

Translating Temperature Modeling Output into EDT Temperature Parameters

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Introduction

Task 006AC of the contract between the U.S. Bureau of Reclamation (Bureau) and Mobrand-Jones & Stokes (MJS) requires that MJS develop rules and procedures for transforming output from temperature models being developed for the Yakima River into temperature parameters useable by the Ecosystem Diagnosis and Treatment (EDT) model. This report documents the completion of that task.

After discussions with the temperature modelers (Mark Mastin, John Vaccaro, and Frank Voss – U.S. Geological Survey [USGS]), we decided to focus the modeling effort on the spring to early fall months (April–October) and maximum temperature. The opinion of the modelers was that the Bureau’s flow alternatives would have little effect on winter temperatures in the Yakima and Naches rivers.

This document is intended to be used with a reference Excel workbook named “Example of calculating all EDT Temperature attributes directly from Temperature Models.xls.” The reference workbook provides numerical examples of all of the calculations necessary to translate temperature model output to ratings for EDT temperature attributes. This document is intended to provide context and detail on special considerations that apply to various EDT temperature attributes.

Definition of Temperature Attributes

EDT includes three attributes describing temperature in a reach: 1) Temperature Maximum, 2) Temperature Minimum, and 3) Temperature Spatial Variability. Each of these attributes is described in more detail below. As previously mentioned, this document will focus on Temperature Maximum, as this is the primary attribute affected by the Bureau’s flow alternatives in the Yakima and Naches mainstems. However, for completeness we have included discussion of Temperature Minimum and Temperature Spatial Variability.

Temperature Maximum (by month)

This attribute characterizes the maximum daily temperature within the reach for the month. The effect of temperature on salmonids species is a combination of the

maximum temperature experienced and the duration (number of days) of warm temperature. Rating definitions in EDT were crafted to capture both of these components (Table 1).

Table 1. Categorical Rating Definitions for Temperature Daily Maximum

Index 0	Index 1	Index 2	Index 3	Index 4
Warmest day: <10°C	Warmest day: ≥10°C and <16°C	>1 d, with warmest day 22– 25°C or 1–12 d, with ≥16°C	>1 d, with warmest day 25– 27.5°C or >4 d (non- consecutive), with warmest day 22– 25°C or >12 d with ≥16°C	>1 d, with warmest day 27.5°C, or 3 d (consecutive) ≥25°C or >24 d with ≥22°C

Temperature ratings in EDT are continuous between 0 and 4. Non-categorical conclusions for temperature are based on the number of days during the month that a particular temperature criterion was exceeded. Step 1 in computing a rating from daily maximum temperature data is to count the number of days in the month by temperature categories:

- Category 1 – # Days <10°C
- Category 2 – # Days ≥10°C and <16°C
- Category 3 – # Days ≥16°C and <22°C
- Category 4 – # Days ≥22°C and <25°C
- Category 5 – # Days ≥25°C and < 27.5°C
- Category 6 – # Days ≥27.5°C

Step 2 is to take these counts and determine the rating using the rules in Table 1. This procedure is best explained using an example and should be implemented using the Visual Basic procedures described in Appendix 1 of this report.

Example:

	<10°C	≥10°C and <16°C	≥16°C and <22°C	≥22°C and <25°C	≥25°C and <27.5°C	≥27.5°C	
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Cat 6	
Month	# Days	# Days	# Days	# Days	# Days	# Days	EDT Rating
1	31	0	0	0	0	0	0
2	28	0	0	0	0	0	0

	<10°C	≥10°C and <16°C	≥16°C and <22°C	≥22°C and <25°C	≥25°C and <27.5°C	≥27.5°C	
	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Cat 6	
Month	# Days	# Days	# Days	# Days	# Days	# Days	EDT Rating
3	21	10	0	0	0	0	0.8
4	0	30	0	0	0	0	1.5
5	0	21	10	0	0	0	2.3
6	0	4	17	9	0	0	3.3
7	0	0	8	20	3	0	3.75
8	0	0	4	20	7	0	4
9	0	0	20	10	0	0	3.5
10	0	22	9	0	0	0	2.2
11	23	7	0	0	0	0	0.7
12	31	0	0	0	0	0	0

Temperature Minimum (by month)

This attribute characterizes the winter water temperatures for a reach. The rating is based on the daily mean temperatures for the reach during winter months. The effect of cold temperature on salmonid species is a combination of the temperature experienced and the duration (number of days) of cold temperature. Rating definitions in EDT were crafted to capture both of these components (Table 2).

