Alternatives to Glyphosate for Vegetation Management in Los Angeles County

Technical Committee Report

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Southern California Coastal Water Research Project

SCCWRP Technical Report #1103

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January 2020
Technical Report 1103

MEMBERS OF THE TECHNICAL COMMITTEE WORKSHOP

Top row, left to right: Mark Lombos, Daniel Schlenk, Kenneth Schiff, Dennis Chiotti
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Photo date: October 16, 2019

EXECUTIVE SUMMARY

Glyphosate is the most widely used herbicide in the world. According to the California Department of Pesticide Regulation, over 113,000 pounds of glyphosate active ingredient was reported as used in Los Angeles County during 2017. In May 2019, the Los Angeles County Board of Supervisors restricted the use of glyphosate at all County facilities and instructed County Public Works to convene an expert panel to explore alternatives for vegetation control. Part of that process was to engage an independent Technical Committee to evaluate the advantages and disadvantages of each alternative method proposed by the County. This report summarizes the findings of the independent Technical Committee.

The independent Technical Committee was comprised of leading experts in the fields of integrated pest management, weed science, ecotoxicology, human toxicology, and a municipal practitioner. The Technical Committee reviewed 12 alternative methods for eight different criteria, provided by County staff.

The Technical Committee had a number of findings:

- **Chemical methods are amongst the most effective, safest, and least expensive methods available**
  All of the post-emergent and pre-emergent herbicides proposed by the County are evaluated for worker and environmental safety, then registered with the US Environmental Protection Agency and the California Department of Pesticide Regulation. These chemical methods were ranked amongst the safest and most effective methods for glyphosate replacement. However, all of the chemical methods require specific training and knowledge of when, where and how to apply each of these chemicals. There are clearly times and places where they are not the most effective method. Herbicide selection for the type of plant, time of year, application geography and landscape, presence of non-target organisms, application method, public notification system, and climate, all play an important role. Proper training and a well-developed Integrated Pest Management Control Plan is crucial for utilizing these methods.

- **Mechanical methods can be effective, but have their drawbacks**
  Mechanical methods, where feasible, can be effective at vegetation management as a replacement for glyphosate. These methods are time-tested and generally have an easier training curriculum compared to chemical methods. Optimal applications include small areas, along fence lines, or weed management close to desirable sensitive plants. However, chemical methods are far more effective at eradication of weeds than mechanical methods, tend to be far less labor intensive, and typically are less expensive. For example, mowing is a non-selective destructive method, by definition damaging habitat and disrupting existing ecosystems. Moreover, mowing does not kill roots and plants will immediately begin the process of re-growing, necessitating the re-application of this method in a relatively short amount of time (hence, the increased costs). Finally, there is some modest risk of fire if mechanical methods like mowing strike a rock or exposed metal object causing sparks.

- **Physical methods are generally impractical**
  Hand removal methods were deemed generally impractical as a replacement for glyphosate because they are labor intensive. This is particularly true in an area as large

as Los Angeles County. In addition to cumulative labor costs, work force development was also discussed as a factor. With this overarching finding in mind, the Technical Committee identified the advantages of physical methods including mulching, which promotes moisture retention, reduces erosion, provides some habitat improvement, while minimizing surface area for weed germination.

- **Biological methods are infeasible at large scales**
  Biological methods were deemed infeasible as a replacement for glyphosate because of their limited applicability. Generally speaking, the challenges of grazing far outweigh the benefits. Similar to mowing, grazing does not kill roots and treated areas will re-grow. Moreover, there are a variety of unintended consequences from grazing including contributions of fecal matter exacerbating bacteria pollution problems, increasing erosion, and compromising public safety when animals break free from the treatment area. With these limitations in mind, advantageous applications were identified, such as goats on steep hillsides where mowing is impractical.

- **Keeping a well-stocked toolbox of methods as part of the County's vegetation management plan will be important for future success**
  Since no method is perfect, and every method has its optimal application, the Technical Committee recognized that the County needs a toolbox approach. The key is to ensure that the County managers know when and where each method is best applied, and that staff is well-trained on executing each method to protect themselves and their co-workers, the public, and wildlife. Updates to the County's Vegetation management Plan and Integrated Pest Management Plan are likely outcomes.

