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PSNH

Public Service of New Hampshire

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July 19, 1983

Mr. Theodore E. Landry, Chemical Engineer
U.S. Environmental Protection Agency
Region I, Permits Branch
John F. Kennedy Federal Building
Boston, MA 02203

T. E. LANDRY
AUG 1 1983

Dear Mr. Landry:

Please find enclosed a copy of our final report, "Predictive Model and User Guide for Spring and Fall Optimization of Power Spray Module Operation at Merrimack Generating Station". This report has been reviewed by the N.H. Water Supply and Pollution Control Commission and the N.H. Fish and Game Department, and the recommendations contained in the report relative to power spray module operation have been approved for implementation by these agencies via the attached letter, R. A. Nylander (NHWSPCC) to W. A. Harvey (PSNH), July 7, 1983.

We are submitting this report and its recommendations for EPA approval. We are requesting that the report's proposed user guide for PSM operation (Table 2) and schedule for PSM operation (Table 4), following the recommendations of the report, be approved for implementation as a clarification of the present NPDES permit, No. NH0001465.

If you have any questions concerning the report or this request, please call me at (603) 669-4000, Ext. 2364.

Sincerely,

Wayne E. Nelson
EXT - 2364

Wayne E. Nelson
Staff Biologist

WEN/srcy
Enclosures

cc: R. A. Nylander, NHWSPCC w/o enclosure
C. Thoits, III, NHF&G w/o enclosure
W. A. Harvey, PSNH w/o enclosure
J. B. Lander, PSNH w/o enclosure

Public Service Company of New Hampshire
Predictive Model and User Guide for
Spring and Fall Optimization of
Power Spray Module Operation at Merrimack Generating Station

FINAL REPORT

INTRODUCTION

The present hydrothermal modeling effort was undertaken as a result of consultation with the N.H. Water Supply and Pollution Control Commission (NHWSPCC), N.H. Fish and Game Department (NHF&G), and U.S. Environmental Protection Agency (USEPA). This consultation concerned the potential elimination of the S-4 mixing zone monitoring station and optimization of Power Spray Module (PSM) operation in the spring and fall months, May, October, and November. Optimization of PSM operation is the primary objective of this analysis and the resulting predictive model and user guide.

BACKGROUND

Variances allowing suspension of PSM operation were granted by the NHWSPCC for the periods: January through March, 1974 and 1975; December through March 1975 - 1976; and December through March (December 1 - April 1) 1976 through 1979. In 1978, in response to public and continuing Company concern with perceived, excessive PSM energy consumption during spring and fall months, PSNH retained the environmental consulting firm, Normandeau Associates, Inc. (NAI) to develop a simple hydrothermal model which would allow for optimization of PSM operation in spring and fall months. The results of this effort was the NAI report, "Merrimack River Thermal Dilution Study, 1978", April 1978. The NHWSPCC approved the PSM operating guidelines proposed in the NAI report on June 14, 1978. These guidelines allow suspension of PSM operation between October 1 and June 1, providing ambient river temperature is less than 68°F and river flow exceeds 2500 cfs. They were incorporated in the June 26, 1979, Merrimack Generating Station NPDES Permit.

Permit Pages 12 & 13

ANALYSIS

The NAI model and study guidelines for PSM operation have proven unsatisfactory in application for the following reasons:

1. The model's original form and application lack the degree of flexibility necessitated by varying environmental conditions of ambient flow and temperature.

2. The model arbitrarily assumes a requirement for complete water column mixing at mixing zone station S-4.

3. The data utilized in the development of the NAI model does not allow for the prediction of mixing zone surface temperatures (T_{mix}) under conditions of incomplete water column mixing.

4. In its original form, the model's accuracy was not readily verifiable through the use of available river flow and station operating and environmental monitoring data.

