6-1-2011

Road Management Plan for Brackett and Pond Roads, Wakefield, NH

University of New Hampshire Stormwater Center (UNHSC)

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Road Management Plan for Brackett and Pond Roads, Wakefield, NH

Prepared for
The Acton Wakefield Watersheds Alliance

Prepared by
The University of New Hampshire Stormwater Center

Prepared with Support from NH Department of Environmental Services
June 2011
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Project Sponsors
NH Department of Environmental Services

Project Team
UNH Stormwater Center
James Houle, CPSWQ
Robert Roseen, PhD, PE, D.WRE

Wakefield Road Agent
Dan Davis

Acton Wakefield Watersheds Alliance
Linda Schier

NHDES Coastal Watershed Coordinator
Sally Soule
Road Management Plan for Brackett and Pond Roads, Wakefield, NH

Report by the University of New Hampshire Stormwater Center

EXECUTIVE SUMMARY

The purpose of the Road Management Plan is to address the declining water quality of Lovell Lake caused by runoff from Brackett and Pond Roads carrying sediment and phosphorus. Unimproved roads are commonplace in the Lakes Region of New Hampshire in an area with a substantial seasonal population. Unimproved roads and associated maintenance are well documented as major sources of sediment and phosphorus to surface water and may account for as much as 80% of the sediment load and 40% of the phosphorus load within a watershed. Studies have shown that during highly erosive storm events, sediment concentrations may be observed to exceed 100,000 mg/L with averages for gravel roads >3,000 mg/l (Clinton and Vose 2003) whereas a typical low use paved road would be ~100 mg/L (Hagen and Walker 2006). The impacts from these sediment laden waters can be substantial and directly impact the value, aesthetics, and usability of our lakes. As seasonal populations grow and become permanent, the number of road miles and driveways will increase, and maintenance demands for these unimproved surfaces will increase.

Another issue of concern is that road maintenance practices, while improving road drainage, often contribute significantly to erosion and sedimentation. The process of improving roadside conveyance through ditching is routine and a necessary element of road maintenance. However, the addition of erosion and sedimentation control practices to this routine maintenance will reduce the threat to surface waters.

A range of strategies exist to reduce impacts ranging from practical road maintenance techniques, to road and drainage improvements, and non-structural approaches (i.e. catch basin cleaning, vegetative stabilization) targeted to minimize erosion and sedimentation. This Road Management Plan (RMP) presents recommendations for Brackett and Pond Roads, and a review of locations identified to be primary problem areas. The locations are prioritized for cost and sediment load. This review finds that by addressing the top 7 of the 14 identified locations, over 44,000 lbs of sediment per year can be eliminated from reaching Lovell Lake. That represents 79% of the total estimated sediment load from the 14 sites. These 7 improvements are estimated to cost $28,300. Costs include only materials. Labor and equipment are not included as these are anticipated to be a component of existing operations and maintenance by municipal staff. Costs do not represent detailed design costs which are still required and are for planning purposes only. These estimates are useful for planning, pursuing additional funding and illustrating the relative ranking of each location.

The approaches and techniques recommended in the RMP can all be implemented by existing Town staff. Recommendations include additional equipment and labor demands, both available
for purchase or hire. The equipment expenses range from minimal to that equivalent to a large service vehicle.

A generalized management approach for Brackett and Pond Roads is described below. At most sites, treatment strategies were very similar and consisted of: 1) establishing stable, adequately sized drainage, 2) with upstream sedimentation structures (i.e. hooded deep sump catch basins, gravel check dams), 3) installation of road crossings for surface runoff, 4) use of water quality controls post culvert that could filter, infiltrate and dissipate high velocity flows, and 5) stabilized conveyance to the lake.
BACKGROUND

Lovell Lake is a 538-acre lake that is both spring-fed and fed by small streams, including Horse Brook to the northwest. Lovell Lake outlets into the Branch River in the village of Sanbornville to the west. From here, the Branch River flows in a southeasterly direction to Milton, NH where it joins the Salmon Falls River on the Maine-New Hampshire border. The Salmon Falls River eventually empties into the tidal waters of the Piscataqua River in Portsmouth, New Hampshire.

Lovell Lake is a Tier 1 waterbody, which means it marginally supports water quality standards due to elevated levels of certain indicators such as phosphorus and chlorophyll a. According to the Salmon Falls Headwater Lakes Watershed Management Plan, the phosphorus levels in Lovell Lake need to be reduced in order for the lake to meet the NHDES criteria for High Quality Waters (AWWA and FB Environmental 2010).

From a community perspective, lakes are one of the most valuable natural resources providing for recreation, relaxation, aesthetic appeal and bringing in much needed tourism dollars and revenue to the adjacent towns. Lakes and their surrounding lands also provide habitat for plants, wildlife and aquatic life.

The largest challenge to protecting area Lakes is the threat of untreated runoff from impervious surfaces and developments. Soil erosion, in particular, is the single greatest source of pollution to Lovell Lake. Soil contains the nutrient phosphorus, which has the potential to promote algae blooms when it enters a lake in large quantities. As the algae die off, the water becomes depleted of oxygen, affecting fish and animals that depend on the lake water.

September 2008, in an effort to address this concern, a team of 32 local volunteers and technical staff from the Lovell Lake Association, Acton Wakefield Watersheds Alliance, York County SWCD, NH DES, and Maine DEP conducted a survey of the watershed and identified 161 sites that are contributing polluted runoff to Lovell Lake. Teams documented polluted runoff sources from roads, properties, driveways, and shorelines using cameras and standardized field data sheets. Survey results and recommendations were compiled in the Lovell Lake Watershed Survey Report.

The survey teams identified 161 sites that were either impacting or had the potential to impact water quality in Lovell Lake. Ten of the 38 sites associated with roads were along Brackett and Pond roads as well as many driveway and residential sites that were a result of water flowing off of those roads. Many of the residents along Brackett and Pond roads have developed strategies to prevent their driveways and properties from washing into the lake and the AWWA Youth Conservation Corps has installed erosion control measures at nine associated properties but the problem must be managed at the source.

In 2010, AWWA was awarded a NHDES Watershed Assistance grant to undertake some of the recommendations from the Plan including partnering with the UNH Stormwater Center to find solutions to the chronic drainage problems along Brackett and Pond roads. This report is intended as a guide for Wakefield town officials and the Public Works department as they set priorities for road maintenance projects throughout the Town.
INTRODUCTION

Many of the unimproved roads used today were designed with very different considerations than new roadways. Most have evolved from primitive trails and pathways once used by early settlers. As needs and traffic increased, these paths became roads which were gradually improved with gravel or crushed stone. For the most part, designs and maintenance were simple and minimal. Repairs and improvements would be in response to complaints or damage from erosion from large storm events with the primary goals of elimination of ruts, stabilization of surfaces and eliminating mud. As development, population and tourism have increased, roads are exposed to ever-increasing weights and volumes of traffic. This in combination with increasingly intense rain events has resulted in an increased need for road maintenance and reconstruction budgets.

The development and implementation of a Road Management Plan is a means for controlling and managing the increased demands pro-actively. This process can reduce expenditures associated with frequent maintenance by identifying and targeting problem areas for drainage improvements. This process can also reduce the impacts to the lakes and streams, a central component to the surrounding communities. Studies have shown that erosion from gravel roads can account for more than 80 percent of the sediment threatening water quality (Van Lear, et al. 1995, Reidel 2003).

Resources to better manage gravel roads are plentiful. This report references two primary manuals, the Gravel Road Maintenance Manual (MEDEP 2010), and the Gravel Roads Maintenance and Design Manual (USDOT, 2000). Recent guidance prescribes a general approach involving stabilized ditches, use of sedimentation basins, and sizing drainage infrastructure such that it can adequately convey large storm events without overwhelming the system and causing severe destabilization and washout. Other examples may include regrading road profiles/elevations to support natural drainage patterns, stormwater conveyances above and below the surface of roadways, and improving and stabilizing channels and ditch maintenance procedures (Scheetz and Bloser 2008).

Historically, common road design for unimproved roads was basic, and simply conveyed water off and into roadside ditches, eventually to streams and surface waters (Figure 3). Ditches may not have been stabilized, and may or may not have included the use of culverts and catch basins. Without the use of culverts and catch basins, drainage is left to wash over road surfaces, and pond in low lying areas. Concentrated flow over the gravel surfaces can lead to road washout, and the need for frequent maintenance. Poor drainage in low areas can result in ponded areas, flooding, muddy surfaces, and impeded travel.

Common maintenance of roadside ditches involves the cleaning and removal of accumulated materials including leaves, sediment, and vegetation which reduce the capacity for roadside conveyance. Ditch clearing is commonly performed by the excavation of materials with a backhoe. However, the removal of materials, while improving the conveyance for the short-term, typically leaves behind unstabilized channels prone to erosion. Where the vegetation has been removed, the channel sidewalls cut steeply, and large armor stone removed, channel erosion will occur.
Unimproved roads and ditch maintenance practices have resulted in tons of sediment being deposited into streams and lakes, in addition to requiring significant amounts of ongoing maintenance. In addition to increased sediment loading, the majority of phosphorus loading is generally associated with runoff from impervious areas. Nutrients, such as phosphorus, are often attached to road sediments, and is often an increased concern with unimproved gravel roads. This was shown in a total phosphorus budget that was conducted for the Lake George Watershed in New York. The budget showed that 43% of all the phosphorus that entered the lake was from the developed areas which accounted for only 5% of the land area within the watershed (Waterkeeper 2008). In Wakefield, which is less developed than Lake George, 16% of the phosphorus comes from developed areas, which account for 4% of the land area in the watershed (AWWA 2010). A large majority of phosphorus is associated with sediment and can thus be controlled by sediment reduction.

The strategies recommended in the RMP include a focus on practical road maintenance techniques, road and drainage improvements, and non-structural approaches focused on stabilization of erodible soils. These strategies include: 1) establishing stable, adequately sized drainage, 2) with upstream sedimentation structures (i.e. hooded deep sump catch basins, gravel check dams), 3) installation of road crossings for surface runoff, 4) use of water quality controls post culvert that could filter, infiltrate and dissipate high velocity flows, and 5) stabilized conveyance to the lake.
Steps in the Road Management Plan Process

The general approach and methodology used in this study is outlined in this section.

1. **Inventory of roads:** An initial inventory was taken of the infrastructure and drainage controls associated with Brackett Road. This included man-made and naturally evident drainage paths, approximations of total sub-drainage areas and general site characteristics such as slope and distance to receiving water bodies.

2. **Assessment of road condition:** Multiple field trips and site trips were planned during and immediately following large rain events. Drainage patterns were documented and potential for erosion examined. Thirteen potential sites were identified as in need of general repair or reconstruction. Assessments for pollutant load contributions were then calculated for each area.

