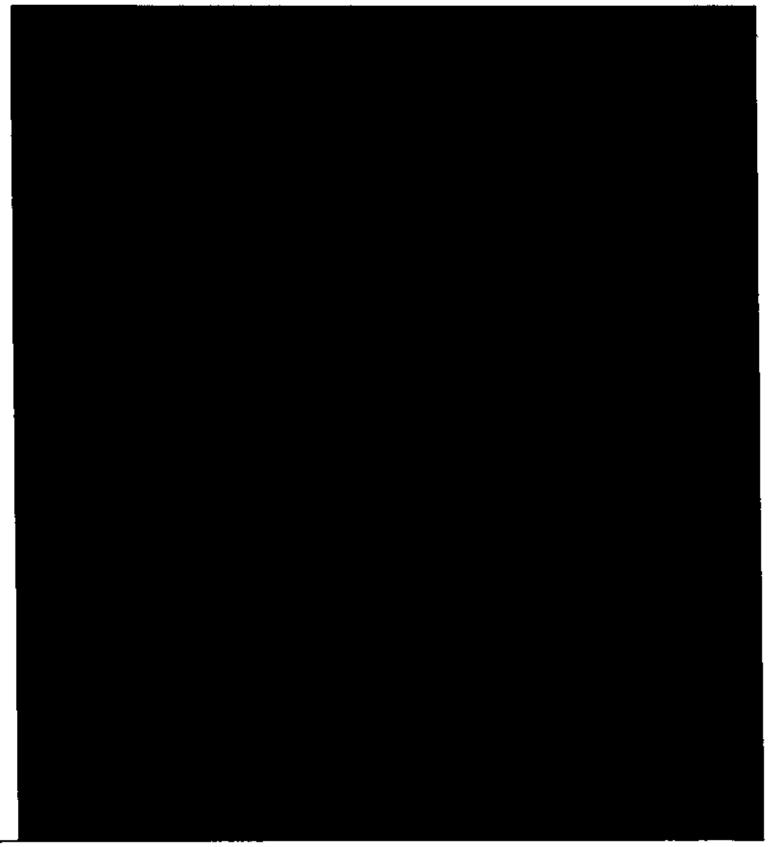
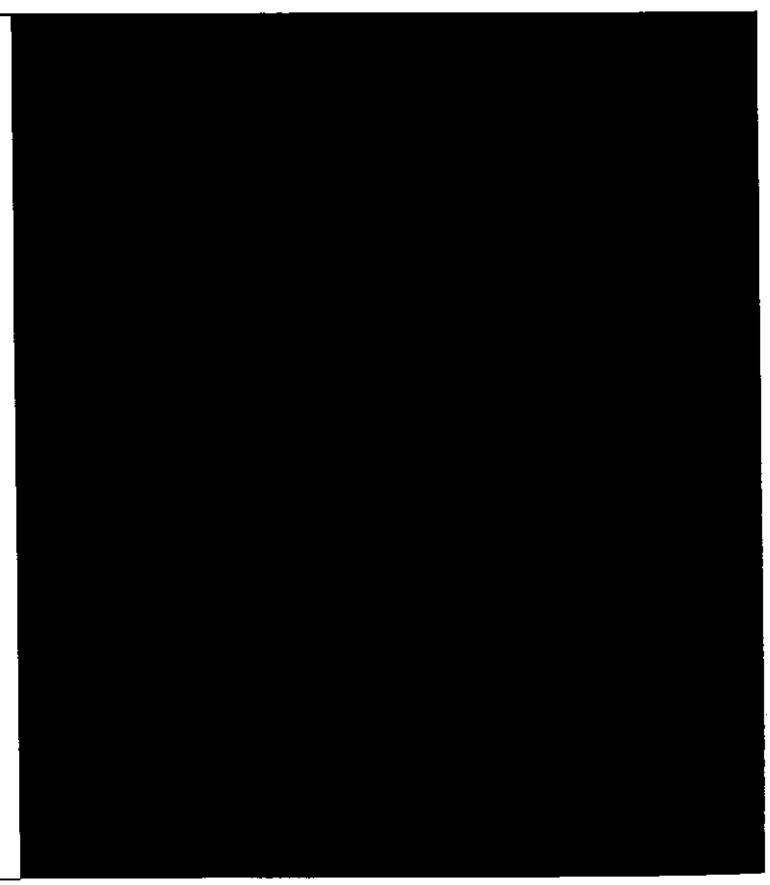


Peer Reviews of Water Quality and Quantity

Upper North East, Lower North East and Southern CRA Regions

A project undertaken as part of the NSW Comprehensive Regional Assessments

March 2000



PEER REVIEWS OF WATER QUALITY AND QUANITY

UPPER NORTH EAST, LOWER NORTH EAST AND SOUTHERN CRA REGIONS

A compilation of peer reviews prepared by

L Bren and T J Doeg

A project undertaken for
the Joint Commonwealth NSW Regional Forest Agreement Steering Committee
as part of the
NSW Comprehensive Regional Assessments
project number NA 61/ESFM (part)

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The project has been overseen and the methodology has been developed through the NSW Ecologically Sustainable Forest Management Group which includes representatives from the New South Wales and Commonwealth Governments and stakeholder groups.

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PROJECT SUMMARY

This report describes a project undertaken as part of the comprehensive regional assessments of forests in New South Wales. The comprehensive regional assessments (CRAs) provide the scientific basis on which the State and Commonwealth Governments will sign regional forest agreements (RFAs) for major forest areas of New South Wales. These agreements will determine the future of these forests, providing a balance between conservation and ecologically sustainable use of forest resources.

Project objective/s
The following report is a compilation of the peer reviews carried out on a project undertaken for the Ecologically Sustainable Forest Management Group titled " Water Quality and Quantity for the Upper North East, Lower North East and Southern CRA Regions". This project was carried out by consultants, Sinclair Knight Merz and CSIRO Land and Water. The peer reviews aimed to evaluate the accuracy of data, identify any limitations in the methodology used and identify any further work required.

Methods
Two experts were appointed to critically review the report. Leon Bren from the University of Melbourne, reviewed the water quantity aspects; and TJ Doeg, an independent environmental consultant based in Melbourne, Victoria, reviewed the water quality aspects.

The independent assessment required; a review of the data and methods used: the accuracy of findings and recommendations, and their strengths and weaknesses; evaluate the reliability of findings when applied and incorporated in the RFA; and to identify any improvements or omissions.

Key results and products
Each of the experts provided a written submission reviewing the report.

Both reviewers agreed that the report produced adequate results and modelling for testing the impact of forestry on water quality and quantity. Both reviewers indicated areas which require further research and investigation, but make clear recognition of the lack of comprehensive data available to the authors at the time the report was prepared. The reviewers commend the results and conclusions the authors were able to make in these circumstances.

1. INTRODUCTION

1.1 BACKGROUND

The following report is a compilation of the peer reviews carried out on a project undertaken for the Ecologically Sustainable Forest Management Group entitled " Water Quality and Quantity for the Upper North East, Lower North East and Southern CRA Regions". This project was carried out by consultants, Sinclair Knight Merz and CSIRO Land and Water. The project required the collation of all available data and literature on water quality and quantity. It described the impacts from forested land management on water quality and quantity in the NSW RFA regions and piloted the modelling of these impacts.

Water was identified as an important issue for the Upper North East (UNE), Lower North East (LNE) and Southern RFA regions. The project aimed to investigate issues, such as rural and town water supply and potential impacts of forestry activities on waterways.

Greater detail on the project can be found in the project specification attached to the letter sent to experts undertaking the review, which is contained in Appendix A.

1.2 OBJECTIVE OF THE PROJECT

The objective of the peer reviews was to carry out an independent assessment and appraisal of the methods and data used to develop the Water Quality and Quantity project, as carried out by Sinclair Knight Merz and CSIRO Land and Water.

Specific aspects to be addressed included:

- Review of methods and data used;
- The results of the data review;
- Relative accuracy of predictions;
- Description of the limitations of predictions and the implications of these limitations;
- Strengths and weaknesses and scientific validity of the methods/systems used for data collection and modelling;
- Suitability of any assumptions and what limitations these cause;
- The overall expected reliability (which incorporates sensitivity) for use in the RFA;
- Are there any errors of fact or logic?;
- Possible improvements in the method, data and modelling.

The requirements for the peer review were outlined in a letter to the two experts contained in Appendix A.

2. PEER REVIEW BY LEON BREN

Leon Bren is with the Department of Forestry at the University of Melbourne, Victoria.

2.1 SUMMARY OF PEER REVIEW FINDINGS

The report entitled "ESFM Project: Water Quality and Quantity for the Upper and Lower North East, Southern RFA Regions" was prepared to assist the RFA process in its assessment of the impact of forests. The report gives a review of the world-wide literature on the impact of forestry operations on both water yield and water quality. A "modelling framework" is then devised which uses real catchments along the NSW coast to provide a modelling framework. Data on these catchments including forest type, extent, and rate of logging is input. The water yield models use an assumed "Kuczera curve" which gives the mean water yield as a function of tree age. This is based on the experience of Melbourne Water and has a maximum water use at about age 35 years. The water yield results suggest that scenarios involving logging and regeneration will lead, to some extent, to reduced water yields in the long term. The modelling also examines water quality effects and suggests that the major logging impact on water quality is due to runoff from roads. However, the effect of logging is relatively small compared to the natural rate, and the overall rates of material loss from the forested catchments are relatively small.

My peer review concludes that the report is a good piece of work and, within the context of data availability, well done. Probably the major difficulty is the extrapolation of the "Kuczera curve" for pure, even-aged stands of mountain ash to NSW coastal forests. There is a limited suite of data from the Karuah Project near Dungog (NSW) which shows some of these characteristics. However, this reviewer believes that the results of the modelling on water yield can only be viewed as a "best guess" in the absence of more comprehensive data. If the matter is of importance then steps could be taken to collect information.

