Findings and Recommendations for

Stabilizing Stream Temperature and Volume

in the Vermillion River Watershed

Recommendations to the Vermillion River Watershed Joint Powers Board on the feasibility of establishing a voluntary water-quality thermal pollution trading program in selected zones of the watershed.

December 2008
Introduction

To the Vermillion River Watershed Joint Powers Board

This document presents findings and recommendations to the Vermillion River Watershed Joint Powers Board (VRWJPB) on the optimal regulatory and market framework to preserve stream flow and temperature stability in the Vermillion River Watershed. It also makes recommendations about establishing a market-based water-quality thermal trading program within the area of the watershed with designated trout streams. Most market-trading efforts to control water pollution focus on reduction of nutrients, such as phosphorus or nitrogen. The concept of thermal trading is unique, and this study is one of the first in the nation to focus on market-based methods of preventing stream volume and temperature increases.

The Vermillion River Watershed Joint Powers Organization (VRWJPO) co-sponsored this study to assess thermal trading with the U.S. Environmental Protection Agency (EPA). The VRWJPO is a Joint Powers Organization enabled by Minn. Stat. Ch. 103B, the Metropolitan Surface Water Management Act. This Act requires the VRWJPO to develop plans and goals for management of water resources, and provides regulatory and capital project authority to implement the watershed plan. The goal of this project was to determine whether a market-based regulatory framework was a viable way for the VRWJPO to meet its regulatory objectives. The EPA’s Targeted Watersheds Grant program provided $675,000 for this effort, matched by $250,000 in funding and in-kind services from the VRWJPO and many partners in the project. The Minnesota Pollution Control Agency (MPCA) and the University of Minnesota St. Anthony Falls Laboratory contributed substantial funding and in-kind services to explore heat movement and impact for this project and other temperature-sensitive water resources in Minnesota.

The grant did not require the VRWJPO to institute a thermal trading program. Only the VRWJPB has the authority to decide whether thermal trading is the best way to implement its regulatory program. This document provides facts, findings, and recommendations to assist the VRWJPB in weighing this decision.

The VRWJPO received the EPA grant because the Dakota and Scott County communities within the watershed are rapidly developing. The Vermillion River Watershed is a rarity among developing urban watersheds, with more than 49 miles of designated trout streams. The brown trout, which requires cool water to reproduce and thrive, is the indicator species for this project.

Definitions

Thermal trading – Allowing a proposer of land-use changes that would increase the temperature of the Vermillion River or its tributaries to mitigate the temperature change off-site if it is more economical, as long as the mitigation ensures that current stream temperatures are maintained.
Preservation of the brown trout fishery also is an important part of the VRWJPO’s overall plan, affecting not just regulatory processes, but capital improvement and education efforts as well. Surface water quality (objective 2 from the VRWJPO Watershed Plan) articulates the VRWJPO’s regulatory objective, which is to “minimize impacts of runoff from land-disturbing activities… and preserve a viable cold-water fishery by developing stormwater rate and volume control techniques.” However, this is not solely a “save the trout” objective. It is also an effort to save the trout streams from impairment in as cost-effective a manner as possible.

The VRWJPO recognizes that the choice to regulate imposes costs. What initially attracted the VRWJPO to the idea of a market based regulatory system is its potential to be a cost-effective means of achieving environmental compliance. In addition, the VRWJPO recognizes that if the temperature exceeds a certain level in designated trout streams in the Vermillion River, these streams may be listed as impaired for a designated use. This impairment would trigger studies, load allocations, and regulations that could be expensive and potentially prescriptive for communities near trout streams. If the VRWJPO and communities in the watershed can prevent temperature increases and impairment in the trout streams, citizens and the environment will benefit.

The EPA Targeted Watersheds Grant Steering Team has provided these findings and recommendations for the VRWJPB’s consideration after more than two years of monitoring, modeling, and investigation. We hope it is helpful to the VRWJPB in deciding what regulatory strategies for maintaining temperature and preserving the brown trout fishery are in the best interests of the watershed and its citizens. We also believe that findings are useful for guiding the capital improvement and education program elements of the VRWJPO.

Respectfully submitted,

EPA Targeted Watersheds Grant Steering Team

Several members of the original Steering Team, from left to right: Steve Taff, Jay Coggins, Tae Kim, Tom Berry, Kim Alan Chapman, John Jaschke, Marybeth Block, Lee Marlowe, Paula Liepold, and Paul Nelson.
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Thanks to Key Project Personnel

*The following people have been central to implementing the grant and developing this proposal, and the Steering Team would like to recognize their contributions.*

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Executive Summary

In August 2006, the U.S. Environmental Protection Agency (EPA) awarded the Vermillion River Watershed Joint Powers Organization (VRWJPO) a three-year Targeted Watersheds Grant to determine the optimal regulatory and market framework to preserve stream flow and temperature stability in the Vermillion River Watershed’s trout streams.

The EPA, VRWJPO, partner agencies, and project participants wanted to know if a market-based thermal trading option would be effective in preventing increases in runoff volume and temperature that accompany land-use changes, such as residential or commercial development. There are compelling reasons why maintaining volume and temperature in the Vermillion River trout streams is important to watershed residents, businesses, and land owners:

- Recent monitoring data (2005-2007) suggest that temperatures in some stream reaches are at levels that stress brown trout (18 degrees C) and occasionally spike to levels that young trout can’t survive for long (23 degrees C or above).

- Temperature increases in the 49 miles of designated trout stream in the Vermillion River Watershed may lead to these reaches being listed as impaired under the federal Clean Water Act. Such an impaired waters listing brings costs and responsibilities, potentially including mandatory controls.

- Planned future residential and commercial development (based on 2020 and some 2030 projections for Dakota and Scott Counties) will likely increase the export of heated runoff to designated trout streams.

- Climate projections for Minnesota suggest the possibility of warming air temperatures, more intense storm events, and higher evening temperatures, all of which will have a heating impact on streams.

Despite these warning signs, Vermillion River streams sustain a healthy trout population, a population that is holding its own and even expanding its range. This is not a contradiction; it is a confirmation that portions of the Vermillion River are transitional areas from a cold water community to a warm water community, and that the river is resilient, with features that help it adapt or cope with change:

- Twenty years ago the Vermillion River did not support a trout population. Effective regulations, sufficiently planned development, and better river stewardship have improved water quality in the Vermillion River enough to support trout.
Evidence confirms that groundwater makes up an estimated 80 - 85 percent of the Vermillion River’s flow. During hot and dry periods, the consistent cooling infusion of groundwater stabilizes the stream temperature, allowing trout and other cold water organisms to survive.

