Campbell River Water Use Plan

Monitoring Program Terms of Reference

- **JHTMON-10 Upper and Lower Campbell Lake Reservoirs Shoreline Vegetation Model Validation**

September 20, 2013

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1 Program Rationale

1.1 Background

During the Campbell River Water Use Planning (WUP) process, the Wildlife Technical Sub-committee (WTC) identified eight uncertainties regarding the impact of facility operations on wildlife use. These uncertainties were subjected to a rigorous assessment of 'relative importance' that allowed the list to be pared down to just two issues which were ear-marked for immediate attention in the form of a monitoring study (Bruce 2002a). The first of these was the lack of information on the amphibian habitat use in the area and its overlap with areas impacted by WUP operations and is the subject of Monitor 9. The second uncertainty was concerned with the validity of a newly-developed, lacustrine shoreline vegetation model (SV model) that was used to predict changes in shoreline plant ecosystems of each reservoir or diversion lake in response to operational change. The latter is the subject of the present monitor.

The SV model was developed in response to the WTC's need to quantify operational impacts on obligate and facultative aquatic wildlife within the Strathcona, Ladore, and John Hart project areas. A direct assessment of operational impacts, along with a detailed inventory of wildlife use in the area, was considered to be well beyond the scope of WUP because of time and resource constraints involved. In response to these data collection constraints, the WTC adopted an alternative habitat-based approach to assessing wildlife consequences of operational change that relied on a modeling exercise to predict likely changes in riparian ecosystems. By associating seasonal habitat requirements of wildlife species residing in the area with specific plant ecosystem types, it was believed that inferences could be made regarding wildlife impacts by tracking changes in the aerial extent and location of these plant ecosystems (Bruce 2002b, Blood 2001, McLennan and Veenstra, 2001).

To carry out this habitat based assessment, the WTC required two types of information; 1) a database of wildlife species-use in the area, including resident times, habitat uses, and preferred plant ecosystem types; and 2) a model that predicts changes in plant ecosystem types in response to operational change (specifically reservoir water levels through time). With the help of the WTC, a 'wildlife use' database was compiled by Bruce (2002c) in which the WTC expressed considerable confidence in its content (i.e., errors, if any, were likely to be minor). However, the shoreline vegetation model developed to predict changes in plant community type did not receive the same level of confidence. This was largely because the approach used in the model to predict community type changes, though thought to be conceptually sound, was largely un-tested. As a result, the WTC only accepted the results of the SV model on the *proviso* that a monitor be carried out to validate the model through confirmation of model predictions.

1.2 Management Questions

The WTC identified the following set of management questions to be addressed in this monitor:

1) Does the lacustrine shoreline vegetation model accurately predict the reservoir elevation bands that bound the predefined plant community types?
2) If the model is in error, is the magnitude of the error such that it would warrant a change in the predicted outcome of the WUP (e.g., Figure 10.1)?
3) Are there changes to the modeling approach that could improve its accuracy for implementation in future WUP reviews?
4) Is it reasonable to expect that most riparian plant ecosystems require shoreline slopes to have a gradient less than 15% to perpetuate (presumably because it allows for the accumulation of nutrient rich soil through time)?

   The present model assumes that shoreline gradient would have to be 15% or less to allow soils to accumulate and hence allow for plant growth. The selection of this criterion was somewhat arbitrary and then later supported by professional opinion of the WTC. This assumption may not be correct. Thus the aerial estimates of plant ecosystem extent used to assess the impacts of operational change may not be correct.

Though not explicitly requested by the WTC, the monitor also implicitly addresses the following management question:

5) Has the distribution of riparian plant ecosystems changed following implementation of the WUP and if so, can the change be attributed to the WUP operation?

1.3 Summary Hypotheses

The general approach to resolving the management questions listed in Section 1.2 is to first determine whether the model predictions were accurate through a test of the following hypothesis:

$H_0$1: Measured elevation bands defining the upper and lower extents of each vegetation community type in the area are not significantly different than those predicted by the shoreline vegetation model.

The hypothesis will be tested separately at each location where the shoreline vegetation model is applied. This would allow an evaluation of model performance under various hydraulic conditions.

Acceptance of $H_0$1 would require no further follow-up analyses. However, rejection of $H_0$1 would lead to a detailed evaluation of the modeling error; firstly, to determine whether it would be large enough to have changed WTC and Consultative Committee (CC) deliberations and conclusions (Management Question 2); and secondly, to uncover shortcomings in the modeling process so as to make changes to improve future accuracy if possible (Management Question 3).

Management Question 2 will be addressed largely through inference and subjective analyses as it cannot be structured into a testable hypothesis. Management Question 3 will be addressed through exploratory analysis, including a characterization of modeling errors, a re-evaluation of the model’s underlying concepts and assumptions, and test of alternative modeling approaches to determine whether modeling accuracy can indeed be improved. Hypothesis testing in the latter case will be dependent on the results of preceding analyses and cannot be formulated at this time.

Management Question 4 will require resolution through geostatistical analysis of plant ecosystem polygons overlaid on topographical or bathymetrical data, leading to the test of the following hypothesis:

$H_0$2: The likelihood that a particular plant ecosystem type occurs within a predicted reservoir elevation band is not dependent on shoreline gradient.