Other comments/criticisms made in this peer review are:

- Explicit consideration should be made of the points of similarity and of differences between rainfall, annual flow pattern, and rainfall variability, and the mountain ash catchments to help put "error-limits" on the extrapolation of the Kuczera curve;
- Explicit consideration should be made of the impact of sequences of wet or dry years on the flows and whether the perceived low/high flows might be attributable to logging;
- Explicit consideration should be made of the impact of sources of mortality other than logging (insect attack, fire, etc.);

- The perceptions of water resource managers in the regions as to whether there is a Kuczera type " age effect" on water yield should be sought, and the literature search broadened to include " lower level" papers;
- The water quality modelling makes little consideration on the impact of farming practices on water quality;
- A review of modifications of conclusions in a mixed species environment and an examination of the applicability of the " even-aged forest" assumption to forests within the region.

The authors of the report have shown competence in their modelling and approach and, in general, have operated in a vacuum of information. Given the task they have made a first-class job in producing testable hypothesis on the impact of regional logging on water resources. In general their report has many qualifications relating to this lack of data.

2.2 SOME OF THE PROBLEMS FACED IN FOREST HYDROLOGY: A SHORT DISCUSSION ON A CURRENT DIVERGENCE OF OPINION

A recent conflict aired in Water Resources Research show up some of the problems of forest hydrology research, and makes rather similar findings to this peer review. A brief discussion follows.

Jones and Grant (1996) used data from three small watersheds (60-101 ha) and three pairs of large basins (60-600 km^2) in Oregon's western Cascades to evaluate effects of timber harvest and road construction on peak flows. Among other things, they concluded that (1) forest harvesting has increased peak discharges by as much as 50% in small basins and 100% in larges basins; (2) the major mechanism responsible for these changes is the increased drainage efficiency of basin attributable to the integration of the road/patch clear-cut network with the pre-existing stream network; and (3) the entire population of peak discharges is shifted upward by clear-cutting and roads.

Subsequently, Thomas and Megahan (1998) reanalysed the data used by Jones and Grant. Their abstract reads as follows:

> *"Data from three small watersheds (60-101 ha) and three pairs of large basins (60-600 km^2) in Oregon's western Cascades were used to evaluate effects of timber harvest and road construction on peak flows. We could not detect any effect on cutting on peak flows in one of the large basin pairs, and the results were inconclusive in the other two large basin pairs. One small watershed was 100% clear-cut, as second was 31% patch cut, with 6% of the area affected by road construction, and a third was held as a long –term control. Peak flows were increased up to 90% of the smallest peak events on the clear-cut watershed and up to 540% for the smallest peak flows on the patch-cut and roaded watershed. Percentage treatment effects decreased as flow event size increased and were not detectable for flows with 2 year return intervals or greater on either treated watershed. Treatment effects decreased over time but were still found after 20 years on the clear-cut watershed but only for 10 years on the patch-cut and roaded watershed".*

The question posed by this is why do two groups of scientists working with the same data (described as " a large and complex data set") obtain quite different results? Who is right and who is wrong? Irrespective of this, it does not illustrate how, even with a given data set the interpretation may differ from scientist to scientist. Of further relevance to our discussion is the complete absence of any "age-effect" in the Oregon data. Finally, Thomas and Megahan suggest that to advance the discipline of forest hydrology one needs:

- More studies to better understand runoff processes from forested slopes with and without cutting and road effect...;
- Process studies ... nested within carefully controlled small watershed studies to integrate watershed scale approaches;
- Development of physically-based distributed hydrologic models in order to forecast the effects of forest cutting and roading activities on a given watershed. "Once such models have been validated against measured results from controlled small watershed studies of roading and cutting effects, they should provide a viable means for evaluating timber harvest effects in large basins as well."

Basically this is in complete agreement with thoughts expressed below.

2.3 REVIEW OF DATA USED AND METHODS FOLLOWED

2.3.1 Information and Data Used

The report uses the following sources of information:

- Approximately two hundred journal papers or reports, generally selected from the scientific literature. These are wide ranging and generally provide a fair sample of a huge and often inconclusive literature.
- Communication with 44 officers of various organisations including clients, scientists, and managers. As reasonably expected the group is oriented to NSW.
- Background scientific data published in a collection of papers listed in Appendix B (some 64 separate listings). The list appears comprehensive, although the data used varies widely in quality. The report does not explicitly rank some sources above others. The project takes the reported findings more or less at face value, which is both reasonable and probably the only course available.
- Data files from various Government agencies containing forest details or stream water quality. Again, reasonably, the information in these is taken as valid, although throughout the text considerable reservations are expressed concerning aspects of the information (eg "The uncertainty of the estimates largely stems from a lack of information" or "unfortunately there is a dearth of information on sediment loads which can be used to place the modelled values in a downstream context."

The information used appears appropriate to the task; certainly I am not aware of any major sources of information not used in the report or which would have added materially to the report. However, I do feel that the review could have looked more widely at relatively minor papers originating from coastal NSW from water supply engineers, etc. to observe whether there are claims of variations in water yield with age of the forest since this is a critical observation.

2.3.2 Yield Modelling: Methods Followed

The work on water yield ultimately relies on a model of water yield presented by Langford (1976) and Kuczera (1987) and more latterly by a group of scientists led by Vertessy and others (eg Vertessy *et al,* 1996). This work is excellent and pioneering and I have no criticism of it, but it does present a " mountain ash" colour to a non-ash environment. However this comment is tempered by the findings of Cornish and Vertessy (1998) in the Karuah Project catchments which showed, at least, some of the ash characteristics. Reservations about the use of this model are also tempered by the absence of alternative models to use (a theme frequently echoed in the text: eg " it should be recognised that the nature of the yield recovery is speculative as there is no data available for NSW forests....."). More recent work on the physiology of the trees involved and the role of sapwood gives the work more credence, but if the matter is of importance to the population of NSW then ultimately more quality work similar to that of Karuah must be undertaken. The methods followed can reasonably be classified as the drawing of inferences from application of partially calibrated but unverified models. While this is indeed questionable, there is probably little alternative to this.

The major method is sensible and innovative. A yield response curve for each forest type is generated using information on the rainfall (and not much else). A 100 x 100 grid is formed and given a spatial distribution of forest type/age which more or less approximates the forest. A run is then made in which cells are " logged" using a plausible logging scenario, and the water output from the cells for each year given by use of the water yield curve. The results for each area are then presented graphically. As the report points out, the approach is a " substantial simplification of reality." As a peer reviewer, I am reasonably impressed with the approach in the sense that:

- It gives a good appreciation of " cumulative effects" and takes into account the comings and goings of forest due to logging (but not to other depredations, such as mortality, fire, insect attacks or windthrow);
- It considers the current distribution of forest types and the rate of logging in the area; and
- It takes into account the presence of unlogged areas.

However the results obtained must always reflect the yield-age curve and this is the major point of disquiet. Until there is better verification that the Kuczera curve can be applied with some generality the results must be viewed as unreliable, and at best, as an unproven hypothesis as to what might occur.

2.4 RESULTS OF THE DATA REVIEW (WATER YIELD AND WATER QUALITY)

2.4.1 Chapter 2: Water Yield Review

The yield review extends over about 34 pages, and draws heavily from the world-wide literature with a heavy emphasis on the results of Bosch and Hewlett (1982) and Stednick (1996) on the international scene and the results from Melbourne Water experiments and the Karuah catchments in NSW for the local scene. As a peer reviewer I can not " fault" this review. In particular:

- The selection of references used is wide-ranging and similar to those I would have picked. I am not aware of any major references omitted, although there are a few minor references that could have been added.

- The review tends to be limited to situations of even-aged forestry. This is not always the preferred practice in forests managed for community values. In such forests some sort of selection or group selection is more usually practiced. However there is a preference of forestry researchers for working with " pure aged stands."
- It is likely that the management of the riparian zone has an impact on the water use, but this is a current research topic.

However the review realistically classes evidence into " well-established", " limited evidence", and " speculative", and this is a realistic classification.

The water yield review is disappointing in its lack of consideration of the fundamentals of hydrology of the NSW study sites, and comparisons of hydrologic characteristics of these areas with the mountain ash areas at any level. It is recognised that there is little detailed data but there is a large amount of less-accurate data. In particular it would be useful to establish:

- What similarities are there between the hydrology of the study sites and Victorian mountain ash forests? Characteristics could include the seasonality and intensity of rainfall, the " flashiness" of hydrographs, and the average water yield per hectare.
- What differences are there between these sites?
- What is the average ratio of yield to rainfall compared to the ash sites, and are there distinct " wet and dry" periods in each site?
- On hydrologic data grounds is there any basis for claiming " similarity" between the two sites.

2.4.2 Chapter 3: Water Quality Review

Reflecting reality, the main water quality parameter used in the review is sediment load or its surrogate measure, turbidity. The review points out the inherent variability, the need for frequent and expensive sampling, and the difficulty of extrapolation of results. Perhaps unsurprisingly, the review tends to be inconclusive concerning water quality effects of forestry at a broader scale. Compared to the Water Yield review, the Water Quality review is harder to read and lacks a " focus." This probably reflects that any generalities tend to be made by synthesis from many specific observations.

The review does fail to mention (in detail) a number of matters pertinent to forest water quality studies:

- The difficulties of measuring many parameters (eg pH, nutrient concentrations) in very high quality, unbuffered water. Our own Croppers Creek project has shown how difficult it is to get consistent, valid results using field measurement techniques, and that some parameters (particularly pH) seem to fluctuate wildly because of the lack of solution buffering.
- The question of sampling frequency (setting standards for the rate of sampling over time). Clearly the higher the rate of sampling the " better" the results that are obtained, but this puts a very high loading on the measuring agency (particularly if laboratory sample techniques are used).
- Longitudinal dilution and dispersion of solutes in a channel. This shows the attenuation of a pulse of pollutant as it moves downstream. The front and the tail of the pulse tend to move at different rates, while the pollutant becomes mixed with more and more water. The result

is that the average concentration greatly diminishes but the volume of water polluted increases. This process has a large impact on the perceived influence of any land-use operation on water quality.