Trout stressed by elevated stream temperatures move to groundwater-cooled refuge areas, thereby surviving heat impacts that otherwise could be deadly.

Standards developed by the VRWJPO require runoff volume control sufficient to control flow rate and volume from a 2-year, 24-hour storm event. Volume control practices largely rely on infiltration. Infiltration reduces runoff and recharges groundwater, both of which can decrease temperature impacts of new development.

No matter how resilient the Vermillion River has been, land-use and climate change will inevitably affect stream temperatures already considered elevated by some. The Steering Team recommends that the Vermillion River Watershed Joint Powers Board (VRWJPB) takes steps to maintain existing stream temperatures by developing strategies that reduce excessive heat impacts from existing, proposed, and future land use. Suggested strategies to “hold the line” on stream temperatures are included in this document.

Recommendation #1: Allow thermal trading as a voluntary option.

The Steering Team recommends that the VRWJPB allow thermal trading as a voluntary option for developers and landowners, without establishing or promoting a thermal trading program. The Steering Team examined regulatory, scientific, and economic factors involved in water-quality market trading. The consensus among the Steering Team members is that many practical barriers exist to an active thermal trading program in the Vermillion River Watershed at this time.

These barriers make it unlikely that a robust thermal trading market will develop. However, the Steering Team feels that there may be selected cases where trades for off-site mitigation are both viable and economical. The Steering Team recommends that the VRWJPO allow voluntary off-site mitigation for temperature. It may be a valuable option for specific developments or future conditions.

Recommendation #2: Adopt the findings included in this document.

The Steering Team recommends that the VRWJPB adopt the findings included in this document. The regulatory, scientific, and economic research conclusions reached throughout the EPA thermal trading investigation deserve to be widely shared. The project has substantially increased understanding about factors that create, influence, convey, and transfer heat in streams and rivers. These findings will help the VRWJPO and other watersheds to assess current conditions, assign priority to deal with “hot spots,” estimate impacts of proposed land-use
Change, develop cooling strategies, and measure results. The findings also indicate directions that future study should take.

**Recommendation #3: Implement cooling practices at strategic locations.**

The Steering Team recommends that the information and tools developed through the EPA thermal trading investigation be used to implement best management practices that will maintain temperature in the Vermillion River trout streams. These cooling practices should be integrated into new development/redevelopment plans and promoted as retrofits for existing businesses, residential property, public land, and agricultural land. Several tools created during the EPA trading investigation can help identify beneficial and cost-effective locations for cooling practices. Incentives for those implementing cooling practices could include: cost-sharing, technical assistance, potentially future carbon credits (for shading practices), and recognition.

Potential sources of funding for cost-share incentives include:

- EPA grant funding of approximately $10,000 budgeted for establishing trading sites;
- VRWJPO funding for capital improvement projects;
- Funding requested in a proposal for Clean Water Act Section 319 funding for cooling practices demonstration, $120,000 over 3 years; and
- Clean Water, Land and Legacy Amendment funding in 2010.

**Recommendation #4: Continue and improve stream temperature monitoring.**

The Steering Team recommends that the VRWJPO, in cooperation with Dakota and Scott County Soil and Water Conservation Districts (SWCDs), continue and improve temperature monitoring on the Vermillion River, especially in trout stream areas most at risk. A long-term monitoring plan is one of the final products and will contain specific and detailed recommendations.

**Recommendation #5: Reconsider design standards for specific stormwater best management practices.**

The Steering Team recommends that the VRWJPO, project partners and participants, consultants, construction firms, and others working with stormwater best management practices re-examine design standards for specific practices in context of thermal impact. Assessments completed as part of this project confirm that the VRWJPO Runoff Volume Control Standard should work for controlling increases in runoff volume and temperature from new development. However, effectiveness for temperature control depends on the specific design of the stormwater system. In particular, how wet ponds are designed, and whether wet ponds and volume practices are sequenced, affect temperature results. Wet ponds, used to control the rate
of stormwater flow, are found to release heated water to streams during larger storm events, unless infiltration basins adequately contain overflow amounts. Vegetated ponds were found to be one of the most effective cooling practices to prevent stream impacts. Reconstructed wetlands were not effective at reducing heat loading from the most damaging storm in developed areas, but should be investigated for cooling effects on agricultural landscapes because they are proven to significantly reduce heat export. The VRWJPO Runoff Volume Control Standard requiring infiltration of the 2-year, 24-hour storm seems to be effective in containing 98 percent of stormwater volume (and therefore heat from runoff). The new information developed during the EPA thermal trading investigation refines knowledge about the optimal methods of stabilizing temperature in trout streams and should be integrated into BMPs.

**Recommendation #6: Make investigation results, tools, future study suggestions, and findings widely available through targeted education, training, and promotion.**

The Steering Team recommends that the VRWJPO make the investigation results widely available to local, state, and national organizations, both public and private. This can be achieved using existing communication channels, including publications, professional meetings, fact sheets, Web site, providing applications on CD, training, demonstrations, and other strategies.
History and Background Information about the VRWJPO and EPA Targeted Watersheds Grant

The Vermillion River Watershed includes 335 square miles in central Dakota County and extreme southeast Scott County in the Twin Cities Metropolitan Area. The Main Branch of the Vermillion River is 38 miles from the headwaters to the Mississippi River. An estimated 49 miles of the main stem and tributaries are designated trout streams. Currently, 20 communities are all or partly included in the watershed.

In 1984, these communities signed a Joint Powers Agreement to manage the watershed. In 2000, the original watershed management organization dissolved and Dakota and Scott Counties became statutorily responsible for managing the watershed. In 2002, a Joint Powers Agreement between Dakota and Scott Counties created the Vermillion River Watershed Joint Powers Organization (VRWJPO).

The VRWJPO is governed by a Board consisting of two Dakota County commissioners and one Scott County commissioner. The Board is advised by a nine-member citizen advisory group, the Watershed Planning Commission. The counties jointly fund watershed activities and both have established special tax districts within the watershed. Based on tax capacity, Dakota County contributes 96.5 percent and Scott County 3.5 percent of revenue.

The VRWJPO moved promptly to develop the needed policy and infrastructure to manage the watershed effectively. The VRWJPO Watershed Plan was issued in November 2005. The VRWJPO established watershed Standards in October 2006 and VRWJPO Watershed Rules in March 2007.