Table 2. Categorical Rating Definitions for Temperature Daily Minimum

Index 0	Index 1	Index 2	Index 3	Index 4
Coldest day >4°C	<7 d with <4°C and minimum >1°C	1 to 7 d <1°C	8 to 15 days <1°C	>15 winter days <1°C

Average water temperatures in low-elevation reaches are rarely less than 4°C, resulting in a rating of 0, or no effect. Only mid- to high-elevation streams are expected to have ratings much higher than 1.0. For purposes of the Bureau's analysis of flow alternatives, ratings for this attribute will not change from what was entered for the baseline condition from observed temperature data series.

Temperature Spatial Variation

This attribute is defined as the extent of water temperature variation (cool or warm water depending on season) within the reach as influenced by inputs of groundwater or tributary streams or the presence of thermally stratified deep pools. Spatial variation in the summer months is cool water, providing temperature refugia, whereas spatial variation in the winter months is warm water.

Spatial variation in water temperature within a stream reach can be created by the inputs of groundwater along the reach. In regions with extreme seasonal air temperatures, as occurs throughout extensive areas east of the Cascade crest, the spatial variation in water temperature provided by groundwater inputs can be important to the life histories and survival of many aquatic species.

Rating definitions are crafted to describe the extent of spatial variation in a reach due to a variety of water sources (Table 3).

Table 3. Categorical Rating Definitions for Temperature Spatial Variation

Index 0	Index 1	Index 2	Index 3	Index 4
Super-abundant sites of groundwater discharge into surface waters (primary source of stream flow), tributaries entering reach, or deep pools that provide abundant temperature variation in reach.	Abundant sites of groundwater discharge into surface waters, tributaries entering reach, or deep pools that provide abundant temperature variation in reach.	Occasional sites of groundwater discharge into surface waters, tributaries entering reach, or deep pools that provide intermittent temperature variation in reach.	Infrequent sites of groundwater discharge into surface waters, tributaries entering reach, or deep pools that provide infrequent temperature variation in reach.	No evidence of temperature variation in reach.

The Bureau's flow alternatives may in fact alter the amount of spatial variation depending on the amount of irrigation returns and groundwater recharging. However, evaluating changes in spatial variation between alternatives is beyond the capabilities of the temperature models and must be evaluated by professional judgment on a case-by-case basis.

Overview of Temperature Models Used in Yakima Basin

This section addresses how flow data will be used to model temperature and discusses the methods that will be applied to generate temperature predictions. Methods have not been resolved for all areas of the Yakima Basin. We discuss each area separately.

Modeling Temperature for the Riverware Analysis Years

Riverware output will be generated for 23 years. These years are based on flow from 1981 to 2003. Flow will change for each year based on operating assumptions for the flow alternative. Flow input to the temperature models can a generalized hydrograph for this period (median flow of all years or the daily 90% exceedence hydrograph) or a specific year in the series to represent a water-year type (wet, dry, average, etc.). In addition, a meteorological year must be selected for the temperature model. This needs to be a recent year in the series to ensure adequate meteorological data for the temperature model. The temperature model output represents temperature conditions for the type of year defined for flow and meteorological data.

It is not possible to develop a simple look-up table for processing multiple management alternatives. Each alternative needs to be processed separately in the temperature models.

The Bureau will need to consider if it wants a typical year modeled in the Riverware period for each alternative or if additional temperature model runs are needed to evaluate the range in flow and metrological types during the Riverware period (e.g., select a warm, drought year). These choices make no difference on how the model output is processed for the EDT model. In all cases we assume a time series of daily maximum temperatures from April 1 to October 31.

