The Potential Effects of the Proposed Russell Biomass Plant on the Water Quality of the Westfield River

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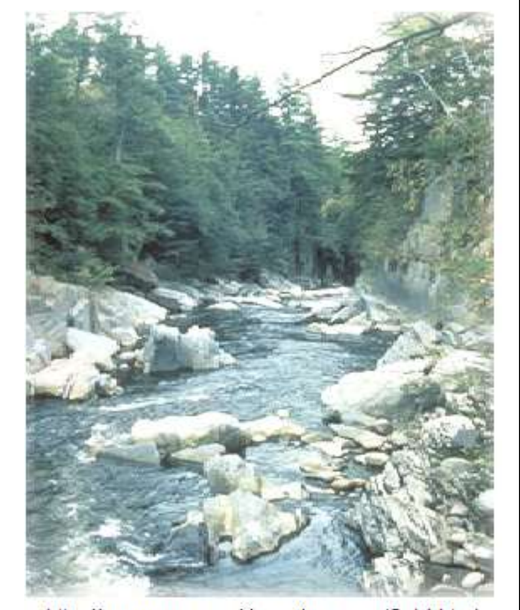
Background Information

Abstract

The Westfield River, which flows through Russell MA, is the proposed site for the Russell Biomass Plant. The plant will remove water from the river for use in its cooling system. Only ten percent of the water will be released back into the river, and this water will be heated and treated with chemicals. Our goal is to predict the effects of the proposed biomass plant on river flow, water temperature, water quality, as well as on organisms living in or around the river. We will use flow and temperature data from the USGS, temperature data from student research, and data from the Expanded Environmental Notification Form for the Russell Biomass Plant to determine the possible impacts of this project on the Westfield River. Our project is part of a broader research project to determine the effects of the Russell Biomass Plant on the surrounding ecosystems of Russell.

Figure 1: This is the site for the proposed biomass plant. The buildings you see here are not part of the biomass project. Photo by K.P. Smith

About the Westfield River



http://www.nps.gov/rivers/wsr-westfield.html

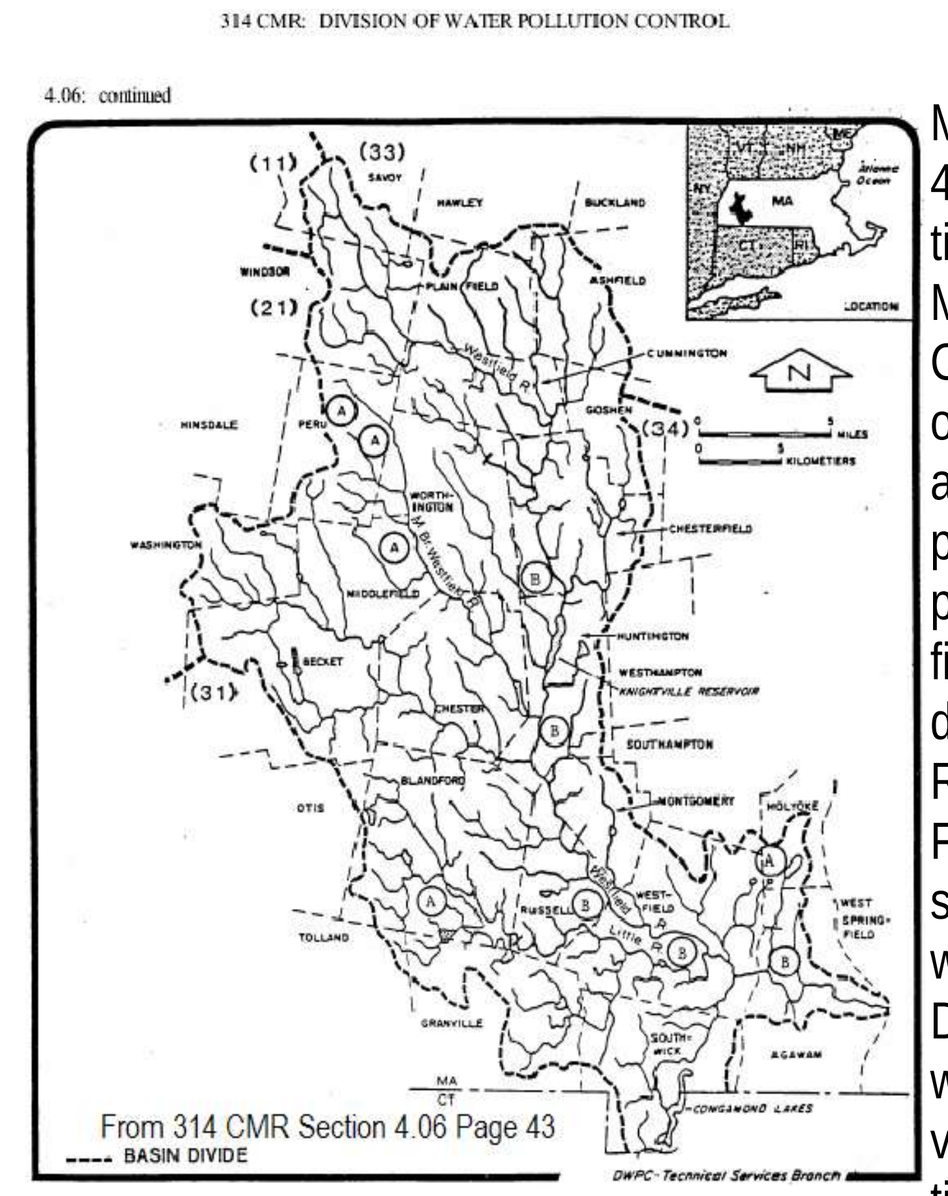
About 78 miles of the Westfield River is nationally recognized as Wild and Scenic. According to the definition set fort by National Wild and Scenic Rivers System, all Wild and Scenic Rivers:

"...possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values..."

