Name of Project: Brown’s Creek Watershed Based Plan

Lead Organization: The Cumberland River Compact

Watershed Identification (name, location, 12-digit HUC, etc.)**:**

The project is located within the watershed of Brown’s Creek, which is part of the HUC12 051302020305 (Cumberland River – Brown’s Creek. The watershed of Brown’s Creek takes up about one-third of the HUC 12; the remainder is drained by Nashville’s combined sewer systems and small streams in downtown Nashville. The Brown’s Creek Watershed drains south central Nashville, flowing NNE from Oak Hill to its mouth in the heavily industrial area east of downtown Nashville. Brown’s Creek empties into the Cumberland River across from Shelby Park, roughly 2 miles upstream from the city center. The watershed is approximately 10,500 acres (16.4 mi^2), in area and contains approximately 14.5 miles of streams listed on the national hydrographic dataset. The population of the watershed is estimated from 2010 census data at approximately 32,000, giving a population density of approx.

Brown's Creek Watershed Location Map

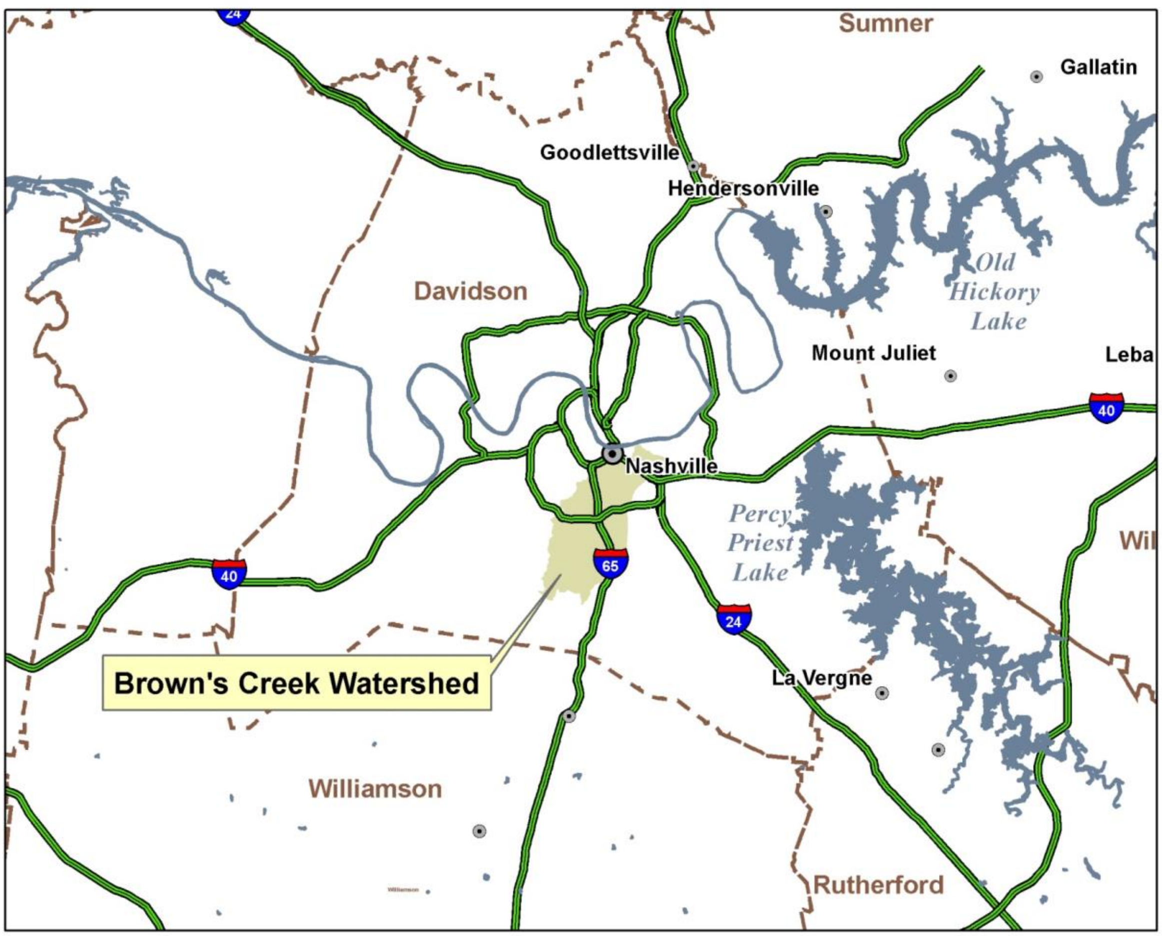


Figure 1: Location of Brown’s Creek Watershed within the Greater Nashville Region

Causes and Sources of Nonpoint Source Pollution in the Watershed

According to the current Draft 303(d) list for 2016, every stream in the Brown's Creek Watershed is considered impaired, with the exception of an unnamed branch draining from the 12th South/Sevier Park neighborhood, which has not been assessed. Total impaired waters make up 13.6 of 14.6 total stream miles in the watershed, or 93%.

The following stream segments within the watershed are listed on the Tennessee 303(d) list:

Waterbody ID	Impacted Waterbody	County	Miles Impaired
TN05130202023 – 0100	East Fork Brown's Creek	Davidson	2.2
TN05130202023 – 0200	Middle Fork Brown's Creek	Davidson	3.5
TN05130202023 – 0300	West Fork Brown's Creek	Davidson	3.6
TN05130202023 – 1000	Brown's Creek	Davidson	0.2
TN05130202023 – 2000	Brown's Creek	Davidson	4.1

All five impaired segments are impaired for ***E. coli, Nitrate+Nitrite, and Total Phosphorus***

Segments TN05130202023 – 0100 (East Fork Brown's Creek), TN05130202023 – 0200 (Middle Fork Brown's Creek), TN05130202023 – 1000 (Brown's Creek), and TN05130202023 – 2000 (Brown's Creek) are impaired for **other anthropogenic habitat alterations.**

Segments TN05130202023 – 0100 (East Fork Brown's Creek), TN05130202023 – 1000 (Brown's Creek), and TN05130202023 – 2000 (Brown's Creek) are impaired for **oil and grease.**

Additionally, we have conducted stream walks in the area and observed high levels of channel erosion. While this erosion may not be contributing to a current problem of sediment impairment, such impairment could potentially emerge in the future, and channel erosion in many areas of the watershed has the potential to pose a physical hazard to humans and structures.