Geographic Areas Covered by Temperature Models

Temperature modeling will cover the following geographic areas in the Yakima Basin:

- Naches River – specifically the Upper Naches (Bumping Reservoir), Tieton (Rimrock), and Lower Naches downstream of the Tieton River;

- Upper Yakima River (Easton to Roza) – specifically the Cle Elum River downstream of Lake Cle Elum and the Yakima River (downstream of Lake Kachess and Keechelus) to Roza;
- Mid-Yakima River (Roza to Prosser); and
- Lower Yakima River (downstream of Prosser).

Methods differ substantially among these areas. We need to address each area separately.

Upper Yakima (Easton to Roza)

At this time two options are being considered for modeling this area of the basin: 1) Riverware Reach Temp + Reservoir Regression and 2) the Reservoir & Reach Regression method.

Both options require development of a temperature regression model for reservoir output. This regression will generate daily temperatures of water leaving the three reservoirs in the upper basin (Cle Elum, Kachess, and Keechelus). The first option would model temperature downstream of the reservoirs using the Riverware Temperature module and would provide temperature data at each Riverware node that would be mapped to EDT reaches in the upper basin. The second option would build a multiple regression (including regression results for reservoirs) and generate a daily temperature estimate just at Roza. Daily temperature at Roza is needed to feed into the SNTEMP model being used in the Mid-Yakima.

The Bureau is currently evaluating these options. This report will describe data processing for both options.

Option 1 – Riverware Reach Temp + Reservoir Regression

This approach would provide temperature output at each Riverware node. This approach will provide a more detailed picture of water temperature by reach in the upper basin. However, the model may not be calibrated to the same extent, as we would like. This will require a more careful application of the model output to EDT. In previous discussions some have expressed a concern that a revised reservoir operation (elimination of “Flip-Flop,” for example) may result in increased temperatures in the Easton reach during late summer because of a reduced volume of water in the river. We need to ensure that we are not overlooking this possible impact on survival. The Riverware option appears to be a better approach for evaluating this possible effect because daily maximum temperature would be provided at each Riverware node.

Processing data from the model to EDT would follow procedures outlined in Section 4.0 of this report.

Option 2 – Reservoir & Reach Regression

This approach is simple and would be completed by USGS. However, this approach will not provide a detailed picture of water temperature by reach in the upper basin. A modified reservoir operation (elimination of “Flip-Flop,” for example) may result in increased temperatures in the Easton reach. We need to ensure we are not overlooking this possible effect on survival.

If this option is selected, then the Bureau must evaluate temperatures generated at each of the reservoirs (reservoir regression output) and temperatures at Roza from the model (the only output from the model) to determine if there is evidence that revised reservoir operations have altered the temperature regime in the upper basin. If the Bureau sees evidence of significant differences in temperature in the upper basin between the current condition and the alternative, then it will need to incorporate this change in reaches upstream of Roza. Inputs for the alternative will not come from the temperature model but will have to be inputted into EDT using tools in the EDT Scenario Builder/DWI. Information to help this process will be the temperature at each of the reservoirs and professional judgment (USGS modelers) regarding temperatures in the Easton reach. Alternatively, if the Bureau does not see a significant difference in temperature at Roza and at each of the reservoirs, then it can safely assume that the flow alternative had little effect on water temperature in the upper basin.

Naches River

Again, two options are being considered for modeling temperature in the Naches River. John Vaccaro offered the conclusion that reservoir operations in the Bumping River have a minor effect on water temperature in the upper Naches River (upstream of the Tieton confluence), suggesting that we may not need to model this area for temperature. However, John did state that Rimrock Reservoir operations could have a significant effect on water temperature in the Tieton and the Lower Naches rivers. The options will focus on how this effect might be modeled.

Option 1 – Riverware Reach Temp in Tieton and Lower Naches + Reservoir Regression

This approach would provide temperature output at each Riverware node. This approach will provide a more detailed picture of water temperature by reach in the upper basin. However, the model may not be calibrated to the same extent as would be preferred. This will require a more careful application of the model output to EDT. We would not bother running Riverware Temperature in the Upper Naches based on John’s conclusions. John’s comments about the Tieton and temperature effects suggest we should be completing a more detailed model run for this area of the basin. We need to ensure that we are not overlooking this possible effect on

survival. The Riverware option appears to be a better approach for evaluating this possible effect because daily maximum temperature would be generated at each Riverware node in the Tieton and Lower Naches rivers.