3. **Selection of appropriate treatment strategies:** Planning level treatment strategies were developed for the thirteen identified locations. Strategies were selected based on their relative cost effectiveness, treatment effectiveness and long term manageability.

4. **Prioritization scheme:** Cost projections and pollutant load reduction assessments were also conducted in order to prioritize areas in need of attention. Planning level solutions,
costs, and treatment efficiencies were developed for all locations and prioritized in this report according to the following criteria:
   a. Ranked by existing load
   b. Ranked by load reductions
   c. Ranked by cost

**LONG-TERM MAINTENANCE OF ROADSIDE DRAINAGE IMPROVEMENTS**

The following recommendations are included for maintenance of roadside drainage. Routine maintenance and the inclusion of sedimentation and erosion control practices is an essential element of long-term reduction in sediment load. The goal of ditch maintenance practices is to minimize disturbance of soils, and when excavation is needed, to employ appropriate stabilization methods.

1. Continued stabilization of roadside ditches through vegetation and stone, and gravel check dams
2. Application of hydroseed following road ditching practices to minimize unstabilized soils.
3. Removal of leaf-litter with leaf vacuums in manner that minimizes unstabilized soils
4. Removal of sediment from sedimentation basins, deep sump catch basins, and check dams.

**OPPORTUNITIES FOR IMPROVEMENTS FOR REDUCTION OF SEDIMENT LOAD**

Structural methods and strategies for reduction of sediment load focus on the following approaches:

1. The use installation of deep sump catch basins installed with hooded outlets as a pretreatment mechanism
2. Stabilized conveyance across/under roadways
3. Application of sedimentation/infiltration basin/filtration for volume reduction
4. Application of energy dissipater
5. Stabilized conveyance to surface waters through the application of hydroseed and stone stabilization.

These practices prevent the substantial and continued accumulation of sediment through erosion of unstabilized areas. In addition, sediment removal and volume reduction practices are added. Volume reduction for small storms is a relatively simple practice. For this region, 50% of storms are less than 0.17 inches in depth, and 75% are less than 0.45 inches in depth\(^1\). Sizing infiltration practices for small storms can reduce the impact from the vast majority of rainfall events.

---

\(^1\) Based on a frequency analysis of Durham daily rainfall data from 1926-2003.
ROAD MANAGEMENT IMPROVEMENTS

1. Crowning of roads to upslope side
2. Paving of chronic problem and high grade areas
3. Regrading and Resurfacing
4. Road materials characterization and composition for road base and road surface

ROAD INVENTORY AND CONDITIONS ASSESSMENT

The Brackett and Pond Roads inventory and conditions assessment were performed on multiple occasions during 2009, 2010, and 2011. Initial review was done in collaboration with an AWWA conditions assessment for problem areas as part of the YCC efforts. The UNHSC returned to do an inventory and assessment during a 2.75”² storm event on August 25, 2010, and returned on multiple occasions in 2011 to detail site specific improvements. During the August 2010 rainfall event, significant erosion and runoff were observed.

Thirteen priority locations were identified. Locations and conditions assessment are provided in Table 1 and Figure 5.

Methods Description

The inventory and conditions assessment was performed during a significant rain event in August 2010 to identify problem areas. During this time, both Brackett and Pond Roads were driven along their complete length. The predominant areas of concern were identified and a basic conditions assessment performed. The conditions assessment is consistent with criteria developed from the Penn State University Dirt & Gravel Roads Center, developed to identify and rank erosion control problem areas. The assessment included the following items: photo-documentation, site description, estimate of the immediate unstabilized drainage area (stabilized areas were not included such as forested or landscaped areas), discharge location (ie. stream, lake, forested area, eroding channel, etc), slope and distance to the discharge location, land use, evidence of past erosion, and an initial attempt at prioritization.

2 Recorded on 8/24/10- 8/26/10 in Durham, NH at the UNH Weather Station, http://www.weather.unh.edu/
Figure 5: Locations of Road Inventory and Conditions Assessment for Brackett and Pond Roads, Lovell Lake
### Table 1: Road Inventory and Assessment with Estimated Annual Sediment Load

<table>
<thead>
<tr>
<th>Location</th>
<th>Approx Road Drainage Area (ft²)</th>
<th>Approximate Drainage Area Description</th>
<th>Discharges to</th>
<th>Slope/Distance to water or forest</th>
<th>Estimated annual TSS load (lbs/yr)</th>
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<tr>
<td>#BR001</td>
<td>2,300</td>
<td>Lovell Lake</td>
<td>30° &lt; = 50 ft to Water</td>
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<tr>
<td>#BR002</td>
<td>34,500</td>
<td>Lovell Lake</td>
<td>Variable-Very Steep &gt; 15%</td>
<td>8,939</td>
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</tr>
<tr>
<td>#BR003</td>
<td>4,400</td>
<td>Lovell Lake</td>
<td>75 ft</td>
<td>760</td>
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<tr>
<td>#BR004</td>
<td>60,000</td>
<td>Natural Drain Path to Lake</td>
<td>~ 10% Roughly 300 ft</td>
<td>10,364</td>
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</tr>
<tr>
<td>#BR005</td>
<td>35,000</td>
<td>Lot 524 &amp; to Lovell Lake</td>
<td>Variable Steepening Slope Through 524 BR</td>
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<td>#BR007</td>
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<td>Totals</td>
<td>261,000</td>
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<td>55,612</td>
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</tbody>
</table>
Detailed Inventory Description

BR001: 405 Brackett Road

Figure 6: BR001 Roadside Drainage Issues and YCC Remedies; (Left) Stabilized Hillside; (Right) Infiltration Steps

Problem:
AWWA noted that historic erosion and flooding is occurring opposite the property located at 405 Brackett Road (identified as “Lot #11”). This location drains approximately 2,300 ft² of area and is moderately to steeply sloped. Much of the area is a gravel driveway on a steep slope draining onto a paved portion of Brackett Road, before continuing downhill across more unstabilized areas, and entering the lake. The property owner, Mark Duffy, at 405 Brackett Road was a Project Host for the 2010 Youth Conservation Corps (YCC) (AWWA 2010).

Solutions:
In 2010, the AWWA Youth Conservation Corps constructed a new stairway with infiltration steps. The steps were backfilled with ¾” stone and 6-8” rip rap stone around the perimeter to stabilize primary erodible areas (Figure 6). The installation is working well and has stabilized the immediate area. Two additions are recommended: 1) a final stone lined conveyance from the bottom of the stairs to the lake, 2) the construction of a stabilized high-flow bypass around the stone berm to channel larger flows down one side of the berm and to the lake.

BR002: Lovell Heights and Brackett Road Crossing

Problem:
At the Lovell Heights Road Crossing, two large culverted drainages converge. During the August 2010 inspection, both drainages were observed to be eroding heavily and discharging
very high sediment laden water to Lovell Lake. The ditches and the large area of unimproved gravel roads intersecting Brackett Road are a major source of sediment that collects at the discharge point to the Lake. Both road crossings appear to be undersized resulting in substantial scour at each outlet. In addition both of the culverts outlets are perched, or raised from the channel bed due to scour. The perched outlet disconnects the perennial stream from any upstream fish migration. Perched culverts degrade habitat by causing further erosion and preventing passage for aquatic organisms. This location drains approximately 11,500 ft² of unstabilized private road area and is very steeply sloped. Long term and short term remediation strategies are discussed. Short term strategies involve using existing culverts under Brackett Road and adding additional stabilization and sedimentation structures. Long term strategies involve replacement of the existing culverts with larger open bottom box culverts as there is ample evidence that larger storm events overwhelm the culverts and wash over the roads creating conditions for severe erosion and wash out.

**Recommended Solutions:**
The following recommendations are offered for this location:

**Short-Term Improvements: Lovell Heights Road**
- Road and channel stabilization
- Installation of an off-line deep sump sedimentation basin at the base of Lovell Heights Road to provide treatment of sediment prior to discharging to the culvert. Discussions with the road agent indicated that historically a catch basin once existed in this location and had either been paved over or filled with sediment such that it no longer functions.
- Energy dissipation structures that slow flows allow for settling of sediment and reduce erosion.
**Short-Term Improvements: 425-429 Brackett Road**

- Road and channel stabilization. Including the extension of pavement from Brackett Road approximately 15 feet up the private road to create a speed bump to divert water to north side of the road into a sedimentation basin.
- The sedimentation basin would provide treatment of sediment diverted from the diversion, to a culvert, into the southern upstream side of the receiving stream.
- Energy dissipation structures that slow flows and allow for settling of sediment and to reduce erosion.

**Long-Term Improvements**

- Road crossing improvements: open bottom culvert or arch structure
- Paving of upgradient roads

Long-term improvements are not included in the cost estimates to follow. They are for future consideration as they are more costly and significant water quality improvements can be gained in the short-term without these road crossing improvements. However, it was noted that the road overtopping during large events results in substantial erosion around the road and hillside. These improvements are considered a high priority.

**BR003: 501 Brackett Road**

![Figure 5: Erosion along a private boat landing and beach (Left) and roadside (Right) at 501 Brackett Road.](image)

**Problem:**

At this location stormwater runoff from portions of Brackett Road runs along both sides of the paved road and down to the lake along the Martell Family campground, private beach, and boat landing. There are two primary areas of focus: the picnic area and beach access/boat landing area. The Martell family have done a tremendous amount of work regrading and stabilizing a grassed picnic area to the south of the landing. Through the use of infiltration terraces the owners have effectively reduced substantial erosion from this location. This area has the potential to be a good demonstration site highlighting homeowner practices that can be utilized on other private properties in the area. The beach access and boat landing area is heavily eroded and currently and lacks adequate drainage. Evidence of substantial sand deposits within Lovell Lake are visible. This location drains approximately 4,400 ft² of area and is moderately to steeply sloped.
Recommended Solutions:
Recommendations for this location are practical and simple. They include:

- Installation of an infiltration swale and perforated drainline on the downslope side of Brackett Road within the public right away.
- At the outlet of the drainline and at the private boat landing, the installation of a culvert and infiltration trench is recommended to provide stabilized drainage to the stream.

BR004: Near Sunshine Acres, Brackett Road

![Figure 8: (Left) A heavily eroded drop inlet and (Right) sediment laden runoff at outlet near Sunshine Acres Campground, Brackett Road](image)

Problem:

At this location an existing drop inlet on the uphill side of Brackett Road drains roughly 60,000 square feet of area including 2 shared driveways with 5-6 houses each. Substantial erosion is occurring from driveways and roadside drainage. A heavily eroding installation of a drop inlet connects to a culvert which crosses under the road. The drop inlet is a safety hazard. The culvert discharges to a naturally forming swale through a wooded area along the property boundary perimeter, and to a constructed swale, past a gas trailer, and into the lake. This location drains approximately 60,000 ft² of area and is moderately to steeply sloped.

