a cost versus benefit perspective. Fish from the impoundment are often exotic, undesirable or common throughout the region. No fish were observed stranded during the removal of the Simkins Dam and the Passive Sediment alternative will not result in significant fish stranding.

Dam removal can impact mussel populations both within and downstream of impoundments. Downstream mussel populations, which have difficulty adapting to sediment inputs from dam removals, can be relocated either to upstream locations or sequestered until conditions allow for their return. Mussel populations should be monitored and relocated upstream of the impoundment.

Fish passage – Negative impacts of dams on riverine fishes in North America have been well documented and have been related to the conversion of flowing to standing waters, modification of downstream flows, and habitat, or blockage of fish movements (e.g., Winston et al. 1991, Martinez et al. 1994, ISG 1996, Kanehl et al. 1997, Waters 1995). Fish migrate for a variety of reasons, doing so either daily or seasonally to find food, locate spawning areas or defend territory. The physical structure of the Bloede dam directly impacts fish production by preventing access to upstream spawning grounds or downstream feeding areas. This is of particular concern for American eel and herring species whose life cyclic depends on free movement between freshwater and ocean habitats.

Fish passage will be improved with dam removal. Seismic survey results do not show any waterfalls or bedrock drops hidden beneath the impoundment sediment (Ortt 2012). Complex flow patterns during variable flows will likely allow for fish passage through the reach but further evaluation following removal will be necessary. Migrating anadromous fish such as alewives and herring are strong swimmers, reaching speeds between 10 and 15 ft/s for short distances and routinely leaping over moderate barriers of 1-2 feet in head differential (Bell 1991, Haro 2004). The Northeast Region NOAA recommended threshold for alosids passage is 6 ft/s. Eels and elvers make use of interstices and marginal habitat and are able to pass under a wide variety of conditions. The Passive Sediment alternative will result in a cobble and boulder step pool channel that will contain low velocity areas, interstitial spaces, turbulent flow, eddies, steep plunge drops and deep resting pools, all elements conducive to fish passage.

Wildlife impacts – With completion of the removal, bird, reptile, amphibian and mammal species will gain available riparian habitat and will also have unimpeded passage through the corridor. As with most dam removals, the total area of riparian wetlands at Bloede will not change appreciably.

Temperature – For typical small dams, long-term water temperatures decrease in the former impoundment area and downstream of the dam. The narrowed cross-section and increased velocity equates to cooler temperatures resembling those of the river upstream of the dam's influence. With the Passive Sediment removal option, temperatures within the impounded reach will decrease. The degree to which temperatures will decrease is not known. The MBSS installed 26 temperature loggers in the Patapsco River, but at the time of publishing, the MBSS had not completed their analysis of initial temperature data. The temperature of the Patapsco will not increase as a result of the dam removal and will likely decrease in the summer months due to decreases solar exposure and subsequent heating.

Recreation – Removal of the Bloede Dam will improve kayak and canoe opportunities dramatically. By removing an obligatory take-out, paddlers and tubers will be able to boat from Ellicott City down to the Chesapeake Bay, something that has not been possible since the 1700s, and from Daniels Dam to the bay with only one take-out at a difficult rock outcrop. The Bloede reach, a steep boulder and cobble channel segment with plunge drops and cascades, will undoubtedly be the most popular kayaking and tubing stretch of the river.

As mentioned above, the Bloede area is also frequently used by park visitors interested in meeting or playing in and around the riffle area below the dam. Also, hikers, runners and bikers pass by the area on either side of the river. There may be sediment deposition on the Grist Mill Trail and that sediment deposition will need to be managed until sediment moves into the lower reaches of the park downstream of the Swinging Bridge. There will be no long-term effects on recreation as a result of the dam removal, and passage around the dam area will be improved. Short-term impacts to park users may occur near the Orange Grove area depending on the final access and staging plan. Project partners will work together to minimize this to the extent possible.