Although the proposed biomass site is not on one of those Wild and Scenic parts of the river, the fact that it is just a few miles downstream of Wild and Scenic portions is a testament to the quality of the river as whole. This also means that mobile species living in the Wild and Scenic portion of the river, such as trout and salmon will also be present near the location of the proposed biomass plant. Therefore, during the course of this project, special attention will be given to evaluating the possible effects of the intake and outflow on fish.

Information From: http://www.nps.gov/rivers/about.html

The Laws Involved



From 314 CMR Section 4.06 Page 43

Massachusetts Law (specifically CMR 314 4.00), sets forth surface water quality regulations. All major sources of surface water in Massachusetts are given a designation (A, B, or C for fresh water like the Westfield River), based on their location, average temperatures, and to a lesser extent their own unique character. The part of the Westfield River on which the biomass plant is planned to be built happens to be defined as a Class B Warm Water Fishery. Indeed, the entire length of the river in the Town of Russell is designated as a Class B Warm Water Fishery. This carries with it a specific set of standards that must be preserved regardless of what development takes place along the river. Due to the proposed outflow, the biomass plant would be bound by these standards. One relevant standard taken directly from CMR 314 section 4.05 is:

"[Temperature] shall not exceed 68°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month)..."

When it comes to water withdrawals, Massachusetts General Laws Chapter 21g is consulted. These laws give the Department of Environmental Protection the responsibility of permitting every water withdrawal from Massachusetts waterways that exceeds 100,000 gallons per day. The proposed biomass plant would definitely fall into this category, and it's intake is covered by the regulations set forth in Section 7 of Chapter 21g:

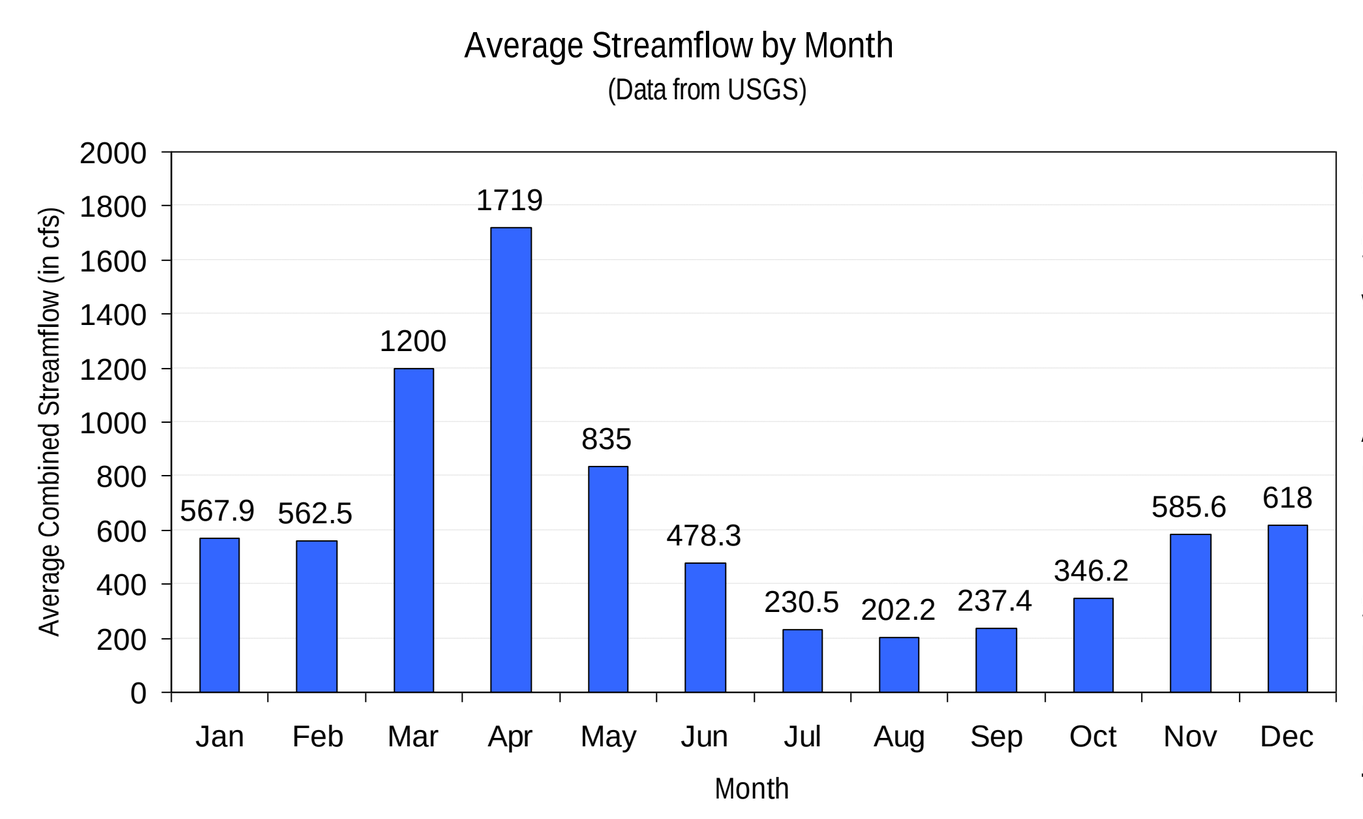
"(9) Reasonable protection of public drinking water supplies, water quality, wastewater treatment capacity, waste assimilation capacity, groundwater recharge areas, navigation, hydropower resources, water-based recreation, wetland habitat, fish and wildlife, agriculture, and flood plains; and;