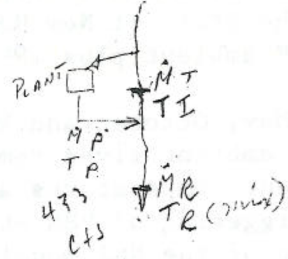
Therefore, PSNH has undertaken a modeling effort utilizing the Normandeau model and ambient river and station operating and environmental monitoring data for the months of May, October and November for ten years of record, 1972 - 1981. A linear regression analysis was performed on this data. A linear relationship was found to exist between the surface river temperature at S-4 and the reciprocal of river flow. This relationship is defined and illustrated in the following pages.

User guide Table 2 provides river flows representative of the 99.7 and 95% upper confidence limits of the least squares analysis of the data in Table 1. These flows have been calculated for T_{mix} 68°-72°F. The Company presently recommends the use of the 69°F T_{mix} and corresponding flows of the "B" columns of Table 2 for PSM start-up and shutdown triggering criteria. The "B" columns are recommended because of the one in forty probability of occurrence, which corresponds to the normal generating station lifetime. The 69°F T_{mix} is recommended, for the present, since it represents the most environmentally conservative case under the State of New Hampshire's cold water fishery thermal standards, i.e. 68°F ambient plus 1°F temperature rise.

The months of May, October and November are the normal transition periods between summer high ambient river temperatures and low flows, and spring/fall periods of low ambient temperatures and higher flows. It is during these periods that the triggering of PSM startup and shutdown would be predicted by the PSNH application of the NAI model. PSM startup and shutdown would be accomplished through use of the proposed user guide.

Flow Model

A simple one dimensional model may be used to show the totally mixed river temperature after the plant discharge canal flow and the river flow rejoin. We assume here that the body of flow is so large that evaporative losses, groundwater additions and precipitation additions are negligibly small. We further assume that thermal energy additions except from the condensers and thermal energy losses except by the PSM system are likewise negligibly small. In this case, the conservation of thermal energy and mass is:



subscripts P = Plant Canal
I = In River
R = Resultant (Plant + River) Mix

$$\dot{M}_P C_p T_P + \dot{M}_I C_p T_R = \dot{M}_R C_p T_{mix}$$

and:

$$\dot{M}_P + \dot{M}_I = \dot{M}_R$$

where: $\dot{M}_P$, $\dot{M}_I$, $\dot{M}_R$ are water mass flows in the canal, in the river before the canal and after the canal, respectively.

C_p is the specific heat.

T_P, T_R, T_{mix} are the homogenous water temperatures at the same places above.

Since: $\dot{M}_P = \rho D_P$, $\dot{M}_I = \rho D_I$, $\dot{M}_R = \rho D_R$

where: ρ = water density (assumed constant)

D_P, D_I, D_R are the volumetric flows at the same places as above.

The conservation equations simplify to:

$$D_P \, T_P + D_I \, T_R = D_R \, T_{mix}$$

$$D_P + D_I = D_R$$

Eliminating D_I results in :

$$D_P \, T_P + (D_R - D_P) \, T_R = D_R \, T_{mix}$$

or:

$$(T_P - T_R)\, D_P = (T_{mix} - T_R)\, D_R$$

We recognize that $T_P - T_R$ is the temperature rise through the station, $\triangle T_C$, and that $T_{mix} - T_R$ is the temperature rise of the river. Solving for T_{mix} results in:

$$T_{mix} = \frac{\triangle T_C\, D_P}{D_R} + T_R \qquad \text{Eq. 1}$$

which is the Normandeau equation. This equation may be used to show the expected relation of the parameters to one another. In particular, if upstream river temperature is held constant and the plant operates at a steady state, then it appears that there is a linear relation between the well mixed temperature, T_{mix} and the reciprocal of river flow, D_R. Thus:

$$T_{mix} = (\triangle T_C\, D_P)\, D_R^{-1} + T_R = m\,x + b \qquad \text{Eq. 2}$$

where:

slope, $m = \triangle T_C\, D_P$

intercept, $b = T_R$

independent variable, $x = D_R^{-1}$

Model Input

To test the veracity of Eq. 2 would require river cross-section measurements of average T_{mix}, T_R and D_R over a suitably long averaging time. This has been considered in the Normandeau study. We elect here to examine the relation of T_{mix} to D_R in order to see if a predictable relation exists that would indicate the critical river flow that results in certain maximum temperature limits.

