UCRL-PRES 207956

Allocation and Stakeholder Modeling of TMDLs

John Marano

Consultant to National Energy Technology Laboratory

Jeffrey Stewart

Lawrence Livermore National Laboratory

November 18, 2004

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Overview of NETL/LLNL TMDL Modeling Efforts

- ***Objectives***
- ***Allocation Modeling***
  - -*methodology & example*
  - -*next steps*
- ***Stakeholder Modeling***
  - -*methodology & example*
  - -*next steps*
- ***Application to TMDLs***
- ***Points of Contact***

Allocation & Stakeholder Modeling for TMDLs

Project Objectives

- ***Develop modeling tools to improve the science and allocation process for deciding TMDLs***
- ***Create models that can be used nationwide***
- ***Obtain validation and acceptance of tools from EPA***
- ***Initial focus of effort is on heavy metals TMDL for Dominguez Channel in the LA Basin***

- **Collaboration between:**

  LLNL – Lawrence Livermore National Laboratory

  NETL – National Energy Technology Laboratory

TMDL Allocation & Implementation

Issues & Options

- **Considerations include:**
  - **Cost, technical achievability & effectiveness**
    - economic performance
    - minimum cost / trading
  - **Political, social & economic factors, equity**
    - balance between WLAs & LAs
    - ability to pay
    - equal concentrations, loads, reductions, geographic, etc.
  - **Administrative policies & procedures**
    - ability to translate WLAs into NPDES permitting
    - ability to translate LAs into implementation plans
  - **How to engage stakeholders**

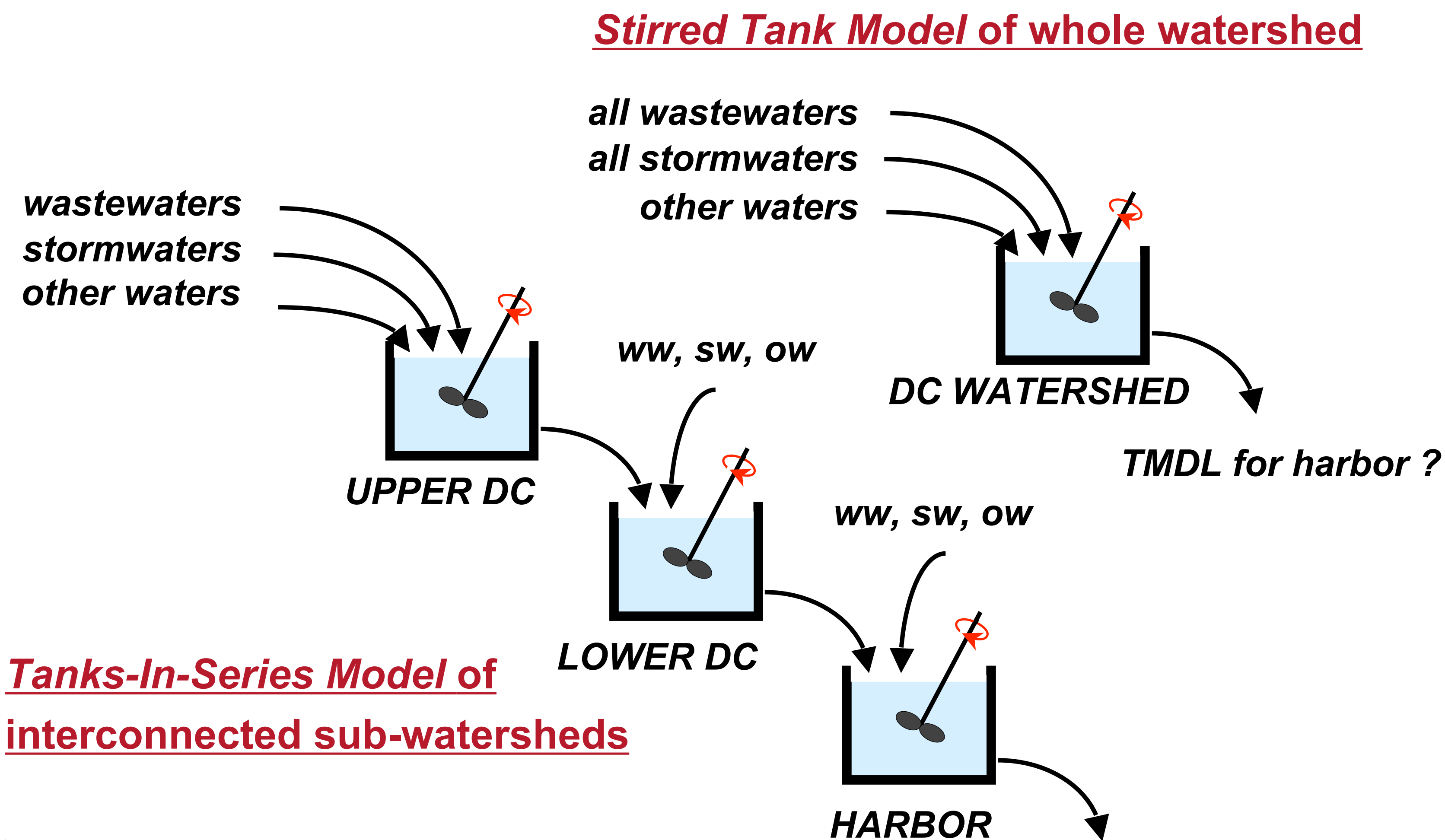
Inclusion of costs in TMDLs is required but has been *ad hoc*

TMDL Allocation
Modeling Decisions

- **Material balances for pollutants of interest**
  - **must consider spatial & temporal effects**
- **Spatial effects**
  - **Predict rates for all sources and sinks,**
    e.g. "active" sediments
  - **Transformation of pollutants**
    e.g. Hg (metallic) ↔ Hg (ionic) ↔ Hg (organic)
    e.g. dissolved or total metal
- **Temporal effects**
  - **Instantaneous or average concentrations**
    e.g. 1st 30 min. of rain event
    e.g. annual vs. seasonal