USGS will have to compute a temperature from the Upper Naches (Bumping) to feed the Lower Naches temperature model. We can use this output to confirm that operations are not affecting the Upper Naches temperatures.

Processing data from the model to EDT would follow procedures outlined in the Section 4.0 of this report.

Option 2 – Reservoir & Reach Regression

This approach is simple and would be completed by USGS. However, this approach will not provide a detailed picture of water temperature by reach in the Tieton and Lower Naches rivers. A modified reservoir operation may result in increased temperatures in these reaches. We need to ensure we are not overlooking this possible effect on survival.

If this option is selected, then the Bureau must evaluate temperatures generated for the Upper Naches River at the confluence of the Tieton River, water temperature leaving Rimrock Reservoir, and temperatures at the mouth of the Naches River from the model (the only output from the model) to determine if there is evidence that revised reservoir operations have altered the temperature regime in the Naches Basin. If the Bureau sees evidence of significant differences in temperature between the current condition and the alternative, then it will need to incorporate this change in the Tieton and Lower Naches reaches. Inputs for the alternative will not come from the temperature model but will have to be inputted into EDT using tools in the EDT Scenario Builder/DMI. Information to help this process will be the temperature at each of the reservoirs and professional judgment (USGS modelers) regarding temperatures by reach. Alternatively, if the Bureau does not see a significant difference in temperature in the Tieton River and at the mouth of the Naches River, then it can safely assume that the flow alternative had little effect on water temperature in the Naches River.

Mid-Yakima (Roza to Prosser)

This is the primary area for modeling temperature. The USGS will be generating temperature estimates using SNTEMP. The model will be developed using temperature data collected in the latter half of 2005. This was an exceptionally dry year for the Yakima Basin, so data are not typical. USGS will be running the temperature model this winter with existing data and will revise the model after collecting more data in 2006.

Scarce data exist on return flows other than those data collected during the second half of 2005. Model runs outside this period will assume that return flows are the same as the latter half of the 2005 irrigation season or can be estimated based on returns of one or two index or long-term gaging stations.

Daily maximum temperature will be provided at each Riverware node. The Bureau has mapped these nodes to EDT reaches. The SNTMP model explicitly models the 24-hour mean water temperature with an energy-balance model. Maximum water temperatures are estimated from a diurnal fluctuation model within SNTMP, and, as such, are slightly less accurate than the mean water temperature.

Methods for translating temperature to EDT ratings are described in Section 4.0 of this report.

Lower Yakima (Prosser to mouth)

The Bureau is talking to Pat Monk about contracting with him to model temperature in the Lower Yakima. We assume that temperature generated from this model will be in the same format as the SNTMP temperature model (daily maximum temperature at multiple locations).

Converting Temperature Model Output to EDT Ratings for Temperature Maximum

Computing EDT ratings from a series of daily maximum temperatures is a fairly straightforward process. Step 1 is to determine the number of days in the month that the maximum temperature was in each of the categories described previously. Step 2 is to take these counts and determine the EDT rating using the day counts for each category.

Appendix 1 of this document describes a series of procedures developed to compute the Temperature Maximum rating for a time series of data. These procedures were written in VBA and included in the Excel sample file. Step 1 is a procedure (*GetCatCounts()*) that evaluates a temperature value by category and counts the number of days in the month that the temperature was in each category.

Step 2 must evaluate the month summary from Step 1. The procedure (*GetTempMaxRating(Days As Long, Cat1 As Long, Cat2 As Long, Cat3 As Long, Cat4 As Long, Cat5 As Long, Cat6 As Long)*) is a function that returns the EDT

rating. This procedure is fairly complicated and was developed by trial and error as we applied the EDT model in various watersheds. The complications are by necessity to cover the wide range of temperature combinations. Also, we have had to apply some interpolation to the rating definitions in Table 1 of this report to cover all combinations.