Recommended Solutions:
- Within the public right of way, the installation of a new hooded deep sump catchbasin is proposed to replace the degraded drop inlet. The culverted road crossing should be re-evaluated for sizing, and potential replacement.
- Working with private property owners, it is recommended that a swale (stabilized with vegetation and stone) and an infiltration basin in combination with energy dissipation be installed to provide stabilized drainage to the lake.
- Working with the private property owners and the YCC to identify runoff reductions from the 2 shared driveways. There is substantial runoff volumes from these areas. Infiltration
trenches, raingardens, and rubber razors are recommended to prevent runoff from becoming concentrated.

BR005: 524 – 536 Brackett Road

Figure 9: Evidence of heavy erosion down a private driveway at 524 – 536 Brackett Road.

**Problem:**
At this location, runoff channels along Brackett Road from the uphill drainage area along the side of the road. At a low point runoff flows across the road to the downhill side eroding a channel down a private driveway (524 Brackett Road). There is evidence that the Road area in front of 524 Brackett Road has been repeatedly replaced. This location drains approximately 35,000 ft² of area and is moderately to steeply sloped.

**Recommended Solutions:**
- The installation of a stabilized swale and road crown to the uphill side of the road is recommended. This will need to be done in partnership with private property owners as Project Hosts.

BR006: 629-654 Brackett Road

**Problem:**
At this location water discharges from a large detention basin at 629 Brackett Road down a steep slope and to a corrugated metal pipe underneath the driveway. Water flows along the road, predominantly on the uphill side, and eventually crosses the road (BR007) through a culvert and to the lake. A small fraction of the runoff does flow along the lake side of the road and down the driveway of a house located at 654 Brackett Road.
Figure 10: (Left) Detention pond with recommended addition of outlet structure at 629 Brackett Road; (Right) Eroded area along the uphill side of the road at 629-654 Brackett Road.

Recommended Solutions:
- The addition of an outlet control structure to provide a slow release from existing detention pond.
- The installation of a stabilized swale is recommended within the public right of way to provide drainage.
- An energy dissipater and infiltration basin is recommended for the swale outlet.

BR007: 654 Brackett Road

Figure 11: (Left) Roadside swale; (Center) Sheet flow and poor road crow to downhill; (Right) Swale running from culvert to Lake adjacent to 654 Brackett Road.

Problem:
At this location a deep cut swale has formed on the uphill side of the road with evidence of erosion on steep near vertical side slopes. The poorly crowned road carries runoff across the road.
to the downhill side. Currently a damaged corrugated metal pipe has been installed in front of the property at 654 Brackett Road and travels under the road at low elevation and slope. The existing pipe discharges to a small wooded area between two private properties and then flows down a steep grade to the lake. This location drains approximately 32,000 ft2 of area and is steeply sloped.

**Recommended Solution:**
- Improvement of road crown to uphill side and stabilization of roadside swale.
- The installation of a hooded deep sump catchbasin is proposed within the public right of way. This will stabilize the culvert inlet and provide sediment removal.
- The existing drainage should be evaluated for proper sizing and considered for replacement as needed
- A swale stabilized with vegetation and stone is recommend and along the steep slope to provide drainage to the lake. This will entail working with private property owners to host the project.

**BR008: 714 Brackett Road**

![Figure 12: (Right) Runoff and ponding at location in need of culvert; (Left) Sheet flow across a private driveway to a small swale at 714 Brackett Road.](image)

**Problem:**
At this location water runs along a shallow roadside ditch on the upper side of the road, pools, and flows across the road at a low elevation opposite 714 Brackett Road. Substantial ponding water occurs at the low point in the road and the access point to the two driveways. Water then
flows along a homeowner constructed berm across the driveway and down a small constructed swale through a wooded area. The swale empties into the backyard of a private residence, depositing sand, and then sheet flows over unstable soils to the lake. This location drains approximately 6,500 ft² of area and is moderately to steeply sloped.

**Recommended Solution:**
- The installation of a stabilized ditch on the uphill side to the road, leading to a hooded deep sump catch basin.
- The installation of a culvert underneath the roadway, from the catch basin within the public right of way
- Improvement of the existing swale, stabilized with vegetation and stone, is recommend and along the steep slope, and across the homeowners yard, to provide drainage to the lake. This will entail working with private property owners to host the project.

**BR009: 726 and 740 Brackett Road**

![Figure 13: Area showing need for drainage underneath roadway at 726 Brackett Road](image)

**Problem:**
At this location water flows along a roadside ditch along the uphill side of the road and pools in low lying area before crossing to a small step pool constructed on private property in front of 726 Brackett Road. Water then flows along a small constructed swale through a wooded area down a moderate slope and to the lake. This location drains approximately 7,100 ft² of area and is moderately to steeply sloped.

**Recommended Solution:**
- The installation of a stabilized ditch on the uphill side to the road, leading to a hooded deep sump catch basin.
- The installation of a culvert underneath the roadway, from the catch basin within the public right of way
• Improvement of the existing step pool and swale, stabilized with vegetation and stone, is recommend and along the steep slope, and across the homeowners yard, to provide drainage to the lake. This will entail working with private property owners to host the project.

BR010: Between 772 – 758 Brackett Road

![Figure 14: Shared private driveway showing evidence of heavy erosion.](image)

**Problem:**
At this location water flows down shallow ditch along the uphill side of the road and down a shared driveway. Wooden razors are located at two locations across the shared driveway that provides some flow conveyance toward the road edge. However there is evidence of heavy erosion indicating these measures are often overwhelmed. This location drains approximately 3,600 ft2 of area and is moderately sloped.

**Recommended Solution:**
• The installation of a stabilized ditch on the uphill side to the road, leading to a hooded deep sump catch basin.
• The installation of a culvert underneath the roadway, from the catch basin within the public right of way
• An alternative could involve re-crowning the road to better direct drainage to the lakeside road edge combined with the development of a stabilized swale to convey water across the private driveway entrance and to a constructed infiltration area.
• Either approach will entail working with private property owners to host the project.
BR011: Roadway running downhill to 1023 Brackett Road

Figure 15: Erosion down and along the road is evident in a storm event

Problem:
At this location water runs along approximately 20,000 ft² of unimproved gravel road. Substantial erosion down the roadway is evident.

Recommended Solution:
- Recrowning of the roadway such that the entire road section drains to the uphill side.
- Installation of a stabilized swale to convey water off the road and along the uphill edge to a forested location associated with BR012 within the public right of way.
- Installation of an infiltration area and level spreader into the wooded area below.
BR012: Forested area uphill and across from 1023 Brackett Road

![Forest Area Image]

Figure 16: Ditch turnout that could be reconstructed as sedimentation basin treat road runoff

**Problem:**
At this location water runs along approximately 20,000 ft² of unimproved gravel road where significant erosion is evident. The area is moderately to steeply sloped.

**Recommended Solution:**
- In combination with improvements associated with BR011, construction of a sedimentation and infiltration area is recommended.
- The infiltration area would have a high flow bypass or spillway in combination with a level spreader berm.

BR013: End of Brackett Road, beginning of Pond Road.

![End of Road Image]

Figure 17: (Left) Erosion down and along several thousand feet of road; (Right) Substantial runoff and erosion leading to small perennial stream at junction of Brackett and Pond Roads.
Problem: At this location water runs down a moderate slope along approximately 25,000 ft² of unimproved roadway. Large unstabilized areas generating runoff are visible on private property. The runoff eventually discharges into a perennial stream that travels toward Lovell Lake. The road crossing appears to be undersized resulting in substantial scour at the outlet of the 4’ diameter culvert. The culvert outlet is perched, or raised from the channel bed due to scour and disconnects the perennial stream from any upstream fish migration.

Recommended Solution:

Short-Term Improvements
- Re-crowning of the roadway such that the entire road section drains to the uphill side.
- Within the public right of way installation of a stabilized swale to convey water off the road and along the edge of the road.
- There are undeveloped forested locations along the road where a sedimentation and infiltration area could be constructed.
- Installation of a hooded deep sump catch basin
- Culvert installation to convey runoff across Roberts Cove Road and to the perennial stream.

Long-Term Improvements
- Road crossing improvements: open bottom culvert or arch structure

Long-term improvement is not included in the cost estimates to follow. They are for future consideration as they are more costly and significant improvements can be gained in the short-term without these improvements.

PR001: 240 Pond Road

Figure 18: A perennial stream cascading down a steep slope to a culvert crossing on Pond Road.

Problem: At this location a perennial steam flows down an extremely steep slope to a sharp turn in the road adjacent to 240 Pond Road. There is a small natural depression where water collects
before passing under the road through two recently replaced HDPE culverts. The watershed area is large and has not been calculated. This location has a history of over topping and periodic road washout. This site is not a substantial sediment load. The quality of water at this location is very high.

**Recommended Solution:**

- The existing drainage should be evaluated for proper stream crossing and sizing.

**PR002: 358 Pond Road**

![Figure 19: Area showing need for drainage along a steep hill on Pond Road](image)

**Problem:**
At this location water flows down shallow ditches along both sides of the road. The uphill side of the road empties into a small unmaintained culvert inlet and under the road to a forested area beside 358 Pond Road. This location drains approximately 6,600 ft2 of area and is steeply sloped.

**Recommended Solution:**

- Recrowning of the roadway to the uphill side.
- The installation of stabilized ditch on the uphill side to the road, leading to a hooded deep sump catch basin.
- Installation of an infiltration area and level spreader into the wooded area below.

**COST ESTIMATES**

Cost estimates have been prepared for each of the locations identified in the road inventory (Table 2). Cost estimates were done on two levels, first for materials, and second for labor and equipment. Labor and equipment costs are anticipated to be internalized into existing operations. Labor costs are based on an estimated 2 person work team, equipment time is based on the use of 1 piece of heavy equipment (typically a backhoe or dump truck) and an operator. The labor was
Table 2: Cost Estimates for Recommended Improvements for Materials, Equipment, and Labor

<table>
<thead>
<tr>
<th>Location</th>
<th>Materials Cost</th>
<th>Labor (days)</th>
<th>Equipment (days)</th>
<th>Labor and Equipment Cost</th>
<th>Grand Total</th>
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<td>8.0</td>
<td>$20,800.00</td>
<td>$26,840.00</td>
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<td>2.0</td>
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<td>$6,350.00</td>
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<td>4.5</td>
<td>$12,900.00</td>
<td>$16,630.00</td>
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<td>$11,410.00</td>
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<td>$23,830.00</td>
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<td>6.0</td>
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<td>$19,990.00</td>
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<td>7.0</td>
<td>$18,600.00</td>
<td>$22,310.00</td>
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<td>2.5</td>
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<td>$7,580.00</td>
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<td>Cumulative Total</td>
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<td>Multiplier (25%)</td>
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<td></td>
<td>$211,125.00</td>
<td>$267,640.00</td>
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</table>

based on 8 hour days at $50/hr including wage and benefits. Equipment cost was estimated at $1800/day for one piece of heavy equipment and 1 operator. The total estimated time and labor component for all of the recommendations is 71 days for full installation with a materials cost estimate of $56,600. At approximately 1 day per week dedicated to BMP improvements, the projects could be implemented in less than 2 years. Recommendations could be implemented with existing personnel or as services for hire.