We assume here that the temperature measured at S-4 represents T_{mix} at this cross-section and that the river flow measured at a gaging station represents D_R. The time averaging interval is over a month in order to smooth out variability unrelated to plant operation. Monthly averages for May, October and November over the period of record were assembled. These are shown in Table 1 and plotted as circles on the Figures.

Linear Regression Analysis

The data were analyzed using a standard least square analysis. The resulting linear relationship is plotted on the Figures where T = T_{mix}, and Flow = D_R. The analysis determines the standard error of the fit of the data to the straight line. To be conservative, the 99.7% confidence limit upper bound is shown. It would be expected that a data point above this line would have less than an 0.15% chance of happening or roughly 3 times in 2000 years. Since the plant lifetime is 40 years, one would not expect this to occur. Lifetime probability is shown by the 95% confidence bound.

Results

One notes that to reach a temperature of 69^{o}F the regression line has to be extrapolated beyond the data base of observed values. In particular, the extrapolation for November is severe, indicating the unlikely chance of ever measuring a monthly average 69^{o}F at S-4. Table 2 shows the critical average flows needed to reach the 99.7% confidence temperature limit. These values are to be contrasted to the lowest flow values found in the data base, which are 3984, 960 and 1095 for the months of May, October and November, respectively. Only for the month of May were the flows low enough to have permitted an excessive temperature at S-4. In actuality, the observed average temperature at S-4 did not exceed 65.1^{o}F.

User Guide

During May, it is desired to know when to place the PSM system into operation. The first week of average daily flow at the gaging station is obtained and averaged. This seven day average is compared to Table 2 for May. If the average found is less than that shown for the desired temperature, the PSM system is sequenced on. If the average found is more than that shown, a sliding seven day average is formed using the most recent seven days. When the sliding average is eventually less than that shown for a desired temperature, the PSM system is sequenced on.

The same procedure is used for October and November except that it is desired to know when to shut down the PSM system. In this case, the seven day average flow must be more than that shown for the desired temperature. On the basis of the information provided in Table 3, "Time of Occurence of Ambient River Conditions of 68°F and Minimum Stream Flows Required for a T_{mix} of 69°F", it is recommended that acquisition of flow information for the seven day sliding average begin on September 24 for a potential shutdown of the PSM system beginning on October 1, if User Guide conditions for PSM system shutdown via the model are met.

On Table 2, the user is given the choice of using values corresponding to a 3 times in 2000 years chance of occurring and a once in 40 years chance of occurring.

Table 4 provides an outline of "Proposed Power Spray Module (PSM) Operation".

TABLE 1 INPUT DATA

Year	May		October		November	
	D_R	T_{mix}	D_R	T_{mix}	D_R	T_{mix}
1972	11555	57.24	1694	58.01	5043	-
1973	9211	54.32	1599	59.11	5823	-
1974	8615	53.92	1741	54.77	3008	46.04
1975	4824	62.42	6266	56.33	7538	46.35
1976	7593	56.80	3861	55.15	2909	41.90
1977	3984	65.10	8476	53.82	4731	48.74
1978	8305	60.08	960	61.80	1095	50.06
1979	8591	59.02	4587	56.21	4005	44.65
1980	4552	-	1603	59.90	2114	42.80
1981	5699	60.08	5728	53.80	8351	44.60