The pattern associated with Temperature Maximum is based on the returning ratings. Pattern multipliers are between 0.0 and 1.0, where 1.0 represents the maximum rating in the time series (the Excel file includes a pattern example).

Special Considerations When Converting Temperature Model Output to EDT Ratings

EDT baseline characterization for Temperature Maximum for the current condition (current flow regulation and average metrological condition) is based on an average rating derived from representative temperature stations for as many years of data as possible. However, not all reaches are well represented by the existing temperature stations in the Yakima and Naches rivers, forcing us to judge if existing temperature data was truly representative of the reach. A good portion of the reaches used ratings that were strictly based on the temperature datasets. However, a significant portion of the reach ratings were based on adjusted ratings using professional judgment (known source of cool/warm water entering reach, groundwater sources, etc.). Bottom line, there is not a 1:1 correspondence between temperature datasets and EDT reach ratings in all mainstem reaches.

The temperature modelers are confident their models will correctly capture differences in temperature between scenarios (including the current regulated condition). However, they are less confident they can accurately predict temperature given the limited datasets available for calibration. We want to ensure that temperature effects in EDT for a scenario are based on the predicted **change** in temperature and not the actual predicted temperature. This requires some adjustment to the predicted values before inputting into EDT. Alternatively, we do not adjust the model predicted temperatures. This option may be valid depending on how well the models are able to predict temperature in the Yakima and Naches rivers and is definitely easier.

Our preferred solution for adjusting the temperature data would have been to adjust the temperature model output to the observed temperature data that was used to develop the ratings in EDT. The adjustment equations would be based on a comparison between the predicted daily maximum temperatures and the observed daily temperature used in EDT. However, as we noted above, there is not a clean relationship between observed temperature and EDT ratings. Given this, our best

solution is to compute adjustment factors using the resulting EDT ratings (predicted vs. observed).

Adjustment factors are computed by regressing (intercept = 0) predicted baseline ratings against the baseline ratings in EDT for Temperature Maximum for the months of April to October. This provides only seven data points per reach, so ideally, these regressions should use information from multiple reaches.

We describe this process in more detail and point out some limitations of this method. Refer to the Excel file to see an example of these adjustments. This process requires that the temperature models be run once for the current condition (regulated median flow with average metrological conditions) and once for the flow alternative (modified median flow with average metrological conditions).

Step 1 of the process is to calculate EDT ratings for the predicted baseline condition for each reach and query the EDT L2 Dataset for Temperature Maximum for the current condition and for the same reach. The EDT rating for this attribute is shaped by month using a pattern, so the pattern associated with this attribute/reach also needs to be queried from the database.

Expanded Temperature Maximum ratings are computed by the following equation:

$$TempMnMx_m = R \times P_m$$

where $TempMnMx_m$ is the EDT rating in month m , R is the EDT rating for Temperature Maximum from the L2 Dataset, and P is the monthly pattern multiplier for month m .

Table 4 is an example set of ratings for some hypothetical data. These values are used to demonstrate the process. Increasing the observed daily maximum temperature by 5% created the predicted values. We assume that this is an accurate representation of how the modeled temperatures might be biased (a fixed percentage up or down).

Table 4. Hypothetical Temperature Maximum Ratings Used in the Example

Month	Predicted Rating	Observed Rating in EDT
Apr	1.5	1.5
May	2.6	2.3
Jun	3.5	3.3
Jul	4	3.75
Aug	4	4
Sep	3.5	3.5
Oct	2	2.2

Note: Predicted ratings are calculated from the temperature models for the current condition [median regulated flow for the simulated time series and average metrological year] and observed ratings are expanded ratings from the EDT current condition.

Taking the results in Table 4, we fit a linear regression to the data with intercept = 0 (Figure 1). In this example the regression is a fairly good fit ($R^2=0.97$). When evaluating greater biases ($> \pm 10\%$) we discovered that the regression fit is not nearly as good. This is because the rating definitions are not linear. Each regression should be evaluated before applying it to the process.