The inventoried locations are further ranked by load and cost in Table 3.

**POLLUTANT LOAD ESTIMATES**

Pollutant loads from identified areas were estimated using the information gathered in the road inventory process. Estimates of sediment and phosphorus load were calculated using the Simple Method to Calculate Urban Stormwater Loads. This method is ideal for planning purposes as it requires readily available information with respect to land use and rainfall. While actual loads may be different, the Simple Method is a reasonable approach for estimating both pollutant load, and in particular for comparison of different best management practices, for examination at the watershed and subwatershed scale. The Simple Method estimates contaminant loads based on land use, annual runoff, drainage area, and system performance. It does not factor in volume reductions for infiltration.

\[ L = 0.226 \times R \times C \times A \times RE \]

\( L \) = Annual load (lbs)
\( R \) = Annual runoff (inches)
\( C \) = Pollutant concentration (mg/l)
\( A \) = Area (acres)
0.226 = Unit conversion factor
\( RE \) = Best Management Practice removal efficiency (%)
Treatment Strategy Performance

Table 3: Treatment Performance of Recommended Strategies for Sediment and Phosphorus

<table>
<thead>
<tr>
<th>Treatment Strategy</th>
<th>TSS Removal Efficiency</th>
<th>TP Removal Efficiency</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Basin</td>
<td>50%</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>Catch Basin</td>
<td>9-10%</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>Infiltration Basins</td>
<td>85-90%</td>
<td>65-85%</td>
<td>2, 3</td>
</tr>
<tr>
<td>Stilling Basin</td>
<td>5-17%</td>
<td>NA</td>
<td>4</td>
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<tr>
<td>Bioretention</td>
<td>85-97%</td>
<td>34-85%</td>
<td>1, 5</td>
</tr>
<tr>
<td>Infiltration Trenches</td>
<td>85-90%</td>
<td>60-85%</td>
<td>2, 3</td>
</tr>
<tr>
<td>Dry Well</td>
<td>85%</td>
<td>85%</td>
<td>3</td>
</tr>
<tr>
<td>Vegetated/grassy swales</td>
<td>30-90%</td>
<td>29-43%</td>
<td>6, 7, 9</td>
</tr>
<tr>
<td>Porous Pavement*</td>
<td>85%</td>
<td>85%</td>
<td>3</td>
</tr>
</tbody>
</table>

*With infiltration bed
References include (1) UNHSC, (2) (McCarthy 2008), (3) (DEP 2006), (4) (McLaughlin 2008), (5) (NJDEP 2004), (6) (Storey et al. 2009), (7) (Zhang et al. 2009), (8) (Claytor and Schueler 1996)

Prioritization by Load and Cost

From this, the top 7 locations are identified to account for 79% of the total sediment load (44,000 lbs per year) from the priority locations. These 7 locations are estimated to cost $28,300 in materials for associated improvements. The rankings are listed in Table 4.
Table 4: Table of Inventory Ranked by Estimated Sediment Load, Reductions, and Cost

<table>
<thead>
<tr>
<th>Location</th>
<th>Approx Road Drainage Area (ft²)</th>
<th>Estimated annual TSS load (lbs/yr)</th>
<th>Estimated annual TSS load post tx (lbs/yr)</th>
<th>RE%</th>
<th>Cost</th>
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<tbody>
<tr>
<td>#BR004</td>
<td>60,000</td>
<td>10,364</td>
<td>1,178</td>
<td>89%</td>
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</tr>
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<td>9,069</td>
<td>1,284</td>
<td>86%</td>
<td>$4,880.00</td>
</tr>
<tr>
<td>#BR002</td>
<td>34,500</td>
<td>8,939</td>
<td>1,016</td>
<td>89%</td>
<td>$6,040.00</td>
</tr>
<tr>
<td>#BR007</td>
<td>32,000</td>
<td>8,291</td>
<td>1,174</td>
<td>86%</td>
<td>$1,910.00</td>
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<tr>
<td>#BR011/12</td>
<td>20,000</td>
<td>5,182</td>
<td>990</td>
<td>81%</td>
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<tr>
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<td>25,000</td>
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<td>268</td>
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<tr>
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<td>Totals</td>
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<td>55,612</td>
<td>6,919</td>
<td>90%</td>
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</table>

*Costs are planning level estimates of materials only. Labor and equipment are not included.
RECOMMENDED STRATEGIES

This section provides general information on long term maintenance and improvements to unpaved gravel roads. It includes practical tools and details on many of the strategies discussed in the Road Management Plan including ditching, crowning, road surface materials, and other road maintenance practices. It should be used as a general reference when more information is required.

The following recommended strategies include 1) Road maintenance, 2) Structural strategies in the form of drainage improvement, and 3) non-structural strategies such as regulations and ordinances, the role and formation of road associations, and preservation of vegetated buffers to protect surface waters.

Road Maintenance

Erosion and Sedimentation Control in Roadside Ditching Practices

Maintenance of roadside conveyance is an essential component of road maintenance. If conveyance of roadside ditches is reduced, erosion and damage to roadways can occur. However, the practice of roadside ditching in the absence of proper stabilization and erosion and sedimentation control can be a significant source of sediment. Erosion and sedimentation control measures should be used where maintenance activities involve ditching, clearing, or excavation resulting in unstabilized soils. A list of recommended practices for road managers and DOT maintenance staff is listed below (AASHTO 2004). Practices focus on ditch, channel, and inlet and outlet protection, and revegetation of disturbed or bare areas, and the use of sedimentation control practices as needed.

- Use temporary vegetation to provide immediate ground cover until permanent landscaping is in place. It is desirable to re-seed and mulch any disturbed areas at the end of the day.
- Other erosion control measures (such as silt fence, check dam, etc.) should be installed prior to commencing work and left in place and maintained until the site is stabilized.
- Areas should be re-vegetated with native seed mixes that require minimal care.
- Temporary structural erosion control measures should be installed when cleaning culverts or cleaning ditches that discharge into streams, wetlands, lakes or ponds.
- When cleaning ditches, temporary check dams should be used wherever they are necessary and placed so that the crest of the downhill dam is at the same elevation of the toe of the uphill dam.
- Check dams should be left in place until the ditch is re-vegetated.
- Temporary sediment traps should be placed at the inlet of a culvert that drains into a stream, wetland or other water body. Sediment traps should be constructed by excavating an additional 1/3 meter (one foot) below the ditch invert for a distance of six meters (20 feet).
- After the project site is stabilized, any accumulated sediment should be removed before removing check dams.
To improve habitat and reduce erosion, consult with the environmental staff regarding incorporation of appropriate soil bioengineering practices, such as live willow cuttings/stakes/posts and live willow wattles to stabilize disturbed and/or eroding stream banks.

- Sediment control structures should not be placed in streams
- The smallest practicable work zone is cleared to minimize erosion
- Length and steepness of slopes should be minimized. Place terraces, benches, or ditches at regular intervals on longer slopes.
- Maintain low runoff velocities in channels by lining with vegetation, riprap, or using check dams at regular intervals, in addition to minimizing steepness and slope length.

Recommended Equipment

The following is a list of recommended equipment for use in road maintenance practices. Descriptions include approximate costs of purchase of equipment. One alternative to purchasing equipment, common for municipalities, is to hire the service out. Many of these services are relatively inexpensive.

**Hydro-Seeder**
The use of a Hydro-seeder is recommended for vegetative stabilization after the maintenance and clearing of roadside ditches. Hydro-seeders are available as truck bed mounted system and tow-behind systems on trailers. These prices vary with respect to the quantity and type of mulches they are capable of spreading. Tow behind systems range from $5,000 - $30,000. Truck bed mounted systems by range from $10,000 - $14,000.

**Leaf Removal Equipment**
The use of a leaf-vacuum is recommended as an alternative to excavation of leaf materials from roadside ditches. The use of an excavator while effective for removal of materials creates unstabilized channels by continually disturbing ditches and not allowing vegetative stabilization. Tow-behind leaf vacuums systems from range from $1,500 - $3,000.

**Catch Basin Cleaners**
The cleaning and removal of sediment from deep sump catch basins will need to occur routinely. Vactor trucks costs are on par with typical large vehicles. Costs for vactor trucks begin at $125,000 and range upwards. Alternatively, catch basin cleaning is commonly hired out, and can be completed typically around $50-100 per catch basin.

Road Materials

This section excerpted from the York County Soil and Water Conservation District publication on Camp Roads (2007).

There are three basic types of soil: gravel, sand, and fines (listed in order from largest to smallest particle size). Gravel and sand particles are readily distinguishable to the naked eye. Fines (silts and clays) are generally comprised of particles too small for the eye see. Each soil type has specific properties that make it best for different aspects of road building. Gravel is very durable and drains freely. Sand also drains efficiently. Fines pack and bind well and they help shed water, because they do not drain well (YCSWCD 2007).
Road base material should be:

- Somewhat coarser than the road surface material (3”-4” maximum particle size); and
- 0 to 7 percent fines (this promotes subsurface drainage).
- The base layer should be 18 inches or thicker.
- Road surface material needs to pack well, be durable, and shed water.

Road surface materials should be:

- A maximum particle size of 2 inches (for a smooth ride) and
- 7 to 12 percent fines (to pack well and shed water).
- The surface layer should be about 4 to 6 inches thick.

**Crowning and Grading**

*This section excerpted from the York County Soil and Water Conservation District publication on Camp Roads (2007).*

Road crowning and grading are the primary means by which surface water is drained off the road surface. To crown a road means to create a high point that runs lengthwise along the center of the road. Either side of this high point is sloped gently away from the center toward the outer edge of the road. Crowning is the quickest way to get water off the road, preventing significant erosion of the road surface. An insufficient crown will allow water to puddle on the road surface; this will create potholes or erode the road surface. The potholes will continue to grow each time a vehicle splashes through them, resulting in the loss of fine clay particles that are necessary for a good road surface. Standing water will also seep into the roadbed, weakening the road and making it susceptible to tire rutting. Proper grading will prevent potholes from forming and provide a safer surface for travel. Figure 20 below shows how crowning promotes surface water drainage (YCSWCD 2007).