Data & Results of Hydrology Modeling are required for Allocation Modeling

Levels of Aggregation of Watershed



Simplified Waste Load Allocation Example

Assumptions

- **Reduce "heavy metal" from industrial and municipal wastewater dischargers**
  - stirred-tank model of watershed
  - only wastewater treatment considered
  - 2.5 μg/L achievable using BACT
  - anti-degradation rule in effect
  - only treat portion of wastewater to meet target
  - technology will reduce treated water conc. to "zero"
  - wastewater discharges are kept constant
  - treatment costs not function of concentration

Simplified Waste Load Allocation Example
Scenarios Considered

- **Allocation Options**
  1. Equalization of Effluent Concentrations
  2. Minimum Total Treatment Cost
  3. Equal Percent Removal
  4. Percent Removals Proportional to Raw Loads
  5. Equalization of Waste Loads
  6. Equalization of Waste Load Reductions
  7. Equalization of Costs for Reductions
- **Impacts**
  - Trading
  - Increased Discharges

Simplified Waste Load Allocation Example

Current Loadings

Wastewater Source	Flow: Discharge MM gpd	Total Metal: Concentration µg/L	Total Metal: Load kg
Discharger 1 - Industrial	650.0	18.0	16176
Discharger 2 - Municipal	175.0	24.0	5807
Discharger 3 - Municipal	40.0	45.0	2489
Discharger 4 - Industrial	25.5	3.0	106
Discharger 5 - Industrial	10.5	3.2	46
Discharger 6 - Industrial	8.0	4.5	50
Discharger 7 - Industrial	2.8	4.0	15
Discharger 8 - Industrial	1.3	1.2	2
Other Dischargers*	60.0	5.0	415
Total	973.1	12.0	25106

*All dischargers less than 1.0 MM gpd

Simplified Waste Load Allocation Example

Equalization of Effluent Concentrations

	Waste Load Allocation			Load Reduction			Cost Model	
	Flow	Total Metal		Flow	Total Metal		Annualized Cost	
Wastewater Source	Discharge MM gpd	Concentration μg/L	Load kg	Treated MM gpd	Absolute kg	Percentage %	$/day Total	M $/kg Removed
Discharger 1 - Industrial	650.0	2.5	2247	559.7	13929	86.1%	1679166.67	44.00
Discharger 2 - Municipal	175.0	2.5	605	156.8	5202	89.6%	470312.50	33.00
Discharger 3 - Municipal	40.0	2.5	138	37.8	2350	94.4%	160820.55	24.97
Discharger 4 - Industrial	25.5	2.5	88	4.3	18	16.7%	20970.96	434.22
Discharger 5 - Industrial	10.5	2.5	36	2.3	10	21.9%	11424.20	410.34
Discharger 6 - Industrial	8.0	2.5	28	3.6	22	44.4%	17594.21	290.30
Discharger 7 - Industrial	2.8	2.5	10	1.1	6	37.5%	5248.94	329.93
Discharger 8 - Industrial	1.3	1.2	2	0.0	0	0.0%	0.00	N/A
Other Dischargers*	60.0	2.5	207	30.0	207	50.0%	270000.00	475.20
Total	973.1	2.5	3361	795.4	21745	86.6%	2635538.03	44.24

*All dischargers less than 1.0 MM gpd

anti-degradation

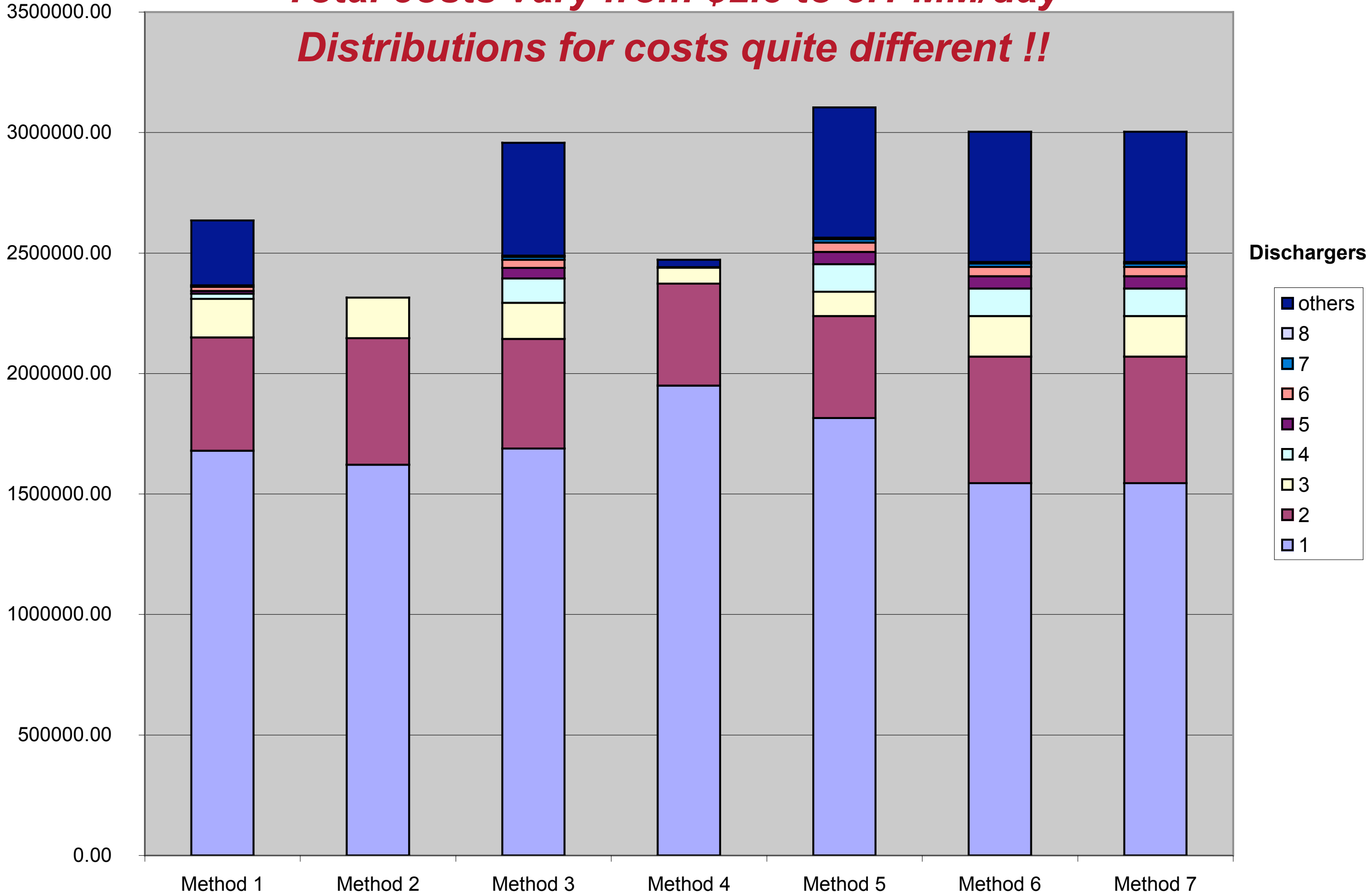
Load Reduction = 21745 kg/yr (86.6%)
(same in all scenarios)

