

Task 2.10 Final Report

Evaluation of Alternatives

for the project entitled

**Dairy Best Available Technologies
in the Okeechobee Basin**
(SFWMD Contract No. C-11652)

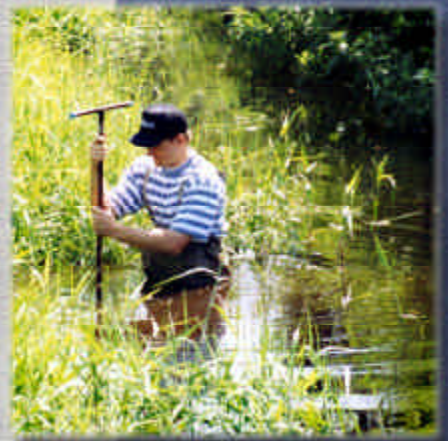
Submitted by

SWET, Inc.
**Soil and Water Engineering
Technology, Inc.**

In Association With

**MOCK•ROOS
CH2M HILL
ENTEL**

June 16, 2002



The
SWET
Team

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**Evaluation of Alternatives
(Ranking Best Available Technologies)**

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Executive Summary

The best available technologies identified in previous project tasks were scored and ranked. The evaluation was based on the objectives and criteria for the technology evaluation developed in Task 1.4.

The goal of the Dairy BAT project, defined in the original Statement of Work, is clear and unchanging. The objectives and criteria were the first products of the project, and were developed prior to the information and knowledge the project team ultimately gained. They are, therefore, reconsidered and clarified in that light. Specifically, certain objectives have become more important than others have; and certain criteria within those objectives have gained priority. In particular, a deeper understanding of stakeholder issues and concerns alongside technical consideration has affected the importance of specific objectives and criteria.

The objectives and criteria (SWET 2001a) have been reordered to recognize two levels of priority, and to interpret the overlap between some of the objectives and criteria in defining a precedence of one over another (Table ES-1).

TABLE ES-1
Priority and Priority Scores of the Project Objectives

Objective	Priority	Priority Score
Maximize Water Quality Benefit	1	2
Maximize Cost-Effectiveness	1	2
Maximize Ease of Implementation	1	2
Minimize Socioeconomic Impacts	2	1
Maximize Engineering Feasibility	2	1

Each technology and combinations of technologies previously identified was ranked on each criterion as high (2), medium (1), or low (0). Each objective and criterion was defined as either a first and or a second priority objective with scores of two and one, respectively. The total score for a technology was calculated and similarly provided first and second priority scores to each criterion within each objective. The scores were calculated as follows:

Technology score for each criterion =
Objective Score x Criterion Score x Technology ranking score

Total Technology Score =
 \sum Technology scores for each criterion for all criteria in all objectives
for that technology.

Scores of individual technologies revealed significant differences between technologies in each technology group. In the manure collection technologies, feed/shade barns where scraping and collecting was a design component were ranked highest for all objectives.

Settling ponds were ranked first in solids removal technologies, primarily because application would involve minor changes to existing systems on most farms. It is a very simple technology already in use on many farms, at least informally. Chemical treatment of soils ranked highest within that technology subset because of water quality benefits and cost effectiveness. It is a one-time application concept with direct and immediate effects on runoff water quality.

Land treatment of either untreated or treated waste streams ranked highest among biological treatment options due to its ease of implementation. It is a process already used by most, if not all, the dairymen. Immediately following land treatment in the rankings were other technologies that are already known to the farmers, including stormwater retention and reuse, and anaerobic lagoon technologies. Treatment wetlands and vegetated buffers were ranked next, followed by the less well known or more experimental technologies.

Overall results for the combined technologies was based on the ability of the systems to reduce P runoff concentration and volume while providing something of value to the dairy, without a complete restructuring of the dairy operation.

Treatment of field soils with edge-of-field collection, and runoff treatment and re-use ranked first. This method had the greatest and most rapid impact on runoff concentration, and was the only technology combination that clearly affected load (by reducing runoff volume and concentration). In addition, it ranked high in terms of cost effectiveness and ease of implementation. Runoff collection and re-use ranked second for the same reasons.