See Figure 2 below for map of impaired streams and their respective impairments.

This watershed based plan addresses sediment, pathogen, nutrient, habitat alteration, and oil and grease within the Brown's Creek watershed. With full implementation, the goal of the plan will be to remove all impaired segments from the 303(d) list of impaired streams.

The most common source of nutrient and *E. coli* loading, according to the 303(d) list, is MS4 discharges, high levels of urbanization, and failing collection systems. Flashy conditions due to high urbanization carry pathogens and nutrients into the storm sewers and streams, and the high flows contribute to bank erosion. This suggests that restoration work in the watershed should be centered around three primary activities – public education about pathogen and nutrient sources and pathogen mitigation practices; runoff containment, infiltration, and mitigation through green infrastructure practices; and bank repair/protection.

Brown's Creek Impaired Streams Map

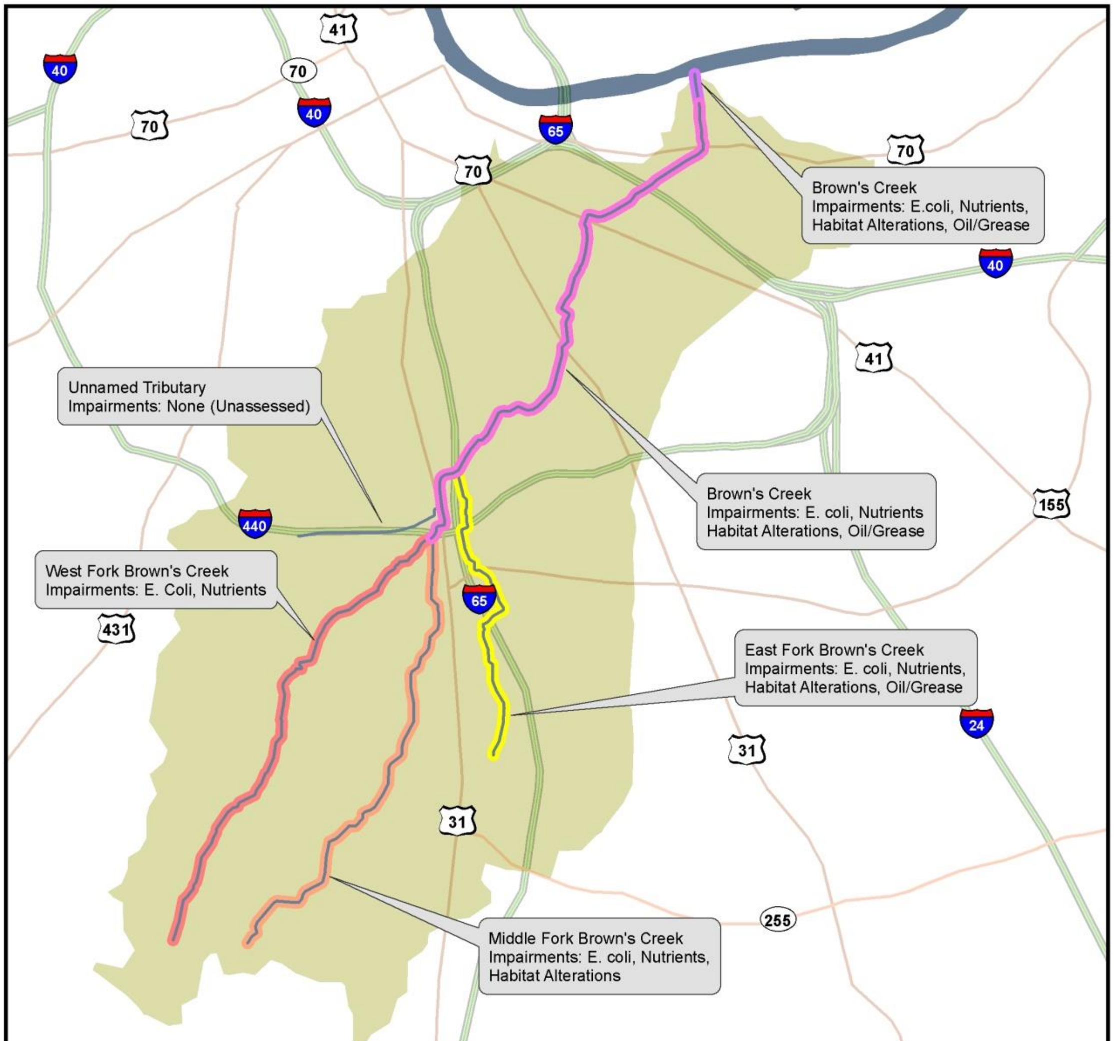


Figure 2: Map of impaired streams in the Brown's Creek watershed

Each stream segment on the map is highlighted with a different color, and impairments for that segment are indicated. Segments are shown defined on the TDEC 2014 Draft 303(d) list. The Brown's Creek watershed includes five 303(d) listed impaired stream segments totaling 13.6 miles. The remaining unassessed, unnamed stream totals 1.05 miles. Total stream miles in the watershed total 14.65 miles, though this does not include many wet-weather conveyances, intermittent small streams, and other small drainages.