(10)Reasonable economic development and the creation of jobs in the Commonwealth."

By evaluating the proposed intake and output, along with the proposed temperatures of said output, along with river flows calculated using a number of different methods, we will attempt to apply Massachusetts' regulations to the proposed biomass site.

Possible Effects of Water Intake

Will the Proposed Intake Have an Effect on Average River Flows?



One possible problem with a water intake from a river is a change in total river flow. In this section, the possibility of a change in total river flow during times of average flow will be investigated.

All flow data used in this project came from the USGS using their real-time streamflow for Massachusetts website (http://waterdata.usgs.gov/ma/nwis/current/?type=flow). Since the USGS has no monitoring station close to the proposed biomass site, the three monitoring stations located upstream on the three branches that converge to form the Westfield River in Russell (identified by the USGS as the Huntington Branch, the Knightville Branch, and the Middle Branch/Goss Heights Branch) were added together to get an estimate of the streamflow that could be expected at the proposed site.

The data was then averaged and broken down by month, resulting in the figure at left. As this graph shows, the average monthly flow for the Westfield River varies greatly throughout the year, however, it usually remains over 200 cubic feet per second. To determine the possible effects of the biomass plant's proposed net intake on average flow, the intake data presented by Russell Biomass LLC in their Expanded Environmental Notification Form was converted into cubic feet per second and compared to average flows. The average net intake was between .819 and 1.214 cubic feet per second. As stated by Russell Biomass, it seems safe to state that there will be no significant effect on the river assuming average flows. During periods of low flow however, there is more concern, which requires more in depth analysis, found below.

Will the Proposed Intake Effect Total Flow During Low Flows?

7Q10 (cfs)	
Expected 7Q10	27
After High Intake	26.181
After Low Intake	25.786

1Q10 (cfs)	
Expected 1Q10	22.95
After High Intake	22.131
After Low Intake	21.736

4Q3 (cfs)	
Expected 7Q10	31.21
After High Intake	30.391
After Low Intake	29.996

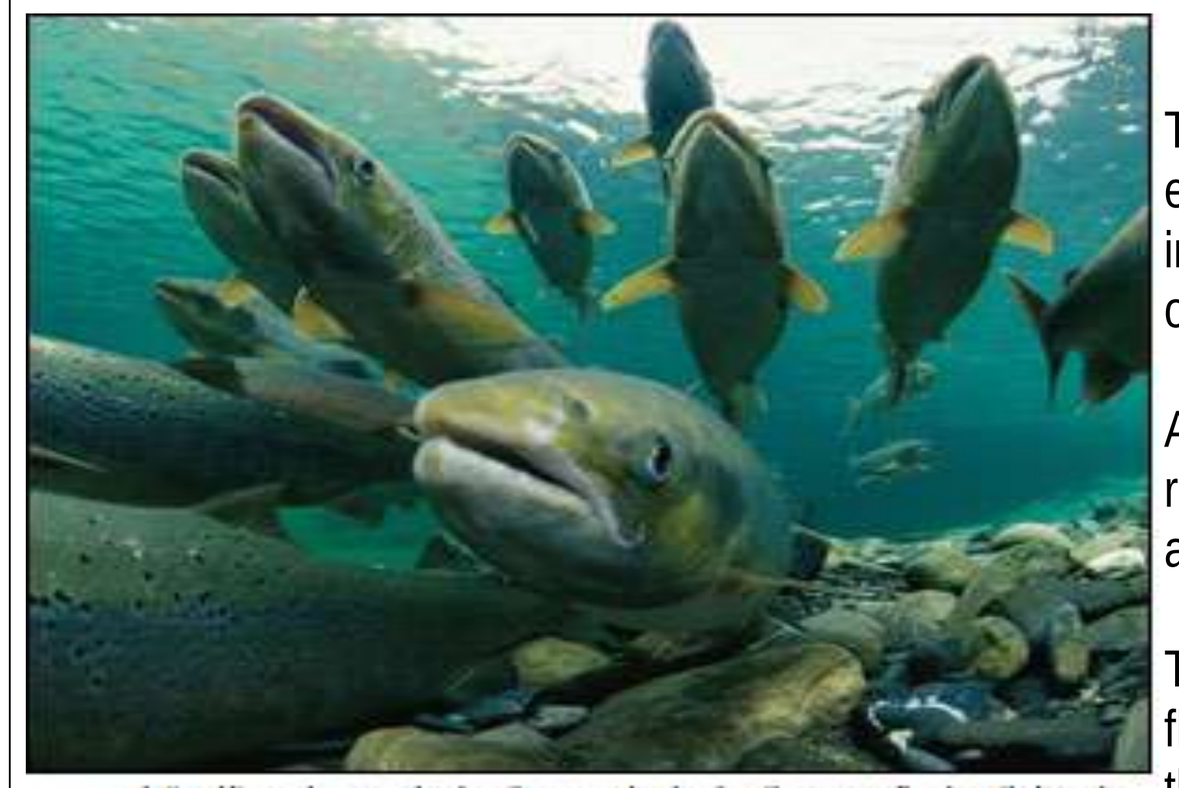
Although it seems the intake will have virtually no effect on average flows, low flows present a different problem. Therefore, several low flow values were calculated and used to determine possible flows after an intake. The values displayed on the table to the left are average low flow values calculated using DFLOW 3.0, a computer program available through the Environmental Protection Agency (http://epa.gov/waterscience/dflow/) used by professional planners and environmental consultants to gauge the effects of a proposed project on river flow. Three low flow possibilities were calculated. The 7Q10, the 1Q10, and the 4Q3. These numbers represent statistical probabilities, not necessarily actual streamflows. Note: The 7Q10 reported by Russell Biomass was 30 cfs. The 7Q10 calculated with DFLOW was 27 cfs. To err on the side of caution, the lower 7Q10 will be used when evaluating possible effects.