Confinement barn-based technology combinations may provide sidestream benefits and can provide complete capture of wastes if total confinement is achieved, but are much costlier – for most dairies very significant reconstruction would be required. In addition, the runoff conditions would persist for a long period as they came into agronomic balance, at which point the field runoff concentrations still be in the range of 500 – 1000 ppb TP. Complete confinement of the herd would be experimental for the Okeechobee basin, as it has never been attempted in south Florida.

While there are technologies that can achieve total capture of dairy waste phosphorus and treat it to the target goal of 40 ppb TP concentration in final runoff, none of the technologies are likely to achieve the goal within the project budget. A reduction of captured runoff to between 100 ppb and 150 ppb after alum treatment is projected to be the best that can be achieved within the budget. An engineering design applying this technology is expected to predict exactly how much TP loading from the farms will be reduced and projected annual volume-weighted concentration. Monitoring before and after technology application on the selected farms will provide the performance evaluation and the basis for a final recommendation concerning wider application.

Introduction

The goal of the Dairy Best Available Technologies Project (Dairy BAT) is:

An unbiased selection, implementation, and monitoring of the Best Available Technologies to significantly reduce dairy industry phosphorus exports to the Okeechobee Basin and bring about the most effective and substantial water quality improvements in the shortest possible time (SWET 2001a).

This report describes the final technology ranking process and recommendations, applying the objectives and criteria developed for the project (SWET 2001a) to the various technologies and technology combinations already identified in the Literature Review, and Formulate Technology Alternatives, Final Report Tasks (SWET 2001b, SWET 2001c). The objectives and criteria are now reconsidered, however, in light of the knowledge gained in execution of the project to date.

As the project progressed, it became clear that no single technology application would meet the project goal, so technology combinations were developed. These combinations are not considered as sums of the individual technologies, because they represent a different level of change for the dairies and have combined effects greater than each individual technology. These combined technologies, discussed in the final report for Task 2.6, Formulate Technologies, are thus judged separately.

This report first reconsiders the objectives and criteria developed for the project. The individual technologies and combined technologies are then ranked separately. The ranking and results of each ranking process are then discussed.

Objectives and Criteria Reconsidered

Goals, Objectives and Criteria for evaluation were the first products of the project. They were developed *a priori* of the information and knowledge the project team ultimately gained. The goal of the project remains unchanged. The objectives and criteria, however, have now been reconsidered and clarified in the light of our improved understanding. Specifically, certain objectives have become more important than others have; and certain criteria within those objectives have gained priority.

A deeper understanding of stakeholder issues and concerns alongside technical consideration has affected the importance of specific objectives and criteria. An important part of the project has been the continuing dialogues with the dairymen in the basin, the dairy industry, and the owner/managers of the three dairies selected for this project. Each of the dairymen was interviewed extensively during the development of the animal nutrient management assessments (SWET 2001d). Two stakeholder meetings were attended by almost every dairyman in the basin. There were also frequent informal contacts with the project dairies throughout the last year. The critical concerns of the dairymen became clear during this process, particularly cost-effectiveness. The dairymen's strong desire for technology that would provide benefit to the dairy and not provide only "regulatory relief" was evident. The ability to incorporate the technology into the existing system was critical, as was the ability of the dairyman to be able to operate the system with a minimum of additional training or a requirement for special expertise.

The technologies selected for application to the dairies are important not only to the farmer, but also to the public agencies charged with dairy support and dairy regulatory functions. Results of formal and informal discussions with the agency stakeholders were included in our prioritization of objectives and criteria. Thus, water quality improvement (concentration and/or load) was defined as a primary concern. Technologies will be implemented to achieve the best improvement possible. In addition, however, a concern for the sustainability of the industry in the basin was also identified as an essential component of any solution. Thus, reduction in phosphorus concentration while maintaining the industry in the basin becomes the most critical objectives. The other objectives were considered slightly less important. A simple scoring process for objectives and criteria gave twice as much emphasis to a primary component as to a secondary component. Ranking each technology with respect to the criteria was approached in a similar fashion.