where: D_R in cubic feet per second, cfs

T_{mix} in deg. Fahrenheit

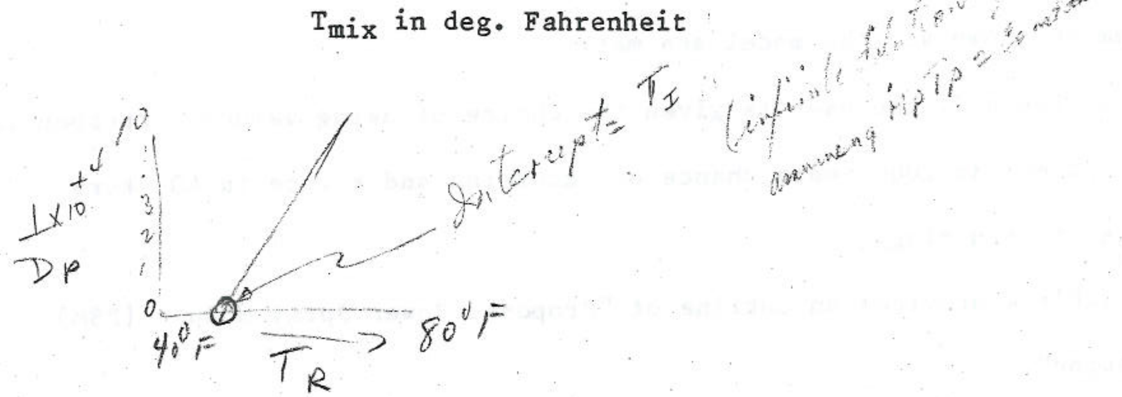


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TABLE 2 CRITICAL TEMPERATURE REQUIRED FLOWS

	A			B		
T_{mix}	May D_R	Oct D_R	Nov D_R	May D_R	Oct D_R	Nov D_R
68	5103	778	268	4254	672	226
69	4682	707	251	3957	618	214
70	4325	648	237	3699	572	203
71	4019	598	224	3472	533	194
72	3753	555	213	3272	498	185

where: T_{mix} in deg. Fahrenheit

D_R in cubic feet per second

A. represents 3 times in 2000 year chance of occurring.

B. represents one time in 40 year chance of occurring.

* 7Q10 = 550 cfs @ Franklin
= 667 cfs @ Manchester

may 1 T = 52°
may 28 T = 58°
Sept 28 T = 58°
nov 1 T = 44°
Estimates USGS @ Concord, NH 1980-1981 data

RECOMMENDATIONS

The present PSNH hydrothermal modeling effort has produced a feasible, verifyable predictive model for optimization of PSM operation at Merrimack Generating Station in the spring and fall months, May, October and November. The accompanying user guide should supplant the NAI study guidelines presently in effect in the Merrimack Station NPDES permit.

The Company presently recommends the use of the 69°F T_{mix} and corresponding flows of the "B" columns of Table 2 for PSM start-up and shutdown triggering criteria. The "B" columns are recommended because of the one in forty probability of occurrence, which corresponds to the normal generating station lifetime. The 69°F T_{mix} is recommended, for the present, since it represents the most environmentally conservative case under the State of New Hampshire's cold water fishery thermal limitations, i.e., 68°F ambient plus 1°F temperature rise. However, the present 69°F T_{mix} triggering criteria should not preclude the use of a higher T_{mix} from column "B" of Table 2 in the event that model verification at the 69°F T_{mix} proves unnecessarily conservative.

It is recommended that river temperature monitoring station S-4 be retained initially for one year as a means of new model accuracy verification. Merrimack Station compliance with New Hampshire's cold water fishery thermal limitations via the user guide will constitute model verification. Following new model and user guide verification, river temperature monitoring station S-4 may be discontinued, with the exceptions noted below.

When one Merrimack Station Unit is out of service, or when unusual environmental conditions of high river flows and low mixing zone temperatures prevail during the summer months, June through September, PSM operation will be governed by New Hampshire's cold water fishery thermal limitations. Under these exceptions, compliance will be according to continuous, in situ, river surface temperature monitoring at mixing zone station S-4. The Company will continue to operate all available PSM's during the summer months, June through September, when both Units are in service and operating, as in the present NPDES permit.

The Ambient river temperature monitoring station should be placed in service on or about May 1, prior to anticipated user guide need for ambient data. After PSM system shutdown in October/November, no river or canal temperature monitoring should be required until the following May, for PSM system startup for the summer months.

On the basis of the information provided in Table 3, "Time of Occurence of Ambient River Conditions of 68°F and Minimum Stream Flows Required for a T_{mix} of 69°F", it is recommended that aquisition of flow information for the seven day sliding average for October begin on September 24 for a potential shutdown of the PSM system beginning on October 1, if user Guide conditions for PSM system shutdown via the PSNH model are met.