The U.S. Environmental Protection Agency (EPA) Targeted Watersheds Grants program, formerly called the Watershed Initiative, has awarded funds to watershed projects for the last six years. The guidelines indicate the EPA’s interest in: 1) creative approaches to preserving or restoring water quality; 2) broad-based partnerships to achieve watershed improvement goals; 3) watersheds with fully developed plans; and 4) watersheds with a mix of urban and rural landscapes.

The VRWJPO submitted an application in concert with many partner agencies in 2004 for the 2005/2006 funding cycle. All proposals must be submitted to the EPA by the Governor or a Tribal Leader. The initial effort was not approved for submission by the Governor. In 2005, the VRWJPO submitted a revamped proposal for the 2006/2007 funding cycle, which was submitted by the Governor and funded by EPA.

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The VRWJPO received $675,000 for three years, and the EPA requires local match of $250,000. The project, “Creating the Optimal Regulatory and Market Framework to Preserve Stream Flow and Temperature Stability in an Urbanizing Trout Stream in the Midwest,” began in August 2006 when funding was received, and the grant will end in August 2009.
Project Goals and Tasks

The goal of the Targeted Watersheds Grant is to create the optimal regulatory and market framework to preserve stream flow and temperature stability in an urbanizing trout stream in the Midwest and explore thermal trading as a method of meeting volume and temperature standards.

To achieve this goal, the original VRWJPO proposal established seven primary tasks. As the project scope altered, three additional tasks were added. The ten tasks are:

- **Evaluate current regulatory mechanisms in a market-trading context.** What federal, state, and local regulations apply to stormwater volume and temperature? How do the VRWJPO’s current standards and rules work? What authorities does the VRWJPO have? What authorities do local government units have? How would a water quality trading program fit into the whole regulatory environment? What future regulations are coming that would affect a trading program?

- **Conduct a scientific and landscape assessment of existing and potential water temperature attenuation functions.** How does heat move in the watershed? What role does land cover play? How much heat does runoff lose before it reaches the stream? How does groundwater affect stream temperatures? Once heat reaches the stream, how long does it last and how far does it travel? What types of storms bring the most heat to the stream?

- **Establish the tradable critical functions of the watershed.** What is the commodity to be traded? Is it volume, heat export from the land, heat contribution to a point in the stream, or stream impact overall? Within what geographic area can trading take place? Can trading be done anywhere within a trading zone or only upstream from new development?

- **Set uniform regulatory standards and criteria to support market trading.** How does trading fit into the Vermillion River Watershed Plan, Standards or Rules? How does it fit into approved local water plans? What is the “cap” under which trades will take place? How will off-site trading locations be managed? Are the tools to determine compliance adequate?

- **Create a currency for trading watershed functions.** Should a trading program trade volume or heat? Which are the most valuable trades? How is the value of off-site mitigations going to be determined? How much is an off-site mitigation near the river reach worth compared to one further away?

- **Develop the regulatory and market framework for implementation.** What is the size of the market for thermal trading? Who will be the coordinating body for trades? What happens if off-site mitigation locations aren’t maintained or kept in a specified land use? What role do local government units play in trades? What costs and infrastructure would be needed to implement trading?
- **Monitor critical watershed functions and other indicators.** How are the trout doing now? Are designated trout streams reaching temperature ranges where trout are stressed or threatened? What role does groundwater play in cooling the streams? What other organisms may be threatened by increased heat?

- **Conduct outreach activities.** Does the general public understand the impacts of temperature on trout streams? Do local government units, developers, and landowners want a thermal trading option? Can other jurisdictions and the broader scientific community benefit from the findings? Do decision-makers understand how trading might work? Are the findings and tools developed going to save the VRWJPO and other watersheds time, effort, and money?

- **Establish trading sites.** What are the highest priority areas for cooling practices? Are new or re-development sites the only ones contributing heat to the stream? Where is land available for off-site mitigation? How well will the tools to estimate impacts on stream temperature work? How will sites be monitored?

- **Fulfill grant administration responsibilities.** Is the EPA receiving required reports? Is the project over or under budget? Have partners provided sufficient matching funds or in-kind services? Are contracts being completed as scheduled? Has the Steering Team stayed focused on the primary goal?

The Steering Team’s role has been to complete these tasks, as well as provide regular updates to decision-makers and partners through the VRWJPO Board meetings, the Watershed Planning Commission, and the Technical Advisory Group.
Findings: What We’ve Learned

While the questions listed in the project’s 10 tasks seem straightforward, the answers are often complex and lead to even more questions. The findings listed here range from mundane to surprising to ground-breaking. Together, they give the VRWJPO a “big picture” view of heat movement in the watershed.

The findings are organized into four categories: General, Scientific, Economic, and Regulatory. The General category covers several assumptions made before the investigation began. For each finding, reference sources are cited.

**General Findings**

The Vermillion River is an urbanizing trout stream. State demographics and land-use data and projections confirm it. According to Metropolitan Council data, between 1970 and 2005, Dakota County lost more than 7,500 acres of non-urbanized land (undeveloped, agricultural, steeply sloped or wetland); added 3,592 acres in major four-lane highway; and more than doubled its residential acreage from 20,150 to 58,455.¹ According to Minnesota Household Projections 2005-2035, issued by the Minnesota State Demographic Center in August 2007, Dakota County’s population will increase by 38.4 percent by 2035, and Scott County’s will increase 170.3 percent.² Land-use projections for 2020 show substantial residential and commercial development plans within the vicinity of trout streams.³

Temperatures greater than 18 degrees Celsius adversely affect the brown trout’s habitat selection, growth, reproduction, and mortality. A thorough literature review conducted by J. Bell⁴ as part of this investigation identified heat’s adverse impacts on brown trout.