Fishing – Angling opportunities within the Bloede impoundment are currently hindered by sediment from the Simkins removal. After the Bloede dam is removed, fishing opportunities in the impoundment will improve greatly, particularly for the put and take trout fishery. Trout seek out complex flows, resting pools, undercut banks and riffle tail outs. The coarse substrate uncovered by the Bloede removal will provide added habitat for a variety of fish species. Sediment accumulation downstream of the dam to the tidal reaches will decrease as evacuated sand fills pools. Anglers will need to take advantage of the exposed habitat in the Simkins and Bloede reaches until the downstream habitat recovers. The Passive Sediment alternative will improve fishing in the impoundment area, and will decrease fishing quality downstream until the evacuated sand transports into the tidal zone.

Cultural resources – The Bloede Dam is eligible for the National Register of Historic Places, primarily due to its unique design and association to early hydropower development. Dam removal will eliminate the structure and is thus an adverse impact according to Maryland Historic Trust and National guidelines. Dam removal will need to follow the processes outlined in Section 106 of the National Historic Preservation Act. The dam has been modified extensively since hydropower was discontinued. None of the original turbines or power generating equipment remains, and the ceiling of the interior was removed. Large amounts of concrete support were added to the original concrete slab and buttresses, so the interior does not resemble the original design. The gateworks were damaged or completely washed away by the 1972 tropical storm, and since then, a large concrete fish ladder, fences and signage have been added to the dam. Removal of the dam could include retaining a portion of the structure, but this may conflict with the goal of improving public safety by eliminating climbing hazards.

While removal of the Bloede Dam would alter the built history of the site, it also provides an opportunity to restore and highlight the natural history of the area. The important role shad and herring played as a food source for early settlers, bait fish for larger species, and commercial enterprise should not be overlooked. Decline of this fishery as a result of mill dams was recognized as early as the 1700s and led the Maryland Legislature to pass the Act for the Preservation of the Breed Fish in 1768. Removal of the dam allows for the restoration of these historic species and the opportunity to spotlight this part of the state's cultural history.

Aesthetics – Based on the surrounding geology and the natural appearance of streams in eastern Maryland, the removal of the dam and impounded sediment will create one of the most picturesque natural sections of river in the Piedmont area. Steep bedrock contacts throughout the reach, combined with cascading riffles and pools, will create an attraction and an amenity to the State Park. The sound of the rushing water may not be as loud as the Bloede dam fall, but people will be able to get close to the river in this segment, something that is currently either unsafe or prohibited.

With dam removal, park users that walk, run and bike along the Grist Mill Trail and River Road will no longer see a dam but will be able to enjoy a more natural scene than is visible today. The sanitary sewer pipe will still disrupt the view but only downstream of the dam site.

Public Safety – State Park records indicate that people were killed at the Bloede Dam in 2005, 2006 and 2008, and the dam probably claimed other lives prior to the State Park keeping incident report records. Many others have been injured climbing or swimming on or near the dam. Removal of the Bloede dam will eliminate the attractive nuisance and risk associated with children playing on or around the dam and abutments. The risk of injury from play on or around the sewer pipe will still remain, but is not the legal responsibility of the State of Maryland, as the pipe is owned and maintained by Baltimore County. Most importantly, injuries and fatalities related to jumping or falling off of the dam will cease. Emergency responders will no longer be needed for dam related injuries. Park users should be educated as to the risks involved with kayaking and rock climbing, as there may be exposed rock outcrops or boulder segments that could be dangerous.

Old dams fail with regularity across the U.S., and dams only become less stable with time. Unless maintenance is conducted continuously for the life of the dam, it will eventually fail. Dam removal will also permanently eliminate the risk of dam failure and downstream flooding.

4.4 Removal with Active Sediment Management

The positive and negative impacts for the Active Sediment alternative are essentially the same with regard to the ecological, aesthetic, and public safety issues described in the previous section. Here are a few notable differences:

4.4.1 Dam removal impacts (exclusive to active sediment management)

Synergics (1989) suggested a slurry and suction dredge operation to remove the impoundment sediment. The same report also offered alternatives, including using the dam as a sediment trap during drawdown and using conveyor belts to offload sand to a truck loading area. All of these options have merit, but we believe that suction dredging is not practical given that the material is predominantly coarse sand and very easily drained. Once the dam is drawn down, the sand should dewater and will be relatively easy to excavate. Partial or staged drawdown could be used to trap sediment upstream of the dam, but the dam is nearly full of sediment, so traps would need to be installed downstream of the dam. Coffer dams made of stone, jersey barriers or sand bags could be placed downstream of Bloede. Sand would settle out in the traps and could be mechanically removed and trucked away. However, this would involve wet excavation and would thus increase the number of truck loads necessary. Another option would be to allow the sand to transport down to Gun Road, then trap and excavate the sand at that location. The reach upstream will transport the sand readily, and this method would greatly reduce the impact to River Road.