Simplified Waste Load Allocation Example

Treatment Costs Summary

Total costs vary from $2.3 to 3.1 MM/day

Distributions for costs quite different !!



Simplified Waste Load Allocation Example

Impact of Trading

- **Scenario 2 is lowest cost option for allocations**
- **All other scenarios present opportunity for buying & selling load reductions based on the $/kg cost of each discharger to remove pollutant**
- **For example, if Scenario 1 is used:**
  - Discharger 1 will be willing to increase treatment beyond required, if someone is willing to pay them greater than $44,000 per kg reduction
  - Discharger 4 will want to reduce treatment below required, if someone is willing to charge them less than $434,000 per kg reduction
- **Market will be driven toward optimal cost structure *i.e.* Scenario 2**

Simplified Waste Load Allocation Example
Effect of Increased Discharges

- **Depends on whether pollutant criteria are based on maintaining discharge concentration or waste load**
- **For example, consider results for Scenario 1 with:**
  - 10% increase in flow for all dischargers
  - Untreated concentration & cost to treat unchanged
- **If discharge concentration may be maintained**
  - Only must treat additional flow
  - Costs increase by $264,000 per day
- **If Waste Load may not increase**
  - Must treat more of original discharge to reach lower concentration
  - Costs increase by $582,000 per day

Simplified Waste Load Allocation Example
Conclusions

- How allocation is done has large impact on total costs and who pays what
- In theory trading, or some other mechanism can drive costs down and still achieve same overall reductions
- How allocation is applied, *i.e.* total mass or concentration-based waste loads, has big impact on future treatment costs if water usage increases

Status of Allocation Modeling for Dominguez Channel
Next Steps

- Need to set up model using “real” information on Dominguez Channel watershed
- Need to include non-point sources (run-off)
- Need to consider discrete rain events
- Need to expand to “multi-tank” model of watershed
- Need to also consider implementation schedule and effectiveness of treatment options
- Need to provide database of pollution control technologies & strategies

Development of a Stakeholder Preference Model

1. Identify stakeholder groups
2. Conduct interviews to identify important "relevant" issues
3. Categorize issues into attributes with distinct differences
4. Review structured list of issues and attributes with stakeholders to assure differences are easily understood
5. Conduct stakeholder interviews to calibrate issues and attributes
6. Develop software model with issues and attributes data
7. Conduct preference tradeoff with stakeholder groups
8. Use model to evaluate proposed implementation plans

Development of a Stakeholder Preference Model: Steps 1-3

- Identify stakeholders through information the decision makers provide and stakeholder references
- Conduct interviews to determine broad list of stakeholders' concerns
- Reduce issues list to those that are "relevant" to a possible implementation plan and review with stakeholders to explain why some issues may have been excluded from the list

Stakeholder understanding and agreement on the final list is important before preceding to the next phase

Development of a Stakeholder Preference Model: Step 4

- Develop and review structured list of issues and attributes to ensure that they reflect both the important concerns and that there are well-defined differences between each attribute. It is important to develop distinctions between attributes. If the difference between attributes is too large or too small, tradeoffs become meaningless

Development of a Stakeholder Preference Model: Step 5

- **Calibrate issues and attributes with stakeholders interviews:**
  - **Example:** Time Options either 1 year, 3 years, 5 years or 10 years.
  - Situation: A company normally requires 3 years to upgrade a facility. Less than 3 years requires serious disruptions. 5 or 10 years means the issues can be considered a lower priority and delayed.
  - **Calibration:** A company may determine 10 years should be given the highest utility (preference) of 1.0 since it can postpone action for several years. The difference between 5 and 10 years is not significant (a shorter delay period before acting) and may be given 0.9. The next option is 3 years which requires immediate but not urgent action and therefore may be given 0.7. The selection of 1 year would disrupt their normal business operation and may be assigned 0.1.

    These numbers are explained to and selected by the stakeholder and will be used to create a utility curve that will inform the decision maker how a stakeholder's preferences change as the time line changes.

    A similar exercise is used for each issue. Slight variations occur when the options are discrete or continuous.

Development of a Stakeholder Preference Model: Steps 6-7

- **The issues and attributes are inserted into the stakeholder preference model**
- **To establish the weights among competing issues, interviews are conducted requesting the decision makers to make tradeoffs between different issues:**
  - **Example:** Time Options of 1 year, 3 years, 5 years or 10 years
    Cost Options ($ million) of $1, $3 , $5 or $10 for equipment upgrades
  - **Situation:** Repeating the time options from the previous slide, a company also has multiple cost options for equipment upgrades. The site manager has an annual budget to cover up to $ 2 million in facility upgrades. Amounts above $ 2 million and below $ 4 million are made be the facility Vice President who requires 18 months notice. Amounts above $4 million dollars requires approval from the board of directors and may reflect poorly on the local site management.
  - **Calibration:** The interviewer asks the stakeholder to choose the most preferred combination (best and worst) option of the two listed- Option A: Time = 1 year and Cost $ 1 million dollars or Option B: Time = 10 years and Cost = $10 million dollars. Assume Option A is preferred. The next question would require the stakeholder to make Option B as attractive as Option A by only reducing time. The answer may be that Option B would be equal to option A if it offered a Time of 3 years and a Cost of $10 million dollars. A series of these exercises allow us to determine the stakeholder's relative preference of cost versus time or any other matched pairs. This establishes relative weights among issues.