Total annual precipitation in the basin was estimated at 48 inches, amounting to approximately 42,000 acre-feet/yr for the watershed. However, approximately 550 acres of the basin (5.2%) is also drained by the Nashville combined sewer system, which does not have any overflow points within the watershed. As a result, approximately 2,200 acre-feet/yr of rain falls on areas where surface flow will be funneled into the CSS. Since these areas are heavily urbanized, we expect low infiltration, meaning most of this 2,200 acre-feet/yr will be transported out of the watershed. Once this was accounted for, storm runoff load was estimated from the model as ~16,000 acre feet. We presume most of this storm load is driven by urbanization. Typical evapotranspiration ratios in Middle Tennessee are 0.5-0.6, indicating a likely range of runoff of 17,000-21,000 acre-feet/yr for a watershed of this size. Choosing a value of 0.45 for the runoff ratio for the 60% of the watershed that is pervious (~12,000 acre-feet/yr) and adding the ~16,000 acre-feet of storm load (as this urban watershed will have a higher than normal runoff), we end up with a final estimate of runoff ratio of 0.67 (28,000 acre-feet/yr) for total flow at the outlet of Brown's Creek. This is a reasonable runoff ratio for an urbanized watershed in this region of the country, and this estimate produces an estimated flow at the mouth of Brown's Creek of $39ft^3/s$. Long term discharge data shows a 35-year average discharge as measured at the Nashville Fairgrounds (this station encompasses about 2/3 of the watershed area) of ~$19ft^3/s$, which would suggest a discharge at the mouth of about 28-$29ft^3/s$. This value is a bit lower than our estimate, but does not account for increased urbanization or the fact that the lowermost third of the watershed is the most urbanized. Therefore, we think that $39ft^3/s$ is a reasonable average value for a watershed of this size. This figure was used as our average discharge in loading calculations. The areal runoff generation average of ~$2.5ft^3/s/mi^2$ ($39ft^3/s$ over a $16mi^2$ watershed) is higher than that of the Cumberland River Basin as a whole (~$40{,}000ft^3/s$ over a ~18,000 mi^2 watershed), which is to be expected in an urban watershed.

Nutrients and Sediment

Total nitrogen, phosphorus, and sediment loading in the Brown's Watershed was estimated from the Center for Watershed Protection Model, using publicly available data from the NLCD 2011 dataset, the NRCS, and the city of Nashville. Unavailable data was estimated using our best educated guess. Using the CWP model, we estimated total nitrogen loading at 83,897 lbs/yr, total phosphorus loading at 20,270 lbs/yr, and total sediment loading at 4,927,560 lbs/yr (2463 tons/yr). These values are difficult to estimate due to the number of assumptions needed. Metro Water's 2011 MS4 annual report estimated total suspended sediments at 1,912,141 lbs/yr (956 tons/yr), total phosphorus at 9,106 lbs/yr, and nitrate/nitrite 19,525 lbs/yr. Erosion is noted to be a major contributor to sediment loading, with examples of collapsing, rapidly eroding streambanks observed throughout West and Middle Forks of Brown's Creek. For the purposes of this plan, we will use the Metro Water estimates.

Pathogens

The most recent available data for pathogen loading was provided by Metro Nashville Water in the 2011-2012 annual report, regarding sampling conducted in 2011 on all three forks of Brown's Creek and two stations in Brown's Creek proper. Following the recommendations of the TMDL, we do not consider wet weather flow values. Metro Water conducted four 5-sample, 30-day samplings and provided the geometric mean for all 20 samples. In this sampling, dry weather CFU/100ml ranged from 23-1203 in West Fork Brown's Creek, 52-2420 in Middle Fork Brown's Creek, 31-547 in East Fork Brown's Creek, 118-2420 in the lower reach of Brown's Creek proper, and 29-387 in the upper reach of Brown's Creek proper. Geometric means for these five segments were 198, 222,128, 501, and 116 respectively – these values were compared to the maximum concentration recommended by the TMDL to obtain our updated percent reduction goals for each segment.

Maximum concentrations (calculated from TDEC criteria and the Cheatham Watershed TMDL) are 126CFU/100ml for a 30-day geometric mean, and a maximum value of 941CFU/100ml for all streams in the watershed. Middle Fork Brown's Creek is listed on the 2014 303(d) list as impaired but excluded from the TMDL (presumably unimpaired or unassessed at that time) ; we use the 941CFU/100ml value for it as well.
In the case of the Metro Nashville Water sampling listed above, the upper reach of Brown's Creek no longer exceeds the TMDL, and the East Fork only barely exceeds the criteria. The West and Middle Forks and the lower reach of Brown's Creek proper violate both the mean and maximum criteria severely.

Oil and Grease

The East Fork of Brown's Creek, as well as Brown's Creek proper, is additionally listed on the 303(d) list for oil and grease. We noted a permitted discharge from CSX's 250-acre Radnor Yard terminal, allowing for up to 15mg/L of oil (~22ppm by volume once the different density of oil is accounted for) in stormwater discharges, noting that this value is at the technical limit for stormwater oil-water separation technology. Assuming 48" of annual rainfall and substantial (~75%) runoff from the railyard (mostly impervious or compacted surfaces), runoff produced from the yard could be approximately 32,670,000 ft^3 annually. This provides an upper bound for permitted oil pollution of ~720 cubic feet of oil annually, equivalent to dumping a little over a third of a standard barrel in the creek each day, though the actual value is almost certainly far less. It is unclear how much oil is being discharged from Radnor Yard (and how much from the other massive parking areas at Hundred Oaks Mall, Home Depot, Carmax, and industrial areas further downstream), but since the stream remains impaired by oil and grease, additional remediation will be needed to trap/filter oil in the East Fork and in Brown's Creek proper.

Habitat alterations

As with oil and grease, habitat alterations are nearly unquantifiable, and indeed the 303(d) list is generally unclear as to what particular problems are even responsible for their assessment. However, o bservations suggest significant changes to natural stream and riparian habitat due to riparian buffer loss, invasive plant species infestations, erosion, and channelization. Urban sewer infrastructure and CCC-era flood control has left many stream sections as little more than concrete channels. Habitat alterations will be discussed further later in this plan.