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BACKGROUND

Los Angeles County has an active and effective vegetation management program to minimize the risk from invasive plants, infrastructure damage, public safety, and flood control. The various County Departments utilize the County's Best Management Practices for Vegetation Control as guidance in implementing these activities (Bell and Lehman 2015). This guidance includes a wide variety of methods including physical methods such as hand pulling or hoeing, mechanical methods such as mowing or tilling, biological methods such as grazing, and chemical methods including post-emergent herbicides or pre-emergent pesticides. Post-emergent pesticides are applied to plants after they have sprouted while pre-emergent pesticides are applied to the ground to prevent sprouting.

Glyphosate [N-(phosphonomethyl) glycine], with the common trade name Round-Up, is one of the most common post-emergent herbicides used in the world (Woodburn 2000). This low-cost, non-selective, translocating herbicide has been in use since 1974 and 1.6 billion kilograms (4 billion pounds) of glyphosate active ingredient was applied in the United States in 2015, approximately 19% of estimated global use of glyphosate (Benbrook 2016). According to the California Department of Pesticide Regulation (CDPR), 113,522 pounds of Round-Up™ active ingredient was applied in Los Angeles County during 2017 (https://calpip.cdpr.ca.gov/main.cfm)[1].

In March 2019, the Los Angeles County Board of Supervisors temporarily ceased the use of glyphosate at all County facilities until receiving further information on current glyphosate use and alternative vegetation controls. In May 2019, after receiving a response from County Public Works, the Board of Supervisors directed all County Departments to ban the use of glyphosate and instructed Public Works, in conjunction with County Counsel, the Departments of Public Health, Parks and Recreation, Beaches and Harbors, and the Agricultural Commission to convene a panel of experts to explore options for vegetation management, especially in areas where the use of traditional alternatives to glyphosate-based products is problematic, then report back to the Board of Supervisors.

In September 2019, Public Works provided clarification to all County Departments to cease use of all herbicides in vegetation management, including non-glyphosate-based products, until the completion of the alternatives evaluation report and further action by the Board of Supervisors.

Objectives of this Report

The objectives of this report are to document the findings of the independent Technical Committee tasked with identifying the advantages and disadvantages of non-glyphosate alternative methods for vegetation in Los Angeles County. The list of alternative methods was provided by the County, included chemical and non-chemical methods, and included glyphosate as a point of reference. Likewise, the list of evaluation criteria was provided by the County, although the option for adding evaluation criteria was allowed. This report does not provide recommendations for the preferred alternative(s); recommended alternatives are the role of the County.

[1] Non-commercial use, such as by homeowners, is not reported to CDPR and is therefore not included in the total.

APPROACH AND METHODS

Formation of the County Review and Recommendation Process

In July 2019, County Public Works initiated a two-step review system for alternatives to Glyphosate. The first was the creation of an Advisory Committee, which consists of the managers for the various Departments within the County responsible for vegetation management and implementing the Vegetation Control Plan. The members of this Advisory Committee include:

- Public Works (stormwater, transportation, waterworks)
- Agricultural Commissioner
- Fire and Forestry
- Beaches and Harbors
- Custodial Landscaping/Facilities Management
- Parks and Recreation

These County Departments conduct a large variety of vegetation management operations such as wildland control, roadside control, facilities maintenance, fire suppression, habitat restoration, flood control, parks and other public places, amongst others. Almost all applications are land based, although some water-based applications exist including flood control channels and non-body contact lakes.

One primary role of the Advisory Committee was to prepare the list of potential alternatives that could be used for glyphosate, particularly since these are the County Departments who will be implementing the alternatives.

The second tier of the review process is a Technical Committee, comprised of experts in a variety of disciplines, who are not county employees or have vested interests in the outcomes of the review. Led by an impartial facilitator, these subject matter experts provide a review of the advantages and disadvantages of each alternative. The areas of expertise include:

- Human toxicology
- Aquatic toxicology
- Integrated Pest Management
- Weed science
- Local Practitioner

The primary role of the Technical Committee is to provide expert opinion on the alternatives proposed by the Advisory Committee. To that end, the disciplines and the members selected for the Technical Committee were vetted by the Advisory Committee.