**Definitions**

- **2-Year, 24-Hour Storm** – The storm event upon which the VRWJPO’s stormwater runoff standard is based. It is all storms less than 2.6 inches of precipitation falling in a 24-hour period.
- **Acute** – Impacts that are brief and severe.
- **Base flow** – A stream’s flow during times when rainfall and snowmelt are low.
- **Chronic** – Impacts that continue for a long time or recur frequently.
- **Cooling practices** – Stormwater best management practices that also provide cooling benefits to streams, such as shading, commercial roof disconnection, green roofs, groundwater infiltration, vegetated ponds, and other practices.
- **Design storm** – A specific rainstorm type based on historical records of air temperature, dew point, wind, and solar radiation used in a model or other calculations.
- **Dew point** – The temperature at which the air is saturated with water. The dew point is a measure of humidity.
- **Heat export** – The amount of heat that leaves the land when the rain falls.
- **Heat contribution** – The amount of heat that actually makes it into the stream from the land during a rainfall.
- **Heat impact** – How much the heat contribution increases the stream temperature, how long the change lasts, and how far it travels downstream.
- **Impaired waters** – Waters that listed by the EPA on the Clean Water Act Section 303(d) list as impaired for specific use.
- **Impervious** – Not permitting penetration or passage of water.
- **kiloJoule (kJ)** – A measurement of heat, roughly equal to 0.239 calories.
- **Refuge reaches** – those reaches of the trout streams that are naturally cooled by groundwater discharge and support all ages of trout.
The optimal water temperature for brown trout is 12-18 degrees C. The metabolic rate of brown trout increases at temperatures greater than 19 degrees C., creating stress and high energy demand. Brown trout cannot survive long at temperatures greater than 22 degrees C.

The Vermillion River’s temperature is near levels of concern in some locations. The Vermillion River Monitoring Network 2007 Report prepared by Dakota County SWCD\(^5\) concludes that average temperatures at most monitoring stations, especially those in the trout stream portions of the Vermillion River, were near the 18 degrees C threshold for chronic impacts. A technical memo completed by LimnoTech\(^6\) showed that in 2006 temperatures were measured above the 23 degree C acute impact level in some stream reaches.

The Vermillion River’s flow volume has increased. Increases in river flows have been documented by the 1998 U.S. Army Corps of Engineers study\(^7\), the 2002 Vermillion River Volume Study\(^8\) conducted by Montgomery Watson Harza, and the 2005 Vermillion Watershed Management Plan\(^3\). There are many reasons for the increased volume, including increasing impervious surface and rainfall, and several factors that offset those increases.

The Vermillion River did not support trout twenty years ago. It is thought that wastewater discharges wiped out the brook trout fishery in the 1950s or 1960s. Brown trout were re-introduced in 1990, and since that time have expanded their range. The Vermillion River’s current condition supports brown trout and should be established as the temperature baseline.

Climate trends may increase trout stream temperatures regardless of land-use decisions made in the watershed. “The most recent two to three decades of Minnesota climate have exhibited substantial changes that are consistent with warming and moistening and that are coherent,” according to a March 2008 climate summary\(^9\) from the Minnesota Climatology Working Group, consisting of the DNR’s State Climatology Office and the University of Minnesota.

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**Scientific Findings**

The chronic temperature threshold for brown trout is 20 degrees C for 24 hours or more, and the acute temperature threshold is 23 degrees C for one hour or more. To preserve the brown trout fishery the occurrence of these temperature conditions should not increase.

Trout stream reaches can be classified into those that support young-of-the-year, adult trout only, or no trout. B. Nerbonne and K. Chapman\(^10\) classified the Vermillion River system into reaches by trout population and temperature regime. Reaches that support young-of-the-year are the sensitive to stream temperature increases, but have protective groundwater cooling features that some adult-trout-only reaches do not have, so protecting both types is important.

The rainstorm that exports the greatest amount of heat for various land cover types is a half-inch rain that falls on a hot and humid day and has a four percent probability of occurring in any given year. An analysis of the storms in the region\(^11\) shows that heat export from impervious surfaces (commercial roof, concrete, asphalt, bare soil) during this half-inch storm exceeds the 23 degree C acute temperature threshold. This “design storm” that exports the most heat was used in the model as a worst-case scenario.
The half-inch design storm may not represent that storm that provides the greatest heat contribution and impact to the stream, and may not provide sufficient information about the heat export from agricultural land. The 2-year, 24-hour storm is the event upon which the Vermillion River Watershed standards are based and is likely to better reflect heat export from both developed and agricultural land. It may be valuable to recalibrate the models using this bigger storm type to provide a more comprehensive understanding of heat export consistent with the current watershed standards. However, this additional investment may be postponed until other barriers to a market-based trading program change.

Land covers that are impervious surfaces export the most heat from the half-inch design storm. An analysis by the University of Minnesota St. Anthony Falls Lab (SAFL)\textsuperscript{12} showed that commercial roofs, concrete, asphalt, and bare soil export the most heat. Heat-reducing practices are most important for these land covers.

Air temperature is the primary heating influence on stream temperature. Comparison of stream temperatures with air temperatures show that stream temperature closely tracks air temperature. (See graph at right.)

Groundwater is the primary cooling influence on stream temperature. Groundwater makes up 80-85 percent of the Vermillion River’s flow. Its cooling influx maintains relatively stable temperatures in certain stream reaches.

Vermillion River reaches have cool spots related to specific groundwater discharge points. Stream monitoring data and information from the longitudinal temperature survey\textsuperscript{13} show specific locations where groundwater discharge points create cool spots or refuge reaches. Maintaining these cool water refuges and preventing thermal degradation of reaches with adult trout is of critical importance in sustaining trout populations and providing predictable habitat in the face of unpredictable climate factors and unintended human impacts.

Groundwater infiltration is important everywhere in the watershed. Efforts to define “groundwatersheds” or groundwater trading zones served to re-emphasize that interconnections in the sub-surface make establishing boundaries problematic. Groundwater impacts on stream temperatures are not tradable.

Infiltration practices that contain or reduce stormwater volume also reduce heat impacts on streams. A SAFL study\textsuperscript{14} suggests a volume standard that contains stormwater on site contains much of the heat content as well. Applied Ecological Services’ (AES’s) overview of the literature on cooling practices (in process) indicates that infiltration practices such as soil amendment, permeable pavement, bioretention ponds, and infiltration beds reduce heat export.
Stream shading reduces chronic, but not acute, heat impacts on streams for the half-inch design storm. Modeling suggests that shading is an effective method of cooling streams, but does not prevent an initial temperature “spike” that exceeds the 23 degrees C acute threshold for trout.

Disconnecting commercial roofs reduces acute and chronic heat impacts on streams for the half-inch design storm. Modeling suggests that disconnecting commercial roofs and allowing runoff to infiltrate on-site is an effective method of reducing acute and chronic heat impacts on streams. Green roofs are also effective, but much more expensive to implement.

Unvegetated detention ponds (rate-control ponds, wet ponds) export heat at higher levels and rates than residential roofs, short grass, corn, tall grass, forest or wetlands. The storm analysis\textsuperscript{10} showed that vegetated ponds export no heat from the half-inch design storm.