Illustrative Implementation Plan Options by Issues (Measure)

Benign Foot Print	Range
Pristine	1
Discharges below requirement	2
Discharges meet requirement	3
Discharges occasionally exceed requirement	4
Discharges regularly exceed requirement	5

Reduction in Capacity	Range
Percent reduction	0
Percent reduction	1
Percent reduction	2
Percent reduction	….
Percent reduction	….
Percent reduction	15

Timeline	Range
Start Implementation	1 year
Start Implementation	2 years
Start Implementation	….
Start Implementation	….
Start Implementation	10 years

Upgrades to facility	Range
Cost in million(s)	1
Cost in million(s)	2
Cost in million(s)	….
Cost in million(s)	….
Cost in million(s)	10

Illustrative Implementation Plans Selected for Evaluation

Pro Business

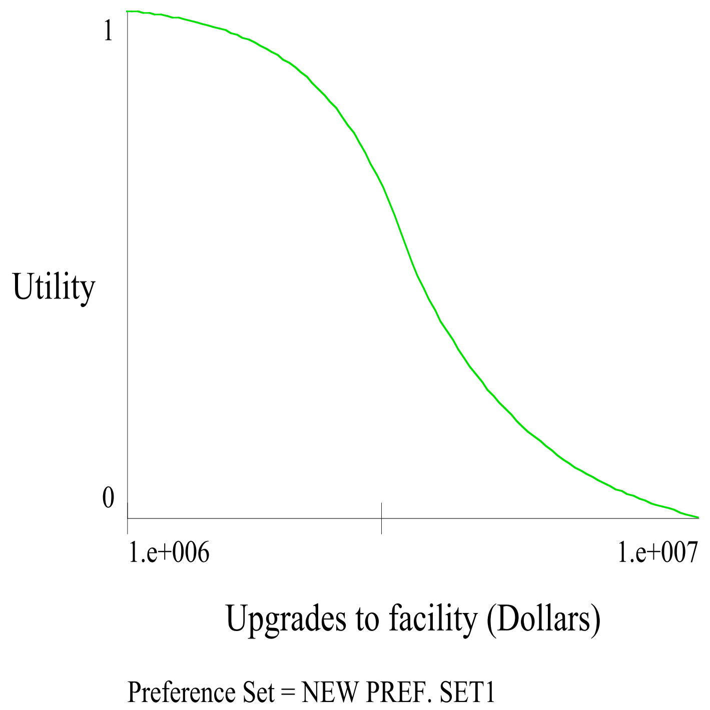
- Discharges meet requirements
- Reduction in capacity = 0
- Timeline = 5
- Upgrades to facility = $1,000,000

Pro Environment

- Pristine watershed
- Reduction in capacity = 10%
- Timeline = 2 years
- Upgrades to facility = $5,000,000

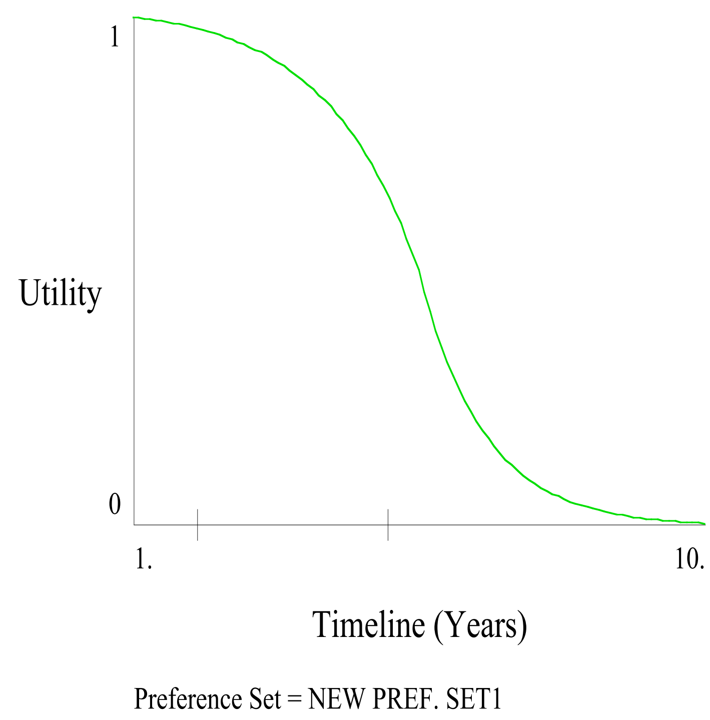
Cost to Upgrade a Facility

- Initial interviews identified costs to range between $1 to $10 million dollars
- Follow up interviews identified much more concern once cost exceeded $3 million
- Once costs exceeded $7 million dollars, the importance of each additional dollar diminishes



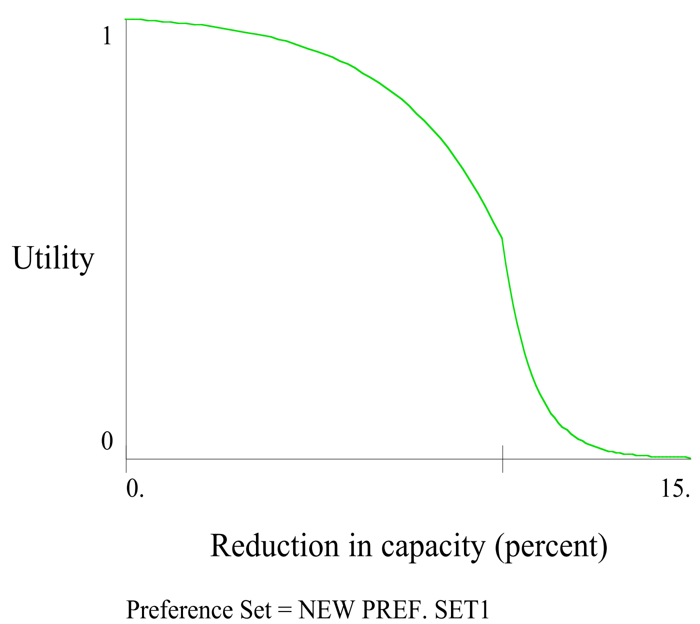
Time to Implement Plan

- Interviews identified an implementation schedule taking longer than 3 ½ years as a significant concern
- Once the plan exceeded 7 years, each additional year became less significant