![Figure 20: Crown profile (YCSWCD 2007).](image)

Grading is the process of smoothing and crowning a gravel road. This practice involves using a grader with a steel cutting blade to redistribute soil material. The grader is the most frequently used piece of equipment for general camp road maintenance. It can be very versatile when used
by an experienced operator. Regular grading is an effective means of redistributing ridges of road material that has either been washed to the road edge or has been pushed to the edge by vehicle traffic. These little ridges will defeat the purpose of crowning by catching water before it can drain off the road (Figure 21), and channeling it along the outer edge of the road surface. This problem has the potential to cause severe damage to a road surface during periods of heavy rain. Always make sure that water can get off the road by smoothing the edge of the road with the grading blade. Usually, camp roads are regraded by scraping this material from the outer edge of the road, and pulling it back into the center (YCSWCD 2007).

![Figure 21: Sand and vegetation build-up prevents drainage to sides of road(YCSWCD 2007).](image)

**Dust Control Strategies**

*This section excerpted from the York County Soil and Water Conservation District publication on Camp Roads (2007).*

Dusty conditions occur when a road surface has dried out. Soil fines can actually shrink due to moisture loss which, in turn, loosens and weakens the road surface and cause a loss of soil fines, which are essential in maintaining the integrity of a gravel road surface. Soil fines are the binders that hold the road surface material in a tight, hard mass. The fewer the fines, the looser the gravel, which adversely affects traction and can result in erosion (YCSWCD 2007).

**Chemically Treated Roads**

*This section is an excerpt from the Wyoming Technology Transfer Gravel Roads Management Manual (2010).*

A chemically treated unsealed road has had dust suppressant (other than water) or soil stabilizer added to it recently enough to bind together or significantly alter the road’s surfacing material from its original, untreated state (Wyoming Technology Transfer Center 2010).

All gravel roads will give off dust under traffic. After all, they are unpaved roads that typically serve a low volume of traffic, and dust is usually an inherent problem. The amount of dust that a gravel road produces varies greatly. In areas of the country that receive a high amount of moisture, the problem is greatly reduced. Arid or semi-arid regions such as the desert southwest...
and much of the great plains region in the USA are prone to long periods of dry weather. Similar regions around the globe can have similar weather patterns. Dust can really bring complaints in these areas if there are residences located near the road and traffic is high. The quality and type of gravel also has some effect on the amount of dust. Some limestone gravels can dust severely while some glacial deposits of gravel with a portion of highly plastic clay can take on a strong binding characteristic that will resist dusting remarkably well. Still, in prolonged dry weather, there will be dust! Whether to provide some type of dust control or not can be a hard decision to make. Virtually all methods of dust control require annual treatment. The cost can be prohibitive if traffic volume is low. On the other hand, if traffic is high, the cost of dust control can more than pay for itself with the benefits of reduced material loss and reduced need for blade maintenance. At this point, many agencies will face pressure to pave the road. It may actually be a good economic decision in the long run, especially if there is good indication that traffic will continue to increase in the future. However, never pave a road before it is ready! There is good information on making this decision in Appendix D (USDOT 2000).

Reclaimed pavement is old pavement that has been ground up. It looks similar to road gravel, but it is more granular and darker because of the residual asphalt. The most common and effective use of this material is on steep road segments that have had problems with surface erosion. It is also effective on other high stress areas such as sharp turns and intersections. The residual asphalt in this material acts as a binder, which makes it more resistant to erosion (YCSWCD 2007).

**Structural Strategies**

![Image](image.png)

**Figure 22: Ditch Turnout (MaineDEP 2010).**

**Sediment basins and Ditch Turnouts**

A sediment basin is a water impoundment created by constructing an embankment or by excavating a natural depression. Sediment settles out while the runoff is stored in the basin (McCarthy 2008).
The Lake George Reservoir and Sediment Basin Cleanout Program uses sediment basins like the one shown in Figure 23 to slow the stream velocity encouraging sediment to drop out of suspension and be stored in a basin prior to it reaching Lake George. These basins are then capable of having the stored sediment be removed on a regular basis with excavation equipment and dewatering techniques (District 2007).

Ditch Turnouts divert the stormwater runoff in a roadside ditch into a series of check dams and spreaders that convert the ditch flow into sheet flow that distributes across a buffer (McCarthy 2008).

**Deep Sump Catch Basins**

Deep sump catch basins are similar to sediment basins in that their primary function is to encourage sediment to settle out of runoff during storm events. Catch basins are precast systems that are part of a storm drain or piping system. Sediment enters a catch basin through either an inlet or a grated opening on top of the system (LGA). Deep sumps are typically 4 feet deep below the outlet. Sediment removal is best when configured in an offline configuration. Catch basins can be used in combination with hooded outlets to improve sediment removal performance. Hooded outlets are described in greater detail below.
Catch basins have been successfully used as a roadside stormwater management tool by the Lake George Association in New York. An example of a catch basin used in the Lake George project is shown in Figure 24. Catch basin maintenance, as described by the Lake George Association, requires scheduled clearing of debris in and around the basin to allow stormwater to enter the basin. Additional maintenance is required to remove trapped sediment from the basin. If the excess sediment is not removed the ability of the system to settle out sediment is reduced or removed completely.

**Hooded Outlets and Catch Basin Inserts**

While catch basins are prevalent throughout the drainage systems within the United States, many basins are not suited for efficient pollutant and sediment removal and are ideally a pretreatment to additional Stormwater BMPs (EPA 2006a). Since there is not always the option to have further treatment due to monetary or space constraints, retrofits can help achieve higher pollutant reductions. Hooded Outlets/Inserts are designed to assist deep sump catch basins with the removal of oil, grease, trash, debris, sediment, and other floatables by improving the removal efficiency of the catch basin. Some inserts are designed to drop directly into an existing catch basins, while others may require retrofit construction (EPA 2006a). The Round Snout®, a type of hooded outlet retrofit, is designed to fit cylindrical or round structures and has been reported to achieve TSS reduction by 56% and TP reduction by 46% (BMP 2011b; Lambert 2007).
Infiltration Basins

Infiltration basins are located either on the surface or below ground and are designed to temporarily store runoff from storm events. Infiltration basins may be capable of infiltrating all or a portion of an event. In some cases basins are designed to release stormwater that exceeds the storage capacity of the basin (McCarthy 2008).
Media Filter

Media filters such as bioretention and raingardens are among the most common LID stormwater approaches in use today. In general, runoff flows into landscaped depressions, where it ponds, filters through a soil mix, and infiltrates into the ground, or is connected to storm drains. The engineered soil mix and vegetation mimic the water quality treatment and infiltration similar to undeveloped areas. Soil mix design is essential to the performance and longevity of these systems. While the mix must contain enough fines and organic matter to sustain vegetation and slow down infiltration rates, too much of these components may cause systems to clog prematurely eliminating any water quality benefits.

Infiltration trenches

An infiltration trench is a stone-filled excavation used to temporarily store runoff and allow it to infiltrate into surrounding, natural soil. Typically, runoff enters the trench as overland flow after pretreatment through a filter strip or vegetated buffer. An infiltration trench is suitable for
treating runoff from small drainage areas (less than 10 acres). Installations around the perimeter of parking lots, between residential lots, and along roads are most common (McCarthy 2008).

![Figure 28: Infiltration Trench (Akan 2002).](image)

**Dry Well**

A dry well is a cylindrical underground pre-cast system with perforated sides that allows captured stormwater to infiltrate in the ground while retaining the debris and sediment carried by the stormwater. The debris and sediment will remain in the well and will require periodic maintenance to be removed (LGA 2011).
Road Crossing and Conveyance

Culvert Crossings
Culverts are conduits that convey streamflow, sediment, and debris through a roadway embankment. Properly designed and constructed culverts also enable the passage of aquatic and terrestrial species. Other culverts transporting groundwater or runoff should disperse the water into vegetated buffer areas capable of handling the water without eroding Culverts should be installed when: a stream, brook, seasonal runoff channel, or subsurface drainage way must be directed under the road. This keeps the road from disrupting the natural drainage system Culverts transport streamflow, seasonal or storm event related runoff, and subsurface drainage ways underneath roadways. When possible culverts should be designed as not only a method of conveyance for water ways, but also as an effective method to convey the aquatic life, sediment and debris that are transported within these water ways(MaineDEP 2010; USFS 2005). Table 5 provides examples of culvert types and when each type is applicable.
<table>
<thead>
<tr>
<th>Culvert Type</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal (corrugated)</td>
<td>1. inexpensive for sizes &lt; 24”</td>
<td>1. expensive for sizes &gt; 24”</td>
</tr>
<tr>
<td></td>
<td>2. easy to install</td>
<td>2. easily crushed and</td>
</tr>
<tr>
<td></td>
<td>3. 25-year life</td>
<td>3. permanently deformed</td>
</tr>
<tr>
<td>Plastic (HDPE)</td>
<td>1. inexpensive for sizes &lt; 18”</td>
<td>1. easily broken if not handled carefully</td>
</tr>
<tr>
<td></td>
<td>2. &gt;25-year life</td>
<td>2. more difficult to install to</td>
</tr>
<tr>
<td></td>
<td>3. less freezing</td>
<td>grade with respect to envelope backfilling operations</td>
</tr>
<tr>
<td></td>
<td>4. easily cut with power saw</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. smoother interior bore surface for heavier water and debris flow velocity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. lightweight</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. bounces back from frostheaves</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>1. 50-year life</td>
<td>1. expensive</td>
</tr>
<tr>
<td></td>
<td>2. smoother surface for heavier water flows</td>
<td>2. heavy</td>
</tr>
<tr>
<td></td>
<td>3. handles heavier truck weights with shallow gravel cover</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Culvert Types, Advantages, and Disadvantages (MaineDEP 2010).

Figure 32: Concrete box culvert with wing walls (USFS 2005).

**Shallow –Stabilized Dips**

A stabilized dip is a depression in a road surface the allows high water levels within a ditch to flow across the road surface in a controlled manner. A stabilized dip is commonly used in place of a culvert to handle moderate flows in areas of low traffic. Stabilized dips may also be used in conjunction with an undersized culvert that is unable to handle high flows (Andersen 2007).
**Rubber Razors**

Rubber razors are rubber strips that protrude above the road surface to intercept and divert water while letting vehicles pass. These structures should not be used on roads that are plowed (Andersen 2007; MaineDEP 2006).