The objectives and criteria of the project (SWET 2001a) have been ordered to recognize two levels of priority, and to interpret the overlap between some of the objectives and criteria in defining a precedence of one over another. For objectives and criteria within objectives, first priority components were given a score of two and second priority components were assigned a score of one. Each technology was ranked on each criterion as high (2), medium (1), or low (0). Weighted scores for each technology were calculated by multiplying the objective priority score by the criterion priority score and the technology ranking for each priority and criterion. The resulting values were summed to calculate the overall score for each technology or technology combination.

$$\text{Technology score for each criterion} = \text{Objective Score} \times \text{Criterion Score} \times \text{Technology ranking score}$$

$$\text{Total Technology Score} = \text{SUM (Technology scores for each criterion for all criteria in all objectives for that technology).}$$

First Priority Objectives and Their Criteria

Maximizing water quality improvements, maximizing cost effectiveness, and maximizing ease of implementation became first priority objectives of the best technology selection process. These objectives focus directly on the two major components of the project – the dairy and the phosphorus leaving the dairy and entering the Lake Okeechobee drainage (Table 1).

TABLE 1
Priority and Priority Scores of the Project Objectives

Objective	Priority	Priority Score
Maximize Water Quality Benefit	1	2
Maximize cost-effectiveness	1	2
Maximize Ease of Implementation	1	2
Minimize Socioeconomic Impacts	2	1
Maximize Engineering Feasibility	2	1

Objective: Maximizing Ease of Implementation

Maximizing ease of implementation is an objective closely linked to, but separate from, cost effectiveness, and is the third of the primary objectives. The first three criteria (Table 4) are closely linked, but farmer acceptance is the most important of the three. Without farmer acceptance of a technology, it will not be constructed. However, if the technology is acceptable, familiarity with the technology will decrease the dairyman's training and startup time. Startup time also has a technology-based component, as some technologies or combinations may take longer than others to fully incorporate into the dairy process.

The other two objectives are secondary because they are largely affected by the three primary objectives. For instance, because the project is designed to work from the source of the phosphorus (the dairies), maximizing cost effectiveness on each farm was found to minimize environmental and socioeconomic impacts in many cases. Thus, cost-effectiveness is a primary objective largely driving regional impacts, with the secondary objective focusing more on environmental than socioeconomic issues. Engineering design feasibility was directly connected to and driven by ease of cost effectiveness and ease of implementation. The objectives and their criteria are ranked as either first or second priority. First priority is given a score of two, and second priority a score of one.

Objective: Maximize Water Quality Improvements

Maximizing water quality improvements is part of the primary project goal statement. Thus, the objective must also be primary to the technology rankings. The criteria of the objective can be ranked in importance with respect to the technologies (Table 2). If TP load reduction, TP concentration reduction, and response time are maximized, compliance with the target TP concentration will consequently be maximized. Therefore, the first three criteria are first priority, and compliance components are secondary. Further, because other Class III water quality standards were not specifically considered as part of the project, high performance for this criterion is still considered an added, not primary benefit for the technology.

TABLE 2
Ranking of Criteria for Maximizing Water Quality Improvements

Criteria	Priority	Score
Maximize TP load reduction	1	2
Maximize TP concentration reduction	1	2
Minimize TP Reduction Response Time	1	2
Maximize Compliance with Target TP concentration (40 ppb)	1	2
Maximize compliance with numeric class III standards	2	1

The dairy assessments revealed that bringing the dairies into agronomic balance is a common improvement need if TP runoff concentration is to be reduced. However, if balance was achieved, runoff TP could only be reduced to between 500 ppb and 1000 ppb. Further

reduction must come with P load reduction (reducing runoff volume as well as concentration). The speed with which a TP reduction would occur was given a high priority because the more rapidly TP load is reduced; the quicker Lake Okeechobee will be benefited. Maximizing compliance with the target TP concentration is directly related to reducing P load and concentration, but implies the greatest amount of reduction possible and, therefore, was also ranked with a high priority. Compliance with numeric Class III water quality standards was set to a lower priority because it was not a specific goal of this project.

Objective: Maximize Cost-Effectiveness

Cost-effectiveness is a critical objective for implementation of new technologies by the dairy industry in the Okeechobee Basin. Operation and maintenance costs are critical to the dairymen and the dairy industry. Weighting of these criteria reflects the issue of farm costs (Table 3).

Since the sale price of milk is not under the control of the milk producers, they must know and control O&M costs in order to survive. Costs that do not directly contribute to milk production, such as operating a technology that only meets regulatory needs, is very expensive within the dairy operating parameters, since it cannot produce more milk.