- The influence of "extreme events" on water quality and stream behaviour. These extreme events can be either drought or heavy rainfalls; in either case the results obtained will be very different from periods of "normal" rainfall. Any methodology that purports to be "scientific" must somehow take this variation into account.

All of these processes give difficulty for forest regulatory authorities. However the reviewers have done a competent job in assembling a large amount of information and placing it in a reasonably readable context.

2.4.3 Chapter 4: Modelling Framework

This chapter describes:

- An overall classification of measuring sites in accordance with "downstream of forest" or "downstream of mixed land uses";
- The selection of catchments used to develop and apply the models, classification according to land use, and data available for each site;
- Broad characteristics of the forest on each catchment and the forest harvesting which might conceivably follow; and
- "Stress indicators" for the streams according to the "Stressed Rivers Assessment Process".

The report very realistically makes the point that the areas were selected on the basis of data availability rather than any notion of "representativeness", although this then gives interpolations or extrapolations as an immediate bias. A methodology is then outlined (Section 4.5) for application to other areas in the CRA region. This involves collation of a considerable amount of information on the forest. As might be expected many qualifications are made, the general theme being "make the error bars big."

The selection appears realistic and reflects the reality of using available information rather than the more usual scientific approach of stratified random sampling. It would be of interest to make some critical evaluations of the accuracy and precision of the data collected and the methodologies used but this information is probably not available.

2.4.4 Chapter 5: Yield Modelling

The basis of the yield modelling is the "Kuczera Curve" and the use of this dominates the results. The curve suggests that forests have a minimum water yield at about 20-30 years of age and come back to an "old-growth" water yield over the remainder of their growth. When logged, for a few years, water yields are in excess of the "old growth" and then the inexorable decline starts. The modelling basically:

- For each year forms a table of age classes;
- Uses a look-up table to allocate the contribution of each age class; and
- Sums these to give the total catchment yield.

The modelling has a number of problems:

- The age-water yield relation is adopted for clear felled mountain ash using yield curves developed from Victorian experience. There is a limited evidence based on the results from Karuah (Cornish and Vertessy, 1998) that some NSW eucalypt species at least give somewhat similar results. The diminished stream flow response was first observed when the major 1926 and 1939 fires burnt completely burnt many large catchments simultaneously, whereas NSW coastal forests have never quite had that level of instantaneous forest change. In the absence of other information it is reasonable to use the relationships, but it is a substantial extrapolation. By the standards of other parts of Australia the Melbourne Water forests have an unusually even "all-year" flow and hence the distinction between the "low-flow" and "high flow" periods are not well-defined.
- The modelling ignores year-to-year variations, and hence is based on "average years" in which "hydrologic noise" has been removed. This tends to simplify relationships (perhaps necessary for such a report). Probably my one criticism is that some attempt could or should be made to match variation attributable to forest harvesting to variation attributable to usual weather variation. The methodology suggested is Monte Carlo type simulation. This can give a closer approximation to reality, at the expense of more "noise". In very dry years there is very little impact of forest management on water yield because there is little runoff. In very wet years any influence is masked by the large amount of runoff.
- The modelling ignores seasonal variations, and in the author's experience this is often more critical than "over the year" flows because landholders depend on river flow at low flows for stock watering or provision of domestic supplies. Thus additional water at times of high flows has a low (or even negative) utility, while additional waters at low flows can mean the difference between a good and bad year. Further development of the yield modelling could or should take into account two additional factors:
  - Low flow variation and flood flow variation and the effects of forest harvesting, and
  - The possibility of long dry runs and long wet runs and the perceived effect on stream flow and catchment water yield.
- The modelling ignores source of natural mortality or forest change. Thus because of fires or occasionally other catastrophes (insects) the old forest is killed.

Unfortunately much of the important politics of the "effects of forestry" debate pivots around the question of the validity of the assumed age-yield, and thus it is important that the maximum information be gained on whether there is any coherent NSW data originating from Water Supply Conferences, theses, and such sources. In this regard it is interesting that Melbourne Water launched its catchment hydrology investigations because water supply engineers "felt" that the water yields had diminished since the 1939 fires. It would be relevant to see if there is a "consensus of feeling" on this topic within the water supply industry along the NSW coast.

2.4.5 Chapter 6: Water Quality Modelling

A more complex approach than the water yield modelling, with lots of assumptions concerning the specifics of process. As a peer reviewer I do have reservations about the validity of the assumed chain of processes, but these do not differ much from those expressed by the author of the report. Perhaps (and not surprisingly) the results show a small increment in sediment loading attributable to logging over that which is attributable to the presence of roading. The authors do not make the conversion from total sediment load to the use of nephelometric turbidity units. They also have little to say about the position in the stream hydrograph at which stream pollution particularly occurs.

Of interest is the rather low values for sediment yield computed in Table 6.c: if this is the case then sediment yield is hardly a concern.

2.5 STRENGTHS, WEAKNESSES, AND SCIENTIFIC VALIDITY OF METHODS/SYSTEM USED

The strength of the presentation is the garnering of information around the world and detailed information from eastern Australia, the synthesis of this data into reasonably rigorous computational methods, and the application to actual catchments using rates of forest harvesting and the age structure of the forest, and the qualifications made regarding both major and subtle interpretations.

The weakness of this is the major assumption concerning the water use of forests as a function of age, and the lack of concern about other factors which may perturb the forest.

The methodology is prediction based on reductionism (ie basing the assessment of the response of the whole to the sum of the parts). Although science is involved in the development of knowledge of response of the parts, the use of complex models without a formal verification and comparison using valid field data to the model predictions is not a part of science. Thus it is the reviewer's belief that the use of the models may meet a management or political aim, but does not add to the scientific knowledge of the effects of forestry on the water quantity and yield from these areas.

Elaborating on this further; the classic paradigm of science is:

- Hypothesis formulation (eg: that younger trees use more water, logging leads to younger trees, and hence logging leads to reduced water yield);
- Collection of data with which to accept or reject such hypothesis; and
- Testing of the hypothesis.

At this stage, for most areas only the hypothesis formulation has been done. There is some data collected from the Karuah project which, guardedly, supports the major contention, but nothing else. Thus the findings of the report can not be regarded as "scientific" but rather testable hypothesis arising from the application of science to meet management aims. This is an entirely valid procedure provided the tentative nature of such hypothesis is borne in mind, and provided there is a mechanism for adjustment in the light of new and better data.

2.6 ERRORS OF FACT OR LOGIC

Although there was occasional disagreement with the emphasis on particular points, no errors or fact or logic were detected. The authors were conscientious in pointing out major limitations in the methodology used.

2.7 IMPROVEMENTS

Within the current document the following are suggested as possible improvements:

- An additional search of the literature on NSW water yield to see if there is a perception of an "age affect" in the water yield, as measured by water engineers;

- A formalised comparison of the hydrograph properties and rainfall properties of the NSW catchments with corresponding mountain ash catchments to at least indicate whether responses can be classed as "similar" or "dissimilar";
- An examination of the impact of runs of dry years or wet years on relative water yield;
- An examination of the impact of forestry on "drier season" and "wetter season" flows, and discussion of the errors involved;
- A review of modifications of conclusions in a mixed species environment and an examination of the applicability of the "even-aged forest" assumption to forests within the region.

In the long term, there is a clear need for good hydrology work to build up the knowledge of catchment water yield. This would be a substantial research undertaking in its own right.

2.8 CONCLUSIONS

The overall conclusion made in this peer review is that the report is a soundly constructed document that has produced some testable hypotheses concerning the impact of forest practices on water yield. The qualifications on conclusions of the report generally result from lack of data rather than criticisms of the report or its authors. Future work in this area should consider the following tasks:

- Explicit consideration should be made of the points of similarity and of differences between rainfall, annual flow pattern, and rainfall variability, and the mountain ash catchments to help put "error-limits" on the extrapolation of the Kuczrea curve;
- Explicit consideration should be made of the impact of sequences of wet or dry years on the flows and whether the perceived low/high flows might be attributable to logging;
- Explicit consideration should be made of the impact of sources of mortality other than logging (insect attack, fire, etc.);
- The perceptions of water resource managers in the regions as the whether there is a Kuczera type "age effect" on water yield should be sought, and the literature search broadened to include the "lower level" papers;
- An examination of the impact of farming practices on water quality in areas where the water is consumed domestically;
- A review of modifications of conclusions in a mixed species environment and examination of the applicability of the "even-aged forest" assumption to forests within the region.

The authors of the report have shown competence in their modelling and approach and, in general have operated in a vacuum of information. Given the task they have made a first-class job in producing testable hypothesis on the impact of regional logging on water resources. In general their report has many qualifications relating to this lack of data. If the deficiencies are considered of major importance by protagonists then there is a clear need for additional forest hydrology research to fill the gaps in.

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3. PEER REVIEW BY T J DOEG

The following review was prepared by T J Doeg, an Environmental Consultant based in Melbourne, Victoria. Also attached in Appendix B is a letter from Mr Doeg which outlines his views on the water quality chapters of the project.

3.1 SUMMARY

The document "ESFM Project: Water Quality and Quantity for the Upper and Lower North-East, Southern RFA Regions" describes a project with the objectives to "review the literature on the impacts of logging upon water quality and quantity, to collect relevant baseline resource information, and to develop and apply a methodology for modelling the impact of possible logging activities on water quality and quantity" (Executive Summary).