Estimate of Load Reductions

E. coli

Total load reductions needed to reach pathogen standards were estimated by comparing the 2011-2012 Metro Water testing results with established criteria of 126CFU/100ml. This data was more updated than the percent load reduction goals in the TMDL, which is over 10 years old. Based on the estimated *E. coli* loads above, percent load goals of 37% for the West Fork of Brown's Creek, 44% for the Middle Fork of Brown's Creek, 2% for the East Fork of Brown's Creek, and 75% for the lower reach of Brown's

Creek. According to Metro Water measurements, the upper reach of Brown's Creek proper is no longer impaired by *E. coli*

Modeling *E. coli* loading reductions from BMPs is an uncertain process. In the past we have made use of the Center for Watershed Protections Watershed Treatment Model, but many model inputs are based on generalized assumptions, so for this project we will consider it as a guide and make adjustments based on additional information about the watershed. This model accounts for coliform loading on land and does not account for in-stream die off, so the absolute loading values calculated by the model will be orders of magnitude higher than the concentrations required by the TMDL, and not reflective of the final in-stream loads. However, we can still get an estimate of what practices we need by comparing load reductions generated by the model to the total loading generated by the model. Many of the variables in this model are by necessity rough estimates, but in general primary sources are urban stormwater runoff and sewer leakage/illicit connections. Nashville's combined sewer system does not have any outfall or overflow points within the watershed, and in our model we initially estimated that the likelihood of illicit connections was nearly non-existent due to communication from the city that such connections were found perhaps once annually citywide. As a result, out model suggests that almost the entirety of *E. coli* loading is due to urban runoff. However, as we will explain below, there are reasons to make adjustments to the model based on reported circumstances.

In the East Fork of Brown's Creek, total reduction of coliform concentrations by 2% is needed, according to the 2011-2012 data from Metro Water. As the area is mostly developed already, we do not anticipate substantial additional changes to the loading characteristics of this stream in the near future. Necessary *E. coli* load reductions should be achieved incidentally as part of efforts taken to mitigate nutrients, habitat alterations, and oil and grease impairments.

Lower Brown's Creek is by far the most pathogen-impaired section of the watershed, requiring an estimated reduction of as much as 75% based on the data from Metro Water's 2012 annual MS4 report. However, we note that the following annual report covering 2012-2013 noted several significant sources of pathogens that were discovered and eliminated or mitigated, so pathogen loading in these areas may be far less now than at the time of that report. The 2013 report noted four major findings of pollution for the year, two of which directly affected Brown's Creek and could be contributing to the high observed pathogen levels. One such finding was a commercial trucking company wash bay that was discharging directly into a storm sewer leading to Brown's Creek; the other was a sanitary sewer lateral line that was leaking a significant volume of sewage directly into these storm drains. Additionally, the 2013 MS4 report notes that a potential major source of bacterial contamination to Brown's creek is the annual Tennessee State Fair, citing livestock washing bays and animal staging areas that drain directly to Brown's Creek as potential pollution sources. Coincidentally, the highest pathogen concentrations in the 2012 Metro Water MS4 Annual Report were observed during the early October sampling events; this is both a time of low flows and relatively soon after the fair, which occurs in mid-September. The 2013 report notes both illicit discharges were corrected, and that steps are being taken to reduce the impact of the livestock at the state fair on Brown's Creek, so the actual reduction needed today may be far less than the 75% reduction indicated by the 2012 report. The 2013 report also notes that the correction of a single illicit sewage leak into Bosley Springs Branch brought down its impairment enough for the city to petition to have the stream reevaluated and removed from the 303(d) list for pathogens; while Brown's Creek is much larger, it is not unthinkable that all or most of the impairment reduction may have been achieved through these and other repairs. Since this area will represent a later stage in our plan implementation, for now we will assume a moderate reduction is necessary and adjust our work if needed as future monitoring is conducted.

The West Fork of Brown's Creek is also heavily impaired by pathogens, with a needed 37% reduction indicated by the 2012 Metro Water MS4 Annual Report. As with the lower reaches of Brown's Creek, it is hard to say how much of the impairment in the West Fork is driven by non-point sources issues, and how much is driven by broken sanitary sewers and others. Several sections of the West Fork are underlain by sewer infrastructure that is directly in the bed of the creek, with manholes emerging directly from the creek bed.

The Middle Fork of Brown's Creek is also heavily impaired by pathogens, with a needed 44% reduction as indicated by the 2012 Metro Water MS4 Annual report. As with other segments, it is difficult to ascertain how much of the pathogen pollution is actually driven by non-point sources.

The issue of non-point vs. point sources (and fecal matter vs ambient environmental occurrence of *E. coli*) in determining how to address pathogen reduction is a vexing problem. If the problematic pathogen loading is indeed primarily the result of non-point source from urban surfaces (rather than sanitary sewage, dog wastes, etc.), virtually the only way to achieve the massive reductions in pathogen loading will be to capture and treat a substantial fraction of the stormwater that falls in the basin. For the 75% reduction in lower Brown's Creek, for example, this might mean installing storm filters, bioretention, etc. to capture nearly all stormwater from impervious cover in the subwatershed, which would cost tens if not hundreds of millions of dollars to retrofit. If this is indeed the case then the *E. coli* issue will realistically only be solved over several decades as the city's stormwater ordinances impact redeveloping properties. However, if the pathogen pollution is indeed mostly point sources and animal waste, reductions can be achieved by improving monitoring to help the city find these sources, and by creating a comprehensive outreach program to reduce pet waste impacts. As the project progresses, subwatersheds will be modeled individually to provide more accurate descriptions of watershed conditions and inform BMP decision making and implementation.

Regardless of the values needed to reach the state water quality criteria, and the accuracy or inaccuracy of the pathogen modeling described above, *any* activities that lower coliform will be useful in promoting healthier waters and communities. Therefore, we feel that pathogen loading reduction activities will be worth funding even if reduction figures and results of best management practices cannot be modeled, and even if the largest reductions will be done by the city in the course of screening for sanitary sewer system leaks and other point sources. The primary focus of this Watershed Based Plan with regards to pathogen mitigation will be pet waste education, erosion control, point source identification, and stormwater mitigation.