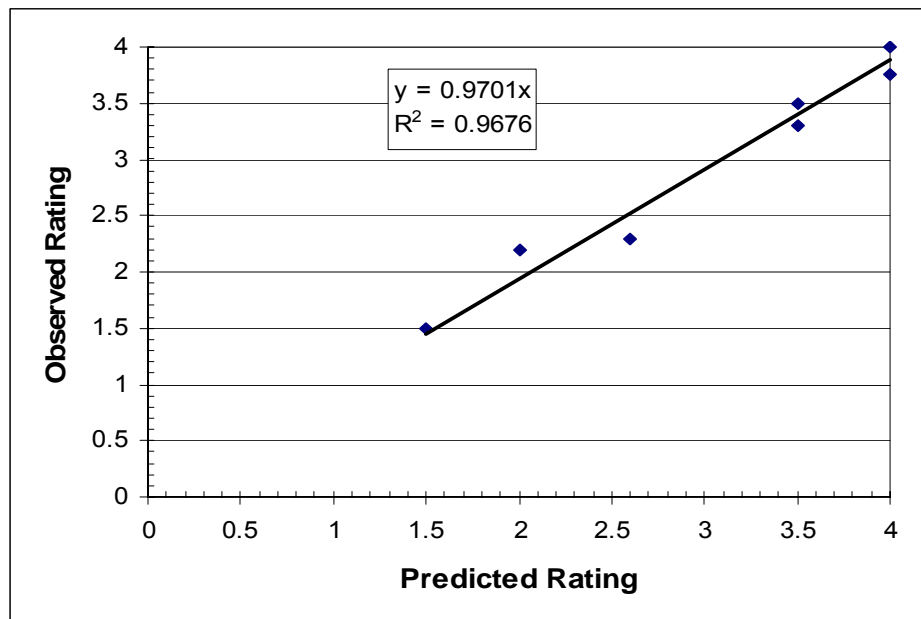


Figure 1. Hypothetical Regression Predicted Rating to Observed Rating for Temperature Maximum

Once a reasonable regression formula is developed, the formula is used for all Bureau alternatives. The basis for using a regression formula developed from the baseline condition is the bias observed in the baseline condition between observed and modeled temperature ratings is consistent when modeling temperature for the flow scenarios.

Patterns for Temperature Maximum for scenarios should be based on the scenario-specific adjusted ratings. Ideally, a unique pattern would be created for each reach being modeled. Patterns are simply calculated by dividing each month's rating by the maximum rating for all months.

The Bureau has also expressed an interest in modeling extreme low-flow conditions (90% exceedence flow, for example). The same regression equations developed previously can be used to adjust the predicted temperatures. However, an additional step is necessary to fully evaluate the effect on temperature in EDT. The baseline EDT model results assume the average condition (median flow and average metrological condition). The baseline condition would need to be revised to reflect this extreme-flow condition. In other words, two scenarios need to be modeled: 1) the regulated-flow condition under extreme-flow and/or metrological conditions and 2) the modified-flow condition under extreme-flow and/or metrological conditions. We assume that the adjustment equations developed previously are adequate to adjust the predicted values for these analyses. The effect on fish performance is evaluated by comparing these model runs (it would not be appropriate to compare results to the existing EDT baseline performance as it is based on the average condition).

*Appendix 1. Visual Basic Procedures Used to Calculate
Temperature Maximum Ratings in EDT*

Appendix 1.1. Procedure Used to Tally Days in Month for Each Temperature Category for Temperature Maximum (procedure was written in VBA for Excel example worksheet)

```
Public Function GetCatCounts()  
  
    Dim d As Integer  
  
    Dim n As Integer  
  
    Dim z As Integer  
  
    Dim x As Integer  
  
  
    Dim Month As Integer  
  
    Dim PrevMonth As Integer  
  
    Dim TempMax As Single  
  
    Dim TempCat() As Integer  
  
  
    Sheets("Compute Temp Max Ratings").Select  
    Range("Starthere").Select  
  
    d = 0  
  
    Month = Range("StartHere").Offset(d, 1).Value  
    TempMax = Range("StartHere").Offset(d, 2).Value  
  
  
    'Reset Array  
  
    ReDim TempCat(1 To 6)  
  
    x = 0  
  
    For d = 1 To 365  
  
        PrevMonth = Month  
  
        Month = Range("StartHere").Offset(d - 1, 1).Value
```

Appendix 1.1 continued.