Downstream effects – Removal of the impoundment sediment upstream of the dam would reduce further transport of impounded sediment downstream. Whereas some of the Simkins sediment has remained on the channel margins upstream of the dam, the steepness of the Bloede impoundment will cause complete evacuation of all of the impounded sediment. Assuming stable sediments upstream of Simkins, the combined Simkins and Bloede removals predict the evacuation and downstream transport of roughly 144,000 to 150,000 cubic yards of coarse sand, with the Bloede Dam contributing roughly 80,000 CY. Removal of the Bloede Dam as modeled in DREAM-1 will result in roughly the same amount of sediment depositing in the same places as was predicted for the Simkins removal. Between 1 - 3 feet of sand deposition is expected in the area between the Thomas Viaduct and the steep riffles below Bloede. This sediment is expected to move slowly out of the reach below over a period ranging from 5-25 years depending on flooding, with the upstream reaches clearing first. Even with active removal of the Bloede sediment, the river will transport the Simkins sediment in roughly the same time frame, so active removal of the Bloede sediment may not result in an appreciable change in recovery time. Sand from Bloede to Gun Road will move through the system within a few years. The channel from the Gun Road area to the mouth of the Patapsco will become aggraded with sand and will most likely take on a braided channel appearance. This condition may persist for more than 10 years until the sand has moved into Chesapeake Bay.

If the Bloede sediment is actively removed, the downstream channel should recover in a shorter time frame than the passive alternative, but there is no way to predict the actual evacuation time, which is dependent on river discharge. Fish and macroinvertebrate habitat would recover faster, as would riparian vegetation. Overbank sediment deposition or deposition on the floodplain would also be reduced, reducing the need for clearing of trails related to sediment depositing on the walk/bike trail.

Aesthetics – Active removal of sediment does not imply active bank stabilization and riparian corridor restoration. However, where passive sediment removal does not necessarily allow for active bank stabilization, active sediment removal gives the option of active stabilization and planting, which can improve the quality of the riparian corridor and reduce the risk of invasion by invasive plants. Active bank stabilization and habitat reconstruction in the impoundment would make the river look better faster than it would in the passive scenario. However, given the bedrock contacts already visible, it is highly unlikely that any active bank work will be needed on river right downstream of the cable stay bridge.

Cost - Active removal of the Bloede sediment would substantially increase the cost of removal. There is no practical on-site storage area that can accommodate 80,000 cubic yards of sand, and so we assume that the material would need to be hauled off-site. Assuming a 15-CY haul capacity per truck and a moderate haul distance of 5 miles (including 2 miles within the Park), excavation and hauling would cost $1,600,000 (assumes $60 per CY to excavate and haul).

4.5 Recommended Approach – Removal with Passive Sediment Management

Inter-Fluve reviewed available models and documents and conducted field surveying and site reconnaissance on several occasions over the past three years. Construction contractors were consulted regarding means and methods, and project team engineers met onsite to discuss construction logistics with the project partners. Our analysis of the best approach for achieving the project goals considered logistics, cost and environmental impacts, both positive and negative. Based on our analysis of alternatives, Inter-Fluve recommends full dam removal with the following considerations:

- Water diversion but not full dewatering
- Full demolition of the right abutment, fish ladder and the entire spillway with mounted jackhammer equipment
- Full versus partial demolition of the left abutment above the sewer pipe using sawcutting and crane removal of cut concrete
- Protection of the Interceptor sewer line and maintenance of no impact condition to the sewer
- Active reuse of concrete on site to the extent possible
- Passive sediment transport of the majority of impounded sediment
- Active stabilization of critical areas on the left bank point bar and near the dam for continued protection of the Interceptor sewer line
- Re-evaluation of post removal conditions and adaptive management of habitat restoration alternatives in the impoundment

The dam removal and construction impacts described in the above sections apply here and do not bear repeating.