### Economic Findings

No heat impacts were detected for agricultural and forested land covers for the half-inch design storm, which limits options for trading. In order to trade on-site heat impacts for off-site heat reductions, BMPs must be installed on land that has heat impacts that need mitigation. In the Vermillion River Watershed, much of the land is agricultural. The model did not detect agricultural heat contributions from a half-inch storm. This means that trading would be restricted and involve trading on-site heat impacts of proposed development for off-site heat impacts of existing development. If off-site mitigation costs are comparable to on-site mitigation costs, there is little economic benefit to off-site mitigation.

Pre-computing the cost in dollars per kJ of heat reduction for all locations and practices is not feasible. The costs of on- and off-site cooling practices vary depending upon location (proximity to stream, upstream or downstream, features of the site, land value). The Steering Team envisioned a database of pre-approved trades that would give developers estimates of dollar/kJ for off-site mitigation practices at specific locations. The variables make such estimates complex and uncertain.

Off-site temperature mitigation sites must be located either upstream or nearby. Models predict that downstream trading locations would create stream hot spots, unless they are very close to the development site. By limiting trades to upstream locations and nearby sites, the potential market is reduced.

There is a limited demand for thermal trading. Market-based trading approaches to pollution are successful only if the market wants the option and will participate. Discussions and focus groups confirm that prospective customers (developers, local government, landowners) are not convinced that off-site mitigation of heat impacts is needed, cost-effective, or value-added.

There is a limited regulatory driver. The VRWJPO Watershed Plan and Standards regulate temperature issues primarily through the runoff volume standard. Analyses completed during this project found that this approach should be effective at controlling volume and temperature increases. (It also adds to the cost of new development.) However,
the current perception is that the runoff volume standard can be met on site. Discussions with a focus group confirmed that developers are risk adverse when it comes to regulatory compliance, and prefer a known solution over one the has some uncertainty. Unless perceptions change and developers identify a cost benefit to meeting the standards with off-site practices, the regulatory driver is limited.

**The market is too small.** Warming and cooling impacts on streams are local. A development site and off-site mitigation must be close together to achieve no net increase in stream temperature. In addition, the mitigation must be upstream of the development site or nearby. These geographic limitations shrink the size of the trading zones, the number of available mitigation sites, and the potential cost-savings for customers.

**Insufficient information is available about cost and performance of cooling best management practices.** More data comparing projected impacts of cooling practices with measured impacts are needed.

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**Regulatory Findings**

The VRWJPO’s authorities derive from the Minnesota Metropolitan Surface Water Management Act, Minn. Stat. Ch. 103B, and Minn. R. 8410, which directs implementation of 103B. These laws and rules require the VRWJPO to develop and implement a Watershed Management Plan, including Standards (defined outcomes or objectives of the plan) and Rules (implementation of the Plan’s policies, objectives and actions).

Language in the **VRWJPO Watershed Plan** (November 2005); **VRWJPO Standards** (October 2006); and **VRWJPO Watershed Rules** (March 2007) all explicitly require new development to have stormwater runoff temperature and volume control. No other federal or state agency holds a permit with the VRWJPO that supersedes the VRWJPO’s authority to require stormwater runoff temperature and volume control.

The VRWJPO has the authority to allow thermal trading as an option to achieve the Standards. The Steering Team feels that there may be selected cases where trades for off-site mitigation are both viable and economical. It may be a valuable option for specific developments or future conditions. Tools developed during this project could be used to simplify the analysis of the trade. The proposer of off-site mitigation must bear the burden of proof that there is no net temperature increase to the stream; protect the off-site mitigation as a conservation easement; trade only in an upstream direction or within a short distance of the proposed activity; receive certification of the practice from the VRWJPO; and obtain approval from the local unit of government.

Municipalities with an approved water plan and stormwater permitting authority can approve or deny off-site temperature mitigation. The **VRWJPO Plan** and **Standards** recognize that the control and determination of appropriate land use are the responsibility of Local Units of Government (LGUs). In Dakota County, cities are LGUs within their corporate limits, townships are the planning and zoning authorities in unincorporated areas, and Dakota County has authority within shorelands and flood plains, and for individual sewage treatment systems in unincorporated areas.
In Scott County, the County is the LGU in unincorporated areas, and cities are the LGU within their corporate limits.

The VRWJPOs Runoff Volume Control Standard effectively controls increases in runoff volume from new development, and may decrease runoff volumes after such development more than existing development or pre-development conditions. The Barr Engineering study (in process) on the effectiveness and cost of the VRWJPO Runoff Volume Control Standard suggests that the current standard works to contain volume increases that occur at developments constructed in compliance with the standard.

Decisions made at the state and federal levels can change the regulatory environment for the VRWJPO regarding stream volume and temperature. If the Vermillion River trout streams are proposed for the federal Clean Water Act 303(d) list as impaired for temperature (leading to development of a Total Maximum Daily Load), further study and temperature reduction allocations may be required.
Recommendations: What Actions We Could Take

In developing the following recommendations, the Steering Team focused on practical, economical, and effective steps the VRWJPO could take to maintain the cold-water fishery in the Vermillion River. As the findings suggest, the investigation provided both good news (cooling groundwater base flow, effective runoff volume standard, improvement of river environment over pre-development conditions) and not-so-good news (stream temperatures close to trout stress thresholds in recent years, shortcomings of stormwater BMPs for temperature control).

Recommendation #1: Allow thermal trading as a voluntary option.

The EPA is interested in exploring market trading options for water pollutants, and efforts by the VRWJPO and partners to design an active thermal trading program have been of national interest. However, developing an active thermal trading program in this watershed at this time is not feasible, although the Steering Team recommends allowing thermal trading as a voluntary option for appropriate development proposals or future conditions.

The major barriers to a thermal trading program include the following:

- **There is little or no demand.** Market-based trading approaches to pollution are successful only if the market wants the option and will participate. Discussions and focus groups confirm that prospective customers are not convinced that off-site mitigation of heat impacts is needed, cost-effective, or value-added.

- **There is a limited regulatory driver.** The VRWJPO Watershed Plan and Standards regulate temperature issues primarily through the runoff volume standard. Analyses completed during this project found that this approach should be effective at controlling volume and temperature increases. However, the current perception is that runoff volume standard can be met on site. Discussions with focus groups confirmed that developers are risk averse when it comes to regulatory compliance, and prefer a known solution over one that has some uncertainty. Unless perceptions change and developers identify a need or cost benefit to meeting the standards with off-site practices, the regulatory driver is limited for stimulating off-site temperature mitigation.