Nitrate+Nitrite

Total nitrate + nitrite was estimated by Metro Water in their 2011 MS4 Annual Report at 19.525 lbs/yr. Presumably the stream is considered nutrient impaired due observations of algal blooms or other factors, indicating that nitrate + nitrite (as well as phosphorus) must be reduced. In our stream walks within the watershed, we noticed some algae growth on surfaces but not an unusually large amount (streams were not "scummy" and covered in algae, for instance, and we did not see large strands of algae in the water in the sections we observed). Therefore we believe that a moderate nutrient reduction is likely needed. Tennessee lacks numerical total nitrate + nitrite criteria, so we will set an arbitrary percent reduction goal of 20% for nitrate + nitrite contamination, or **~3900 lbs/yr.**

Total Phosphorus

Total phosphorus was estimated by Metro Water in their 2011 MS4 Annual Report at 9,106 lbs/yr. Middle Tennessee naturally has unusually high soil/rock phosphorus concentrations (as high as 1 part per thousand, resulting in high phosphorus loads. Tennessee lacks numerical total phosphorus criteria, so we will set an arbitrary percent reduction goal of 20% for phosphorus contamination, or **~1800 lbs/yr**.

Oil and Grease

Oil and grease is another contaminant with no numerical state or EPA criteria – the primary requirement seems to be that is not visibly detectable. Since oil loads and impacts of reduction activities on loading will be difficult to quantify, the safest option is to put in targeted water quality bmp's at locations that can be reasonably expected to be oil and grease "producers" (e.g. major parking lots, the CSX yards, illicitly connected restaurants or automotive facilities, etc.)

Habitat Alterations

As habitat alterations are essentially unquantifiable, we cannot provide a load or load reduction goal. However, from our observations there are ample areas where riparian and stream bottom habitat is in extremely poor condition. We note that nearly the entire stream riparian zone is infested with invasive plant species, and much of the stream bed in several sections is altered by CCC-era construction projects that have left the stream with a concrete base or walls. Removal of the invasives will be a never-ending process that will be well beyond this watershed plan; one goal of the plan will be to promote a sustainable movement to improve riparian health beyond the period of this plan. Stream bed restoration may be possible in some areas, but much of the concreted channels are due to in-bed sewer infrastructure, which will be infeasible to reroute, and certainly beyond the scope of this project. Streambank stabilization will help restore natural bank slopes in riparian zones, and restoration of riparian areas will also be helpful.

Sediment

Brown's Creek is not considered impaired for sediment, yet had substantial channel erosion and more sediment relative to flow rate than our previous study in Mansker Creek, which was considered impaired. As a result we believe that sediment should be addressed as a precautionary measure, preempting future 303(d) impairment listings. As Tennessee uses qualitative sediment standards, for our modeling purposes we examined other states' criteria to see what reasonable quantitative sediment standards might be in order to determine estimated load reductions needed for this precautionary work. Most states either use qualitative standards or have multi-criteria exceedance standards, which complicate modeling efforts and preclude an estimation of a specific load reduction value. We observed that New Jersey, South Dakota, and Utah do have numerical sediment standards (calculated as a 30-day average) of 25.0mg/L, 30.0mg/L, and 35.0 mg/L respectively. Of these three criteria, we chose to use New Jersey's criteria of 25.0mg/L, both because it was the lowest and because of the three states, New Jersey was closest to Middle Tennessee in climate and land cover (being mostly urban or forest).

Based on an estimated precipitation (48") and estimated runoff ratio for the watershed of 0.67 (see above), we estimated the average discharge for Brown's Creek to be approximately 39ft^3/s. Using a value of 25.0mg/L (708 mg/ft^3) as our total suspended sediment criteria, we estimated the maximum annual TSS load for Brown's Creek at ~655 tonnes (~721 tons). Metro Water estimated sediment loading at approximately 956 tons/yr (see above). Based on these figures, we estimate that annual sediment loading should be reduced by a minimum of 235 tons. To account for some of the uncertainties in loading values and BMP efficiency, we will set a slightly higher load reduction goal of **250 tons/yr** in order to reduce the chance of future impairments.

BMP List, Educational Activities and Budget

Based on our above estimates for the non-numeric criteria load reductions and potential sources for pathogen loading, the following BMP activities should be sufficient to restore the Brown's Creek watershed for most impairments. BMPs will be located in specific subwatersheds based on the impairments found in those stream segments. These BMPs focus on nutrient and pathogen, and oil and grease reduction, as well as habitat alterations to the extent practical (in many areas, structural habitat alterations will simply be beyond the scope of this plan, as in the case of the established sewer lines along the creek). Additionally, we will address sediment as pollutant – while not an impairment currently, it has potential to be one in the future, and channel erosion has been observed to be significant. Measures to reduce sediment through channel protection also have the dual benefit of reducing total phosphorus due to the region's high soil phosphorus levels.

BMPs

Streambank stabilization: Streambank erosion is considerable in the West Fork and Middle Fork of Brown's Creek. Streambank erosion contributes to nutrient loading due to the high levels of phosphorus in local soils, and additionally contributes to sediment loading, though this has not yet been considered to be an impairment in the watershed. Stormwater flow reduction will help reduce the erosive power of the watershed's waterways, but the existing eroded banks are vulnerable and will need repair in order to maximize load reductions. For this watershed plan, we envision a minimum of 5,000 feet of bank protection using natural methods (e.g. cedar revetments, coir logs, etc.). Streambank stabilization will be conducted primarily in the Middle and West Forks of Brown's Creek, but also in the other stream reaches if more eroding areas are identified.