This peer review concentrates on the water quality chapters (3, 4 and 6) of the report.

In general, the attempt to predict the impacts of forestry activities on sediment generation and delivery is laudable and should be encouraged. The approach used is deliberately simple, in line with the amount and quality of the available data. However, while concentrating on the appropriate key aspects of sediment generation and delivery, in developing the model, the authors make a number of assumptions that are not fully explained or justified, and they base many of the key calculations on speculative relationships. In one case, important experimental data is ignored, as its use would not produce results consistent with current sediment load data (rather than investigating changes to the speculative relationship that would produce the same result).

Hence, the predictions made as to sediment loads are unsound in absolute terms (this is not to say they are wrong, but if they turn out to be correct, it would be more through chance than as a result of the accuracy of the model predictions). This is recognised by the authors and explicitly noted in the limitations to the project.

It can be easily shown that small changes to the speculative relationships have the potential to significantly change the absolute values of the sediment generated and delivered.

The failure of the model to come up with accurate predictions can be attributed to a number of factors. One of these is the lack of an adequate amount of data relating the key factors of sediment generation and delivery to different environmental conditions (e.g. rainfall intensity, distance from drainage line). Hence, in producing a model, the relationships are required to be speculative, and hence inherently subject to error. This should have been appreciated even before the start of the exercise.

However, it should also be noted that the time frame associated with the project (6 weeks) was clearly inadequate to achieve a better level of resolution. Within this time frame, the results are about as accurate as the ESFM Group members could have expected.

On the other hand, the relative relationships of sediment loads between catchments can be seen as sound. The key factors that would influence sediment generation and delivery are included in the model (rainfall, road density, type and usage), so that catchments with higher rainfall episodes of higher intensity will generate higher sediment loads. The validity of the exact relationships (in terms of percentages) is unclear, as it is based on speculative linear relationships. If these are not linear, then the scale of the relative changes would not be sound.

A number of suggestions that would improve the accuracy in the short term are presented within the report. However, these improvements would be marginal, as the main limitations are in the fundamental components of the model (which it is noted could not be solved in the short term). The only immediate solution to the deficiencies in the model would be to determine a more widespread consensus about the nature of the relationships included in the model. This could be done in a workshop environment with key experts in each of the fields. While this may improve acceptance of the model, any actual improvements in accuracy cannot be established.

Additionally, a sensitivity analysis should be conducted to determine which components of the model have the potential to most influence the outcome. These would be the highest priority factors targeted at any workshop.

In summary:

- The absolute values of sediment load increases predicted by the model are unsound;
- The relative rankings between catchments represent the "best guess" available; and
- The accuracy of the absolute rankings between catchments cannot be estimated, but again, probably represents a "best guess" for interim planning.

The combination of these factors, I consider, potentially quite disturbing. The authors continually stress the uncertainties in the absolute estimates, but if the history of models is any example, there will be a tendency to use the modelling results out of context, and use the model to predict absolute loads and absolute impacts of different scenarios. This should be resisted and the model should only be used for the purposes for which it was designed and within the limitations outlined by the authors.

Specific questions asked of this peer review are included below, followed by a more detailed review of the chapters in the document.

3.2 REVIEW OF METHODS AND DATA USED

Rather than repeat previous reviews of the broad impact of logging activities on water quality, the authors concentrate on trying to elucidate the three basic relationships that would allow predictive models to be constructed over a wide geographic area. These are:

- The nature of sediment sources and their spatial distribution with respect to the stream;

- The nature of the delivery pattern from source to stream and potential for storage both on the hillslope, in erosion control structures, and in near-stream areas; and
- The effectiveness of best management practices with respect to sediment production and delivery.

It is noted that sediment is only one of the potential impacts of logging on water quality, and that other parameters (pH, dissolved oxygen, and nutrients) are largely ignored. Given the aims of the project, this is entirely appropriate.

3.3 THE RESULTS OF THE DATA REVIEW

The review adequately updates some of the recent knowledge in the area, concentrating on the important areas identified. In the main, the review has two main failings.

- Unfortunately, a significant proportion of the review relies on papers that are unpublished, in press or submitted. It is impossible to determine whether the results of these papers have been accurately reviewed (but as most were produced by the report authors, it can be safely assumed that they have been).
- However, it also fails to concentrate on some of the essential issues that eventually arise as part of the modelling process. For example, only passing mention is made in the review of the paper by Novotny and Chesters (1989) that details the relationship of sediment delivery ratio to overland flow pathway length. This is the basis of a fundamental assumption in the modelling process. It is suggested that a deal of "back reviewing" should have been conducted, where steps and information identified in the modelling processes are incorporated in the review afterwards. This would have greatly enhanced the readers understanding and possible acceptance of the modelling process.

3.4 RELATIVE ACCURACY OF THE PREDICTIONS

The accuracy of the predictions regarding sediment generation and delivery based on the trial logging scenario cannot be estimated. Given that the parameters and factors in the model are based on a blend of published data and speculative components, small errors in each step will compound through the steps of the model. Without knowledge of the errors or sensitivities in each of the steps (which has not been done), there is no way of calculating the accuracy.

This limitation is recognised by the authors and is stated quite clearly in the text of the report:

> "*It should also be stressed that there is considerable uncertainty in the estimates. Some of the modelling inputs and parameters are based on published literature, and others are based on speculation. Model parameterisation could be altered to incorporate better information when it becomes available, and some of the more speculative aspects could be modified to be consistent with a consensus view*"
> (p. 72).

It only takes a few simple sensitivity calculations to demonstrate the potential problem. For example, a change in the time decay constant for sediment generation by 0.1 (from the suggested 0.7) can generate errors in the final calculation of that step in the order of 10% for certain rainfall intensities. A number of other examples of this are cited in the main review below.

The relative accuracy between different catchments probably represents a " best guess" given the limitations in available data and the short time frame of the project. The ranking of catchment impacts is based on the best available knowledge of which factors drive sediment generations and delivery and so are probably accurate. However, the absolute values for each catchment are unsound.

3.5 LIMITATIONS OF THE PREDICTIONS AND THE IMPLICATIONS OF THESE LIMITATIONS

The major limitation of the prediction is that the model cannot be used with confidence to test the impact of various alternative scenarios in detailed planning. The implication of this is that we cannot progress beyond the broad predictions that could have been made even in the absence of the model that:

- The higher the rainfall, the more sediment that will be generated and potentially delivered to drainage lines; and
- That roads are the main source of these sediments, so increasing the density or usage of roads will increase sediment generation and delivery.

Unfortunately, exactly how much more or less can not be predicted accurately with any confidence by this model, so the model cannot be used to ultimately establish a management regime that would confidently reduce sediment generation and delivery (and hence water and environmental quality) to acceptable levels.

3.6 STRENGTHS AND WEAKNESSES AND SCIENTIFIC VALIDITY OF THE METHODS/SYSTEMS USED FOR DATA COLLECTION AND MODELLING

Both the strength and the weakness of the system lie in its simplicity. The model is conceptually simple, and so is transparent to the user. While there is a myriad of factors that can influence the generation and delivery of sediment, it concentrates on the major fundamental aspects of the forest environment for which we have some understanding, and some data. The strength is that a simple model can be produced from these aspects that can produce outputs consistent with current observations, and therefore predict the impact of future developments.

The weakness is that the relationships between the key factors are largely speculative. Any number of relationships between key factors could have been produced to explain current observations. But it is whether the selected model can accurately predict changes in the future is the ultimate test of a model, and this one falls short in that regard (a fact recognised and admitted by the authors).

Despite all the above comments, one cannot question the scientific validity of the approach, methods or systems. The development of the model followed standard procedures in its production – select the key factors involved, establish a relationship between those factors, and test those relationships against a known outcome (current sediment loads). The data collected was appropriate, adding additional data (such as the " zeroth" order stream GIS layer) as available.

A further weakness lies in the lack of assessment of the errors or sensitivity of the model. Given the knowledge that reported sediment loads are extremely variable, it is essential that the model reflect this variability, producing a range of likely outcomes, rather than a single figure.

3.7 SUITABILITY OF ANY ASSUMPTIONS AND WHAT LIMITATIONS THEY CAUSE

There are a number of key assumptions made in the model:

- A linear relationship between rainfall intensity and sediment generation from the GHA and snig tracks;
- That the threshold rainfall intensity that generates no sediment is 10mm/hr on the GHA/snig tracks;
- That the threshold rainfall intensity that generates no sediment is the same for each year after logging;
- A two step function for generation rates from permanent roads that is linear up to 60mm/hr, over which rates are constant;
- The generation rates for permanent roads are time invariant;
- An exponentially declining relationship between sediment yield and time (i.e. the change in generation between Year 0 and Year 1 is greater than between Year 1 and Year 2 etc);
- The Sediment Delivery Ratio is dominated by overland flow distance;
- The relationship between delivery ratio and distance to the stream is based on a simple exponential decay; and
- The conversion of generation rates from Hazard 2 to Hazard Classes 1 and 3 is a simple arithmetic function.

None of these are particularly well justified in the report, often based on one or two published or unpublished data or opinions. While most of the assumptions probably are correct (or represent reasonable "best guesses"), the limitation of the assumptions lies in the selection of appropriate constants and coefficients that turn the assumptions into relationships. These selections are never adequately justified and small changes to these constants and coefficients can have large changes in the predicted results.

The second assumption (the 10mm/hr rainfall intensity threshold) does not accord with experimental evidence.

3.8 THE OVERALL EXPECTED RELIABILITY (WHICH INCORPORATES SENSITIVITY) FOR USE IN THE RFA

The reliability of the absolute results of the modelling could not be used with any confidence in the forest planning process. It would be unsound to model different logging scenarios and make management decisions based on the absolute impacts of each scenario. This would be particularly true if the aim was to use the model to design a logging and management regime to achieve a specified "safe" absolute level of sediment load in the rivers.