![Diagram of Rubber Razor](image)

**Figure 33: Rubber Razor** (MaineDEP 2006).

**Energy Dissipaters**

Energy dissipaters are designed to reduce water velocity and prevent erosion within a water way. Examples of various types of energy dissipaters are internal and external dissipaters, natural scour holes, stilling basins, riprap, vegetated ditches, debris racks and concrete or steel baffles (Olsson Environmental Sciences 2004; USFS 2005).
Non-Structural Strategies

Vegetated Buffers and Filter Strips

Vegetated filter strips, are gradually sloped vegetated areas that are designed to receive runoff as sheet flow from adjacent impervious areas. These vegetated areas function by reducing runoff velocities allowing water to infiltrate as sediment settles (Horsley Witten Group 2010; McCarthy 2008b). Vegetated buffers also reduce sheet flow velocities but they differ from filter strips in that they are not necessarily an engineered or constructed system. A buffers primary function is to provide a physical barrier between a body of water and adjacent land use. This is achieved by utilizing natural vegetation (ie. forest, shrubby uplands, or floodplains) or purposefully planted vegetation that mimics undisturbed forest. Undisturbed forest has minimal erosion and sedimentation due to established vegetation cover. In addition to vegetation, the forest floor contains litter and debris which increase surface roughness further reducing surface flow velocities encouraging infiltration and a reduction in erosion (Grace III 2002).
Improved Regulations and Ordinances

Planning for better stormwater management is challenging because water resources are not confined to municipal boundaries and watershed plans are not always integrated into master plans. In addition, the visions supported by master plans are not always implemented through regulations or zoning. Sound planning should help communities (and their neighbors within the watershed) set the groundwork for sound policies and ultimately better protection of valuable water resources. While most communities have a master plan or comprehensive plans outlining a vision for the community, many land use decisions are made on a parcel-by-parcel basis. These parcel-by-parcel decisions can have cumulative impacts on water resources, stormwater infrastructure, and municipal budgets. A growing trend is emerging where municipalities are updating local regulations and developing guidelines to reflect the higher treatment standards of today. One of the most applicable methods is updating stormwater management standards in the planning board’s site plan review regulations. Updated stormwater regulations or the development of a separate stormwater ordinance typically reflect a BMP toolbox which now includes many systems capable of advanced stormwater management. These systems often incorporate some form of filtration and/or infiltration. Development of improved regulations

Figure 35: Filter Strip Plan and Profile View (Claytor and Schueler 1996)
will mean that new developers will be part of the solution in building the necessary infrastructure that protects water resources and ultimately decreases municipal expenses saving taxpayers money.

**Formation of a Road Association**

A guide created by the York County Soil and Water Conservation District (SWCD) with assistance from the Maine Department of Environmental Protection to assist with the formation of road associations can be found at [http://www.maine.gov/dep/blwq/docwatershed/road_association_guide.pdf](http://www.maine.gov/dep/blwq/docwatershed/road_association_guide.pdf) (SWCD 2009). The document cites a $1 spent in routine maintenance will save $15 in capital repairs.

Reasons listed for the development of a Road Association are:

1. Improve road safety and drivability.
2. Reduce maintenance costs over time.
3. Provide liability protection for association members.
4. Sustain the clarity and quality of your lake’s water.
5. Protect the value of your lakefront property investment.

**GENERAL CHARACTERIZATION OF LAND-USE WITHIN WATERSHED**

**Un-Improved Gravel and Low-Volume Roads**

**Predominant Land Cover:** Unstabilized roads, and roadside drainage

**Description:**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Pollutant Sources</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Hydrocarbons</td>
<td>Antifreeze and Hydraulic Fluids</td>
<td>1</td>
</tr>
<tr>
<td>Lead and Heavy Metals</td>
<td>Gasoline Additives</td>
<td>2</td>
</tr>
<tr>
<td>Organics</td>
<td>Diesel and Polycyclic Hydrocarbons</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Aromatic Hydrocarbons (PAH's)</td>
<td>4</td>
</tr>
<tr>
<td>Copper</td>
<td>De-icing salts containing chlorides</td>
<td>1</td>
</tr>
<tr>
<td>NaCl</td>
<td>De-icing agents</td>
<td>3</td>
</tr>
<tr>
<td>Salts, Petroleum-based organics, Synthetic polymer, Electrochemical product, Clay additives</td>
<td>Dust Suppresant</td>
<td>4</td>
</tr>
</tbody>
</table>

References include (1) (The Low Impact Development Center et al.), (2) (Lagerwer and Specht 1970), (3) (Forman and Alexander 1998), (4) (Piechota et al. 2002).
Table 7: Predominant Pollutant Concentrations for Un-Improved Gravel and Low-Volume Roads

<table>
<thead>
<tr>
<th>Source Area Unit</th>
<th>TSS mg/L</th>
<th>TP mg/L</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unimproved Poorly Maintained Gravel Surface</td>
<td>3198 (Abs Range 6.0-71,600)</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>Gravel Road</td>
<td>197-885</td>
<td>0.23-0.99</td>
<td>2</td>
</tr>
<tr>
<td>Transportation/Communication/Utility Runoff</td>
<td>100</td>
<td>0.2</td>
<td>3</td>
</tr>
</tbody>
</table>

References include (1), (Clinton and Vose 2003), (2) (Sheridan and Noske 2007), (3) (Hagen and Walker 2006).

Residential

Predominant Land Cover: rooftops, driveways, roads, and lawns

Residential land uses range from high density, represented by the multiple unit structures of urban cores, to low density, where houses are on lots of more than an acre, on the periphery of urban expansion. Linear residential developments along transportation routes extending outward from urban areas should be included as residential appendages to urban centers.3

Table 8: Predominant Pollutant Sources for Residential Land-Use

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Pollutant Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Solids, Sediment, and Floatables</td>
<td>Streets, lawns, driveways, roads</td>
</tr>
<tr>
<td>Pesticides and Herbicides</td>
<td>Residential lawns and gardens, roadsides, utility right-of-ways, soil wash-off</td>
</tr>
<tr>
<td>Organic Materials/Oxygen Demanding Substances</td>
<td>Residential lawns and gardens, animal wastes</td>
</tr>
<tr>
<td>Metals</td>
<td>Automobiles, soil erosion</td>
</tr>
<tr>
<td>Oil and Grease/Organics Associated with Petroleum</td>
<td>Roads, driveways, illicit dumping to storm drains</td>
</tr>
<tr>
<td>Bacteria and Viruses</td>
<td>Lawns, roads, soil erosion, leaky sanitary sewer lines, animal waste, septic systems</td>
</tr>
<tr>
<td>Nitrogen, Phosphorus, and Other Nutrients</td>
<td>Lawn fertilizers, animal waste</td>
</tr>
</tbody>
</table>

Source: U.S. EPA 1999 (Preliminary Data Summary of Urban Storm Water BMPs).

Table 9: Predominant Pollutant Concentrations for Residential Land-Use

<table>
<thead>
<tr>
<th>Source Area Unit</th>
<th>TSS mg/L</th>
<th>TP mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential (General)</td>
<td>100</td>
<td>.40</td>
</tr>
<tr>
<td>Med. Density Residential</td>
<td>85</td>
<td>.52</td>
</tr>
<tr>
<td>Residential Roof</td>
<td>19</td>
<td>.11</td>
</tr>
<tr>
<td>Residential Street</td>
<td>172</td>
<td>.55</td>
</tr>
<tr>
<td>Driveway</td>
<td>173</td>
<td>.56</td>
</tr>
</tbody>
</table>

5 Caraco (2001), default values averaged from several individual assessments; 3 Camp, Dresser, and McKee, Merrimack River Watershed Assessment Study, Draft Screening Level Model, January 2004

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LGA, L. G. A. "Reservoirs and Sediment Basins."


The Low Impact Development Center, I., Consultants, G., Florida, U. o., and University, O. S. "EVALUATION OF BEST MANAGEMENT PRACTICES FOR HIGHWAY RUNOFF CONTROL Appendices To User’s Guide for BMP/LID Selection (Guidelines Manual)."


U.S. Department of Transportation.


APPENDIX A: TERMINOLOGY

Best Management Practices (BMP's): Methods and means that have been determined to be the most effective, practical approaches of preventing or reducing pollution and detrimental impacts from stormwater runoff (Durham).

Buffer: A vegetated area or zone separating a development from a sensitive resource or neighboring property in which proposed development is restricted or prohibited (Durham).

Impervious Surfaces: A material with low permeability that impedes the natural infiltration of moisture into the ground so that the majority of the precipitation that falls on the surface runs off or is not absorbed into the ground. Common impervious surfaces include, but are not limited to, roofs, concrete or bituminous paving such as sidewalks, patios, driveways, roads, parking spaces or lots, and storage areas, compacted gravel including drives and parking areas, oiled or compacted earthen materials, stone, concrete or composite pavers, wood, and swimming pools (Durham).

Polycyclic Aromatic Hydrocarbons (PAHs): PAH’s are “a group of organic chemicals that includes several petroleum products and their derivatives” (EPA 2009b).

Pollutant: A pollutant is a substance that adversely affects the usefulness of a resource and is in a form that can be incorporated into, or be ingested by organisms within, the environment (EPA 2009b).

Chlorides: Chloride is a salt compound resulting from the combination of the gas chlorine and a metal. Common chlorides include sodium chloride (NaCl) and magnesium chloride (MgCl2) (EPA 2009a).

Unimproved Road: An unimproved road is a gravel or low use road that does not contain drainage features (Wyoming_Technology_Transfer_Center 2010).

Runoff: Stormwater runoff is the generated when precipitation from rain and snowmelt events flows over impervious surfaces (NPDES 2011).

Sediment: Sediment is a collection of loose particles that settle at the bottom of a body of water. Sediment is generated from the erosion of soil or from the decomposition of plants and animals (EPA 2009b).

Sheet Flow: Sheet flow is a shallow lateral flow traveling across an impervious surface.

Total Suspended Solids (TSS): TSS is a “measure of the filterable solids present in a sample, as determined by the method specified in 40 CFR Part 136” (NPDES 2004).

Gravel Roads Management Systems (GRMS): When referring to management systems, historically such systems have been referred to as ‘gravel roads management systems’ or ‘gravel roads maintenance systems.’ In keeping with this precedent, the term ‘gravel roads management or maintenance system’ (GRMS) is used to refer to systems designed to plan and program
unsealed roads maintenance and improvement processes (Wyoming_Technology_Transfer_Center 2010).

**Drainage Terms:** When a road is more than simply tracks in the surrounding countryside made by four (or more) wheeled vehicles one should describe it as ‘formed’ or ‘improved.’ To some, an ‘improved’ road merely has ditches and other drainage features, while to others, an ‘improved’ road also has imported surfacing aggregate (Wyoming_Technology_Transfer_Center 2010).

**Dirt Roads:** Use of this term by roads professionals is discouraged, though it is popular with the general public. Though sometimes synonymous with the term ‘earth roads’ below, the term ‘dirt roads’ should not be used due to its multiple meanings (Wyoming_Technology_Transfer_Center 2010).

**Earth or Native Soil Roads:** This term should be used to describe roads surfaced with soil from the immediate vicinity. To some, even a road that has material pulled up from the borrow pit to form the road is no longer an ‘earth’ road. When using these terms, care should be taken to indicate whether or not the native soil has been moved from its original location to the road (Wyoming_Technology_Transfer_Center 2010).