Reduction in Capacity

- The first 6-7 percent reduction is of minimal concern
- After 7 percent reduction, concern increases significantly
- The last 2-3 percent reduction has little significance



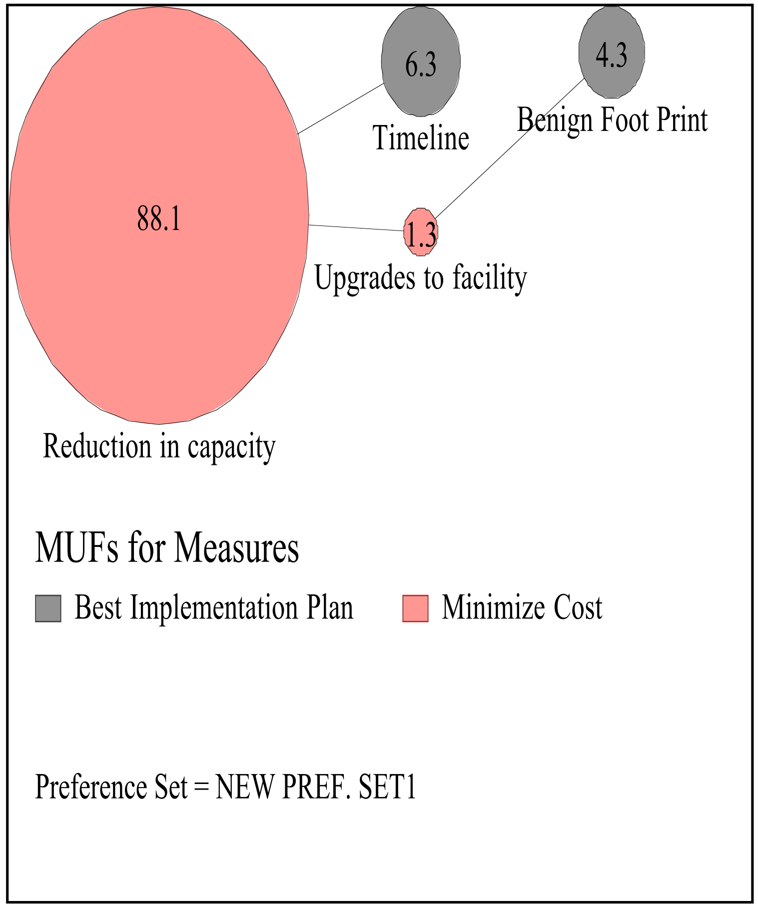
Environmental Goals

- The questions asked in this section allowed the stakeholder to set a range above and below the regulatory requirement
- A step function expresses the choices instead of a continuous function

Label	Utility
Pristine	1.0
Discharges below requirements	.90
Discharges meet requirements	.60
Discharges occasionally exceed requirement	.25
Discharges regularly exceed requirements	0

Decision Makers Establish Weights and Tradeoffs

- The decision maker has selected the importance of each measure relative to the others
- Lines identify measures that were formally traded and the numbers represent the relative weight given to each measure

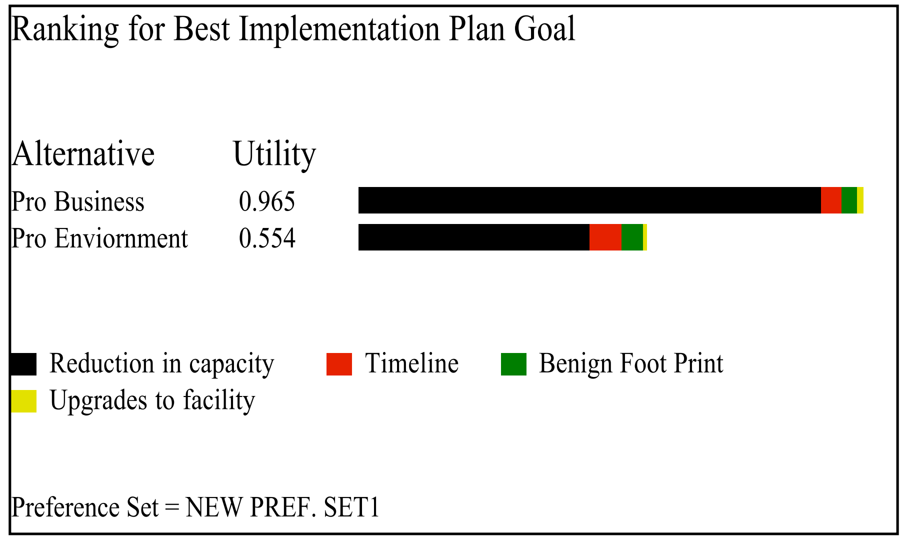


Decision Makers Weight Selection Option

- **Weight can be selected by:**
  - Equal weights by stakeholder issues
  - Equal costs among stakeholders
  - Minimum costs
  - Highest environments criteria
  - Local economic concerns
  - Equal reductions or concentrations
  - Etc.