The 7Q10 represents a low flow averaged over a period of seven days that is expected to occur once every ten years. The 1Q10 is the one day low flow that is expected to occur once in a period of ten years. Both of these numbers are used by planning professionals to gauge the effects of a project on physical aspects of a river. The 4Q3 is a little different however, it is the lowest flow averaged over 4 days that is expected to occur every three years. This number is used to estimate the effects on a river's aquatic life and the surrounding ecosystems.

Russell Biomass LLC supplied possible intakes and outputs with their Expanded Environmental Notification Form. The "high intake" number to the left is the low flow minus the highest reported net intake. The "low intake" is the low flow number minus the lowest reported net intake. The lowest reported net intake was determined by taking the lowest total withdrawal minus the proposed highest output and was .819 cubic feet per second. The highest reported net intake, which was adjusted by taking highest total intake minus the lowest proposed output came out to be 1.214 cubic feet per second.

According to the Expanded Environmental Notification Form, the proposed plant will never withdraw more than 10% of even the low flows of the river. According to these figures, as long as their intakes and outputs remain at the levels reported, it does not appear that it is at all likely that 10% of total river flow will ever be taken out of the river, even during periods of a 10 year low flow. Flows however are not the only possible problem. Another possible is temperature change, which is discussed later.

Could the Intake Effect Fish?



http://teacher.scholastic.com/scholasticnews/indepth/endangered_species/animals/popups/images/salmon.jpg

To the left is a picture of a group of Atlantic Salmon. The Westfield River is well known for these endangered fish, which are stocked yearly in the river. This section will evaluate whether adding an intake to the Westfield River will have an effect on the salmon population, or the river's population of other aquatic life.

An intake in the river can cause harm to fish population in two ways. First, the intake could lower the river flow enough to render it uninhabitable. Second, the intake structure could suck fish into the plant and kill them.

The first possibility has been disproved by the sections located above. Even during times of very low flows, the intake structure will not remove nearly enough water to significantly change river flows. Since there will likely be no noticeable change, aquatic life should not be effected by this aspect of the intake.