The test of $H_0$2 should be done for each plant ecosystem separately, as well as for all types as a group within the drawdown zone. During the WUP, the WTC assumed that a 15% gradient formed a reasonable threshold for plant growth, but other values should be investigated, including the possibility that plant growth is independent of gradient.

Management Question 5 for will involve a simple comparison of 'before' and 'after' states following implementation of the WUP, i.e.,:

$H_0$3: Plant community distribution following implementation of the WUP does not differ significantly from the measured state prior to implementation.

As in $H_0$1, hypothesis $H_0$3 will be tested separately for each study reservoir and diversion lake. If the SVM model proves valid (i.e. $H_0$1 is accepted), then it can be inferred that observed changes (i.e., $H_0$3 is rejected) are likely be attributed to WUP operations.

1.4 Key Water Use Decision

The shoreline vegetation (SV) model was used in two ways during the WUP process. The first was numerically, where predictions were made on the future elevation boundaries of specific plant ecosystems following implementation of a test operating alternatives (e.g., Figure 10.1). This was only carried out on Upper Campbell Lake Reservoir, which was the only system with sufficient data to populate the model. The model was used in the Lower Campbell Lake reservoir as well, but with uncertain results due to the fact that the model was only populated with Upper Campbell Lake Reservoir data. The second use of the model was conceptual, where the model's underlying concepts and assumptions were applied to logically derive likely outcomes given what was understood at that time of an operating alternative's impact on local hydrology. This was generally done for all of the diversion lakes, though there was considerable uncertainty regarding the impact of flow changes on lake elevation.

In both cases, modeling results lead the WTC to conclude that the consequences of proposed operational changes were either benign or positive, and because of the high level of uncertainty associated with these results, decided to abandon the issue of operational impacts on wildlife habitat as an issue for consideration during WUP trade-off analyses. Contributing to that decision was the fact that benefits to a number of other values, including fish and recreation, appeared to coincide with wildlife habitat values, and that there appeared to be no compelling evidence (from the modeling exercise) that any of the proposed operating strategies would cause a worsening of wildlife habitat conditions. The WTC did note however, that evidence to the contrary would cause a reversal in their decision and thus impact future WUP decisions. For this reason, the WTC deemed it imperative that a monitoring study be carried out to verify the conclusions drawn from the SV modeling results.

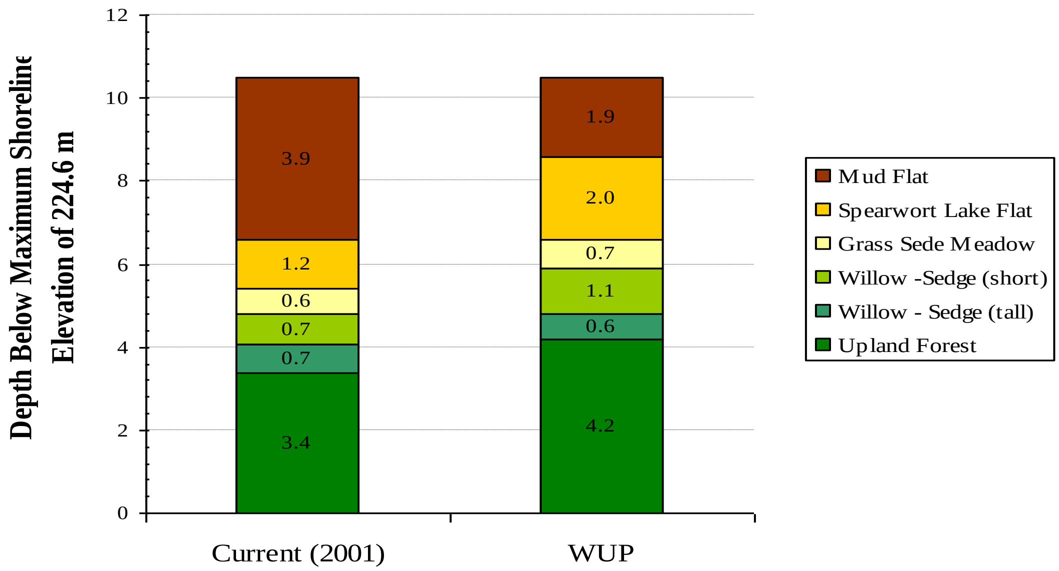

Figure 10.1 Example of a numerical shoreline vegetation model result that compares the measured elevation bands of existing plant communities to that predicted following implementation of the WUP. Numbers indicate the depth range of each plant community type.