**Gravel Roads:** This term is problematic due to its widespread use with multiple meanings. To some, a ‘gravel’ road implies crushed alluvial rock while to others it simply implies that surfacing material has been imported. Roads made with a crushed shale surface may be called a ‘shale road’ or they may be simply known as a ‘gravel road;’ the situation is similar for other roads surfaced with a particular type of crushed or processed aggregate. Given these ambiguities, this term should be used with caution, and when it is used, it should be concisely defined. Chemically Treated Roads: A chemically treated unsealed road has had dust suppressant (other than water) or soil stabilizer added to it recently enough to bind together or significantly alter the road’s surfacing material from its original, untreated state (Wyoming_Technology_Transfer_Center 2010).

**Surface Treated Roads:** Roads comprised of aggregate topped with a sealant, typically asphalt, cutback asphalt or emulsified asphalt, are referred to as ‘surface treated roads.’ They may also be referred to as ‘bituminous surface treated’ or ‘BST’ roads. When a layer of aggregate chips is placed on top of the asphalt, the road may be referred to as a ‘blotter road’ or a ‘chip seal road.’ When no chips are added, the road may be referred to as an ‘inverted penetration’ (‘invert pen’) road. Other terms referring to various surface treatments include ‘armoring,’ ‘armouring,’ ‘metalling’ and ‘running course.’ These terms are not in widespread use and their use is discouraged. If they are used, they should be concisely defined (Wyoming_Technology_Transfer_Center 2010).

**Paved Roads:** The use of the terms ‘paved’ and ‘unpaved’ is discouraged because they have such widely disparate meanings to different people and in different parts of the world. To some, any road with constructed layer(s) to carry traffic is considered a pavement, while in other places any road with a semi-permanent surface is ‘paved,’ while to still others, the term ‘pavement’ implies
that the road is constructed with hydraulic or asphaltic concrete and is placed with a screed (Wyoming_Technology_Transfer_Center 2010).

**Sealed Roads:** When a road’s surface is semi-permanent and water-resistant, the road is said to be ‘sealed.’ ‘Unsealed’ roads are those with a granular surface that are or may be maintained on a routine basis with a motor grader, and are the road types whose repair and maintenance is the topic of this paper (Wyoming_Technology_Transfer_Center 2010).

**Porous Media:** Material with open connected pore spaces that allows water to percolate through it such as granular soils, gravel, crushed stone, pervious pavements, and woven and non-woven geosynthetics (Durham).

**Redevelopment:** Any man-made change to previously improved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, and drilling operations (Durham).

**Riparian:** Referring to anything connected or immediately adjacent to the shoreline or bank of a stream, river, pond, lake, bay, estuary or other similar body of water (Durham).

**Riparian buffer:** The naturally vegetated shoreline, floodplain or upland forest adjacent to a surface water body. Riparian buffers provide stormwater control flood storage and habitat values. Wherever possible, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and freshwater wetlands (Durham).
APPENDIX : WHEN TO PAVE
Appendix D: When to Pave a Gravel* Road
by Kentucky Transportation Center, University of Kentucky at Lexington, KY

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- Introduction
- Gravel or Paved: A Matter of Trade-offs
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  3. When Traffic Demands It
  4. After Standards Have Been Adopted
  5. After Considering Safety and Design
  6. After the Base and Drainage Are Improved
  7. After Determining the Costs of Road Preparation
  8. After Comparing Pavement Life and Maintenance Costs
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  10. After Weighing Public Opinion

- Stage Construction

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*Gravel as used here may refer to sand and gravel, or to crushed stone.
A Word About the Term “Paved”

What is meant by a “paved” road? For some, a light chip seal coat is considered paving. For others, paving is four or more inches of bituminous asphalt or “hot mix.” The primary purpose of a pavement is to protect the subgrade. As the loads get heavier, the pavement thickness must be increased.

Generally speaking, bituminous concrete (hot mix asphalt) has little real load-bearing capacity of its own until it reaches a thickness of two inches. In fact, the Asphalt Institute has a firm policy of recommending a minimum pavement thickness of 4 inches full depth asphalt or 3 inches asphaltic concrete plus a suitable granular base even for low volume roads. Their research shows that 4 inches of hot mix will carry about 10 times as much traffic as 2 inches of hot mix when constructed over thin granular bases.

Introduction

Two-thirds of the highway systems in the United States and more than 90 percent of all the roads in the world are unsurfaced or lightly surfaced low volume roads. In Kentucky, more than 19,000 miles of local roads have gravel surfaces.

Most local roads were not designed with the same considerations used in the design of state and interstate highways. Most have evolved from primitive trails. Paths of least resistance first created by wild animals were later used by settlers. As needs and traffic increased, these traveled ways became roads which were gradually improved with gravel or crushed rock. Little engineering went into these improvements. Using available materials and “keeping them out of the mud” were the extent of efforts to maintain a road.

Gravel or Paved: A Matter of Trade-Offs

The decision to pave is a matter of trade-offs. Paving helps to seal the surface from rainfall, and thus protects the base and subgrade material. It eliminates dust problems, has high user acceptance because of increased smoothness, and can accommodate many types of vehicles such as tractor-trailers that do not operate as effectively on unsurfaced roads.

In spite of the benefits of paved roads, well-maintained gravel roads are an effective alternative. In fact, some local agencies are reverting to gravel roads. Gravel roads have the advantage of lower construction and sometimes lower maintenance costs. They may be easier to maintain, requiring less equipment and possibly lower operator skill levels. Potholes can be patched more effectively. Gravel roads generate lower speeds than paved surfaces. Another advantage of the unpaved road is its forgiveness of external forces. For example, today vehicles with gross weights of 100,000 pounds or more operate on Kentucky’s local roads. Such vehicles would damage a lightly paved road so as to require resealing, or even reconstruction. The damage on a gravel road would be much easier and less expensive to correct.

There is nothing wrong with a good gravel road. Properly maintained, a gravel road can serve general traffic adequately for many years.
Should We Pave This Gravel Road? A Ten Part Answer

When a local government considers paving a road, it is usually with a view toward reducing road maintenance costs and providing a smooth riding surface. But is paving always the right answer? After all, paving is expensive. How does a county or city know it is making the most cost-effective decision?

We will consider ten answers to the question, “Should we pave this gravel road?” In fact, they are ten parts of one answer. If one of the ten is not considered, the final decision may not be complete. The ten answers taken together provide a framework for careful decision making.

Answer 1: After Developing a Road Management Program

If the road being considered for paving does not fit into a countywide road improvement program, it is quite possible that funds will not be used to the fullest advantage. The goal of a road management system is to improve all roads or streets by using good management practices. A particular road is only one of many in the road system.

A road management system is a common sense, step-by-step approach to scheduling and budgeting for road maintenance work. It consists of surveying the mileage and condition of all roads in the system, establishing short-term and long-term maintenance goals and prioritizing road projects according to budget constraints.

A road management system helps the agency develop its road budget and allows the use of dollars wisely because its priorities and needs are clearly defined.

Through roadway management, local governments can determine the most cost-effective, long-term treatments for their roads, control their road maintenance costs, and spend tax dollars more wisely. Local governments that stick with the program will be rewarded with roads that are easier and less costly to maintain on a yearly basis. Pertinent information about all roads will be readily available for years to come instead of scattered among files or tucked away in an employee’s head.

Steps in a Road Management Program:

1. **Inventory the roads.** The amount of time available and the miles of road in a county or city will determine how much detail to go into.

2. **Assess the condition of the roads.** Develop simple and easy techniques to use each year. Maintain a continuing record of the assessed condition of each road so that changes in condition can be noted easily and quickly.

3. **Select a road management plan.** Select the most appropriate treatment to repair each road, bridge, or problem area.

4. **Determine overall needs.** Estimate the cost of each repair job using generalized average costs and tally up the total. Establish long-range goals and objectives that in turn will help the agency justify its budget requests.

5. **Establish priorities.** Keep good roads in good shape (preventive maintenance) and establish a separate budget, or request a temporary increase, to reconstruct really bad roads.

Answer 2: When the Local Agency Is Committed to Effective Management

A commitment to effective management is an attitude. It is a matter of making sure that taxpayers’ money is well spent— as if it were one’s own money. It does not mean paving streets with gold but it does mean using the best materials available. It does not mean taking short cuts resulting in a shoddy project but it does mean using correct construction techniques and quality control. A commitment to effective management means planning for 5 or even 10 years instead of putting a band-aid on today’s problem. It means taking the time to do things right the first time and constructing projects to last.

Consider a child’s tree house compared to a typical three-bedroom house in a Kentucky town. Because each protects people from the wind and rain each comes under the definition of a shelter. However, the tree house was built with available materials and little craftsmanship. The other was planned, has a foundation, sound walls and roof and, with care, can last hundreds of years. One is a shack and the other is a family dwelling. Only one was built with a commitment to excellence.

Many roads are like the tree house. They qualify under the definition but they are not built to last.

The horse and buggy days are over. We are in an age of travelers’ demands, increasing traffic, declining revenues and taxpayer revolts. We are expected to do more with less. Building roads to last requires an attitude of excellence. Such an attitude helps to make better decisions, saves money in the long run, and results in a better overall road system.
The life of a road is affected by the number of vehicles and the weight of the vehicles using it. Generally speaking, the more vehicles using a road, the faster it will deteriorate. The average daily traffic volumes (ADT) used to justify paving generally range from a low of 50 vehicles per day to 400 or 500. When traffic volumes reach this range, serious consideration should be given to some kind of paving.

Traffic volumes alone are merely guides. Types of traffic should also be considered. Different types of traffic (and drivers) make different demands on roads. Will the road be used primarily by standard passenger cars or will it be a connecting road with considerable truck traffic? Overloaded trucks are most damaging to paved roads.

The functional importance of the highway should also be considered. Generally speaking, if the road is a major road, it probably should be paved before residential or side roads are paved. On the other hand, a residential street may be economically sealed or paved while a road with heavy truck usage may best be surfaced with gravel and left unpaved until sufficient funds are available to place a thick load-bearing pavement on the road.

Written standards in the areas of design, construction and maintenance define the level of service we hope to achieve. They are goals to aim for. Without written standards there is no common understanding about what a local government is striving for in road design, construction and maintenance. In deciding to pave a gravel road, is the local government confident it would be achieving the desired standards?

Design and construction standards do not have to be complex. It takes only a few pages to outline such things as right-of-way width, traveled way width, depth of base, drainage considerations (such as specifying minimum 18" culvert pipe), types of surfacing and the like.