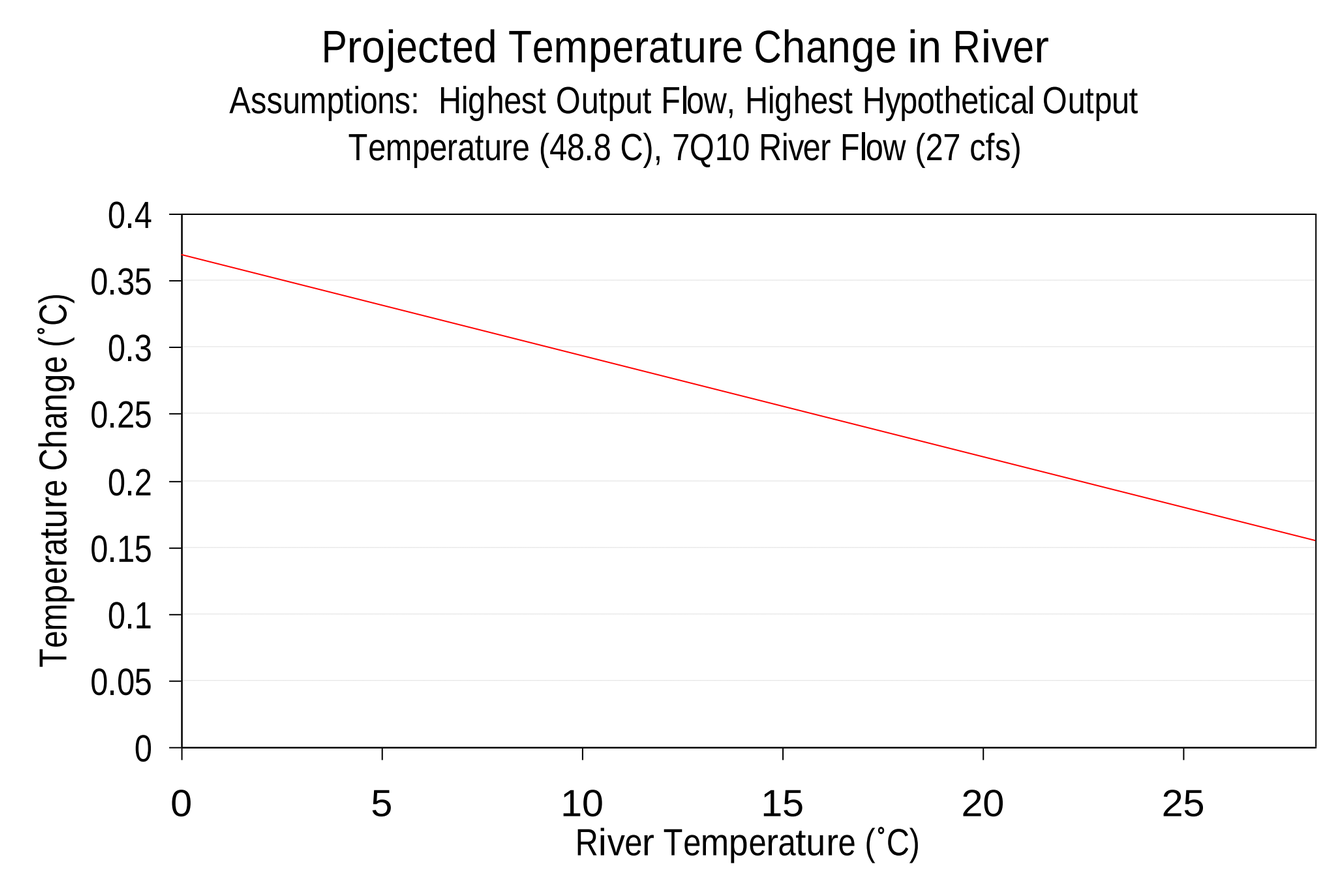
The possibility that fish or aquatic life could be sucked into the intake structure is the other concern. The only data available as to what the intake structure will look like if the plant were to open is from Russell Biomass LLC. They say that the intake structure will be situated at a 90° angle, with the intake facing the bottom of the river. Along with this, it is proposed that there will be a cage-like structure with one inch square holes. Finally, the speed of the flow into this structure was reported as .1 feet per second.

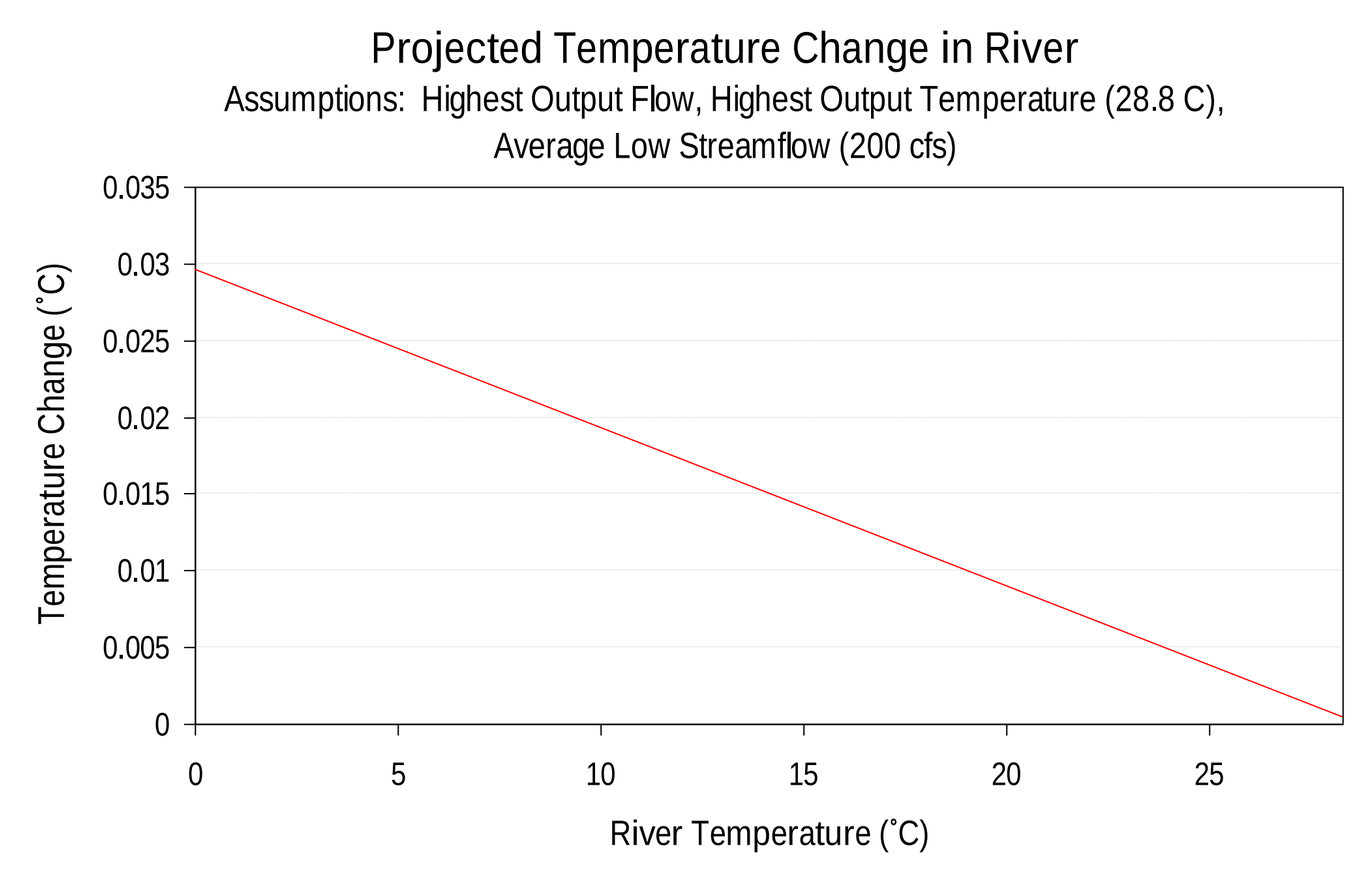
Taking these specifications into account, it will be highly unlikely that any large fish could ever enter this structure. Also, since the water flowing into this structure move so slowly, it is unlikely smaller animals would inadvertently get caught in the intake structure. Undoubtedly, there will be a small portion of animals that either do get involuntarily sucked into the plant or voluntarily swim up the intake tube. However, these numbers will likely be small due to the number of precautions taken when designing the intake structure.