If, however, the aim of the exercise is to compare the likely impact between different catchments or catchment types (according to environmental stress), then there is a far higher degree of confidence that can be associated with the relative rankings of the outputs. Therefore, as a comparative risk assessment tool, the model can probably used with some degree of confidence.

3.9 ARE THERE ANY ERRORS OF FACT OR LOGIC?

There are no major obvious errors of fact.

However, the idea that the selection of constants and coefficients for equations within the model in order to generate the observed sediment loads reported in the literature needs to be questioned. This is especially true if it means rejecting experimental evidence produced from the same experiment from which other data is used. This is suggesting that any relationship that generates an observed result will be sufficient. Logic would suggest that all available experimental data should be used, and the selection of arbitrary empirical relationships should be based around that.

3.10 POSSIBLE IMPROVEMENTS IN THE METHOD, DATA AND MODELLING

One of the major limitations lies in the amount of time available for the project. Within this time frame, the selection of appropriate relationships is based on the opinion of only a few individuals. It may be possible, through a workshop or similar survey, to obtain a better consensus from a wider range of suitable experts as to the form of the relationships.

A further improvement would come from incorporating the experimental data collected on minimum rainfall intensity that initiates sediment generation into the model. Then, additional factors could be explored that would overcome the underestimated sediment load. Again, this could be conducted within a workshop environment.

Unfortunately, any major improvements would only come from significant additional research over many years, covering a wider range of conditions (e.g. the sediment generation curves are only based on 3 experimental rainfall intensities on a single Hazard Class soil in only a few locations).

3.11 DETAILED REVIEW OF WATER QUALITY CHAPTERS IN "ESFM PROJECT: WATER QUALITY AND QUANTITY FOR THE UPPER AND LOWER NORTH-EAST, SOUTHERN RFA REGIONS"

3.11.1 Introduction

The document "ESFM Project: Water Quality and Quantity for the Upper and Lower North-East, Southern RFA Regions" describes a project with the objectives to "review the literature on the impacts of logging upon water quality and quantity, to collect relevant baseline resource information, and to develop and apply a methodology for modelling the impact of possible logging activities on water quality and quantity" (Executive Summary).

This peer review concentrates on the water quality chapters (3 and 6) of the report.

3.11.2 Chapter 3 - Data Review

Introductory remarks

As the authors point out, the potential impacts of logging activities on water quality have been dealt with a number of times in the past and it would seem of little value to merely repeat the process. Unfortunately, the two examples cited are almost unattainable, with one (Doeg and Koehn 1990) being "published" as an "SSP Technical Report" by the Victorian Department of Conservation and Environment, and the other (Dargavel *et al.* 1995) being a "Discussion Paper No. 5" produced by "The Australian Institute", neither of which I assume have been subjected to peer review. A more accessible reference point would have been the paper by Campbell and Doeg (1989)[1], published in the widely available literature and peer reviewed.

The review makes some introductory remarks regarding terminology, suggesting that the approach of Schofield (1996)[2] to define impacts as "Low", "Medium" and "High" based on the level and persistence of impact. The report states that "Where possible we interpret the literature findings within the context of this classification scheme so that the reader can have a qualitative measure of our interpretation of impact across the range of studies" (p. 42). This would have been a valuable approach, but no-where in the subsequent review is this applied or mentioned again.

The review highlights the problems with traditional approaches to investigating the impact of logging on water quality – the "paired catchment" and "experimental plot" scale investigations. Neither really give useful data that can accurately predict the impact of logging over a broader scale. In general, the results from these studies are too site specific (and operation specific) to be easily transferable between regions and catchments and logging operations. Therefore, the authors distil the available information into three categories that are essential to producing a predictable and transportable model of logging practices and water quality:

- The nature of sediment sources and their spatial distribution with respect to the stream;
- The nature of the delivery pattern from source to stream and potential for storage both on the hillslope, in erosion control structures, and in near-stream areas; and
- The effectiveness of best management practices with respect to sediment production and delivery.

The authors correctly assume that if they can elucidate the mechanisms and mathematical relationships between these factors, then it may be possible to predict more accurately the likely impacts over a wide range of conditions. This then forms the basis of the literature review.

Sediment sources

The review of Sediment Sources identifies unsealed roads as the main contributor to sediment generation in managed forests. The review also highlights the dearth of quantitative information for a wide range of soil types conducted in a comparable manner, with only few data presented (see table).

Soil/area	Rainfall simulator	Annual yield	

[1] Campbell, I.C. and Doeg, T.J. (1989) Impact of timber harvesting and production on streams: a review. *Australian Journal of Marine and Freshwater Research* **40**: 519-539.

[2] There are two references to Schofield (1996) in the list – they are the same reference with different page numbers.

"Highly erodible" soils around Bombala	12 t/ha	70 t/ha/yr	Croke, Wallbrink
"more stable" soils near Bermagui	8 t/ha		Croke
Upland Victoria		50-90 t/ha/yr	Grayson
Upland Victoria unsealed roads		30 t/ha/yr	Haydon

It is important to note that the figure of 70 t/ha/yr for soil loss off snig tracks per year from Wallbrink *et al* (1997) fails to note that the error associated with the estimate was ±33 t/ha/yr. With the range of 50-90 t/ha/yr described by Grayson suggests that estimates probably have an accuracy of $\pm\approx 50\%$. This error term has significant potential impacts when generating the model (see later).

The conclusion, stated as " well established" that sediment production rates on roads and tracks decline within the time frame of 2 to 5 years, is not supported by the evidence presented. In one case, it is suggested that Reid (1993) concludes that " yields measured more than 5 years after logging are usually less than 5 times than *[sic]* background rates" (p. 45) while elsewhere the same paper is cited as supporting the conclusion " in terms of sediment production ... recovery times appear to be significantly shorter of the order of 5 years" (p. 47). The data from Wallbrink *et al* (1997) was 6 years after logging, but still showed a significant increase in sediment generation over that of natural forest. In other projects, such as the trial logging in Victoria at Coranderrk, the impact of the road crossing was still evident 7 years after the logging, so I suspect the time frame is too conservative, and should not be stated as " well established".

One missing component from the review is the contribution by log landings. With significantly more disturbance than the average snig track, sediment production on log landings. According to Wallbrink *et al* (1997), losses from this area were 120 ±70 t/ha/yr, almost double that of the snig areas.

Nutrient sources
The review deals in part with nutrient sources. It is unclear from the review why nutrients are included, as they are not dealt with under the three categories noted above, nor are they incorporated into any of the modelling. The overall concentration of the report (as is the concentration in research and in management) is on sediment, so this part is unnecessary.

Sediment delivery patterns and potential for storage
While some of the relevant literature has been reviewed in this section, far more should be made of publications that would be used later in the model. In particular, the last sentence states that " Khanbilvardi and Rogowski (1984) and Novotny and Chesters (1989) reviewed methods of estimating delivery ratios on the scale of plots and hillslopes." (p. 52). I would have thought that the data in these papers would have been fundamental to the modelling process, especially in the context of the three categories decided as important to examine. Rather than some of the other items reviewed, a detailed explanation of what those authors found and concluded (and why) would have been appropriate.

Effectiveness of Best Management Practices
The review outlines a number of studies that looked at the relative impacts of different management regimes on water quality. While the review concludes that BMPs play an important role in reducing the impact of logging on water quality and that forest buffers are an effective measure, it does not make broad generalisations as to what of the suggested

approaches – riparian zone not exceeding 20% of the hillslope length, buffer extent etc – would constitute the Best Management Practice.

Again, a number of papers that would have been relevant to the modelling process are not dealt with at any length. The comment that "" number of equations have been formulated to determine where this condition ... [regarding buffer extent and runoff generating areas] ... applies in complex landscapes" (p. 55) followed by a list of five references. Discussion of these papers in more detail would have improved the preparation of the reader for what is to follow.

Predictive Management

This section outlines a number of significant problems with our ability to predict the future impact of new timber harvesting activities, using previously established methods (e.g. USLE etc), concluding that the ability to use "an empirical relationship such as the USLE in forestry environments is not scientifically defensible" (p. 57). A number of overseas attempts to address this issue are reviewed (WRENSS, ERA and R1/R4), but it would appear that the baseline information for predictive management in NSW has already been set.

As the Inherent Hazard assessment seems to be the starting point for the water quality modelling, I would have liked to see a more in depth review of the methods and the outputs. An important outcome of this review should be the applicability and accuracy of the Inherent Hazard assessment.

Findings of this review

While updating our current knowledge on the impacts of timber harvesting, the findings are largely similar to those from previous reviews. A number of important knowledge gaps at both the temporal and spatial scales still exist, suggesting that the more recent research has not adequately addressed these issues.

The recommendations for Forest Management Practices could have been written 10 years ago. Within the scope of this project, I would have expected an update on the quantitative aspects of these recommendations.

3.11.3 Chapter 4 - Modelling Framework

The chapter begins with an explicit statement of the objective of the project as "to develop a methodology for modelling the impact of logging on water quality and quantity" (p. 62). And to be applicable to all areas covered by the comprehensive regional assessment process for forests in NSW. And all this in a time frame of 6 weeks!

The more sophisticated modelling processes (e.g. WRENSS) have taken years to develop, with considerable resources. While the desire from a management sense is for simple models that can use available data, even this task would take a considerable amount of time.

To collate and process all the data required for the exercise in this time is clearly inadequate. As such, the results of the modelling need to be seen in this light.

The usefulness of the modelling process to the forest planning process would seem to lie in the ability to evaluate the comparative impacts of different harvesting scenarios. While the output of the model in this case is based on one possible scenario, it should be applicable to other scenarios. Hence, before even dealing with the model itself, some criteria can be established that need to be included in the model. These relate to the different possible scenarios that could be conceived, particularly different percentage canopy removal and rates, different proportions of thinning and selection, and different time frames. Also included should be different possible forest management practices such as buffer width and, perhaps, the extent beyond that laid down as a minimum.