Maintenance standards address the need for planned periodic maintenance. A good maintenance plan protects local roads, which for most counties represents many millions of dollars of investment. It also is an excellent aid when it comes time to create a budget.

Considerations include: How often shall new gravel be applied to a gravel road? (Some roads require it more than others do.) How many times per year are roads to be graded? How often and in what locations should calcium chloride or other road stabilizers be applied? What is our plan for checking road signs? (Because of legal liability, a missing sign can be very costly if not replaced.) What is our plan for ditching and shouldering?

Paving a road tempts drivers to drive faster. As speed increases, the road must be straighter, wider, and as free as possible from obstructions for it to be safe. Paving low volume roads before correcting safety and design inadequacies encourages speeds which are unsafe, especially when the inadequacies “surprise” the driver. Because of the vast mileage of low volume roads, it is difficult to reduce speeds by enforcement.

Roads must be designed to provide safe travel for the expected volume at the design speed. To do this a number of physical features must be considered:

• Sight Distance
• Alignment and Curves
• Lane Width
• Design Speed
• Surface Friction
• Superelevation

It may be necessary to remove trees or other obstructions such as boulders from the road’s edge. Some engineers insist that no road should be paved that is less than 22 feet wide. If this standard is accepted, gravel roads must be widened before paving. Bridges may need widening. Considering these and other safety and design factors in the early stages of decision making can help to achieve the most economical road and one that will meet transportation needs. It makes no sense to pave a gravel road which is poorly designed and hazardous.
Answer 6: After the Base and Drainage Are Improved

“Build up the road base and improve drainage before paving.” This cardinal rule cannot be stressed enough. If the foundation fails, the pavement fails. If water is not drained away from the road, the pavement fails. Paving a road with poor base or with inadequate drainage is a waste of money. It is far more important to ask, “Does this road need strengthening and drainage work?” than it is to ask, “Should we pave this gravel road?”

Soil is the foundation of the road and, as such, it is the most important part of the road structure. A basic knowledge of soil characteristics in the area is very helpful and can help avoid failures and unneeded expense. Soils vary throughout the country. For highway construction in general, the most important properties of a soil are its size grading, its plasticity, and its optimum moisture content.

There is a substantial difference in the type of crushed stone or gravel used for a gravel road-riding surface versus that used as a base under a pavement. The gravel road surface needs to have more fines plus some plasticity to bind it together, make it drain quicker and create a hard riding surface. Such material is an inferior base for pavement. If pavement is laid over such material, it traps water in the base. The high fines and the plasticity of the material make the wet base soft. The result is premature pavement failure.

Answer 7: After Determining the Costs of Road Preparation

The decision to pave a gravel road is ultimately an economic one. Policy makers want to know when it becomes economical to pave.

There are two categories of costs to consider: total road costs and maintenance costs.

Local government needs to determine what the costs are to prepare a road for paving. Road preparation costs are the costs of construction before paving actually takes place.

For example, if standards call for a traveling surface of 22 feet and shoulders of two feet for a paved road, the costs of new material must be calculated. Removing trees, brush or boulders, adding new culverts or other drainage improvements, straightening a dangerous curve, improving slopes and elevations, constructing new guardrails, upgrading signs and making other preparations – all must be estimated.

Costs will vary greatly from project to project depending on topography, types of soils, availability of good crushed stone or gravel, traffic demands and other factors. One important factor is the standards. That is one reason why we should carefully consider what is contained in the road policy (#4 above). For larger projects it may be desirable to hire an engineering consulting firm (another cost) to design the road and make cost estimations. For smaller projects construction costs can be fairly closely calculated by adding the estimated costs of materials, equipment and labor required to complete the job.

Answer 8: After Comparing Pavement Costs, Pavement Life and Maintenance Costs

A second financial consideration is to compare maintenance costs of a paved road to maintenance costs of a gravel road. To make a realistic comparison we must estimate the years of pavement life (how long the pavement will be of service before it requires treatment or overlay) and the actual cost of paving. It is at this point that we can begin to actually compare costs between the two types of roads.

Consider the following maintenance options:

A. For both paved and gravel roads, a local government must: maintain shoulders – keep ditches clean – clean culverts regularly – maintain roadsides (brush, grass, etc.) – replace signs and signposts.

B. **PAVED** roadways require: patching – resealing (chip, slurry, crack seal) and striping.

C. **GRAVEL** roadways require: regraveling – grading and stabilization of soils or dust control.

Since the maintenance options in "A" are common to both paved and gravel roads, they do not have to be considered when comparing maintenance costs. These costs for either type of road should be about the same. But the costs of the maintenance options in "B" and "C" are different and therefore should be compared.

Figure 16 shows costs for maintaining gravel roads over a six-year period in a hypothetical situation. If records of costs are not readily available, you may use a “best guess” allowing for annual inflation costs.

Three paving options are listed in Figure 17. Each includes estimated costs for paving and an estimated pavement life. You should obtain up-to-date cost estimates and expected pavement life figures for these and other paving options by talking to your state department of transportation, contractors, and neighboring towns and counties.
Let's consider the cost of a double surface treatment operation and the projected cost of maintaining it before anything major has to be done to the pavement (end of pavement life). We see in Figure 17 that the estimated cost to double surface treat one mile of road is $20,533. Estimated maintenance costs over a six-year period could be:

- **Patching** ...... $1,800
- **Stripping** ...... $500
- **Sealing** ...... $2,000

Total maintenance ........... $4,300

Construction .................. $20,533

Total cost over six years ..... $24,833

When we compare this cost to the cost of maintaining an average mile of gravel road over the same period of six years ($18,065), we find a difference in dollar costs of $6,768. It is not cost beneficial to pave in this hypothetical example, even without considering the costs of road preparation (#7).

This is not a foolproof method, but it does give us a handle on relative maintenance costs in relation to paving costs and pavement life. The more accurate the information, the more accurate the comparisons will be. The same method can be used in helping to make the decision to turn paved roads back to gravel.

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**Figure 16: Gravel Road Maintenance Cost Per Mile**

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<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<td>–</td>
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<td>1,505</td>
<td>1,580</td>
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</tr>
</tbody>
</table>

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**Option**  | **Life**  | **Cost Per Mile**  | **Calculations**  | **Maintenance Per Mile/Year**
--- | --- | --- | --- | ---
Chip Seal - Double Surface Treatment | 6 yrs. | $20,533 | Based on price of $1.75 per sy; 20 ft. wide x 5,280 ft. = 105,600 sf; 105,600 sf / 9 = 11,733 sy x $1.75 = $20,533 | ?
Bituminous Concrete - Hot Mix | 12 yrs. | $58,080 | Based on estimated price of $30 per ton; 1 sy of stone and hot mix/ cold mix 1" thick weighs about 110 lbs. Therefore 3" = 330 lbs. per sy. 11,733 sy (1 mile of pavement) = 3,871,890 lbs. = $58,080 | ?
Cold Mix | 8 yrs. | $48,390 | At $30 per ton, using same formula as hot mix; 2 1/2" of cold mix equals 1,613T x $30 = $48,390 | ?

*These costs must be determined before any conclusions can be reached regarding the most cost-effective pavement method. The thinner the pavement, the greater the maintenance cost. Traffic, weather conditions, proper preparation before paving and many other factors can affect maintenance costs. No Kentucky data exists upon which to base estimates of maintenance costs on low volume roads of these paving options; and, therefore, we offer no conclusion as to the "best" way to pave.

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**Figure 17: Paving Options** (Costs and road life are estimates and may vary)
Answer 9: After Comparing User Costs

Not all road costs are reflected in a highway budget. There is a significant difference in the cost to the user between driving on a gravel surface and on a paved surface. User costs, therefore, are appropriate to consider in the pave/not pave decision. By including vehicle-operating costs with construction and maintenance costs, a more comprehensive total cost can be derived.

Vehicles cost more to operate on gravel surfaces than on paved surfaces, often 2 or 3 times greater than for bituminous concrete roads in the same locations. There is greater rolling resistance and less traction which increase fuel consumption. The roughness of the surface contributes to additional tire wear and influences maintenance and repair expenses. Dust causes extra engine wear, oil consumption and maintenance costs. Figure 18 from AASHTO’S “A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements” shows the impacts of gravel surfaces on user costs. For example, an average running speed of 40 MPH on a gravel surface will increase the user costs of passenger cars by 40% (1.4 conversion factor). The general public is not aware that their costs would actually be less if some of these roads were surface treated.

Add to the gravel road maintenance the user costs over a six-year period. Estimate an average daily traffic (ADT) of 100 cars and 50 single unit trucks, traveling at 40 mph. Estimate that it costs $.25 per mile to operate the vehicles on pavement. Using the chart in Figure 3, we see it costs 1.4 times as much (or $.35) to drive a car 40 mph one mile on gravel road and 1.43 times as much (or $.36) to drive a single unit (straight frame) truck 40 mph one mile on gravel road.

100 cars x 365 days x $.10 added cost x 1 mile = $3,650
50 trucks x 365 days x $.11 added cost x 1 mile = $2,008
User costs for the gravel road is $5,659 per year or $33,954 for a six-year period. Assuming we still do not consider road preparation costs, it now appears justified to pave the road. Such an approach can be used to establish a “rule of thumb” ADT. For example, some agencies give serious consideration to paving roads with an ADT above 125.

Answer 10: After Weighing Public Opinion

Public opinion as to whether to pave a road can be revealing, but it should not be relied upon to the exclusion of any one of points 1-9 already discussed. If a decision to pave is not based on facts, it can be very costly. Public opinion should not be ignored, of course, but there is an obligation by government leaders to inform the public about other important factors before making the decision to pave.

Figure 18: Impacts of Gravel Surfaces on User Costs
Stage Construction

Local government may consider using “stage construction design” as an approach to improving roads. This is how it works. A design is prepared for the completed road, from base and drainage to completed paving. Rather than accomplishing all the work in one season, the construction is spread out over three to five years. Paving occurs only after the base and drainage have been proven over approximately one year. Crushed gravel treated with calcium chloride serves as the wearing course for the interim period. Once all weak spots have been repaired, the road can be shaped for paving.

There are some advantages to keeping a road open to traffic for one or more seasons before paving:

1. Weak spots that show up in the sub-grade or base can be corrected before the hard surface is applied, eliminating later expensive repair;
2. Risky late season paving is eliminated;
3. More mileage is improved sooner;
4. The cost of construction is spread over several years.

Note: Advantages may disappear if timely maintenance is not performed. Surface may deteriorate more rapidly because it is thinner than a designed pavement.

Summary

Some local roads are not well engineered. Today, larger volumes of heavy trucks and other vehicles are weakening them at a fast rate. Paving roads as a sole means of improving them without considering other factors is almost always a costly mistake. Counties and cities should consider these ten points first. Carefully considering them will help to assure local government officials that they are making the right decision about paving a gravel road.