- **The market is too small.** Warming and cooling impacts on streams are local. A development site and off-site mitigation must be close together to achieve no net increase in stream temperature and prevent hot spots. In addition, the mitigation must be upstream of the development site for greatest certainty and effectiveness. These geographic limitations shrink the size of the trading zones, the number of available mitigation sites and potential cost-savings.
The science of measuring, modeling, and mitigating heat impacts on streams is in early stages. A thermal trading program must be able to measure the impacts of land-use change on stream temperature. Monitoring based on regular geographic or temporal intervals may not pick up substantial heat impacts on streams that result from local conditions. This makes trend assessment and compliance detection problematic.

Non-degradation considerations may complicate trading across municipal boundaries. Trading zones based on thermal impacts and conditions do not take into account jurisdictional boundaries. Trades across municipal boundaries may not be consistent with federal MS4 requirements.

New development would bear a disproportionate responsibility for stabilizing stream temperature, because greatest stream impacts may be related to already existing land uses. Existing development, infrastructure (roads, pipelines, rail lines), and agricultural land all contribute heat to the watershed. A broader approach to stabilizing stream temperature would deal with all thermal impacts, not just those associated with new or re-development.

The Steering Team recommends that the VRWJPB allow thermal trading as a voluntary option for specific development plans where off-site mitigation of heat impacts makes sense and is cost-effective. Allowing thermal trades would also provide the VRWJPO with options if the Vermillion River trout streams are listed on the 303(d) list as impaired, if regulations change, or if climate changes affect local conditions.

Tools developed during this project could be used to simplify the analysis of the trade. The proposer of off-site mitigation must bear the burden of proof that there is no net temperature increase to the stream; protect the off-site mitigation using an appropriate legal tool such as a conservation easement; trade only in an upstream direction or within a short distance of the proposed activity for greatest certainty that no net change in temperature will occur in the stream; receive certification of the practice from the VRWJPO; and obtain approval from the local unit of government.

### Action Steps:

1. Allow off-site mitigation of thermal impacts on the Vermillion River if specific conditions are met. The first thermal trading proposal submitted to the VRWJPO will be treated as a pilot project. Any thermal trade resulting from this proposal will be approved by the VRWJPB. The VRWJPB will receive a summary of staff time, costs, and procedural issues before any additional thermal trades are considered or amendments requested to the Watershed Plan.
2. Prepare a fact sheet for project proposers to describe the thermal trading option and help them decide if it is a feasible approach for the project.
3. Prepare a fact sheet for local government units to describe the thermal trading option and provide a checklist of steps proposers must take to achieve a trade.
4. Provide environmental consulting firms that work with project proposers with the land cover heat export/contribution model to calculate a proposal’s heat export/contribution.
Recommendation #2: Adopt the findings included in this document

The findings included in this document are conclusions about which the Steering Team achieved consensus and are well-supported by the scientific, economic, and regulatory research completed under the EPA Targeted Watersheds Grant. They serve as the basis for the recommendations and action steps proposed to the VRWJPB. The findings will assist the VRWJPO staff in developing strategies to protect and improve the watershed, both now and in the future. In addition, the findings provide a baseline for future research and a brief summation that will assist watershed managers in other jurisdictions facing increased stream temperatures in cold water fisheries.

**Action Steps**

1. Adopt the findings included in this document.
2. Make the approved document, as well as data and research upon which findings and recommendations are based, available to partners, participants, and other interested parties through the Web site, e-mail, and direct correspondence.

Recommendation #3: Implement cooling practices at strategic locations

The Steering Team recommends that the information and tools developed through the thermal trading investigation be used by the VRWJPO and partners to implement cooling practices at strategic locations in the watershed. There is some urgency to this recommendation, since many regulatory factors are in play that may lead to the Vermillion River trout streams being listed as impaired on the federal 303(d) list. The VRWJPO, municipalities, businesses, and residents have already been affected by the Vermillion River’s listed impairments:

- From the headwaters to Hastings, the river is impaired for aquatic recreation because the levels of fecal coliform bacteria are too high.
- From Hastings to Red Wing, the river is impaired for aquatic life because it is too cloudy (turbidity) and has elevated levels of PCBs and mercury.
- Three new reaches of the Vermillion River were added to the 303(d) list in 2008, including the South Branch, for turbidity and bacteria.

Every time a new Vermillion River impairment is listed, the VRWJPO incurs the expense of studies and faces more prescriptive methods of reducing pollutant loads. The communities in the watershed will benefit environmentally and economically if an impaired waters listing for temperature can be prevented.

There is no consensus among the Steering Team members about how likely it is that the Vermillion River trout streams will be listed as impaired for aquatic life because of temperature, how
soon such a listing could be proposed, or on what basis an impaired waters listing would be proposed. It is important for the VRWJPO to be aware of factors influencing a potential impaired waters listing of the Vermillion River for temperature:

- The Minnesota Department of Natural Resources (DNR) has classified reaches of the Vermillion River (including a reach in 2008) as cold water streams (2A). This classification requires the Minnesota Pollution Control Agency (MPCA) to assess the Vermillion River’s 2A reaches as if the aquatic life are comparable to, for example, a North Shore stream.

- The MPCA conducted intensive watershed biological monitoring in the Vermillion River during the summer of 2008. The data will be used to help the MPCA and EPA develop an Index of Biological Integrity (IBI) for cold water streams. This IBI is the “yardstick” that will be used to decide if a stream is impaired or not.

- The *Vermillion River Monitoring Network 2007 Report* concluded that “average temperatures at most monitoring stations, especially those in the trout stream portion of the Vermillion River, were near the [18 degrees C] threshold” for optimal trout growth and reproduction. Stream temperature spikes that have briefly exceeded the brown trout’s acute temperature threshold (23-25 degrees C) have been detected in some reaches.

- A report commissioned by the VRWJPO detected temperature increase related to rising air temperatures and elevated night time water temperatures below the Empire Wastewater Treatment Plant near the U.S. Geological Survey gaging station.

- The VRWJPO biomonitoring plan was completed, but data are not yet available.

- Land-use planning documents for 2020 show increasing development pressures on areas tributary to the trout streams.

The MPCA prepares a draft impaired waters list for the EPA in even-numbered years, so the next proposed list will be submitted in 2010. The VRWJPO may have a window of opportunity to target specific cooling practices at strategic locations and measure results against a three-year baseline. As an additional benefit, the Land Cover Heat Export/Contribution Model, a tool developed during the investigation which estimates heat contribution to the river from land-use changes, can be tested under real-world conditions.