Minimizing the cost of P removal means reducing the amount of time and materials that the farmer has to put into the P removal process. If it can be directly inserted into the existing dairy structure and easily incorporated into the dairy operation, it will be more cost effective than a new component to the operation. Technologies that offer only “regulatory relief” are regarded with less interest than those that provide some operational benefit. A field application of a chemical amendment to reduce runoff P concentration would be an example of an activity that provides only regulatory relief. Sidestream-based technologies that the dairyman does not have to manage (generally proprietary technology) are more favorable than technologies requiring extra activity on the dairyman’s part , because those activities result in fixed operating cost increases.

Okeechobee dairies are in a climate and landscape that has led to the development of specific regional dairy infrastructure, operation, and management techniques important to dairy success here. Completely redesigning the infrastructure of the dairies, in addition to being risky, was found to be well beyond the means of the project, and perhaps unnecessary. Thus, capital costs would only have been a primary issue if it were found that there was no potentially satisfactory alternative.

TABLE 3
Ranking of Criteria for Maximizing Cost-Effectiveness

Criteria for Maximizing Cost Effectiveness	Priority	Score
Criterion		
Minimize O&M costs	1	2
Maximize Cost per lb. P removed	1	2
Minimize Capital costs	2	1

Objective: Maximizing Ease of Implementation

Maximizing ease of implementation is an objective closely linked to, but separate from, cost effectiveness, and is the third of the primary objectives. The first three criteria (Table 4) are closely linked, but farmer acceptance is the most important of the three. Without farmer acceptance of a technology, it will not be constructed. However, if the technology is acceptable, familiarity with the technology will decrease the dairyman's training and startup time. Startup time also has a technology-based component, as some technologies or combinations may take longer than others to fully incorporate into the dairy process.

TABLE 4
Ranking of Criteria for Ease of Implementation

Criterion	Priority	Score
Maximize Dairy Farmer Acceptance	1	2
Maximize Familiarity with Technology	1	2
Minimize training and startup time	1	2
Minimize legal and regulatory requirements	1	2
Minimize construction time	2	1

Altering known technologies is a risk for the dairymen that must be considered. Technologies that require restructuring the operation, particularly herd management, are of great concern to the dairymen, as the effects of changes to herd management may not be apparent for many years.

In formulating the technology alternatives and developing the dairy assessments, it became clear that while there were many innovative technologies for waste management, most were in the testing phase. In addition to the unknown factor to properly operate proprietary technologies at new scales, they are likely to be totally unfamiliar to the dairymen. The only way these technologies would be acceptable is for the technology to have a negligible impact on the dairy and minimal dairy involvement.

Second Priority Objectives and Their Criteria

Second priority objectives included Maximizing Engineering Feasibility and Minimizing Environmental and Socioeconomic Impacts. The primary reason for the lower priority ranking was that many or most of the criteria of these objectives were strongly related to criteria in the first priority objectives. Criteria within primary objectives were sometimes restated in the larger (basin-wide) perspective (e.g., O&M costs and Basin Economic Impacts). In addition, some criteria were reduced in importance by basic project constraints such as funding. Again, some criteria were ranked higher than others within an objective and were given values for scoring in the same way, as were criteria in the first priority objectives.

Objective: Maximizing Engineering Feasibility

Engineering feasibility was a primary issue with technologies not already full-scale, or not already present within the local dairy community. These issues result in low rankings in first priority objectives. The ease of implementation objective included criteria of construction time and training, of which scale-up issues are part. In addition, farmer acceptance is likely to be low for a new or scaled technology, and maximizing feasibility is associated with the dairy community's familiarity with that technology.

Within this priority, operational flexibility (proven local effectiveness and redundancy) and adaptability to existing dairy facilities are most important (Table 5). These two criteria are critical in defining changes to the basic Okeechobee dairy system that the dairyman can operate economically and that can be adjusted to fit each dairy. Since scalability and effects of natural disasters are related to the two broader criteria, they were ranked as secondary. The effect of natural disasters, particularly hurricanes and violent thunderstorms, is a general component of dairy construction in the basin. A system that fits in well with the existing dairy likely has similar characteristics (e.g., relatively low construction, set in a location where flooding is minimized if that is an issue). Scalability is associated with adaptability to existing dairy facilities. The best technologies should be adaptable to the full range of dairies in the basin and thus scalable as well.