Of particular importance, the chapter also highlights the inherent difficulties and limitations of the model (p. 72). It is of value to repeat them here as some of the questions posed to this peer review are actually covered in the report:

> "*It should also be stressed that there is considerable uncertainty in the estimates. Some of the modelling inputs and parameters are based on published literature, and others are based on speculation. Model parameterisation could be altered to incorporate better information when it becomes available, and some of the more speculative aspects could be modified to be consistent with a consensus view.*
>
> *It is considered, however, that the uncertainty of the estimates does not detract from the ability of the models to provide information on the relative ranking of proposed measures. While the absolute magnitude of the estimates may be uncertain, the models do codify our current best understanding of the different factors that influence water quality and quantity within the limitations of current data availability.*" (p. 72)

Hence, the assessment of the accuracy of the predictions required by this peer review is answered within the text. They are not accurate, and can only give a comparison relative to other scenarios, or comparisons between catchments on a relative scale. Hence, it would seem vital that the model includes the factors that can be changed in a management sense to make a relative ranking of different options.

For use in the RFA process, it will be necessary to set a "benchmark" from which to evaluate different harvesting options. In this case, a possible scenario has been developed and, I assume, this is the pattern that would have taken place in the absence of the RFA process.

3.11.4 Chapter 6 - Water Quality Modelling

General harvest area and snig track

Sediment load model

The model for GHA and snig tracks (i.e. within the coupe) is based on the simple, but reasonable, premise that the amount of sediment load in a stream associated with a coupe is the product of the amount of sediment generated (P_H) and the proportion of that sediment that reaches the stream (SDR). The amount of sediment generated is a function of the Inherent Hazard category, time and rainfall, while the delivery ratio is based on the distance of the generating point to the stream.

Sediment production function

The sediment generation component of the model is based largely on rainfall simulation data conducted at three times after logging (0, 1 and 5 years) at 3 rainfall intensities on Class 2 Hazard categories. (see Figure 6.a, p. 102).

A function is then generated to these data points giving a linear relationship between rainfall intensity and sediment production for each year.

It is impossible to work out how such a relationship was established. The assumption that the relationship is linear is not justified. Just looking at the points on the graph would suggest otherwise, with the Year 0 sediment production at *ca* 75mm/h very similar to the production at

110 mm/hr. Similarly in Year 2, the production at 110 mm/hr is actually less than that at 75mm/hr. This would suggest a declining relationship with increasing rainfall or a two step relationship with generation constant over some selected rainfall intensity (this is in fact what is selected for permanent roads – see later).

The derivation of the rainfall intensity that generates no sediment production (R_{Ht} of 10 mm/hr) is unclear, being stated that it "was determined after incorporation of the rainfall characteristics used to convert the event based generation rate into an annual rate." (p. 102-103). I can't begin to work out how this was done. It is later stated that the experimental data suggested a value of 27mm/hr, but this would not produce much sediment. So the value of 10mm/hr was selected to generate sediment at a rate compared to, I assume, some observed current data.

This is fairly bizarre and circular. While the relationship is derived from experimental values, a figure derived from the same experimental procedure is rejected, as it does not fit current conditions. Surely, it suggests that some other component of the derived equation is wrong, rather than the minimum rainfall value. To be true to the data collected, it would have been better to examine other factors in the equation – or other more suitable equations, rather than dismiss a piece of crucial evidence.

This is a major potential problem with all modelling procedures. It is standard practice to evaluate a model by testing whether it predicts current conditions. Here it would seem that, if the results of experimental data are included, the current sediment loads are severely underestimated. However, one could come up with any number of equations that predict current conditions. The real test of a model is whether it can accurately and confidently predict future conditions. If key experimental data is rejected because it does not predict current conditions, and a relationship is simply "selected" to predict current conditions, then the confidence in the model to predict future conditions is severely compromised.

The observed data that are used to reject the experimental evidence are not detailed. Given the likely error rate in the observed data – suggested as ±50% above, then the model should be tested against that range of observations. And given that the accuracy of the absolute values likely to come from the model have already been questioned, a better approach would be to incorporate all known experimental results into the model – and then try to work out what additional factors need to be incorporated to produce the observed data.

It is also here that we can start to evaluate the sensitivity of the model. Taking a single rainfall intensity (say 60 mm/hr) at Year 0, the current equation gives a generation of 0.145 t/ha. With a small increase in the R_{Ht} from 10 to 12, the generation is reduced to 0.139 t/ha, and if R_{Ht} is set at 15mm/hr, the rate is reduced to 0.131 t/ha – about a 10% reduction.

The assumption that R_{Ht} is independent of time since logging appears to contradict the conclusion from the review that sediment generation decreases with time since logging. One would expect that, as vegetation cover increases, the resistance to erosion would increase, so that it would take a higher intensity to start generating sediment. Indeed, from the graph, the value at 40mm/hr at Year 5 would appear to be extremely close to zero. Using the same error estimation as above (at 60mm/hr), with R_{Ht} at 10mm/hr, the generation after 5 years is 0.0044 t/ha, but with R_{Ht} at 30mm/hr, it is 0.0026 t/ha, almost half the value.

Similarly, just changing the value of K (the time decay constant) from 0.7 to 0.8 (by 0.1) changes the sediment generation at 60mm/hr by almost 10%.

Simply, it would seem that the sediment generation rate is quite sensitive to small changes in the values of the parameters chosen in the first step of the process.

It is here that we would abandon any thought that the final output of the model would be correct in absolute terms. However, if the same sets of parameters are kept throughout the model, values generated should be comparable in relative terms (as the authors point out).

Converting the generation rate at particular rainfall intensities to annual production rates is, as stated, " not straightforward". The approach used seems reasonable as a simplification, selecting an arbitrary critical duration (30 minutes) and calculating the frequency of each burst intensity at the site for the year, calculating the sediment generated in each burst and adding up all the generation to get a total annual production.

It is also stated that the value of 10mm/hr was " considered justifiable given the simplification of analysing the characteristics of a single burst duration." (p. 103). Given the importance of the selection of an R_{Ht} not consistent with experimental data, this justification should be fully detailed.

As all the data collected came from Hazard 2 class soils, conversions to other classes (1 and 3) are simply made up, assuming that generation from Class 1 soils are 0.75 that of Class 2 and that generation from Class 3 soils are twice that of Class 2. As the authors point out, " there is no empirical evidence to support these factors, other than the fact that the resulting range of sediment production rates are within the range reported in the literature." (p. 104). It is not clear what " ranges" these are. I would have hoped that such important data would have been included in the review section of the document.

Again, the factors are selected to predict, I assume, current conditions. There is, however, nothing in this approach that provides confidence that the factors chosen would predict future conditions as I am sure there are other combinations of constants and factors that could be used to derive the same result.

Sediment Delivery Ratio

The proportion of sediment that reaches the drainage line is a " complex interaction between overland flow distance, soil type, topography, degree of disturbance and vegetation cover." (p. 104). In this case, only the overland flow distance is included in the model. It is stated that this is the dominant factor, but no evidence is presented – either at this point or in the review section. The reference to Novotny and Chesters (1989)[3] should have been fully explained earlier.

The relationship between delivery ratio and distance to the stream is based on a simple exponential decay assumption. It is clearly stated that the rate of decay is based on " the judgement of the authors based on their experience." (p. 105). As for the other parameters noted above, a small change in the selected decay constant would have rather large impacts on the delivery ratio, and therefore the loads exported.

I would have thought that slope would be a fundamental component of the equation as the equation presented is independent of slope. It's not clear whether the inclusion of slope in the Hazard Class calculation would cover its omission here. Increasing Hazard Class would increases the amount of sediment generated, so that the total amount delivered to the stream would differ from class to class, even if it was derived from the same distance to the stream.

[3] Cited as Novotny and Chester on p. 105.

So does that mean that there is an unstated assumption that the SDR itself is independent of slope?

GIS is used to determine the proportion of the areas suitable for logging at various distances from the nearest stream entry point. This included what is called the "zeroth" order stream, generated under another project.

A relationship between the percentage of the potential harvesting area and the distance to the stream was then established – excluding the current minimum buffer width. Using the relationship between delivery ratio and distance to stream, it is then possible to calculate the overall average delivery ratio for the catchment. Within the confines, restrictions and limitations of the model, this is probably a reasonable approach.

The intention of the model is to generate a single average SDR for the catchment. The description of the derivation of this overall delivery ratio is complicated and it is often not clear exactly how it was done (p. 104-106).

Permanent Road Component

The approach to determining the sediment production and export from permanent roads is similar to that as from harvesting coupes in that that the amount of sediment load in a stream associated with a permanent road is the product of the amount of sediment generated (P_R) and the proportion of that sediment that reaches the stream (SDR).

Sediment Production Function

The relationship between rainfall intensity and sediment yield from permanent roads is totally different to that from the GHA and snig tracks. However, two totally different assumptions were used – that generation rates are time invariant and that there is a two step function up to 60mm/hr (over which rates were constant).

While the first assumption is probably fair for well-used and recreation roads, it is against the information presented in the data review for unused roads, where there is a decline in generation over time.

The second assumption is unjustified and has simply been invented as a way to generate reported loads in the literature. It is argued that adoption of the same relationship as used for GHA and snig tracks resulted in sediment production values half of that reported in the literature. As it is clearly recognised that the actual loads generated in the model should be viewed with uncertainty and the only value of the model is to establish relative values (see p. 72), there appears to be no justification to adopt an unsupported function, apart from the "neatness" of the model solution. Given the likely inaccuracies in the other components of the model, this is an unnecessary convolution.