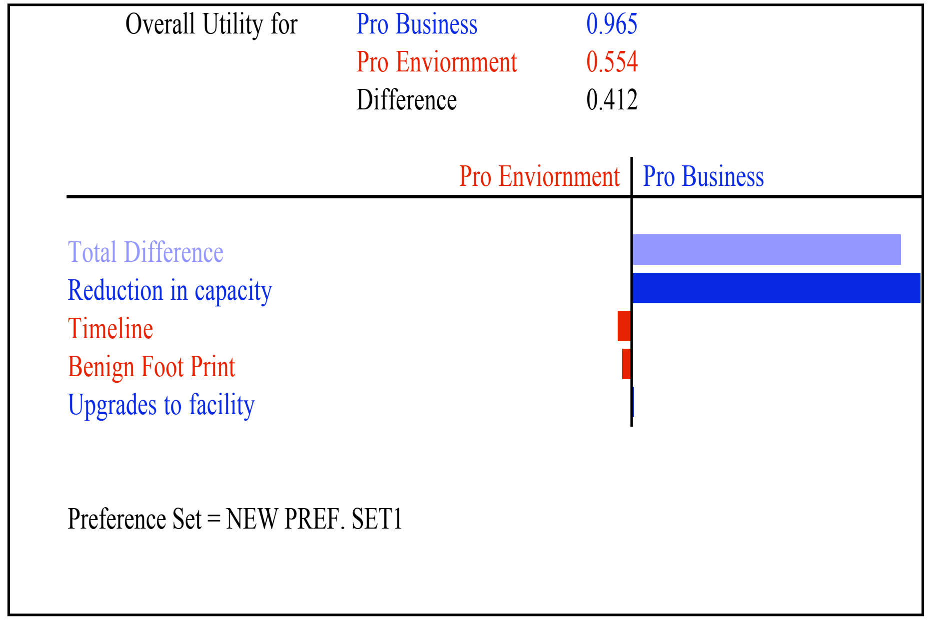
Comparison Between Plans

- Two ranked plans show individual and overall utilities
- Decision makers have selected a much higher weight for cost issues
- Timeline and environment have better individual utilities in the pro environment plan but the overall utility value is lower than the pro business plan due to the higher concern for costs expressed in the weighting by the decision makers



Comparing Plans

- The graph illustrates the difference between competing plans by each issue (measure).



Steps Involved in Producing a TMDL

(Total Maximum Daily Load)

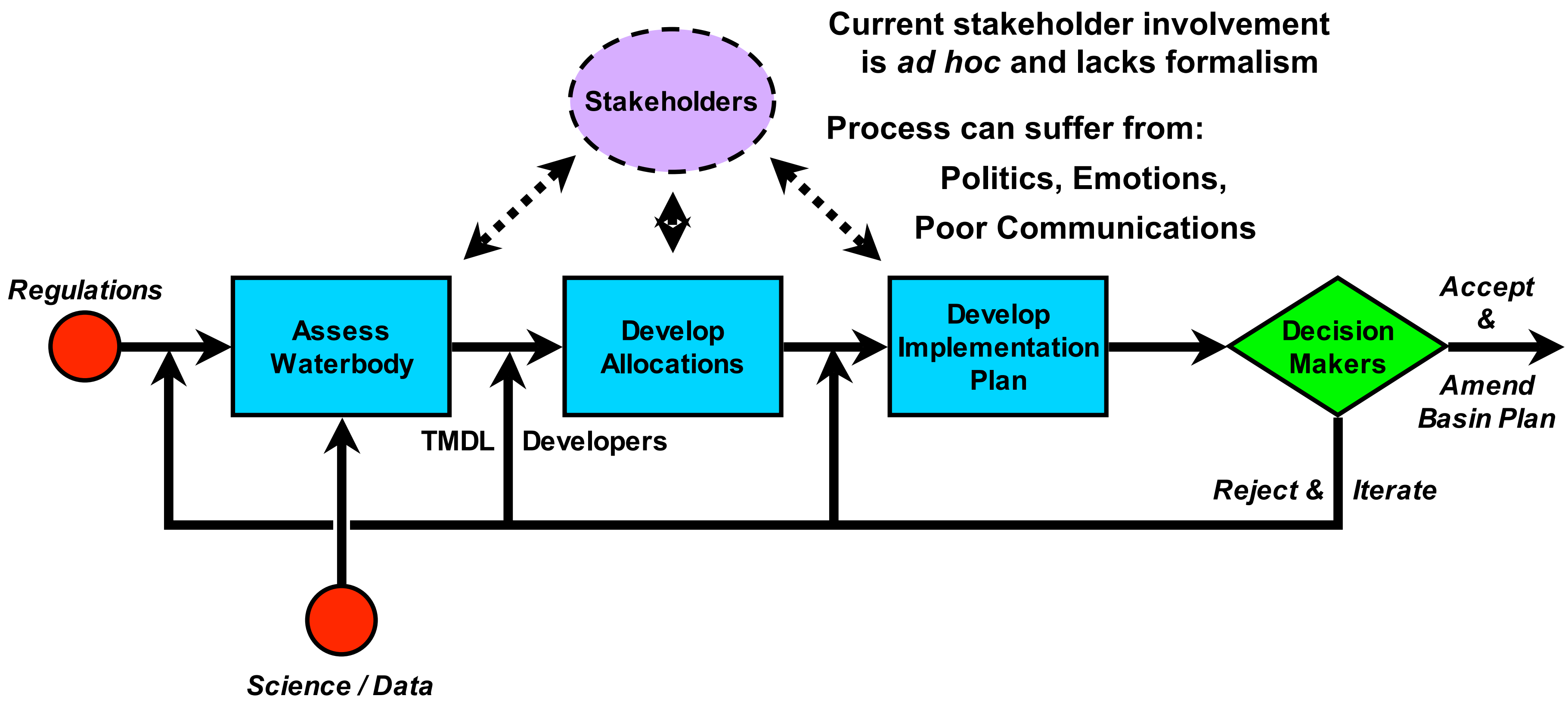
- ***Stakeholder Involvement* –** Stakeholders become involved in TMDL development through local groups working with Regional Water Quality Board staff. Their interests range from pursuing science to support TMDLs to figuring out how to implement new management approaches
- ***Water Body Assessment* –** Pollution sources and loads are determined, and their overall effect on the water body is assessed
- ***Develop Allocations* –** Based on the assessment, pollutant loads are allocated for each source. The allocations must be designed so that the water body will attain applicable water quality standards

CA State Water Resources Control Board P/F0121(April2001)