Riparian buffers: While many of the waterways in the watershed do have riparian buffers, they are often inadequately narrow, and in some places nonexistent. If we assume an adequate riparian buffer is 50ft wide, the 14.5 miles of waterways in the Brown's Creek watershed should have about 175 acres of buffer within this 50 foot zone (~2% of the watershed area). Based on a visual assessment of the condition of the riparian buffer zones of the watershed using Google Earth aerial imagery, we estimate that ~50% of waterway miles are adequately buffered, 35% is inadequately buffered, and the remaining 15% is unbuffered. However, there are also numerous smaller intermittent drainages that are not represented on the national hydrographic database but would benefit from buffering. These figures provide ample reason and opportunity for installation of riparian buffers. Where needed, riparian buffers will be co-located with streambank stabilization measures in order to provide additional protection to vulnerable areas. As part of this watershed plan, we estimate that we will install roughly 5 acres of riparian buffer, amounting to over 4,000 linear feet if the buffers are 50 feet wide. Riparian buffers can help minimize both nutrient and pathogen loading and will be implemented primarily in the upper reaches of the watershed. Much of the lower stretches of Brown's Creek are relatively well buffered already and have little room for additional buffers due to adjacent infrastructure.

Pet waste bag dispensers: One of the main sources of pathogens in urban waterways is pet waste. Pet waste bag dispensers will be installed and stocked in highly visible public locations or high use private locations (such as large apartment complexes). This will help build awareness of the importance of pet waste control and provide residents with the easy means to do so. Pet waste bags are currently being designed by the Cumberland River Compact for another project and will be custom printed with tips on actions residents can take to improve water quality. We anticipate installing 10 dispensers in the watershed. *E. coli* is a problem in all impaired segments, and the pet waste bag dispensers will be installed in the residential areas of each subwatershed.

Rain gardens: Rain gardens contribute to nutrient, pathogen, and sediment control, by infiltrating stormwater containing pathogens and nutrients, trapping sediment, and reducing high stormflow volumes which contribute to channel erosion downstream. Rain gardens can be placed adjacent to any impervious surface that would otherwise connect to a storm drain or wet weather conveyance, and can mitigate the effects of such surfaces. The Cumberland River Compact has had great success with our rain garden program and anticipates that finding collaborators for rain gardens will not be difficult. This plan will incorporate the installation of 100 rain gardens within the watershed. Rain gardens will be implemented in all subwatersheds.

Permeable pavement

Permeable pavement can help filter pollutants from parking lots and adjacent impervious surfaces, as well as reduce stormwater. Permeable pavement can take the form of permeable concrete or permeable paver systems. Installing permeable pavement as a retrofit has the added benefit of helping advertise this technique, hopefully inspiring additional private investment in permeable parking areas. As part of this project, we intend to put in 4-5 small permeable pavement installations to help establish this technique and filter stormwater.

Storm Filters and other Stormwater Retrofits: This class of BMPs is a catch all, potentially including detention ponds or storm filters draining parking lots. We estimate that there will be opportunities to do several medium sized projects to capture and infiltrate stormwater as an erosion and pathogen control measure. For this plan, we estimate that implementation of 10-20 such structures will be needed to address pathogen and oil and grease contaminations in the watershed, each covering approximately 1-2 acres of impervious cover. These will take place mostly in the lower portions of Brown's Creek and in East Fork Brown's Creek, where impervious cover is greatest and there are numerous large parking areas that could be retrofit. These retrofits can remove oil and grease nutrients, sediment, and some pathogens from stormflows.

Artificial Wetlands: Artificial wetlands can filter out pollutants and serve as stormwater storage. A potential site has been located in the East Fork of Brown's Creek watershed downstream of Radnor Yard. An artificial wetland at this site has the potential to remediate oil and grease polluted runoff from the rail yard.

Stream Daylighting: We have identified a location along a minor drainage with potential for daylighting of a stream to improve local stream habitat.

Invasive species removal: Numerous areas of riparian buffer within the watershed is heavily infested with Japanese bush honeysuckle, Asian privet, kudzu, and many other species. Restoring riparian buffers to natural conditions will help improve stream habitat for riparian species and allow the return of natural forest cover. We estimate that over a hundred acres of impaired riparian zone is in need of restoration – this amount will be beyond a short term solution, as invasive control is a never ending battle, but this project will involve outreach to encourage private landowners to tackle these invasives rather than leaving them alone.

Load Reductions

Without numeric criteria for many impairments, and without a clear differentiation between point and non-point sources of E.coli pollution, we will only provide reduction calculations for nitrogen, phosphorus, and sediment (not an impairment, but a potential future impairment) here.

The majority of *E. coli* reduction will be handled by existing local government programs to detect and eliminate illicit connections, leaking sanitary sewer systems, etc., but the remainder will be handled by structural stormwater practices (rain gardens, water/sediment control basins, stormwater filtration, etc.), and educational outreach program to address pet waste. Habitat alterations and oil and grease will be addressed as described in the BMP description by artificial wetlands, permeable pavement, stream daylighting, and other structural practices, but cannot be quantified with available data.

Phosphorus

Using the pollutant load reduction estimation tool provided in the watershed based plan guidelines, we estimate the following reductions from our BMPs:

Streambank/shoreline protection: 0.17 lbs/ft/yr * 5,000 ft = 850lbs/yr
Riparian buffers: 22.6 lbs/acre/yr * 5 acres = 113 lbs/yr
Rain gardens: 0.06lbs/ft^2/yr x 100 rain gardens x 100 ft^2/garden = 600lbs/yr
Total phosphorus reduction from these measures: **1,563lbs/yr**

We estimate that the remaining 237lbs/yr reduction to reach our loading goals of 1800lbs/yr will be achieved through our outreach work to reduce fertilizer use and encourage proper disposal of pet wastes. The above calculation does not address other structural practices that may also help with phosphorus reduction.