Sediment Delivery Ratio

The calculation of an SDR for the catchment was done in the same manner as for the general coupe, but using area of roads of different types. Within the confines, restrictions and limitations of the model, this is probably a reasonable approach.

Estimate of Road Usage

In order to evaluate the impact of the likely logging scenario, estimates of the change in road usage were derived. These changes were then fed into the model to derive the additional impact of road use in the future.

3.12 COMMENTS ON THE ADOPTED MODELLING APPROACH AND RESULTS

While it is stated that the model developed is deliberately simplified to match the availability of suitable data, the broad approach should be generally seen as appropriate to the task. It is a desirable thing to have predictive information on the likely impacts of different logging scenarios and options. And the simplest model format is to calculate the amount of sediment generated by a particular action or a particular source, then calculate how much of that sediment is actually delivered to the drainage system. This is the approach taken in this project.

Unfortunately, the actual final product is fraught with potential errors (of calculation, not necessarily logic) and limitations that it is hard to see the potential usefulness of the model in its present form.

It is clear that the authors appreciate the types of limitations that are highlighted in this peer review. It is recognised that the functions used to generate the outputs are based on empirical evidence and not on any derived relationship between the actual physical characteristic and effect. It is also recognised that the model is a very simple representation of the real world, where a myriad of factors not incorporated into the model will influence the accuracy of the predictions.

However, the comment that the "adopted approach provides a reasonable 'best guess' that is unlikely to be improved even with the expenditure of considerable effort" (p. 112) is really overstating the potential accuracy of the results. There is no way that the level of sediment generation and delivery to the stream system could be taken on board with any degree of confidence. Even the perceived limitations are those that are fundamental to the accuracy of the model (p. 113):

- The conversion from event-based generation to annual yields;
- Generation rates;
- Sediment Delivery Ratio.

Implicit in these limitations is the selection of the large number of constants, conversion factors and relationships that make up the model. Even relatively small errors in such a large number of empirically derived factors would escalate and make the result quite different to the actual impact. A sensitivity analysis, as noted by the authors (p. 113), would be required before the potential deviation from reality could be even hinted at.

Given that the actual predicted sediment loads in streams are unsound, one would question whether the relative impacts between the catchments can be seen as accurate. It would seem that the dominant factors associated with sediment generation and delivery have been incorporated into the model (rainfall and roads). So the relative increases between catchments are based on the assumptions that:

- The higher the rainfall, the more sediment that will be generated and potentially delivered to drainage lines;
- That roads are the main source of these sediments, so increasing the density or usage of roads will increase sediment generation and delivery.

These are reasonable guesses at the dominant factors that could change between catchments, so the relative rankings can be seen as sound.

The scale of the relative rankings depends on the form of the equations used to generate the outputs. In general these four fundamental assumptions based on the above limitations are:

- A linear relationship between rainfall intensity and sediment generation;
- A speculative non-linear increasing relationship between Hazard class and sediment generation;
- An exponentially declining relationship between sediment yield and time;
- An exponentially declining relationship between sediment delivery ratio and distance from the stream.

To evaluate the accuracy of the scale of the relative rankings, it would be necessary to evaluate the impact of each on the scale of the outcome. While the last two are probably justified, the first need to be investigated. If the relationship on the GHA is not linear and follows the same pattern as the one suggested for roading, then the values from the wetter catchments may be overestimated (and so the relative increase would be smaller than stated).

However, given the current state of knowledge and the limited amount of hard data to base predictions on, it should be concluded that the relative rankings and scales would represent the "best guess" that we can make.

APPENDIX A

Dear

RE: PEER REVIEW OF "ESFM PROJECT: WATER QUALITY AND QUANTITY FOR THE UPPER AND LOWER NORTH EAST, SOUTHERN RFA REGIONS"

On behalf of the ESFM Group as discussed, I wish to offer you the opportunity to peer review the water quantity section of the enclosed report title " ESFM Project: Water Quality and Quantity for the Upper and Lower North East and Southern RFA Regions, November 1998". This report was prepared by Sinclair Knight Merz, on behalf of the Resource and Conservation Division of the Department of Urban Affairs and Planning.

Your engagement for the peer review will be on a " fee for serve" basis covered by a letter of offer. It is understood that this offer involves you, as the contractor, accepting the following terms and conditions. In signing this letter of offer, you agree:

To accept all responsibility for affecting all necessary insurances and superannuation arrangements.
To release from and indemnify the Department against all liability which may result directly or indirectly from any negligent or wrongful act of the contractor.
To not disclose, without first obtaining written approval, any information or material required or produced by the contractor during the performance of the services provided under this offer.
That the property and copyright of all material produced in reports to the Department by the contractor will vest in the Department.

To ensure that there is no conflict of interest, you must inform me on receipt of this offer, if you have had any prior involvement in the project proposed for your peer review.

If so, depending on the level and extent of your earlier involvement, a decision may be required on whether to progress this offer.

Find attached a guide to the intent and outcome of the proposed peer review at Annexure 'A'. If you are unable to perform any of the tasks identified, please advise me as soon as possible.

To assist your review, I have also attached the project specification at Annexure 'B'. This specification was modified during the project, to address with various issues and situation as they arose, including the requirement to report on extremely tight time-lines.

You are one of two experts that the ESFM Group has agreed will critically review sections of the noted report. Following expert peer review, further work will be undertaken on the Southern region. This additional work is being undertaken because at the time of the project, critical data such as vegetation information from air-photo interpretation and drainage information was not available.

It is anticipated, that the peer review will assist the project managers to ensure that the additional work to supplement to project will provide the best information on water quality and quantity in the Southern region and how this is affected by logging operations.

As agreed on the telephone we will pay XX per day for three days (maximum of XX), to enable you to undertake the peer review. Payment will occur on presentation of an invoice and be made payable to whom you instruct. We require the peer review to be completed by XXXX. The outcome will be a single report outlining the findings of the peer review. Twenty copies of the report should be provided to RACD for distribution the ESFM Group members and an electronic copy should also be provided.

If you have nay questions or require any further information, please contact me directly and I will deal with them directly. Contact details are: XXXXXX

Under this arrangement, I am required to instruct you not to contact he principal consultant Sinclair Knight Merz or any member to the project team.

Your assistance in undertaking this peer review is appreciated, and I look forward to receiving your acceptance of this offer.

Yours sincerely

Annexure 'A"

GUIDELINES FOR PEER REVIEW

The following terms of reference have been prepared as a guide for the objective review of the project report.

1. OBJECTIVES OF THE PROJECT

The objective is to carry out an independent assessment and appraisal of the methods and data used to develop the project report titled " ESFM Project: Water Quality and Quantity for the Upper and Lower North East, Southern RFA Regions, November 1998".

The project will include an assessment of the reliability of the project findings. The peer review will also identify any limitations in the methodologies and data and any requirements for additional work. It will ensure the additional work being undertaken for the Southern RFA region can correct or use any improvements in the methods, data and/or modelling.

2. BACKGROUND

See attached project specification.

3. METHODOLOGY

The consultant will review the project contained in the attached report title " ESFM Project: Water Quality and Quantity for the Upper and Lower North East, Southern RFA Regions, November 1998". Specific aspects to be addressed include:

- Review of methods and data used.
- The results of the data review.
- Relative accuracy of predictions.
- Description of the limitations of predictions and the implications of these limitations.
- Strengths and weaknesses and scientific validity of the methods/systems used for data collection and modelling.
- Suitability of any assumptions and what limitations these cause.
- The overall expected reliability (which incorporates sensitivity) for use in the RFA.
- Are there any errors of fact or logic?
- Possible improvements on the method, data and modelling.

Annexure'B'

CRA/RFA PROJECT SPECIFICATION

PROJECT NAME:	Water quality and quantity for the Upper and lower North East, Southern RFA regions.
PROJECT IDENTIFIER:	ESFM Water
LOCATION/EXTENT:	Upper North East, Lower North East, Southern RFA regions
ORGAISATION/S:	Department of Urban Affairs and Planning/Resource and Conservation Division

LINKAGES/DEPENDENCIES:

<u>ESFM</u>
ESFM PA 2: Knowledge and Information project.
ESFM PA 3: Criteria and Indicators for the Upper and Lower North East and Southern Regions.
ESFM PA 4/2: Review of protective measures and forest practices and expression of these into language for information systems.

<u>FRAMES</u>
Yield Schedular including silvicultural prescriptions and schedular.
Net harvestable area project.

<u>E&S TC</u>
Economic Assessment of Water Values.

TYPE OF STUDY:
This report will collate existing data and literature on water quantity and quality. It will describe the impacts from forested land management on water quantity and quality in the Upper/Lower North East and Southern regions and will pilot the modelling of these impacts.

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1. BACKGROUND:
Water has already been identified as an important issue for the UNE, LNE and Southern RFA regions. There appear to be issues with rural and town water supplies, and potential impacts that forestry activities may have on downstream water quantity and quality. It is important to investigate the issues and try to quantify any impacts that may occur.

2. OBJECTIVES OF THE PROJECT:

The objectives of the project are:

- To produce an up to date summary report that provides information on water quality and quantity in the Upper/Lower North East and Southern NSW RFA regions;.

- To provide information on key environmental attributes affecting seasonal and annual water quality and quantity over time and how this is affected by different land management regimes over time.
- To collate the baseline resource information on catchment area, water usage, environmental flows, base geology, forest ecosystems, growth stages and potential impact on seasonal and annual water quality and quantity from forested land activity over time.
- The mapping or modelling of this information.

3. SCOPE OF THE PROJECT:

The following provides the areas covered in an assessment of hydrology and hydrological impacts of land management in the Upper/Lower North East and Southern RFA regions.