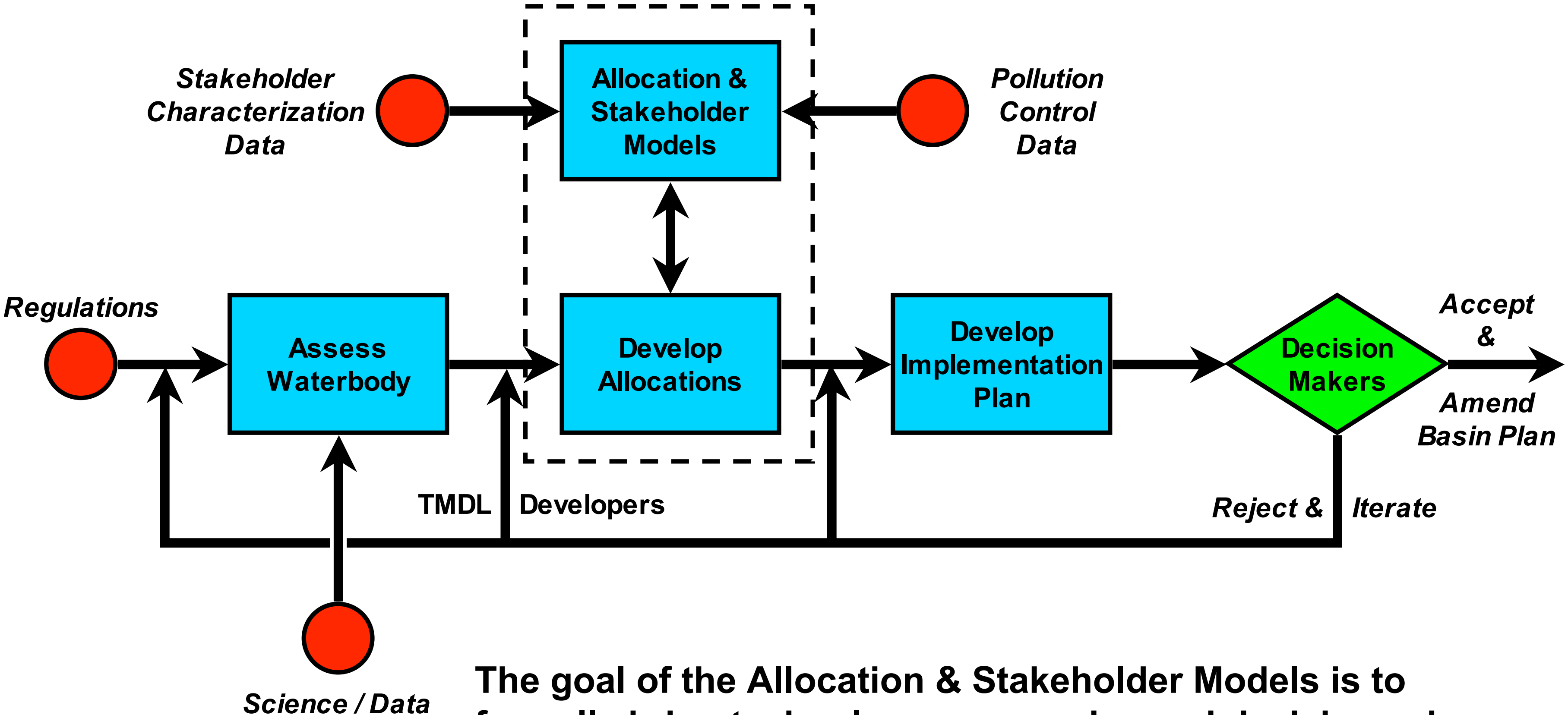
Steps Involved in Producing a TMDL
(Total Maximum Daily Load)

- ***Develop Implementation Plan* – Describes the approach and activities required to ensure the allocations are met. The plan identifies enforceable features and triggers for Regional Board action**
- ***Amend Basin Plan* – Before a TMDL is enforceable it must be incorporated into the appropriate Basin Plan by amending the Basin Plan in accordance with state law**

Current Approach to TMDL Development



An Integrated Approach to TMDL Development



The goal of the Allocation & Stakeholder Models is to formally bring technology, economics and decision science into the allocation process --- *improving communications & reducing emotions!*

Steps in Integrated Approach to TMDL Development

1) Developer uses results of water body assessment to establish watershed and/or sub-watershed TMDL
2) Developer establishes criteria for WLAs and LAs for point and non-point sources

   e.g. equal effluent concentrations, equal loads, etc.

   And Implementation Schedule
3) Developer runs Allocation Model – evaluates cost & effectiveness of several allocation strategies and timelines for meeting watershed TMDL
4) Based on interviews with stakeholder groups, developer creates stakeholder-values preferences metrics

Steps in Integrated Approach to TMDL Development

5) **Developer runs Stakeholder Model using output from Allocation Model & preference metrics – establishes individual stakeholder satisfaction (utility)**

6) **Developer compares individual and overall stakeholder acceptance of allocations & schedule**

7) **Two approaches are available for selection:**

   Feedback Mechanism **–** options considered one at a time, deficiencies identified, option is modified or new option selected, process repeated

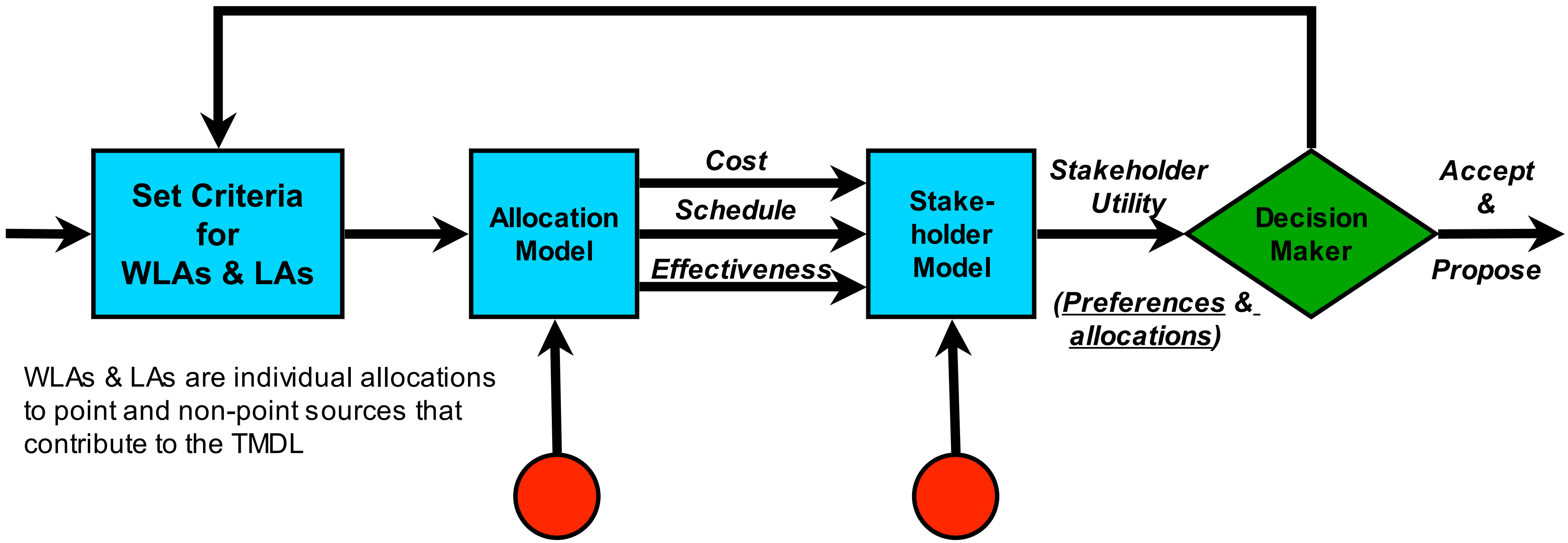
   Feed-forward Mechanism **–** multiple options developed & evaluated, best option selected