The primary focus of implementing cooling practices would not be solely – or even primarily – new development. The VRWJPO standards for runoff volume control have been shown to contain runoff and the heat it brings to the streams. New developments must meet this standard, established in October 2006. Land alterations (including changes to agricultural land) made before 2006 were not subjected to the standard. It may be pre-2006 activities that have increased stream temperature, not more recent development.

Accordingly, to most effectively implement cooling practices, the first consideration is not “what” land-use change is proposed but “where” cooling most needs to take place. The strategic location may be residential, commercial, park or open space, government-owned, agricultural, infrastructure (roads, bridges, airport, rail line), or new proposed use.
The information developed during the thermal trading investigation allows the VRWJPO to accurately identify strategic locations for cooling practices – the “where.” The model also allows the VRWJPO to estimate the heat reduction from cooling practices at any location and, to a lesser degree, the relative costs of implementation. This will provide the citizens in the watershed some confidence that they are getting the best heat reduction for the dollar in the right location.

The mechanism to implement cooling practices would be similar to other incentive programs supported by the VRWJPO to seal abandoned wells, upgrade septic systems, and install stormwater best management practices. An incentive that may be available to willing landowners in the future would be carbon credits for shading practices, if a federal CO₂ cap-and-trade program is undertaken.

The VRWJPB approved an application for Clean Water Act Section 319 funding ($240,000) to provide cost-share for installation of cooling practices (both new and retrofit), including commercial roof disconnection, shading practices, wet pond retrofits, green roofs, residential initiatives, and infiltration practices. The Targeted Watersheds Grant contains $10,000 for trading site identification which can be used to identify locations and promote cooling practices to landowners. In addition, VRWJPO capital improvement project dollars can be used to implement practices, at the Board’s discretion.

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**Action Steps**

1. Request VRWJPO staff to prepare a detailed work plan by February 2009 that identifies strategic locations for cooling practices based on stream sensitivity, estimated heat contribution, and estimated costs. The work plan should outline procedures to market cooling practices, select appropriate cooling practices, oversee installation, and measure heat reductions.

2. Request VRWJPO staff to identify and complete one or more demonstration sites or projects using Targeted Watersheds Grant funds and potentially VRWJPO capital improvement funding during the 2009 calendar year.

3. Seek funding and implementation partners.

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**Recommendation #4: Maintain and improve stream temperature monitoring**

The Steering Team recommends that the VRWJPO, in cooperation with Dakota and Scott Counties, Dakota and Scott SWCDs, and other partners maintain and improve stream temperature monitoring, especially for those stream reaches that have young-of-the-year or adult trout populations and are identified through modeling as most likely to increase in temperature. Recent modeling results indicate that headwater stream reaches are among the most susceptible to temperature increases that adversely affect trout health.
The VRWJPO, both through the EPA grant and the 2009 VRWJPO Work Plan, has taken measures to continue assessing the watershed’s thermal status, including the stream reaches. Among those monitoring efforts currently in process:

- One of the final products is a long-term monitoring plan that will contain specific recommendations on methods of maintaining or developing temperature monitoring for condition assessment. This will be delivered before December 31, 2008.

- The VRWJPO plans a February 2009 Monitoring Summit for Metro area watersheds, which will provide an opportunity to discuss existing locations and needed data.

- The VRWJPO has approved a biomonitoring plan that will involve sampling to determine the presence, abundance, and health of organisms that live in, on, or near the Vermillion River. The results will serve as baseline data, allowing staff to assess the impacts of temperature not only through direct measurement but on biological organisms.

- The MPCA conducted intensive watershed monitoring activities in the Vermillion River during the summer of 2008. The activities were intended to help shape an Index of Biological Integrity (IBI) for stream life and identify any condition problems. Results are pending.

- Dakota SWCD provides an annual report on the Vermillion River Watershed Monitoring Network, which includes temperature data. The Dakota SWCD, which worked with the Steering Team on monitoring for the EPA investigation, has suggested re-installing continuous temperature monitors during the June through September critical heating period at key locations.

- The VRWJPO has approved funding for 2009 to examine the potential impact of water appropriations on the Vermillion River groundwater, which contributes 80 – 85 percent of the river’s flow during summer months.

  Improved temperature monitoring is important to assess the condition of the trout streams, but it is also important in assessing the potential impacts of climate change on the Vermillion River. A review of literature on climate change impacts in the region (in process) shows that projected changes will have stormwater and land-use impacts, temperature impacts, and transitional vegetation impacts. Comprehensive monitoring will allow the VRWJPO to assess the river’s condition through variations in temperature.

  In addition to monitoring the river as a whole and sensitive reaches more intensively, a procedure for site-specific temperature monitoring should be developed for cooling practices demonstration sites. The Land Cover Heat Export/Contribution Model can estimate current heat export/contribution to the stream, as well as project heat export/contribution from installation of cooling practices. Site-specific temperature monitoring will allow the VRWJPO to test the model’s effectiveness and measure direct contribution to the stream.
Recommendation #5: Reconsider design standards for specific stormwater best management practices

The Steering Team recommends that the findings developed in the Targeted Watersheds Grant investigation be used by the VRWJPO, project partners and participants, consultants, construction firms, and others working with stormwater best management practices (BMPs) to re-examine design standards for specific practices. Results of modeling show that some stormwater BMPs characterized as “cooling” have different heat export/contribution impacts than would have been predicted by Steering Team members.

Research on stormwater BMPs that specifically consider thermal impacts on streams is limited, and more work is needed. Stormwater BMPs should be reconsidered in two ways – determining what land cover types export/contribute the most heat to streams and selecting the best stormwater BMP for each land-cover change proposed for design or construction.

Impervious surfaces (commercial roofs, concrete, and asphalt) deliver the most heat to the streams. Consider, however, that 80-85 percent of the Vermillion River’s flow consists of groundwater; the VRWJPO’s stormwater runoff standard requirement for on-site infiltration of the 2-year, 24-hour storm captures 98 percent of runoff (and therefore heat); and that commercial roof disconnection (infiltration on site) drops peak stream temperature impacts below the 23 degrees C. acute level for trout. These findings support the value of infiltration BMPs, such as commercial roof disconnection, pervious pavement, infiltration trenches, raingardens, and other methods that infiltrate ground water. It also suggests that to stabilize stream volume and temperature, efforts should be made to retrofit impervious surfaces developed before the VRWJPO’s Runoff Volume Control Standard took effect.