3.1 Literature review and data collection

- Review available literature and data on hydrological aspects and the broad effects of cleared, grazed, fire agricultural, urban and forested lands on seasonal and annual streamflows over time. However the primary emphasis throughout will be on forests.
- For forests undertake a more detailed review of the impacts of logging, silviculture and plantations upon water yields, flows and quality, including the:
  - The duration and magnitude of the initial increases in water yield and changes in flow and water quality immediately following logging or thinning.
  - The timing and magnitude of maximum yield declines and changes in flow following logging, thinning and planting.
  - The impacts of various silvicultural regimes and rotations, the relationship between increases in runoff and water quality and changes in flow.
  - Effects of roads and snig tracks in various terrain and climate.
- Gather available data on hydrological aspects and the broad effects of land uses.
- Identify knowledge gaps.

3.2 Identification of catchments

- Identify the catchments[1] that have been classified as 'significant' by Fisheries and NPWS.
- Identify catchments used by DLWC in the Catchment Management Committees and to the NSW environmental flow and water quality objectives project.
- Delineate catchments of the UNE, LNE and Southern regions as a GIS layer in a form where significant attributes and impacts and other base resource information can be tagged to catchments and CRA negotiation land units. (The GIS layer should be provided by State agencies).

3.3 Model development

- Identify 4-6 trial catchments in the Upper/Lower RFA regions and 3 in the Southern CRA region which are representative of the (including a lake system) which are representative of the region (encompassing the range of environmental conditions and land use activities).

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[1] What constitutes a catchment will be determined after consideration of the size of catchments and how the Catchment Management Committees have dealt with catchments.

- Utilise available information concerning total yield/production of water, low flow and flow duration curves by sub-catchment and historic and current water quality by sub-catchment. Collect existing information to describe surface and groundwater resources and the nature of water usage by catchment hierarchy: domestic usage, commercial usage (including fisheries), agricultural usage and recreation and the uptake points for these water uses.
- Use available literature and data to develop a pilot model relating changes in forest structure, establishment of plantations and creation of roads to stream flows, water quantity and quality. This should be able to be related to available GIS data layers (notably API Growth stages and roads).
- Use GIS layers on terrain, elevation, rainfall, geology, soils, vegetation (incl. Forest ecosystems), logging, growth stages, roading, etc., to develop catchment hydrology (including evapotranspiration) models. The derived product should be able to represent seasonal and annual stream flows for each sub-catchment, relative to the above environmental variables and land uses and related impacts over time.
- Provide recommendations on extrapolation of the modelling of water quality and quantity for other parts of the Upper, Lower and Southern RFA regions.

3.4 Report

- Provide a draft written report (both a hard and digital copy) covering the above dot points including the literature review and data collection.
- Provide a draft and final written report (both a hard and digital copy) detailing the approach and methodology of model development and the results of pilot models for 4-6 catchments in the Upper/Lower RFA regions and 3 catchments in the Southern regions, to both the ESFM Group and E&S TC. Provision of pilot models for two catchments in Southern RFA will be dependant upon availability of required data layers. The report should detail any recommendations for extrapolation of the modelling of water quality and quantity across CRA regions.

Application of the pilot model for two catchments in Southern RFA region will be dependant upon availability of required data layers.

This project will provide the base information requirements to determine whether a full economic study is justified. If it were required then it would involve an assessment of the potential economic impacts of changes in water quantity and quality from forested catchments. This component will be done by the E&S TC and the project is described in Economic Assessment of Water Values. This project specification indicates that the ESFM water project needs to provide details on the nature and extent of impacts on water quantity (flow and amount) and water quality and how this relates to the uses of water both environmental and human.

4. METHODOLOGY

4.1 Project methodology

- The ESFM Group will pick a suitable consultant.
- DUAP will hire the consultant.
- The consultant will provide the ESFM Group, for consideration prior to proceeding with the project, a proposal for the gathering of hydrological and land use relationship

information on UNE, LNE and Southern regions and details on the pilot to model water quality and quantity in catchments.

- Provision of outline of what they are proposing to do including a table of contents. This will be reviewed by ESFM Group.
- Preparation of draft report including GIS layers, trail catchment modelling and details on the discussion with agencies and key stakeholders such as water suers.
- Provision of draft and review by ESFM Group.
- Further work on project.
- Provision of final draft report and catchment models for review by ESFM Group.
- Further work including incorporating comments.
- Provision of final report.

4.2 Principle organisations and known documents

- Hydrology of the Upper North East CRA Region (Draft report by BRS)
- EIS for the Casino, Urbenville, Grafton, Glenn Innes, Walcha, Coffs Harbour, Dorrigo, and Murwillumbah Management Areas (1994)
- DUAP Director General's EIA report
- State Forests New South Wales research including unpublished data
- Department of Land Water Conservation
- Environment Protection Authority
- Water Resources Council
- Cooperative Research Centre for Catchment Hydrology
- Water Board
- BRS
- NSW Water Conservation and Irrigation Commission - Survey of Thirty Two NSW River Valleys.
- EPA - Proposal Interim Water Quality Objectives for NSW Waters for the relevant catchments.
- EPA - The Northern Rivers: A Water Quality Assessment
- DLWC - Catchment Management Committees' management strategies
- River Flow Objectives Working Group

4.3 Consultants and experts

The ESFM Group will be provided with a list of possible consultants and will need to rank these as to their priority for undertaking the project. Once a consultant has been chosen, they will be approached and hired to undertake the project.

5. CRITICAL PATH

5.1 Outcomes/Outputs

Information on:

- The effects of clearing, forest structure, silviculture, plantations and roading on water quality and quantity.,
- Present and historic total yield/production of water by catchment;
- Present and historic water quality by catchment;
- Catchment area, geology, hydro-geology, flow rates, forest structure, soil, land-use
- History of land management activities (such as fire, logging, growth, road construction and maintenance, grazing and horticulture and their locations relative to the points of water uptake) and
- Impact of past land clearing.
- Table showing details on water usage by sub-catchment i.e amount of water licensed, number of minor license holders and number and name of major license holders, types of products produced; rural or urban water supple etc. .

Models relating changes in forest structure (silviculture practices), establishment of plantations and creation of roads to stream flows and quality.

Pilot catchment models and data on water usage for four representative trial catchments in the UNE, LNE, and two Southern CRA regions.

Recommendations for modelling of water quality and quantity across CRA regions.

5.2 Data Outputs

Integration/Negotiation Stage -

- GIS layer for integration representing catchment boundaries and catchment significance for the UNE, LNE and Southern regions.
- Map of present and planned water uptake points and a table of expected uptake quantities.
- Table of catchments (or sub) by land tenure.
- Table of catchments including net harvestable area in each catchment.
- Where possible, quantitative assessment/modelling of impacts of forest activities, specifically harvesting regeneration, plantations and roads on water quality and quantity on a whole catchment basis including at uptake points.
- Pilot catchment models for representative catchments.

May be able to link any response models for water quality and quantity with the FRAMES schedular.

5.3 Reporting

- Updates on each part of the project will be presented to the ESFM Group, to provide information on the progress of the project.
- Draft and final draft reports for the project will be circulated for comment from the ESFM Group and the consultant will be expected to provide 20 double-sided copies of each.
- Finalised report covering the project (hardcopies and digital copies) which clearly and concisely represent the results, to each member of the ESFM Group. Reports to use the standard CRA format. The consultant will asked to provide 20 double-sided copies of the final water quality and quantity report and a copy which can be used for further copying. Number of subsequent copies to be determined by RACD but the consultant will not provide these copies.

APPENDIX B

Timothy J. Doeg
Environmental Consultant
77 Union Street
Northcote VIC 3070

Phone/FAX: (03) 94818130
E-mail: crowdoeg@mail.mpx.com.au

Aquatic Environmental Consultin
Aquatic Macroinvertebrate Processin
Data Analysi
Report Preparatio
Project Design And Quality Contro

Re: peer review of the water quality chapters in the document "ESFM Project: Water Quality and Quantity for the Upper and Lower North East, Southern RFA Regions".

Dear

Please find enclosed twenty (20) copies of the peer review of the water quality chapters in the document "ESFM Project: Water Quality and Quantity for the Upper and Lower North East, Southern RFA Regions".

This was a difficult document to review. While the approach taken in attempting to model the impact of forestry activities on water quality was appropriate, the end product (the model) cannot be seen as providing accurate estimates of the sediment loads produced by the proposed logging scenario. There are too many empirically derived equations in the model to have confidence in the accuracy of the end result. It should be noted that the authors appreciate this and repeatedly mention it in the text.

A number of assumptions are made that have not been clearly justified. While they may be (and probably are) "best guesses", they need to be clearly explained for the model to have more credibility.

In one case, critical experimental evidence has been rejected because it would mean that the empirical equation selected would underestimate observed sediment loads. This is unsatisfactory.

While the absolute estimates produced by the model are unsound, the relative estimates between catchments are probably the "best guesses" that we would make, as they are based on the key issues associated with sediment generation and delivery. Whether the scale of the relative rankings is accurate, again, depends on the validity of some of the assumptions.

Therefore, if the aim of the exercise is to get a rough comparison between catchments (say, comparing catchments of different "significance"), then the product would be of some use.

My main concern is that, all to often, I have seen data and products like this used out of context or inappropriately. As a simple example, it would be quite easy for the selected figure of 10mm/hr for the rainfall intensity that generates no sediment production to be incorrectly transported into a management regime. I can see that it would be possible for this figure to be used as a critical rainfall that would trigger a suspension in logging activity. Here in Victoria, the Code of Forest Practice states that logging should be suspended in wet weather. This figure (10mm/hr) could then be used to quantify that wet weather trigger. This would be undesirable as the value was selected simply to produce the model and has no basis in experimental evidence.

I hope these comments, and the review, are of some value in your deliberations. Please do not hesitate to contact me if you want clarifications or any additional information on the review.

Yours sincerely,

Timothy J. Doeg