If PrevMonth <> Month Then

' End of month

Range("OutputHere").Offset(PrevMonth - 1, 0).Value = PrevMonth

For n = 1 To 6

 Range("OutputHere").Offset(PrevMonth - 1, n).Value = TempCat(n)

Next n

' Reset Variables

ReDim TempCat(1 To 6)

x = 0

' Complete data for this record before moving to next record

x = x + 1

TempMax = Range("StartHere").Offset(d - 1, 2).Value

' Bin temperature into appropriate category

For n = 1 To 6

 z = TempCat(n)

 If n = 1 Then

 'Category 1

 TempCat(n) = If(TempMax < 10, 1, 0) + z

 Elseif n = 2 Then

 'Category 2

 TempCat(n) = If(TempMax >= 10, If(TempMax < 16, 1, 0), 0) + z

 Elseif n = 3 Then

 'Category 3

Appendix 1.1 continued.

```

    TempCat(n) = If(TempMax >= 16, If(TempMax < 22, 1, 0), 0) + z
Elseif n = 4 Then
    'Category 4
    TempCat(n) = If(TempMax >= 22, If(TempMax < 25, 1, 0), 0) + z
Elseif n = 5 Then
    'Category 5
    TempCat(n) = If(TempMax >= 25, If(TempMax < 27.5, 1, 0), 0) + z
Elseif n = 6 Then
    'Category 6
    TempCat(n) = If(TempMax >= 27.5, 1, 0) + z
End If
Next n
Else
    x = x + 1
    TempMax = Range("StartHere").Offset(d - 1, 2).Value

    ' Bin temperature into appropriate category
    For n = 1 To 6
        z = TempCat(n)
        If n = 1 Then
            'Category 1
            TempCat(n) = If(TempMax < 10, 1, 0) + z
        Elseif n = 2 Then
            'Category 2
            TempCat(n) = If(TempMax >= 10, If(TempMax < 16, 1, 0), 0) + z
        Elseif n = 3 Then

```

Appendix 1.1 continued.

```
'Category 3

TempCat(n) = If(TempMax >= 16, If(TempMax < 22, 1, 0), 0) + z

Elseif n = 4 Then

'Category 4

TempCat(n) = If(TempMax >= 22, If(TempMax < 25, 1, 0), 0) + z

Elseif n = 5 Then

'Category 5

TempCat(n) = If(TempMax >= 25, If(TempMax < 27.5, 1, 0), 0) + z

Elseif n = 6 Then

'Category 6

TempCat(n) = If(TempMax >= 27.5, 1, 0) + z

End If

Next n

End If

Next d

' Write out last month of data series

Range("OutputHere").Offset(PrevMonth - 1, 0).Value = PrevMonth

For n = 1 To 6

Range("OutputHere").Offset(PrevMonth - 1, n).Value = TempCat(n)

Next n

End Function
```

*Appendix 1.2. Procedure Used to Calculate EDT Rating for
Temperature Maximum Based on Number of Days in Each
Category (procedure was written as a function for Excel
example)*

```
Public Function GetTempMaxRating(Days As Long, Cat1 As Long, Cat2 As Long, _  
    Cat3 As Long, Cat4 As Long, Cat5 As Long, Cat6 As Long) As Single  
    Dim Rating3Days As Integer  
  
    '=====
```

' First evaluate if EDT rating is a 4.0 using definition rules - if any of these criteria are true then rating is automatically a 4.0

```
    If Cat4 + Cat5 + Cat6 > 24 Then  
        'Temperature was >=22 C for more than 24 days in month  
        GetTempMaxRating = 4  
        Exit Function  
    End If  
    If Cat6 > 1 Then  
        ' Temperature was >= 27.5 C for more than one day in month  
        GetTempMaxRating = 4  
        Exit Function  
    End If  
    If Cat5 > 3 Then  
        ' Temperature was >= 25 C and < 27.5 for more than three days in month  
        GetTempMaxRating = 4  
        Exit Function  
    End If  
    '=====
```

' Next evaluate if EDT rating is a 3 rating - need to determine if low 3 rating (2.5) or high 3 rating (3.5)

Appendix 1.2 continued.