TABLE 5
Ranking of Criteria for Maximizing Engineering Feasibility

Criterion	Priority	Score
Maximize Operational Flexibility/Stability	1	2
Maximize adaptability to existing dairy facilities	1	2
Minimize effects of natural disasters	2	1
Maximize Scalability	2	1

Objective: Minimize Environmental and Socioeconomic Impacts

Minimizing environmental and socioeconomic impacts was ranked as a secondary objective primarily because of connections to other objectives already considered or relative lack of information (Table 6).

Objectives and criteria in the primary objectives deal directly with economic issues.

Minimizing environmental impacts is directly related to the extent of legal issues and ease of permitting.

Maximizing external funding is largely associated with either well known technologies (ease of implementation issue) or proprietary technology, which carries an expectation of external (primarily or at least partly private) funding, and is difficult to effectively evaluate.

Minimizing environmental impacts and generating high value sidestreams were ranked higher than the other criteria because they have important bearing on the ability of the dairies to function.

TABLE 6
Ranking of Criteria for Minimizing Environmental and Socioeconomic Impacts

Criterion	Complementary Criteria in First Priority Objectives	Priority	Score
Minimize Impacts to the Environment	Ease of permitting; legal issues	1	2
Maximize Generation of High-Value Sidestreams	None	1	2
Maximize External Funding Sources	Related negatively to engineering feasibility	2	1
Minimize Adverse Economic Impacts to Okeechobee Basin	Criteria within Maximizing Cost Effectiveness”	2	1
Minimize Generation of Low Value Side Streams	Minimize O&M costs	2	1

Overall Ranking Results – Individual Technologies

Scores of individual technologies (Table 7) showed that there were significant differences between technologies in each technology group. In the manure collection technologies, feed/shade barns where scraping and collecting was a design component were ranked highest for all objectives. Settling pond technology was ranked first in solids removal technologies primarily because application would involve minor changes to existing systems on most farms. It is a very simple technology already in use on many farms, at least informally. Chemical treatment of soils ranked highest within that technology subset because of water quality benefits and cost effectiveness. It is a one-time application concept with direct and immediate effects on runoff water quality.

Land treatment of either untreated or treated waste streams ranked highest among biological treatment options due to its ease of implementation. It is a process already used by most if not all the dairymen. Immediately following land treatment in the rankings were other technologies that are already known to the farmers, including stormwater retention and reuse and anaerobic lagoon technologies. Treatment wetlands and vegetated buffers were ranked next, followed by the other less well-known or more experimental technologies.

Overall Ranking Results – Combined Technologies

Overall results for the combined technologies was based on the ability of the systems to reduce P runoff concentration and volume while providing something of value to the dairy, without a complete restructuring of the dairy operation (Table 8).

Treatment of field soils with edge of field collection and treatment of runoff and re-use of the water ranked first primarily because it had the greatest and most rapid impact on runoff concentration, and was the only technology combination that clearly affected load (through reducing volume and concentration of runoff). In addition, it ranked high in terms of cost effectiveness and ease of implementation. Runoff collection and re-use ranked second for the same reasons.

TABLE 7

Ranking of Individual Technologies.

(Technologies are organized by type. Both summed scores and scores by objective are provided for comparison)

Overall Technology Scores	Manure collection		Solids Removal		Chemical Treatment		Biological Treatment										
	Freestall barns (scrapped/flushed)	H/A confinement ponds with cooling	Feed/shade barns (scrapped/flushed)	Screen, centrifuge, screw press	Chemical treatment of waste Stream With Solids	Chemical Treatment of Waste Stream Without Solids	Bio-processing ¹	Anaerobic lagoon	Anaerobic lagoon series	Anaerobic batch or unit processes	Methane generation	Plant and algal aquatic systems	Land Application of treated / untreated effluent	Vegetated buffers	Treatment wetland - raw waste stream	Treatment wetland - treated waste stream	Stormwater retention and reuse
Overall Rank	46	58	69	47	57	47	21	58	48	10	23	43	71	51	28	52	59