2 Program Proposal

2.1 Objective and Scope

The primary objective of this Monitor is to address the management questions presented in Section 1.2 by collecting data necessary to draw inferences and to test the impact hypotheses outlined in Section 1.3. The following aspects define the scope of the study:

1) The study area will consist of Upper and Lower Campbell Lake Reservoirs and at least one of the diversion lakes along the Salmon River diversion route. It will be up to the contractor, in consultation with BC hydro staff, to choose which lakes(s) should be studied. All water bodies are expected to have altered reservoir hydrology following WUP implementation. Upper Campbell Lake Reservoir is expected to have the largest change and hence will be the most robust test of the model. Lower Campbell Lake Reservoir is expected to have the least amount of change and is included to assess the model's sensitivity. The salmon diversion lake will test the model's applicability to non-reservoir environments.
2) The Monitor will be carried out over a 10 year period with the majority of work occurring in Years 1 and 10 of the study period. The only data to be collected in the intervening years is water level at key study locations.
3) Sampling will be carried out in a standardized manner and follow a specified schedule to ensure consistency in data quality and collection procedures. All GIS data will be captured and archived according to BC Hydro standards.
4) An interim report will be prepared following the work in Year 1 to clearly describe the location of all transects, equipment installations and other pertinent geographical monuments. Included in the report will be a detailed description of

the methods used, a printed and electronic copy of all data collected to date, and a discussion of initial findings that could be useful in future sampling efforts.

5) A final report will be prepared at the end of the Monitor that summarizes the results collected to date, discusses inferences that can be drawn pertaining to the impacts of the WUP over time, and presents conclusions concerning the management questions in Section 1.2 and the impact hypotheses in Section 1.3.

2.2 Approach

The monitoring study will be carried out in two parts, the first of which will be associated with the validation of the SV model itself and its ability to predict elevation boundaries of local plant community types based of reservoir hydrology. The other part will be an examination of plant community distributions to determine how they may correlate with other environmental attributes (principally gradient) so that a means of calculating aerial extent (*ha*) can be formally developed.

The general approach to the SV model validation will be to compare *in situ* measurements of plant ecosystem boundary elevations with those predicted by the model. It will begin in Year 1 with a collection of baseline data to populate the model, and a data collection phase in Year 10 to compare model predictions to measured values. This will be done separately for each study reservoir and selected diversion lake(s), but because of differing availability of information, will follow slightly different procedures and scheduling (Section 2.3.4).

In addition to comparing predicted versus actual ecosystem boundary elevations, the SV model will also be tested by comparing estimation parameters used in the model to derive these predictions. Data collected in Year 1 of the Monitor will be compared to that used in the WUP, while that collected in Year 10 will be compared to Year 1. Large differences through time, as well as between sites, would be indicative of an unreliable model and will be used as corroborating evidence to the main model validation procedure.

Aerial estimates (ha) of each plant community type were calculated based on the assumption that shoreline areas with gradients less 15% were unsuitable for plant growth. Validation of this premise will be carried out initially through an analysis of existing plant ecosystem distributions in Year 1 of the Monitor, and again in Year 10 when model predictions will be compared to measure values. The analysis will rely on GIS data analysis of 2-D rectified air photo mosaics. As inferred above, the air photo work will be done in Year 1 and Year 10 of the Monitor. The focus of the Year 1 work will be to develop a predictive tool for future use, while the Year 10 work will provide the means to test overall accuracy and utility.

The air photo mosaics and GIS dataset will also provide the means to compare plant ecosystem distributions before and after WUP implementation, and therefore test $H_0 3$ using geo-statistical procedures. It will also provide the means by which the true outcome of the WUP can be assessed regarding its impact of riparian plant communities and associated wildlife. This analysis will corroborate the SV model test results should it prove valid, or act as a fall back should it be rejected. In the latter case, this information can be used to determine mitigation action if required, and be used as a base case for future WUP comparisons.

2.3 Methods

2.3.1 Literature Review

Before all field work is to begin, a cursory review of primary literature will be carried out to assess the current state of knowledge on the effect of reservoir type hydrology on riparian plant community structure. All pertinent articles will be photocopied and collated into binders with a table of contents for easy reference. The collection of articles will be for reference purposes only and is to help in the development and refinement of the model, as well as with the interpretation of model results. No summary report is expected.

2.3.2 Data Capture

2.3.2.1 Shoreline Vegetation Model Validation

Field Work

In situ plant ecosystem boundary-elevations will be estimated by transect analysis at a minimum of five and no more than 10 different locations at each study lake or reservoir. The transects will be located in areas where at least four (preferably all) of the six plant community types identified by MacLennan and Veenstra (2001) are present (see Figure 10.1). Each transect will be oriented perpendicular to the shoreline, begin in a mudflat area, and extend into the upland forest community above maximum reservoir or lake elevation. At the top end of each transect, a permanent bench mark (e.g., numbered survey tag bolted to a boulder or bedrock) will be installed for future reference. The benchmark's location and elevation will be established by GPS and/or traditional survey techniques as deemed necessary, which should include photo-documentation.

Using the plant community definitions developed by MacLennan and Veenstra (2001), boundary elevations between the different plant ecosystems will be measured relative to the benchmark. Boundary delineations may at times be difficult to establish, so it is important that the survey team be well trained at identifying local plants and recognizing plant ecosystem types. Because boundary locations may not always be clearly identifiable, it is also important that the same crew do the survey work at all sites and years so that observer bias can be accounted for when analyzing the data.

To the extent possible, the methodology of MacLennan and Veenstra (2001) should be used to ensure compatibility between their data and those collected here. In the case of Upper Campbell Reservoir, this includes repeating the boundary elevation work on transect locations used in their study. It is unlikely that these transects have been benchmarked, so they will have to be relocated based on the information given in their report and then permanently marked for future reference. Only Lower Campbell Lake Reservoir and the selected diversion lake will require identification of new transect locations.