Overall, the amount of water taken in by the plant will likely not be enough to cause a substantial change in river flow (even during low flows), and therefore will probably have little or no effect on fish or other aquatic organisms. The structure itself, while it will probably kill a small number of organisms, seems to be quite safe and will probably never result in a large number of fish being killed.

Possible Effects of Outflow

Will the Heated Outflow Effect Total River Temperature?





A major concern is the effect that the outflow from the proposed plant, which is hotter than the natural river temperature, will cause a major increase in river temperature. This section will deal with the outflow and it's effect on river temperature. In order to determine the possible effects of the outflow on river temperature, four factors need to be taken into consideration. These are the river temperature, the outflow temperature, the total river flow, and the total flow of the output. The following equation was used to calculate the new river temperature:

Q1 = River Flow
Q2 = Output Flow
T1 = River Temperature
T2 = Output Temperature
R = New River Temperature

Equation Used:

$$R = \frac{(Q1 * T1) + (Q2 * T2)}{(Q1+Q2)}$$

Using this equation, the temperatures of the river and the output are changed proportionally based on their respective flows and added together. Then the total flow is divided by (Q1+Q2), leaving only the total temperature of the river.

When analyzing temperature change data, there are two relevant regulations set forth in the Water Quality Standards. First is the regulation stating that total water temperature change cannot exceed 2.8 degrees Celsius as a result of an outflow such as that from the proposed biomass plant. The other is that a Class B Warm Water Fishery such as this part of the Westfield River cannot exceed 28.3 degrees Celsius. With these numbers in mind, the temperature change assuming certain conditions can be evaluated.

To determine temperature changes, several things must be kept in mind. First, the highest possible output temperature as reported by Russell Biomass LLC is to be 28.8 degrees Celsius. Russell Biomass also talked hypothetically, saying that the temperature of the outflow would never exceed the temperature of the output for the previous use of their outflow system which was 48.8 degrees Celsius. The highest possible outflow reported was .206 feet per second. Using the hypothetical reported high output temperature and flow, combined with the projected 7Q10 for the Westfield River (27 cfs), one can predict the temperature change under this worst case scenario, shown on the top graph.

The bottom graph shows the temperature change assuming a low flow that can be expected at any point during an average year (200 cfs), and assuming the highest temperature of outflow expected (28.8 C). The other assumptions, including the highest outflow and highest outflow temperature were the same.

Both of these graphs show that the temperature change, even under the worst conditions likely to occur is only about .4 degrees Celsius. This temperature change is nowhere near the 2.8 degree Celsius limit that it cannot exceed. Therefore, according to this model, there seems to be no chance that this particular law will be violated.

As for the total river temperature law, in both graphs, one can easily see that the temperature change in the river lessens as river temperature increases. This means that as the river temperature approaches the all important 28.3 degrees Celsius, there is less and less of a chance for the outflow to push the river over the limit. Therefore, it is unlikely that at high river temperatures the outflow will be able to influence

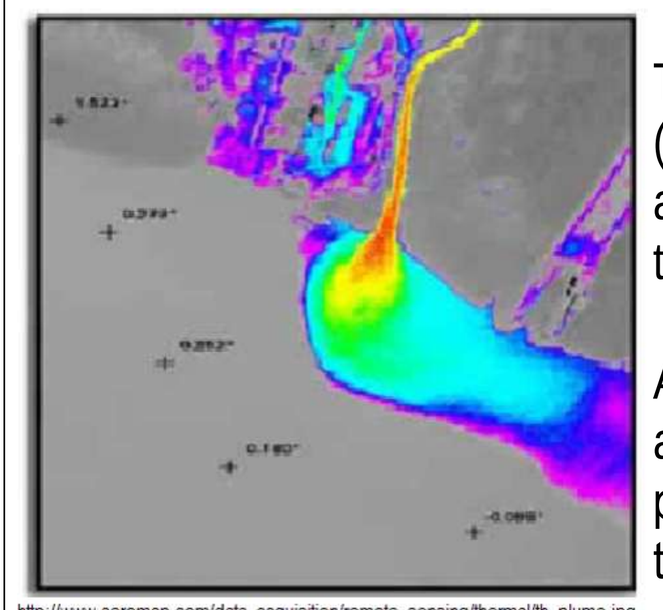
Will Chemicals in the Outflow Effect Water Quality?