Nitrogen

Using the pollutant load reduction estimation tool provided in the watershed based plan guidelines, we estimate the following reductions from our BMPs:

Streambank/shoreline protection: 1.75 lbs/ft/yr * 5,000 ft = 8,750lbs/yr
Riparian buffers: 308.4 lbs/acre/yr * 5 acres = 1,542 lbs/yr
Rain gardens: 0.158lbs/ft^2/yr x 100 rain gardens x 100 ft^2/garden = 1,580lbs/yr
Total phosphorus reduction from these measures: **11,872lbs/yr**

This is well in excess of our load reduction goal of 3,900lbs/yr, indicating that our goals for phosphorus should easily also achieve our nitrogen reductions. Nitrogen reduction will also be achieved through our outreach work to reduce fertilizer use and encourage proper disposal of pet wastes. The above calculation does not address other structural practices that may also help with nitrogen reduction.

Sediment
Sediment is worth addressing as a potential future impairment and because sediment reduction goals also help with phosphorus reduction.

Calculations suggest that these BMPs should satisfy our 250 tons/yr load reduction target for sediment. Using the pollutant load reduction estimation tool provided in the watershed based plan guidelines, we estimate the following:

Streambank/shoreline protection: 0.047 tons/ft/yr * 5,000 ft = 235 tons/yr
Riparian buffers: 3 tons/acre/yr *5 acres = 15 tons/yr
Rain gardens: 0.006 tons/ft^2/yr * 100 gardens x 100ft^2/gardem = 60 tons/yr.
Total sediment reduction from these measures: **310 tons/yr**

This brings our total estimated sediment reduction to well in excess of our 250 tons/yr goal, without even considering the impact of our other incorporated measures, or behavioral changes driven by our educational outreach.

Educational Activities

As part of our watershed based plan, we recommend increasing awareness through educational outreach within the watershed. Outreach should be multifaceted, and while some will be incorporated directly into BMPs, specific activities should be conducted with education and outreach in mind.

Foremost among the educational outreach needs for the watershed is a concerted effort to teach watershed residents about the need for and methods for reduction of nutrient and pathogens through proper fertilizer management, lawn care, and proper pet waste disposal. Such outreach could involve mailers, scientific/educational presentations at local town hall meetings and other public events

Another area in which we have had great success at the Cumberland River Compact is educational talks. We have been hosting a series of weekly talks in the spring and fall at our event space in downtown Nashville, dedicated to a variety of topics relating to the science, history, and preservation of the Cumberland River. These seminars have been well attended and benefit both the public and other non-profits. As part of this plan, we suggest a similar talk series for Brown's Creek, covering project work, water issues, and other environmental topics.

Budget for BMP's and Educational Activities
Based on estimates from our own previous work and that of some of our collaborating organizations, we estimate a possible budget breakdown for this watershed based plan as follows (not including cost of volunteer time).

BMP Name	Quantity	Cost/Unit	Budget Estimate
Major/medium retrofitting projects, including storm filters, bioretention, detention ponds, etc.	10-20	$50,000-100,000 each	$1,000,000
Artificial Wetland Creation	1	$200,000	$200,000
Permeable Pavement	4-5 projects	$40,000-	$200,000

		50,000 each	
Stream Daylighting	1		$100,000
Streambank Stabilization with Revetments/Coir Logs	5,000 linear feet	$75/ft	$375,000
Riparian Buffers	5 acres	$3,000/acre	$15,000
Pet Waste Bag Dispensers w/ bags	10	$1000 each	$10,000
Rain Gardens	100	$500 each	$50,000
Invasive Species Removal	As much as possible		$50,000
		Total	**2,000,000**

Educational Activities

BMP Name	Quantity	Cost/Unit	Budget Estimate
Pet waste and nutrient reduction outreach			$230,000
Educational Talks/Seminars	20	$1,000	$20,000
		Total	**$250,000**

Total Budget for Project:	**$2,250,000**

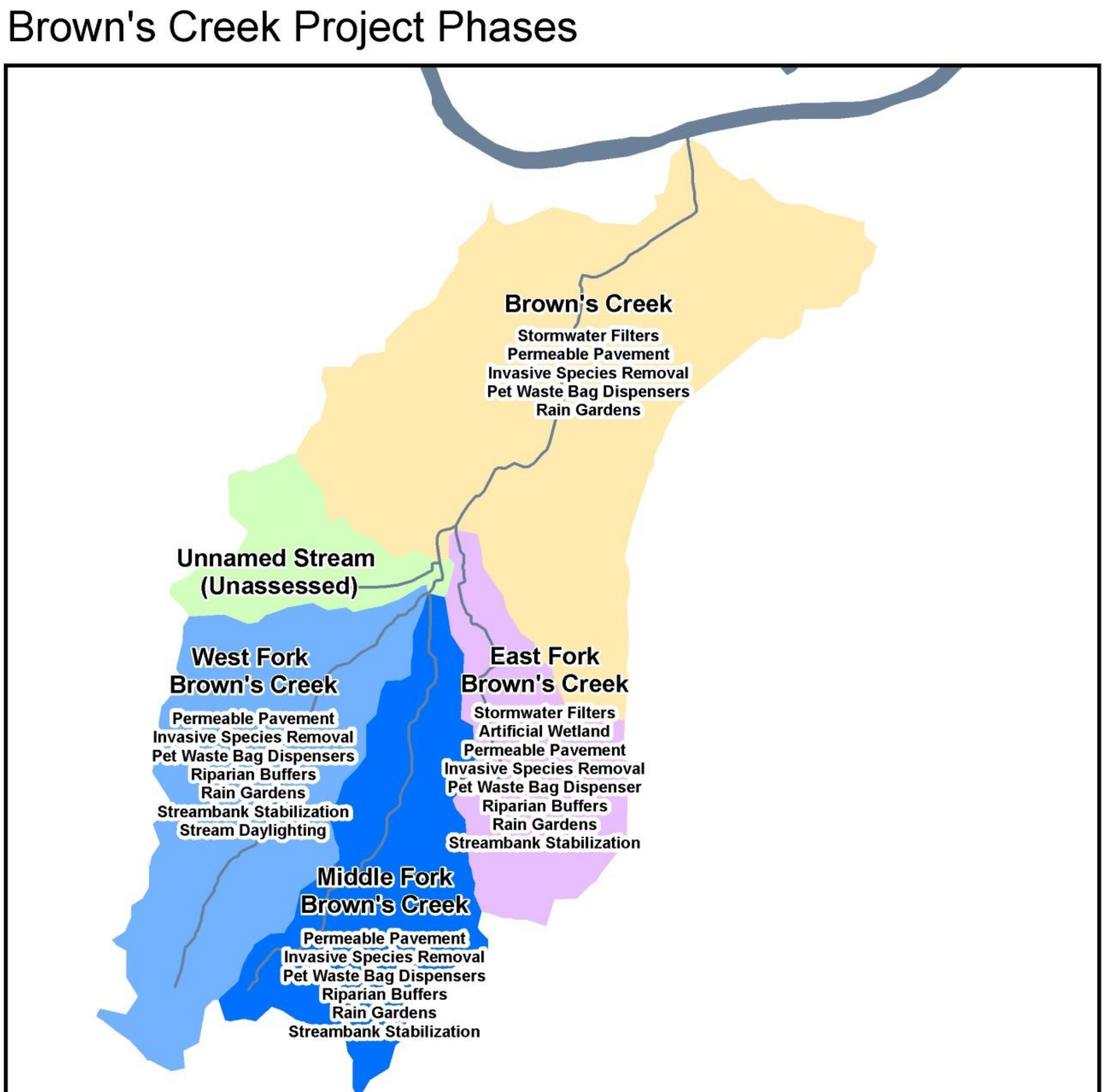
Timeline, Tasks, and Assessment of Progress