Technology Scores by Objective

Objective	Sums of Weighted Criterion Rankings																
Maximize Water Quality Benefit	10	10	14	4	16	16	18	0	4	0	0	10	14	4	4	14	22
Maximize Cost-Effectiveness	8	8	10	14	10	0	8	14	12	0	0	8	14	6	14	14	10
Maximize Ease of Implementation	12	22	30	14	14	16	20	30	18	4	12	10	28	28	2	14	20
Minimize Socio-Economic Impacts	12	12	9	11	10	8	7	9	3	3	10	8	7	7	5	5	5
Maximize Engineering Feasibility	4	6	6	4	7	7	8	0	11	3	1	7	8	6	3	5	2

1. Bioprocessing refers primarily to proprietary technologies using biological processes to manage the waste stream.

TABLE 8
 Combined Technology Systems Overall Rankings and Rankings by Each Objective

Overall Technology Scores					
Combined Technology	Field treatment- stormwater retention/ reuse-chemical treatment	Field treatment- stormwater retention/ reuse-wetland	Confinement for manure collection- solids separation- anaerobic digestion- land application- composting	Confinement for manure collection- solids separation- anaerobic digestion- land application- chemical polishing	Confinement for manure collection- Aerobic digestion- solids separation-land application-chemical polishing
Overall Score	76	65	50	45	31
Technology Scores by Objective					
Objective	Sums of Weighted Criteria Scores				
Maximize Water Quality Benefit	36	28	10	10	10
Maximize cost-effectiveness	12	8	4	4	4
Maximize Ease of Implementation	18	22	20	20	8
Maximize Engineering Feasibility	4	3	11	6	4
Minimize Socio-Economic Impacts	6	4	5	5	5

Confinement barn-based technology combinations may provide sidestream benefits and can provide complete capture of wastes if total confinement is achieved, but are much more expensive. For most dairies, very significant reconstruction would be required. The runoff P concentrations would remain elevated for years as the fields came into agronomic balance. At agronomic equilibrium, field runoff P concentrations would be in the range of 500 – 1000 ppb TP. In addition, complete confinement of the herd would be experimental for the Okeechobee basin, as it has never been attempted in south Florida.

The stormwater retention chemical treatment option has the greatest potential to reach the target goal (Table 9). The conceptual stormwater retention/chemical treatment design projected to achieve a 90 percent TP concentration reduction includes capture of “first flush” runoff and alum treatment as the last step before discharge of captured runoff water. To capture all runoff and treat all water not reused on the farm would require excessive amounts of land. Further, to achieve a final discharge concentration of 40 ppb would likely require a second alum treatment and settling prior to release and thus be prohibitively expensive. Nevertheless, the combined technology proposed comes considerably closer to the goal than any other options or combinations of options considered here.

TABLE 9
The Potential of Various Technologies and Farm Management Changes to Meet the 40-ppb TP Runoff Target

Technology	% Reduction	Initial TP (ppb)	Achievable TP (ppb)	% of goal attained	Reference
Feed P balance	10%	1200	1100	72.5	Van Horn (2001)
Agronomic Balance in the fields	40%	1200	700	82.5	Kidder (2001)
Soil Amendment	40%	1200	700	82.5	Matichenkov et al. (1999)
Constructed Wetland	55%	1200	500	87.5	Kadlec and Knight, 1996
Stormwater retention/Chemical Treatment	90%	1200	100	97.5	Metcalf & Eddy, 1979

Summary

The objectives and criteria defined in the first task of the project (SWET, 2001a) were weighted, and scores resulting from the weightings resulted in ranking of individual and combined technologies. Application of combined technologies that achieved the most rapid and greatest reductions in phosphorus concentrations in stormwater runoff using approaches that are relatively familiar to the dairymen ranked highest. Technologies that were less familiar and cost more tended to rank lower. The lowest ranking technologies were those that achieved the least in terms of reducing the availability or the movement of P, regardless of familiarity or cost.

While there are technologies that can achieve total capture of dairy waste phosphorus, none of the technologies that were considered economically feasible was projected to be able to reach the target goal of 40 ppb TP concentration in final runoff. A reduction of captured runoff to between 100 and 150 ppb after alum treatment is predicted at this time. An engineering design applying this technology is expected to predict exactly how much TP loading from the farms will be reduced and projected annual volume-weighted concentration. Monitoring before and after technology application on the selected farms will provide the performance evaluation and the basis for a final recommendation concerning wider application.

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