As stated earlier, approximately 10% of the water taken in is proposed to be released back into the Westfield River after going through the cooling system. A possible problem with this outflow is that cooling systems are often treated with chemicals to prevent oxidation of pipes and other components and there are concerns about these chemicals being released with the water that is going back into the Westfield River.

Since the plant does not yet exist, there is no information as to what types of chemicals will be used in the cleaning process or in what concentrations. However, a parallel can be drawn between the proposed Russell Biomass plant and the McNeil Generating Station in Burlington, VT. The McNeil Generating Station is of comparable size and function to the proposed Russell Biomass Plant. The water released from McNeil Station is treated to neutralize all chemical additives, however approximately .1 ft^3 of this water will contain and excess amount of salt (NaCl). How much excess has not been released in any documentation we could find.

Considering the flow and volume of the Westfield River, as well as the fact that only 0.10 ft^3 may contain excess salt, the effect on the Westfield River ecosystems will likely be relatively small. Nevertheless, this impact cannot be fully studied with the information currently available, and must be closely monitored during the design process and beyond.

Is the Outflow Likely to Effect Fish?



http://www.aeromap.com/data_acquisition/remote_sensing/thermal/th_plume.jpg

The change in temperature and chemical concentration resulting from the outflow of the proposed biomass plant could have an effect on fish, especially young Atlantic Salmon (pictured bottom right), who spend their first few years of life in the river. Not much can be said about the chemical concentration since there is essentially no information available. However, the temperature change caused by the outflow could possibly pose a threat to salmon or other fish. Salmon are very sensitive to temperature change, so they will be used as an example to determine the effects on all fish populations.

Adult salmon do not live in the river year round, only coming in the fall to spawn. Since the river is relatively cold during this time and adult salmon can tolerate temperatures of about 32 degrees C, there is a low likelihood that adult salmon will have a problem with total river temperature. However, a major concern is something called a "thermal plume", which occurs when a water flow discharges into another with a lower temperature. The picture at left shows a warm stream emptying into a cold one, causing a thermal plume, like one that will likely be created by the biomass plant's outflow. The red parts of the image are hottest, while the dark blue parts are the coldest.

What this means is that in locations immediately around the outflow structure, the river temperature might be very high. In fact, if the outflow temperature was at the highest theoretical temperature (48.8 degrees C), being close to the intake structure could kill an adult salmon in mere minutes. However, it is likely that adult salmon would be able to easily avoid these areas of high temperature, as salmon much prefer relatively cold temperatures.

The same problems with a thermal plume exist when evaluating juvenile salmon populations. While juvenile (0 to 1 years old) salmon, like adults can tolerate short periods of exposure to temperatures of about 32 degrees Celsius (although they thrive at around 20 degrees C), but if the outflow was sufficiently hot, they would not last long near the outflow structure due to the thermal plume.

A unique problem also confronts young salmon (and all other fish in the river for that matter). Young salmon spend the first few years of their lives in the river year round. According to student research, the temperature of the Westfield River can sometimes approach 30 degrees Celsius. At these temperatures, young salmon would have a difficult time surviving for very long, and as the temperatures increase, their ability to survive decreases rapidly.

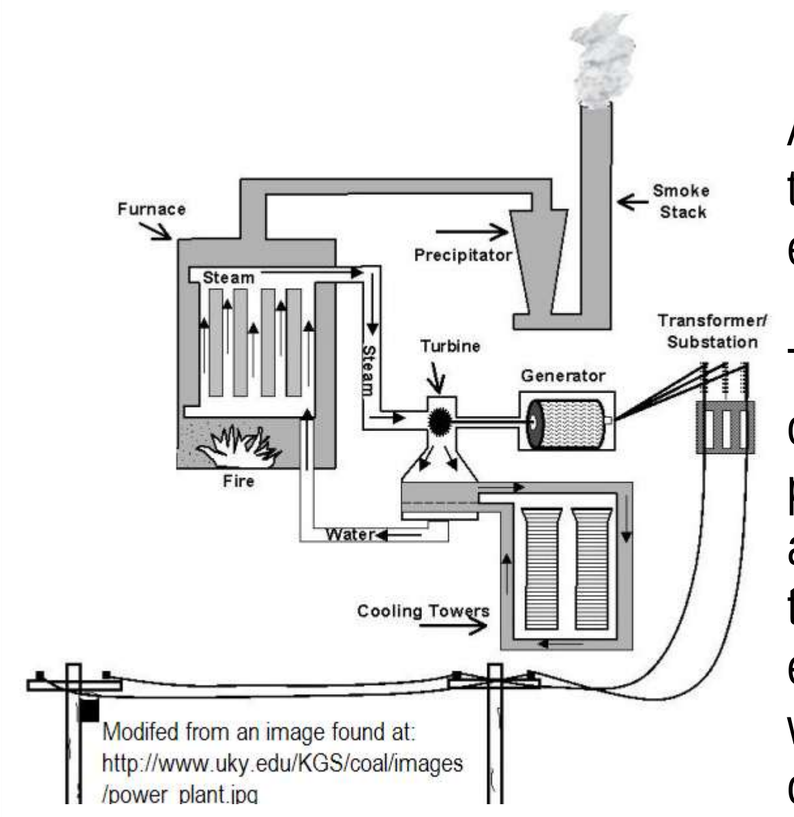
However, it is shown above that as river temperature increases, the temperature change due to the outflow will decrease. At temperatures of 30 degrees Celsius and assuming a 7Q10 low flow the change in temperature would be only .15 degrees Celsius. Therefore, it is unlikely that the outflow would be able to substantially change natural river temperatures or prevent the river from cooling below the lethal limit of temperature.