Daily average water level within the two study reservoirs will rely on the fore bay elevation data presently being collected by BC Hydro. There are no elevation data currently being collected for any of the diversion lakes. Consequently, a water level data recorder will have to be installed in the diversion lake selected for study. The recorder should be installed in such a manner as to minimize the chance of vandalism, yet accurately record water level under all hydrological conditions. It should be accessible for downloading at least two times per year. In all instances, water level is to be recorded at hourly intervals and averaged across each day.

Modeling

At the end of each five-year period, the daily average water level data will be collated into a single file for each study system for use in the shoreline vegetation model. The model will be run separately for each study reservoir and diversion lake, and will output boundary elevation data as meters below maximum elevation. Details of the modeling procedure is provided by Bruce (2002b)

2.3.2.2 Air Photo Interpretation

At Year 1 and Year 10 of the Monitor, 1:20,000 to 1:40,000 scaled air photographs will be taken through BC Hydro's Photogrammetry Department of each study area to identify present location and aerial extent (ha) of the plant community types defined by McLennan and Veenstra (2001). BC Hydro's Photogrammetry will digitally scan, 2-D rectify and collate the air photos to create a mosaic of each study area. A vegetation specialist will, through air photo interpretation, identify the geographic extent of each plant ecosystem on the mosaic and delineate them as a polygon in a GIS database for later use in the field and subsequent analyses. It will be up to the contractor to develop the air photo interpretation procedures. To ensure that all plant ecosystem types are identifiable, the air photos should be taken in colour and at a time when the reservoir is at its normal, minimum operating level, and vegetation communities are most easily identifiable from the air. Given that plant phenology timing and minimum reservoir levels will likely not correspond, a balance will be sought when selecting timing of the flights.

To verify the database's accuracy, a subset of polygons will be selected for ground-truthing where a two-person crew will be sent into the field to verify polygon boundaries and their designated plant ecosystem type. Errors that are uncovered during the survey will be analyzed with the intent of refining the air-photo interpretation techniques initially developed by the contractor. This will lead to corrections in the air-photo mosaic and GIS database used for subsequent analyses.

Following the ground-truthing exercise, the Year 1 GIS database will be integrated with existing Digital Elevation Model (DEM) models (Monitor 1), as well as existing bathymetry and topographic maps. The integrated database would then be used to test hypothesis $H_0 2$ (Section 1.3) and serve as the reference to compare the Year 10 database to test hypothesis $H_0 3$.

2.3.3 Safety Concerns

A safety plan will have to be developed for all aspects of the study in accordance with WorkSafe BC and BC Hydro procedures and guidelines. It is important to note that, because of the remoteness of some of the study areas, all field work must always be carried out by at least two crew members and that appropriate check-in and checkout procedures must be followed.

2.3.4 Data Analysis

2.3.4.1 Shoreline Vegetation Model Validation

Data analysis will proceed on two fronts; the first where predicted and measured boundary elevation bands are compared in a direct test of model accuracy, and the second where estimation criteria used in the model are compared before and after inclusion of new data.

Boundary Elevation Analysis

Boundary elevation analysis for each study water body will be carried out by first subtracting the predicted elevation bands from the SVM model from the individual measurements taken at the transect sites. The set of differences will then be subject to a single factor Analysis of Variance (ANOVA) to determine whether significant differences exist between measured and predicted elevations. Rejection of the null hypothesis of no difference would indicate a failure in the model to accurately predict boundary elevations between plant community types. Acceptance of the null hypothesis would lead to the next phase in the analysis where all differences between measured and predicted elevations are pooled and subjected to a z-test to determine if the mean difference is not significantly different from 0. Acceptance of the null hypothesis would be the first indication of the model's validity. Conversely, rejection of the hypothesis would indicate a strong bias in the model's output and that a correction would be necessary (e.g., reservoir elevation at the transect site is consistently greater or lesser than that measured at the dam forebay).

SV Estimation Parameters

The SV model relies on a set inundation-duration probability distribution functions (*pdf*) that it tries to match by selecting boundary elevations through a trial and error procedure. It is the means by which the model predicts plant ecosystem boundary elevations (Bruce 2002b). The inundation-duration *pdfs* are derived from historical water level data and measured boundary elevations collected at the time of model development (MacLennan and Veenstra 2001). During the WUP, the only data available to develop these *pdfs* were from the Upper Campbell Lake Reservoir where reservoir water level data have been collected since 1984 and the appropriate vegetation surveys were carried out. This version of the model, labeled here as SVM_{2001}^{UCR}, is to be updated in Year 1 as new data are available. Each time new data are added, the potential exits that the inundation-duration *pdfs* will be altered; hence changing the model's output. To determine if the differences are significant, the *pdfs* before and after the addition of new data will be compared using a simple goodness of fit test such as the Kolmogorov-Smirnov 'D' statistic (Zar 1974).

Testing Scheme through Time

Because data availability is different for each study reservoir or lake, so will be the testing procedure. Upper Campbell Lake Reservoir has the best data availability to test model accuracy. Elevation band data was originally collected at this site during the WUP to develop the SVM model and significant changes in shoreline riparian habitat is expected following WUP implementation (Figure 10.2), providing a significant contrast for comparison. However, because of the time delay for WUP implementation, a new dataset should be collected to re-establish the baseline state of the riparian plant ecosystems at that site (Figure 10.3).