Table 4 provides an outline of "Proposed Power Spray Module (PCM) Operation".

TABLE 3

PSNH MERRIMACK GENERATING STATION

Time of Occurence of Ambient River Conditions of 68°F and Minimum Stream Flows Required for a T_{mix} of 69°F+

	May			October		
YEAR	68°F (Mo/WK)	CASE A 4682 cfs (Mo/WK)	CASE B 3957 cfs (Mo/Wk)	68°F (Mo/Wk)	CASE A 707 cfs (Mo/Wk)	CASE B 618 cfs (Mo/Wk)
1981	6/1	5/2 & 5/4	5/4	9/3	>707*	>618*
1980	6/4	5/3	5/3	9/2	9/3	9/1
1979	6/3	5/3 & 6/2	5/3 & 6/3	9/2	>707*	>618*
1978	6/4	6/1	6/3	9/2	9/4	9/4
1977	5/4 & 6/4	5/2	5/3	9/3	>707*	>618*
1976	6/3	6/1	6/1	9/1	>707*	"
1975	6/4	5/3	5/4	9/1	>707*	"
1974	6/2	6/2	6/2	9/2	>707 except 8/3	"
1973	7/2	6/2	6/2	9/2	>707*	"
1972	6/4	6/1	6/3	9/2	>707 except 7/2-3	>618 except 7/2
Mean & Median	6/3	6/1	6/1	9/2	N/A	N/A

+Seven day average basis.
*Flow was never below 707 or 618 cfs on a 7 day average flow basis, May through November.

TABLE 4

PSNH MERRIMACK GENERATING STATION

PROPOSED POWER SPRAY MODULE (PSM) OPERATION

Winter:	November 1 - April 30	No PSM Operation
Spring:	May	PSM Operation: by PSNH Predictive Model and User Guide, or according to N.H. cold water fishery thermal limitations if one Station Unit is out of service.*
Summer:	June - October 1	PSM Operation (all available modules) initiated June 1 and terminated October 1, if conditions for termination exist. PSM operation according to N.H. cold water fishery thermal limitations if one Station Unit is out of service or if cold water fishery thermal limitations can be met with the operation of less than the available number of PSM's.*
Fall:	October	PSM Operation: by PSNH Predictive Model and User Guide, or according to N.H. cold water fishery thermal limitations if one Station Unit is out of service prior to PSM operation termination by the User Guide.*
Both Merrimack Station Units Out-of-Service		No PSM Operation

*River surface temperature at Mixing Zone monitoring station S-4, in conjunction with ambient river surface temperature, will be utilized to determine compliance with N.H. cold water fishery thermal limitations.

NOTED JUL 11 1983 W.A.H

The State of New Hampshire

Water Supply and Pollution Control Commission
Hazen Drive — P.O. Box 95
Concord, N.H. 03301

July 7, 1983

Mr. Warren A. Harvey, Vice President
Public Service Company of New Hampshire
1000 Elm Street
Manchester, New Hampshire 03105

Subject: Merrimack Generating Station
NPDES Permit No. NH0001465

Dear Mr. Harvey:

This will acknowledge receipt of the report entitled "Predictive Model and User Guide for Spring and Fall Optimization of Power Spray Module Operation at Merrimack Generating Station" submitted by the company under letter dated May 26, 1983.

Based on a review of the report by staff members from both this Commission and the Fish and Game Department, it is believed the company has demonstrated that compliance with the thermal elements of the NPDES permit can be achieved through the predictive model and user guide. Therefore, implementation of the recommendations contained in the report relative to power spray module operation is approved provided that the thermal effluent limitations specified in the NPDES permit are met and, that adequate model and user guide verification work is performed at Station S-4.

If we can be of further assistance, please feel free to call on us.

Sincerely,

Russell A. Nylander

Russell A. Nylander, P.E.
Assistant Chief Engineer
Administrator

RAN/cd
cc: Charles F. Thoits, III, F&G Dept.
Wayne E. Nelson, PSNH