8) **Based on the selected allocation option & schedule, an Implementation Plan is developed and forwarded for final approval**

An Integrated Approach to TMDL Development

Feedback Mechanism

Iterate to maximize stakeholder acceptance



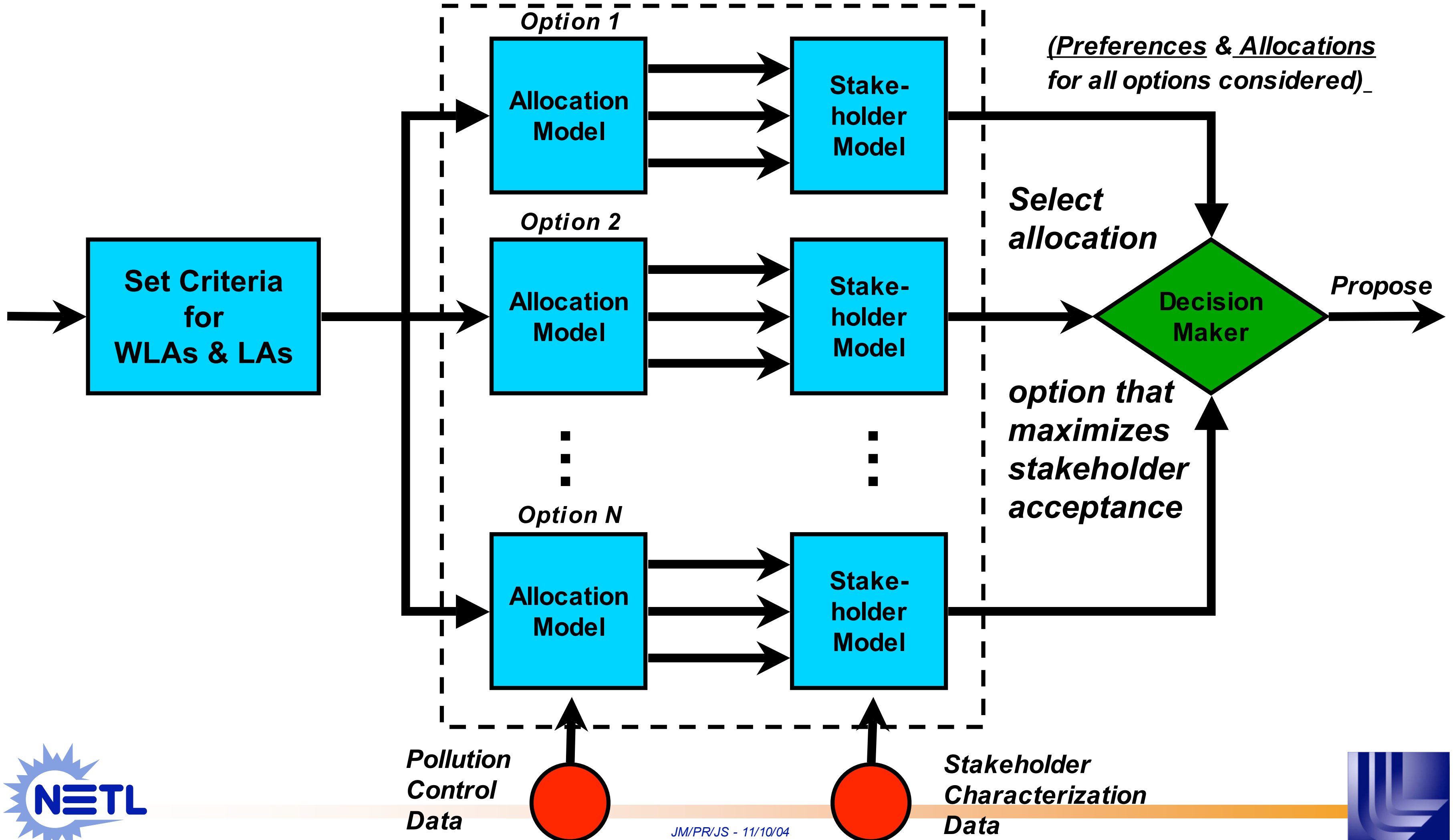
WLAs & LAs are individual allocations to point and non-point sources that contribute to the TMDL

Pollution Control Data:
technology performance & cost
implementation schedule

Stakeholder Characterization Data:
individual stakeholder preferences – metrics developed from interviewing process

An Integrated Approach to TMDL Development

Feed Forward Mechanism



Points of Contact

Kathy Stirling
Project Manager
National Energy Technology Laboratory
One West Third Street, Suite 1400,
Tulsa, Oklahoma 74103-3519
918-699-2008
kathy.sterling@netl.doe.gov

Jeffery Stewart
Group Leader: Applied Statistics and Economics
7000 East Avenue L-644
Lawrence Livermore National Laboratory
Livermore, CA 94550
925-422-3752
stewart28@llnl.gov

Patricia Rawls
Project Manager
National Energy Technology Laboratory
626 Cochran Mill Road
Pittsburgh, PA 15236
412-386-5882
patricia.rawls@netl.doe.gov

John Marano
Consultant to
National Energy Technology Laboratory
1065 South Lake Dr.
Gibsonia, PA 15044
4724-625-5466
marano@zoominternet.net