Changes in plant community distributions are also expected in Lower Campbell Lake Reservoir, though the changes will likely be more subtle. This provides an opportunity to determine the SVM model's sensitivity to predict change. Unlike the Upper Campbell Lake Reservoir, no elevation data was collected during the WUP period, so a data set will have to be collected in Year 1 to provide a baseline for comparison in Year 10, as well as provide an opportunity to assess model sensitivity in both in the short (five years since the WUP) and long term (10 years post WUP implementation) (Figure 10.4)

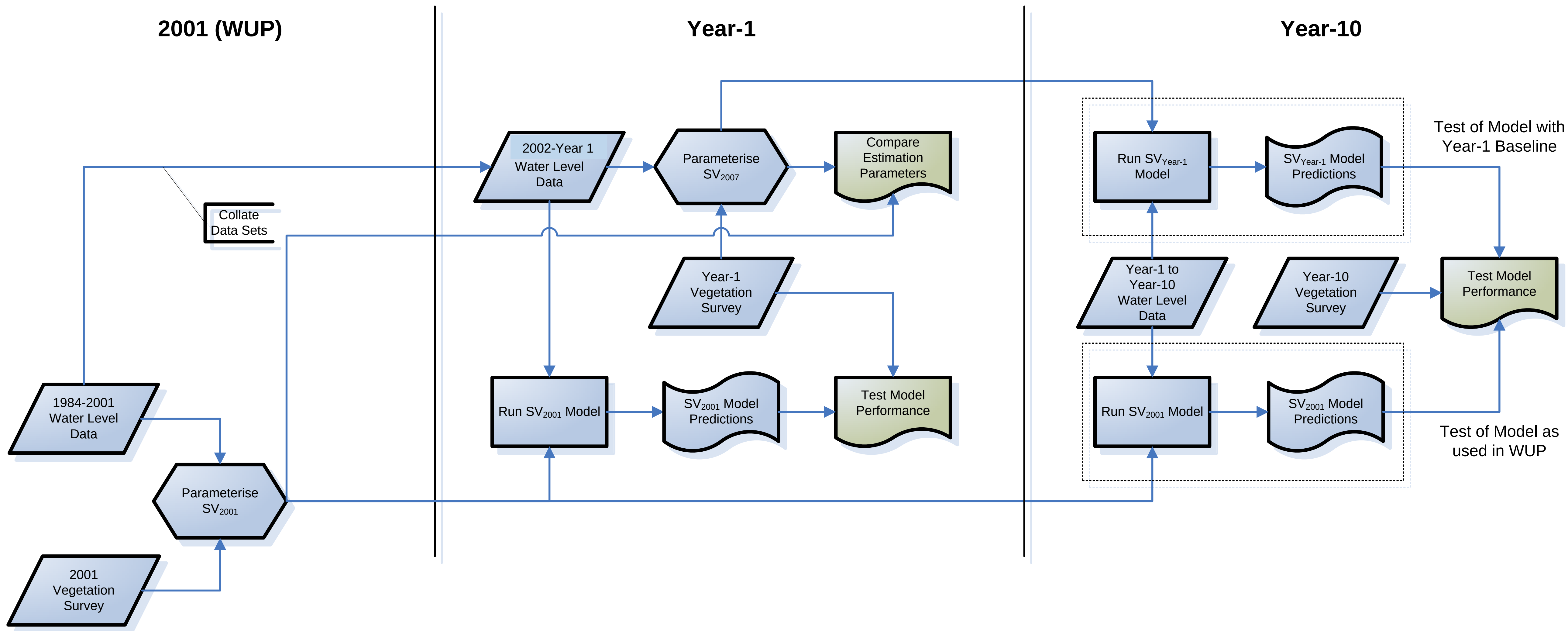

Figure 10.2 SVM Testing Procedure for Upper Campbell Lake Reservoir

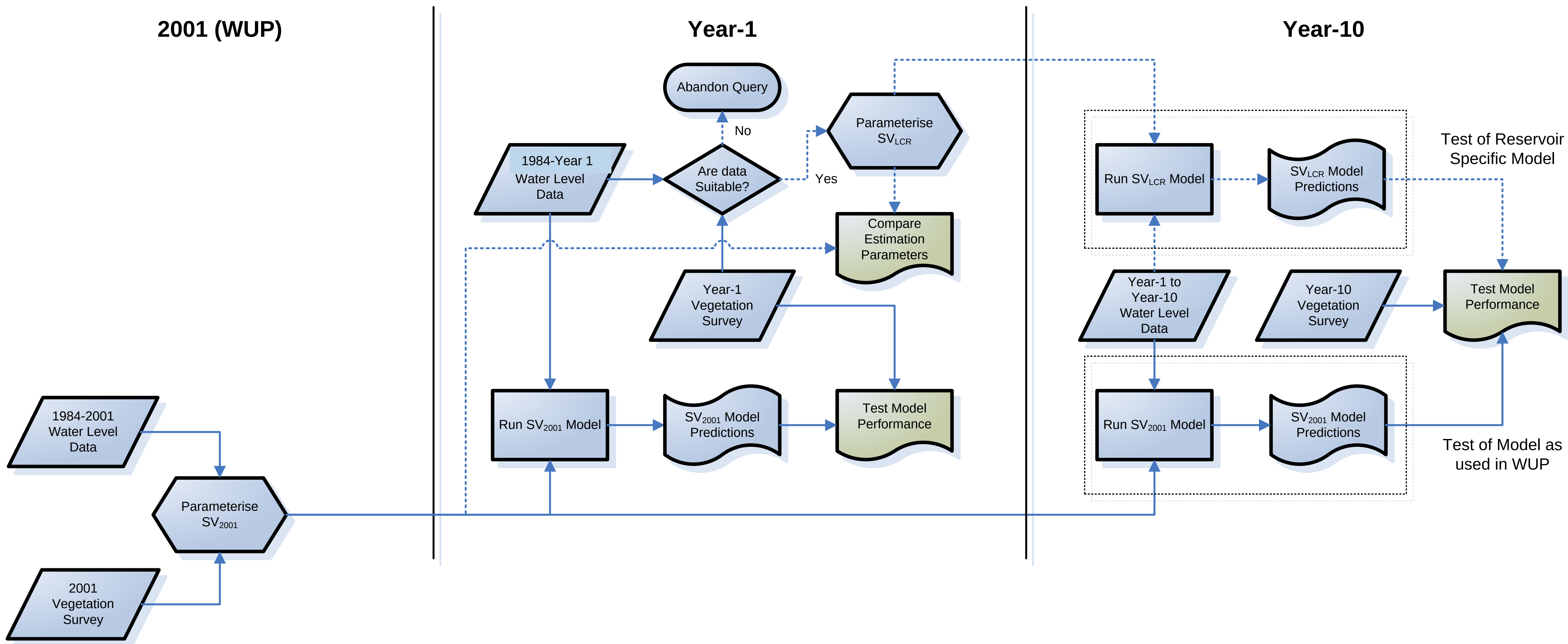

Figure 10.3 SVM Testing Procedure for Lower Campbell Lake Reservoir. Dashed arrows indicate those procedures that can only occur if data are deemed suitable.