If Cat4 > 4 Then

' Temperature was ≥ 22 C and < 25 for more than four days in month

If Cat4 / Days < 0.5 And Cat3 > 12 Then

' Temperature was ≥ 22 C and < 25 C for less than 1/2 of month, yet exceeded 16C for more than 12 days - add these categories and number days ≥ 25 C to determine rating

Rating3Days = Cat3 + Cat4 + Cat5 + Cat6

' If combined number of days is 12 then 2.5 rating, if combined number of days is all days in month then 3.5 rating; ratings scaled between 2.5 and 3.5 based on range number of days

GetTempMaxRating = Round((Rating3Days - 12) / (Days - 12) + 2.5, 1)

Exit Function

Else

If Cat3 + Cat4 = Days And Cat3 > 12 Then

' Temperature was ≥ 16 C and < 22 C or ≥ 22 C and < 25 C for all days in month AND more than 12 days were between 16 C and 22 C - add these categories to determine rating

Rating3Days = Cat3 + Cat4

GetTempMaxRating = Round((Rating3Days - 12) / (Days - 12) + 2.5, 1)

Exit Function

End If

End If

End If

If Cat5 > 1 Then ' Again - if more than one day is ≥ 25 C and < 27.5 C in month than assume a 3 rating

If Cat4 / Days > 0.75 Then

' Over 3/4 of days in month are higher than 22 C - assume this is a high 3.5 rating

GetTempMaxRating = 3.5

Appendix 1.2 continued.

Exit Function

Elseif Cat4 / Days < 0.75 And Cat3 + Cat4 + Cat5 + Cat6 = Days Then

' Less than 3/4 of days in month are higher than 22 C, but all days in month were higher than 16 C

If Cat5 + Cat6 >= 1 Then

'At least 1 day was higher than 25 C - assume this is a 3.75 rating

GetTempMaxRating = Round(3.75, 2)

Else

' All days higher than 16 C but none are higher than 25 C - assume a 3.5 rating

GetTempMaxRating = 3.5

End If

Exit Function

End If

End If

If Cat3 >= 12 Then

' Typically remaining days are all less than 16 C but adding other categories to make certain all categories are covered

Rating3Days = Cat3 + Cat4 + Cat5 + Cat6

GetTempMaxRating = Round((Rating3Days - 12) / (Days - 12) + 2.5, 1)

Exit Function

End If

If Cat3 + Cat4 = Days Then

GetTempMaxRating = 3.5

Exit Function

End If

Appendix 1.2 continued.

```
'=====

' Next evaluate if EDT rating is a 2 rating - need to determine if low 2 rating (1.5) or
high 2 rating (2.5)

  If Cat4 >= 1 And Cat4 <= 4 Then

    ' More than one and less than 5 days temperature was >=22 C and < 25 C

    GetTempMaxRating = 2

    Exit Function

  End If

  If Cat3 >= 1 And Cat3 <= 12 Then

    ' One to 12 days in month temperature was >=16 C

    GetTempMaxRating = Round((Cat3) / (12) + 1.5, 1)

    Exit Function

  End If

'=====

' Next evaluate if EDT rating is a 1 rating - need to determine if low 1 rating (0.5) or
high 1 rating (1.5)

  If Cat2 >= 1 Then

    ' Number of days in month temperature >= 10 C and < 16 C

    GetTempMaxRating = Round(Cat2 / Days + 0.5, 1)

    Exit Function

  End If

'=====

' Finally evaluate if EDT rating is a 0 rating - All days must be < 10 C

  If Cat1 / Days = 1 Then

    ' All days < 10 C

    GetTempMaxRating = 0
```

Appendix 1.2 continued.

Exit Function

End If

'=====

' Added to trap error if unable to determine rating

GetTempMaxRating = 99

End Function