This Watershed Based Plan is envisioned as a comprehensive, 8-10-year long plan, to be completed by 2026. This plan will be divided into four 2-3 year long phases, with Phases 1-3 addressing 3 different sections of the watershed and Phase 4 serving as a wrap up phase to address trouble spots or neglected areas from Phases 1-3. Phase 1 will consist of the Middle and West Forks of Brown's Creek (a mostly residential area), Phase 2 will consist of the East Fork of Brown's Creek, and Phase 3 will consist of the lower reaches of Brown's Creek below the confluences of the three forks. By the beginning of Phase 3, we hope to have buy in from the city and a better handle on development projects such as the fairgrounds redevelopment that our currently unknown. The project area of each Phase under this arrangement ranges from approximately 1250-4200 acres. Funds will be sought from numerous sources, including the city government of Metro Nashville; federal funding, private donors, and corporate sponsors.

See map on following page for description of project phases and BMPs involved in each phase.

Tasks are described in detail above in the BMP section. Project tasks will be distributed among individual phases and subwatersheds based on specific subwatershed impairments and needs. Further modeling coinciding with Phase 1 will identify specific locations and tasks for each subwatershed in the basin.

Progress will be assessed based on percentage of progress tasks completed, remaining work to be done, and updated water quality monitoring data. Tasks associated with each phase will be described in proposals at the beginning of each phase, and each phase will conclude with a report detailing the proportion of project tasks completed, remaining needs, and expected efficacy and impact of completed tasks. This will inform future decision making and help shape the tasks for Phase 4, which will serve as a wrap up phase addressing any uncompleted tasks.



Project Phases

- Phase 1
- Phase 2
- Phase 3
- Unassessed

Figure 3: Map of Project Phases for Brown's Creek Watershed Plan

Project Phases: The Brown's Creek Watershed Plan envisions a 4-phase project over an 8-year period. In each 2-year phase, a different region of the watershed will be targeted. In the final phase, the whole watershed will be addressed, tackling previously unaddressed concerns identified during phases 1-3.

The above map shows a potential geographical breakdown for phases 1-3. The map also includes potential BMP types to be implemented in each watershed.

Phase 1: West Fork of Brown's Creek and Middle Fork of Brown's Creek
Phase 2: East Fork of Brown's Creek
Phase 3: Brown's Creek
Phase 4: Entire Watershed

Criteria to Assess Achievement of Load Reduction Goals

If load reduction goals are met, affected streams will no longer exceed TDEC's state water quality criteria. Independent sampling coinciding with Phase 3 will allow identification of areas in need of additional work, allowing modification of the project during Phase 4 to address the most problematic locations. Since riparian buffers and other natural methods take time to grow and reach full effectiveness, we anticipate that state water quality criteria may not be achieved immediately, but should be achieved for a given stream segment no later than 5 years after the end of the project phase addressing that segment's subwatershed. We anticipate project completion by 2026 and fully supporting conditions in all streams no later than 2030.

Monitoring and Documenting Success

The Cumberland River Compact and others involved in carrying out the watershed plan will keep TDEC-Division of Water Resources aware of restoration activities to allow coordination of sampling. Restoration activities do not have immediate effects and positive results may take several years to appear. However, the duration of the plan means that the early phases of the plan can be assessed, allowing us to go back during Phase 4 and address problem areas or unresolved issues.

In addition to coordinating monitoring efforts with TDEC, we hope to develop a partnership with Lipscomb University, which is located within our project area, to help with monitoring and sample analysis. We also hope to work with the School for Science and Math at Vanderbilt to develop a monitoring protocol and ongoing project.

Observed water quality measurements should be on a positive trend by the end of the plan timeline, such that extrapolating results (i.e. assuming that continued riparian buffers will trap more contaminants as they grow, etc.) would demonstrate meeting state criteria by 2-3 years after the end of the plan implementation. If observations indicate that meeting these criteria are unlikely, the program can be adjusted/extended in light of additional information. Again, for Phases 1-3, we will be able to assess the effectiveness of the program prior to Phase 4 of the project, allowing us to go back and revise the plan as needed.

Successes and needed revisions would be documented at the end of each phase of plan implementation, allowing flexibility in implementation and improving the effectiveness of the plan.