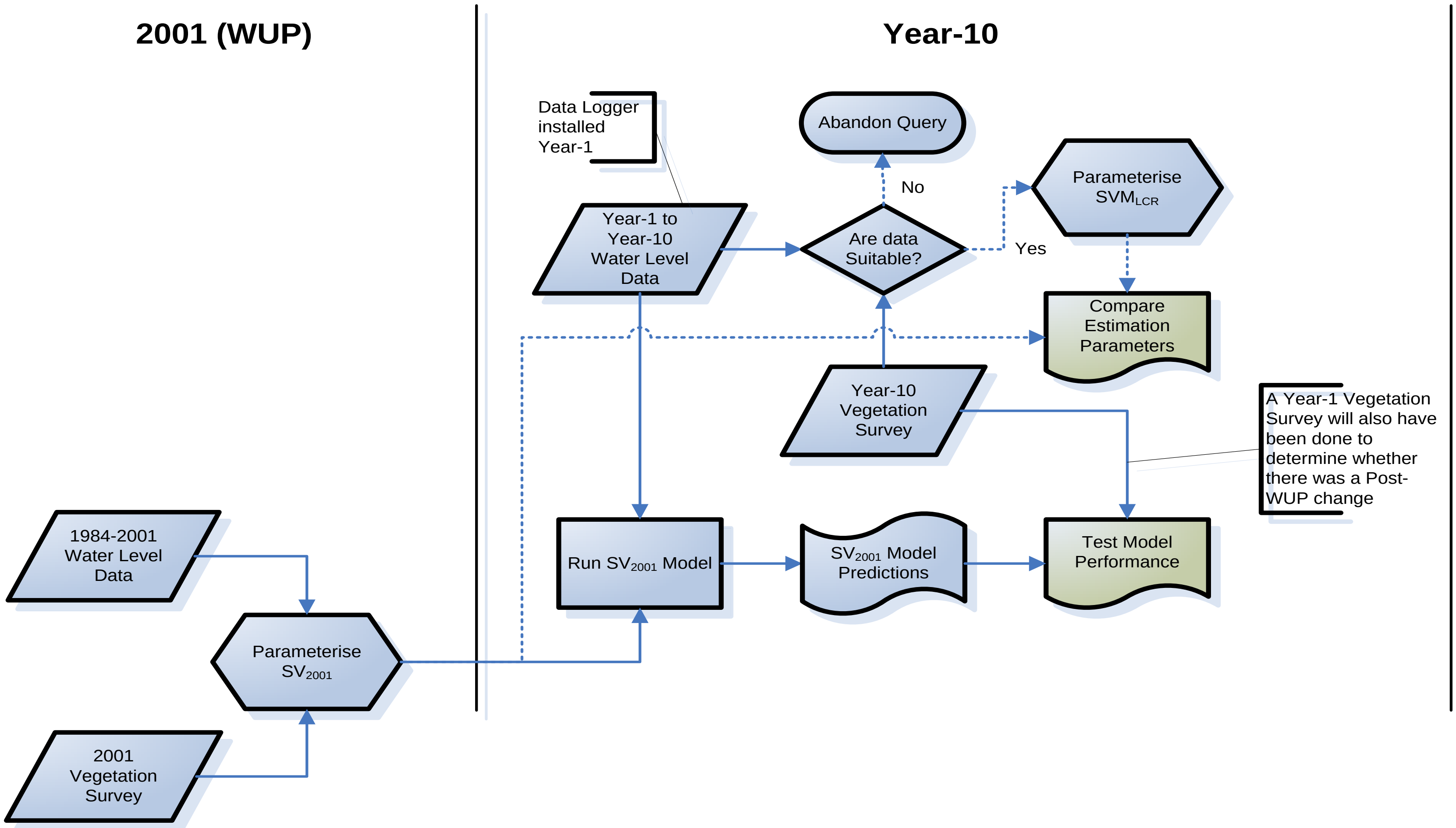

Figure 10.4 SVM Testing Procedure for the diversion lake selected for study. Dashed arrows indicate those procedures that can only occur if data are deemed suitable.

The system with the least data will be the diversion lake, no matter which one is selected for study. No data were collected at the time of the WUP, and unlike the reservoir sites, water level is not monitored on a regular basis. Thus, no testing can be done until Year 10 of the Monitor when sufficient water level data exists to develop model predictions for comparison (Figure 10.4)

2.3.4.2 Air Photo Interpretation

The aerial extent information will be analyzed in several ways. The first will be to confirm the simple conversion protocol used to transform the SVM boundary elevation predictions to an aerial estimate (ha) of each plant community type. The second will be to test the protocol's accuracy by comparing predictions with measured values collected in Year 10 of the Monitor. The last will be a direct comparison of plant community distributions before and after implementation of the WUP.

Converting Boundary Elevation Data into Estimates of Aerial Extent (ha)

During the WUP, it was assumed that shoreline areas with a gradient exceeding 15% were incapable of retaining soil in the drawdown zone when exposed to wave action. To test this assumption, the average gradient of all plant community polygons will be interpolated from the integrated GIS database. Included in the dataset will be at least a subset of polygons where no vegetation growth has occurred. The data will then be organized into a 2 x 2 contingency table that compares the presence and absence of a given plant community type, and whether the average gradient is above or below 15%. The table can be analyzed using the Fisher exact test to test whether the proportion of polygons with vegetation cover is similar between the two categories of shoreline gradient. The contractor is encouraged to explore alternative gradient thresholds using the same analytical technique.

If the data allow, other environmental factors can be explored (e.g., fetch or solar exposure), but such analysis will be considered beyond the scope of the present Monitor.

Validation of the Hectare Estimation Tool

Validation of the hectare estimation tool can only occur in Year 10 of the Monitor when an independent dataset will be available for comparison. The estimation tool will consist mainly of a table of depth intervals (likely 0.1 m) starting at maximum water level down to minimum normal operating range and a corresponding set of values noting the total area of shoreline habitat (ha) within that interval that has a gradient less than 15% (the 15% threshold value is used here as an example; the preceding analysis will determine what this value should be). Thus, for a given range of boundary elevations produced by the SV model, a corresponding aerial extent estimate can be obtained by summing the interval habitat area values in the table that lie in between them, e.g.,