http://www.bio.umass.edu/biology/conn.river/salmon.html

Temperature Tolerance Information From: http://www.krisweb.com/krissheepscot/krisdb/html/krisweb/stream/temperature_sheepscot.htm
Life Cycle Information From: http://animaldiversity.ummz.umich.edu/site/accounts/information/Salmo_salar.html

Alternative Solutions and Conclusions

Alternative Solutions



Modifed from an image found at: http://www.uky.edu/KGS/coal/images/power_plant.jpg

Although the possible effects of the biomass plant on the Westfield River are expected to be insignificant, there is always room for improvement. To ensure that the effects can be lessened further or eliminated entirely, some alternative solutions may be considered.

The first of which is a different outflow structure. As it stands now, the outflow is going to be concentrated in one specific area. However, if the outflow was directed into a pipe lying at the bottom of the river and perforated with small holes, it would allow for greater mixing of outflow water with river water. This would allow the river water to mix with the outflow more quickly and hopefully lessen the effects on total river temperature even further. Most importantly, it would serve to reduce the "thermal plume" effect discussed earlier, meaning that the heated water is equally distributed throughout the river. Therefore, the heated water would be able to mix with the cooler water much more quickly, eliminating "hot spots" where organisms can only survive for a few minutes. Along with the change in the outflow pipe, a series of filters could be added in order to take out any possible pollutants, ensuring that the water that is re-entering the river is as clean as possible.

Although this plan is sound, there is a more drastic (and expensive) alternative that could be used. Pictured above left is a very simplified plan of a zero discharge facility. As you can see, cooling towers are utilized to lower the temperature of the water used in the steam production and in the cooling process (a picture of an existing biomass plant with cooling towers is below). The cooled water is then recycled through the plant and used over and over again. The only time water is lost is when it evaporates through the cooling towers. There are two possible drawbacks to this system. One is that it does not replace any of the water taken from the river (which in this case would not seem to be a problem), and it releases much of the

http://www.burlingtonelectric.com/PhotoGallery/mcneil/page/image3.html
MacNeil Generating station in Burlington Vermont. Note the cooling system on the far left.

Conclusions

Westfield River near proposed biomass site in February. Photo by K.P. Smith

-The intake utilized by the proposed biomass plant will not adversely effect the river, assuming average flow level.

-During low flows, even 7Q10 low flows, the intake effects will remain insignificant.

-The intake structure used will be able to operate effectively without harming any fish or damaging fish populations.

- As the concentrations of possible chemicals in the outflow from the biomass plant are unknown, it is difficult to predict the problems that these chemicals could pose to the river.

. According to calculations using USGS numbers, the fact that the discharge from the plant will be hotter than the river will not adversely effect the river or organisms living in it.

-Although the total temperature change is insignificant, thermal plumes from the discharge could kill fish. However, this can be mitigated by making some simple modifications to the outflow structure.

- Although the effects of the biomass plant appear to be minimal, there are ways that they can be minimized. Utilizing a different outflow structure along with a system or filters, or even a full cooling tower system could lessen the effects greatly or eliminate them all together.

References

"Massachusetts Surface Water Quality Standards" <http://www.mass.gov/dep/service/regulations/314cmr04.pdf>

"USGS—Real Time Streamflow Data for Massachusetts" <http://waterdata.usgs.gov/ma/nwis/current/?type=flow>

"DFLOW—A Tool for Flow Analysis" <http://epa.gov/waterscience/dflow/>

"(Temperature Tolerance of Salmon)" <http://www.krisweb.com/krissheepscot/krisdb/html/krisweb/stream/temperature_sheepscot.htm>

"Animal Diversity Web: Salmo salar (Atlantic Salmon)" <http://animaldiversity.ummz.umich.edu/site/accounts/information/Salmo_salar.html>

"Burlington Electric Department" <http://www.burlingtonelectric.com/SpecialTopics/Mcneil.htm>

"Expanded Environmental Notification Form" prepared for Russell Biomass LLC by Tighe and Bond

"Regulations for Cooling Water" <http://www.epa.gov/waterscience/316b/ph3-proposed-fs.htm>

"Cooling Water Intake Structures" <http://www.eei.org/industry_issues/environment/water/water_316b.pdf>

Russell Biomass Debate Hosted by the Westfield River Environmental Center, Scanlon Banquet Hall, February 16, 2006

Smith, Brittany, 2006. Student Research Project in Progress, Westfield State College.