To complete the Patapsco River restoration through removal of the Bloede Dam, as recommended in this report, additional work remains. State and federal agencies will work with stakeholders to determine the most fitting way to honor the history of the site. Final design engineering will also consider, in more depth, the various aspects of site access, disturbance, breaching and drawdown, sediment management, infrastructure protection and site restoration following removal. Concurrent with design will be meetings with public stakeholders, regulatory agencies and submittal and review of permits. Draft cost estimates for the various alternatives evaluated in the report are given below.

Table 4. Preliminary cost estimate

Alternative	Engineering	Permitting	Construction	Total*
No Action	Minimum costs for Maryland Park Service staff to fence and provide supervision at the Bloede site are $25,000 per year. These costs do not include expenses incurred by the State for maintaining and repairing the fish ladder and dam repairs to prevent failure. These costs could vary from thousands to tens of thousands per year.			
Dam and fish ladder repair	$65,000	$15,000	$800,000	**$880,000**
Removal with passive sediment management	$400,000	$35,000	$700,000	**$1,335,000**
Removal with active sediment management	$400,000	$35,000	$1,800,000	**$2,235,000**

**Costs are +/- 50% and do not include funds for adaptive management and monitoring*

5 Summary

The purpose of this alternatives analysis is to objectively evaluate the pros and cons of dam removal versus alternatives at the Bloede Dam site. The selected alternative must restore the ecological integrity of the Patapsco River by reconnecting upstream and downstream habitat for fish and other aquatic organisms and reestablishing natural stream functions. It must also improve public safety, reduce dam owner long-term maintenance costs and allow for consideration of historic, cultural and recreational values.

A no action alternative, or an alternative that proposes improvements to the dam and fish ladder, does not restore the ecological integrity of the Patapsco River. Although fish passage may be slightly improved with repair of the fish ladder, no fish ladder or fish bypass system has been shown to be fully effective at restoring ecological connectivity through dam sites. While current site aesthetics and usage would be maintained in these scenarios, maintenance costs would remain and will increase over time. Also, though additional safety features could be added, these will not likely fully protect park users. The current fencing, gates and signage have not stopped some people from walking and playing on the dam.

The Bloede Dam is the lowermost dam on the Patapsco, and thus passage for the entire system is dependent on what happens at this site. In addition to meeting maintenance, site safety, fisheries and other ecological goals, removal of the Bloede Dam will provide improved access and recreational opportunities for park visitors, including the uncovering of a picturesque boulder and cobble step pool channel with bedrock outcrops, and allow for an opportunity to recognize the cultural history of the site. It is recommended that the removal process itself employ a largely passive sediment management approach during removal to properly manage impacts.

Short-term impacts will result, including sand deposition in the channel, overbank sediment deposition and temporary trail impacts, short-term disturbance of River Road during construction and ecological impacts to low gradient reaches. However, it is important to realize that long-term benefits outweigh the short-term, ephemeral impacts to the system. The recovery of the Patapsco River following dam removal or dam failure has been demonstrated several times in the past, and that evidence is still visible today. Dams have occupied many places along the river, and most of them were damaged or destroyed by floods. No evidence remains of the effect of these dams on the river either upstream or downstream. For example, a dam once existed at the location of the Swinging Bridge downstream of Bloede Dam. The river in this area fully recovered long ago and the only evidence of the former structure is the mill remnants along the north shore. During Tropical Storm Agnes, massive amounts of bedload inundated the system, creating large gravel and cobble bars and defining the geomorphic boundaries of the system for years. Areas like those near Gun Road were completely buried in layers of sand and gravel. Despite the changes induced by this and other hurricane systems, the Patapsco has recovered. More recently, after just two years, the river reaches upstream of the Simkins and Union dams are recovering. Bedrock outcrops and riffles are exposed, and deep pool habitat is developing.

Each of the alternatives evaluated in this report, with the exception of dam removal, have been tried at this site and have failed to meet the project goals. As science has advanced and demonstration projects have proven, dam removal is the single most effective way to reconnect fragmented habitat for aquatic species and recover ecological processes (currently dormant due to dams) that can lead to healthier, functioning ecosystems.

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