$$Total\ Sedge\ Willow\ Area\ (ha) = \sum_{i=LowerElevation}^{UpperElevation} \left(Area_i \middle| Gradient < 15\% \right)$$

It is important to note that the end result of this estimation tool is an estimate of the total area of the plant community type of interest in the study area of interest. It does not explicitly predict the location and area (*ha*) of specific community polygons.

Verification of model predictions will be done by comparing Total Area (ha) estimates of each plant community type to that measured in the field by polygon analysis using simple regression techniques. A significant regression coefficient (r^2) will be considered a strong indicator of model validity. The regression equation will be viewed as an indication of the bias in the estimation procedure, and may be considered a means of calibrating the model if found to be common in all study sites by an analysis of covariance (ANCOVA). A key component of the analysis will be verification of the assumptions of normality, linearity and homoscedasticity.

Before-After Comparisons

Before-after comparison of plant community type distribution following WUP implementation will be done visually by directly comparing community polygons using maps as the primary communication and analytical tool. The analysis will be largely descriptive in nature, and will assume measurements of polygon location, shape and area are made without error. In the case that the SV model predictions prove to be wrong, the before-after comparison of the air photo mosaics would form the foundation from which an assessment of the true riparian outcome of the WUP and associated wildlife impacts.

2.3.5 Reporting

Two major reports will be prepared as part of this Monitor, as well as annual water level reports. The first report will be documenting the results of all testing done in Year 1 of the Monitor as per Section 2.3.4. This information will provide the first insight into the model's validity and utility, though care should be taken in drawing conclusions. The true test of the Monitor's hypotheses will not occur until Year 10 of the Monitor when the final report will be due.

Because the Monitor will not be repeated for another 10 years, the Year 1 report will be focused on detailed descriptions of the methodologies used in the Monitor to date. It should include:

1) Precise location of all transects benchmarks, and equipment installations,
2) Detailed instructions of methods to be used/repeated in Year 10,
3) Both printed and electronic copies of all data collected, photos, and maps to date to ensure utility and accessibility into the future, and
4) Initial results, derived from hypothesis testing done to date as described in Section 2.3.4.