Wet ponds are in common use as BMPs for stormwater rate control. During intense storm events, heated water that collects in wet ponds can be released, causing spikes in stream temperature. If wet ponds are properly sequenced with adequate volume containment BMPs, heated stormwater infiltrates. If not, wet ponds are capable of delivering high volume, high temperature pulses to the

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**Action Steps**

1. Complete the long-term monitoring plan for temperature on the Vermillion River and its tributaries.
2. Develop steps to improve temperature monitoring on specific sensitive stretches of the Vermillion River and tributaries and develop time and cost estimates to implement the improvements and identify funding sources to complete the improvements.
3. Develop a procedure for site-specific demonstration project temperature monitoring.
stream. Again, the VRWJPO Runoff Volume Control Standard will contain 98 percent of stormwater on site for newer or proposed developments. It is existing wet ponds that deliver heat pulses, and options for vegetating ponds, shading ponds, or enhanced infiltration on site are important design modifications for existing ponds.

Shading stream banks is an inexpensive way to cool sensitive stream reaches, but is only successful in reducing the duration of chronic (greater than 18 degrees C) temperature impacts on trout. It does not mitigate acute (23 degrees C) temperature spikes, so should be only one of many options to consider when preventing heat impacts on streams.

The VRWJPO has applied for Clean Water Act Section 319 funding to install cooling practices and measure the temperature impacts. This would have the dual effect of maintaining stream temperatures and providing more definitive information about which cooling practices work and which do not. However, even preliminary information about the temperature impacts of these BMPs should be shared with those who design, install, or regulate such practices.

### Action Steps

1. Prepare a fact sheet for local units of government on reviewing development or redevelopment plans to ensure that stormwater management practices are effective in capturing heat as well as runoff.
2. Prepare a series of fact sheets on what we know about individual cooling practices from existing research and modeling efforts, and make these widely available to consulting and construction firms.
3. Consult the MPCA on whether information developed on BMPs and temperature should be integrated into the next revision of the statewide stormwater BMPs manual.
4. Request assistance from partners in local government units in identifying properties where commercial roof disconnects, shading, or additional infiltration may be effective.

### Recommendation #6: Make investigation results, tools, future study suggestions, and findings widely available through targeted education, training, and promotion.

The Steering Team recommends that the VRWJPO make the investigation results widely available to local, state, and national organizations, public and private. In a national meeting on water quality trading attended by the overall project leader, the VRWJPO investigation was the only one focused on temperature impacts of stormwater on rivers and streams, making the watershed a national leader in assessing temperature impacts. The information developed during the investigation should be widely shared with various audiences. While many of the findings included in this
document are intuitive, many others are ground-breaking and can be applied to other jurisdictions concerned about the effects of increasing temperature on rivers and streams.

The Steering Team has produced several scientific and economic papers that should be published in professional journals. The final report for the project will be made available online and on CD. In addition, tools produced during the investigation should be made available to water management professionals for use and adaptation for other watersheds. Training on use of the tools should be made available to interested users.

The Land Cover Heat Export/Contribution Model is a GIS-based application that based on Midwestern climate data, the most heat-delivering storm event, and current land cover, can estimate the amount of heat exported from a specific site. It also estimates the amount of heat contributed to the stream at the pour point. Finally, it can be used to project estimates of heat export or contribution change from new development, redevelopment, or other land-use alteration. The model has practical applications for proposers of land-use changes, including developers, consultants, municipal staff reviewing proposals, regulatory agencies, private property owners, and others. In areas with stream reaches sensitive to temperature change, this tool provides a method of estimating in advance of construction whether the land-use change will result in unsustainable heat impacts.

A second tool still under development, the Stream Impact Model, takes the results of the Land Cover Heat Export/Contribution Model, and estimates how the heat contribution will affect the stream itself. It estimates how much the stream will warm, how long the temperature increase will last, and how far downstream the temperature increase will go. These tools, once they are more widely available, will give users the ability to adjust land-use plans to prevent adverse heat impacts on sensitive stream reaches.

The models also provide a scientific foundation for voluntary efforts to mitigate heat impacts from existing land uses. The investigation has provided a greater level of confidence in the VRWJPO’s existing Runoff Volume Control Standard’s ability to contain heat impacts. New developments in compliance with the standard should not contribute significant heat to the streams. Those land-use changes that took place before the standards were in place are more likely sources of heat to the trout streams, and installing cooling practices at key locations may be the most cost-effective method of stabilizing stream volume and temperature.

While the VRWJPO’s runoff volume standard seems to work well to maintain volume and temperature, it is expensive for proposers of new development. In some circumstances, off-site mitigation of thermal impacts may be less expensive. By giving project proposers the option of off-site temperature mitigation, the VRWJPO allows the project proposer to select a way to comply with the standards that best fits the site and circumstances.

The Steering Team and project participants have presented interim results in many professional venues, and will continue to discuss findings in local, statewide, and national conference settings. In addition, investigation data and information serves as a platform for further study. Among those topics that require further research:

- Is runoff volume a surrogate for heat, and would eliminating runoff into streams help maintain temperature stability?
Would recalibrating the models to the larger 2-year, 24-hour storm provide a different picture of heat impacts from developed versus agricultural land?

How might changes in climate affect the Vermillion River temperatures?

Since groundwater is the major factor maintaining sufficiently cool stream temperatures, how do water appropriations affect stream warming or cooling?

The brown trout is the indicator species for this investigation, but what other forms of aquatic life will be affected by changes in stream temperature?

Which cooling practices work best for which land-cover situations?

These and other research questions will be studied further. By widely disseminating the results of this investigation, the VRWJPO will focus and promote efforts to preserve healthy trout populations, build resilient ecosystems, and implement practical cost-effective regulation for prairie rivers such as the Vermillion.

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### Action Steps

1. Prepare the final report on the EPA Targeted Watersheds Grant by September 30, 2009, or sooner.
2. Work with authors of research papers to place investigation results in professional journals or publications widely read by water management professionals.
3. Present investigation findings and results at additional local, state, regional, and national meetings to both professional and citizen audiences.
4. Prepare, in conjunction with the final report, fact sheets for targeted audiences on research findings that affect them, for example: brown trout chronic and acute temperature levels to trout management and conservation groups; benefits of stream temperature shading to parks and public land managers; discussion of infiltration strategies for cooling streams; and more.
5. Provide appropriate user interfaces and training for models.
6. Consider formal or informal networking with other watersheds working to maintain temperatures in cool-water trout streams.

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### For More Information

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