At the conclusion of the Monitor in Year 10, a final report will be prepared that summarizes the data collected to date and discusses in detail the results of all analyses as they pertain to the impact hypotheses in Section 1.3, and more importantly, the management questions in Section 1.2. The report should:

1) Re-iterate the objective and scope of the Monitor,
2) Present the methods of data collection and data analysis,
3) Describe the compiled data set and present the results of all analyses.
4) Discuss the results as they pertain to the hypotheses in Section 1.3 and the Management Questions in Section 1.2,
5) Discusses the consequences of these results as they pertain to the current WUP operation, and how it may influence future WUP decisions, and

6) Include an executive summary that summarizes the results of the Monitor and their consequences as they relate to the success/failure of the WUP decision. It should include recommendations for remedial work if any as well as the scope for future study work.

2.4 Interpretation of Results

2.4.1 Shoreline Vegetation Model Validation

A significant correlation between predicted and measured plant community boundary elevation bands of would be considered a strong indication of the SV model's precision and accuracy. Similarly, a significant correlation of inundation exposure pdf's between measurement periods would also lend support to the model's premise that vegetation growth and community structure along reservoir shorelines is at least in part governed by its hydrology, and that each community type represents an 'arrested state' of successional development. Together, both lines of evidence would be viewed as validation of the model and its underlying premise. Such an outcome would confirm the assumptions made by the WTC during the WUP and validate the decisions that were made regarding the WUP's outcome. In this case the model can be used in future WUP reviews without modification for Performance Measure (PM) development and decision analysis.

Conversely, lack of a correlation in either line of query would lead to a rejection of the model. Whether the model should be abandoned or refined will depend on the nature of the relationship between predicted and measured values, as well as the level of consistency between study sites. For example, acceptance of H_01 in Upper Campbell Lake Reservoir but rejection elsewhere would suggest that the model is only responsive to large changes in hydrology and because of its low fidelity, should be restricted in its use rather than be abandoned. The data collected during the Monitor could shed light on ways to refine the model and improve its fidelity for future use in WUP reviews.

Rejection of the SV model, or the necessity to modify it, would require that an assessment be made on whether the true outcome of the WUP was considerably different from what was originally hypothesized. This will require careful interpretation of the air photo information, as noted below.

2.4.2 Air Photo Interpretation

The contingency analysis should identify threshold gradient below which vegetation growth can occur should hydraulic conditions be suitable. Correlation analysis between predicted and measured total area of plant community types will refute or confirm the relationship and its value in improving the model's utility. The available area of shoreline with a gradient below the threshold value could vary considerably depending on elevation, thus the true impact of a boundary elevation shift may be greater or lesser than that implied in the magnitude of the shift itself.

Rejection of both lines of inquiry would lead to an abandonment of this refinement to the SV model output, and depending on the nature of the difference, could call into question the utility of the SV model itself if its validation proves inconclusive as well. Rejection of either line of inquiry would lead to an inconclusive outcome to this component of the Monitor.

Results of the before-after comparison of air photo mosaics will provide a follow-up means of assessing the true outcome of the WUP regarding its impact of riparian plant communities and associated wildlife. This analysis will corroborate the SV model test results should it prove valid, or be a fall back means of assessment should it be rejected. In the latter case, this information can be used to determine possible mitigation action if required, and be used as a base case for future WUP review comparisons. Used in conjunction with the other information collected in the present Monitor, it could also provide useful information for future model re-development and/or refinement.

2.5 Schedule

The shoreline vegetation model validation Monitor will be carried out over a 10-year period, but with the majority of work being done in Years 1 and 10. In Year 1 of the Monitor, monitoring activities will be focused of the refinement of the SV model based on a preliminary assessment of model validity (Upper Campbell Lake Reservoir only), a redefinition of baseline conditions for comparative purposes in ten years time, the set up of all study site locations, the installation of measuring equipment and survey benchmarks, and a clear definition of all methods and procedures. Formal testing of the SV model will be done in Year 10 when all study sites will be re-sampled to establish shoreline conditions following WUP implementation. In the intervening years, the only monitoring work to be carried out is the continuous recording of water levels at the two study reservoirs and the diversion lake selected for study.

A preliminary report will be prepared Year 1 of the Monitor as per Section 2.3.5, which will include accurate descriptions of all equipment, transect and survey benchmark locations, detailed instructions of all methods and a discussion of preliminary analyses done to date. A comprehensive report on shoreline vegetation model validation will only be prepared at the conclusion of the Monitor in Year 10, as per Section 2.3.5. A summary of the Monitor schedule can be found in Table 10.1.

It should be noted that the schedule presented here is different from that presented in the Campbell River WUP CC report. In the CC report, the time frame for monitoring was only five years. This has been extended to 10 years to coincide with the WUP review period. This increase in time frame was considered to be beneficial to the Monitor as it provides a greater time between measurements for ecosystem changes to materialize, the temporal scale of which is expected to be 5 to 15 years.

2.6 Budget

The total cost of the 10-year shoreline vegetation model validation Monitor is estimated to be $165,068 based on a 2014 start.

3 References

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