Ultimately, the alternatives recommended to the Board of Supervisors will be decided by the staff from the County Department of Public Works, who are members of both committees.

Technical Committee Selection

The expert selection process followed an impartial three-step process:

1) The facilitator nominated a minimum of three individuals for each area of expertise selected by the Advisory Committee

2) The Advisory Committee reviewed and ranked the three nominees within each area of expertise, including an optional veto over any single nominee
3) The facilitator contacted each nominee, in order of ranked preference, to recruit them onto the Technical Committee
4) The facilitator would confirm each Technical Committee member with an official letter of invitation, and an official return affirmation

The number one ranked expert confirmed their participation for each discipline (Table 1).

Table 1. Members of the Technical Committee

Area of Expertise	Name (Affiliation)
Integrated Pest Management	Dr Cheryl Wilen (University of California)
Weed Scientist	Dr Travis Bean (University of California)
Ecotoxicologist	Dr Dan Schlenk (University of California)
Human Toxicologist	Dr Len Ritter (University of Guelph)
Practitioner	Dennis Chiotti (City of Irvine)

The Alternatives

The Advisory Committee prepared a list of potential alternatives to glyphosate in July 2019 based on the Vegetation Control Plan and a survey of the various County Departments on the Advisory Committee. The survey included which activities are currently used and their relative value. The results of this survey are attached as Appendix A. The survey was reviewed by the Advisory Committee and the final list of 12 different alternatives were provided to the Technical Committee. These alternatives fall into one of four method categories (Table 2). The County Agricultural Commissioner and Integrated Pest Manager prepared a list of all potentially used chemicals in the County. These herbicides fall into one of three categories (Table 3).

Table 2. List of alternative methods for Glyphosate removal reviewed by the Technical Committee

Physical	Mechanical	Biological	Chemical
Hand, Hoe Mulching Weed mat	Mowing Flaming Steaming Steaming with Foam Tillage	Grazing	Post-emergent herbicides Pre-emergent herbicides Organic herbicides

Table 3. List of herbicides to be evaluated by the Technical Committee.

Post-Emergent Herbicides	Organic Herbicides (all post-emergent, non-selective)	Pre-Emergent Herbicides
[1]Diquat (Reward) [1]Glufosinate (Cheetah) [2]Fluazifop-P (Fusilade) [2]Clethodim (Vaquero) [3]Triclopyr (Vastlan) [3]Aminopyralid (Milestone) [3]Clopyralid (Transline) [4]Imazapyr (Polaris, Habitat)	Caprylic Acid Pelargonic Acid Acetic Acid Limonene Clove Oil-Cinnamon Oil Clove Oil-Citric Acid	Aminopyralid Indaziflam Isoxaben Chlorsulfuron Dithiopyr Oryzalin Prodiamine Pendimethalin Sulfometuron-methyl

[1]Non-selective /Non – Translocating
[2]Selective – Grass control
[3]Translocated Selective – Broadleaf control
[4]Translocated Non-selective

Charge Questions to the Technical Committee

The Advisory Committee worked with the County Public Works to create four charge questions for the Technical Committee:

1) What are the advantages and disadvantages of each alternative proposed by Los Angeles County? At a minimum, advantages and disadvantages should consider the following factors:
   - Worker safety
   - Public safety
   - Environmental concerns including risk to wildlife
   - Fire risk
   - Equipment recommendations (if any)
   - Ease of implementation
   - Training requirements and protocol development
   - Start-up and ongoing costs, including labor, equipment, and supplies
   - Worker and property liability
2) What are the most important best practices/limitations for implementing each alternative? Some practice areas to consider include access, maintenance and restoration success, reduced risks to native plants, existing practices and minimizing the potential for negative public reactions to alternative method disadvantages (i.e., spraying of alternative pesticides, increased dust, etc.)
3) Are there other alternatives not on the list that should be considered?

The expectation of the Technical Committee was to answer each of these questions for each alternative provided by the Advisory Committee.

Technical Committee Review Process

In preparation for the Technical Committee meeting, an issue paper was produced providing the administrative background, the County's Vegetation Control Plan, the list of glyphosate alternatives for vegetation management, and the Committee's charge questions.

The Technical Committee met on October 16, 2019. The agenda included:

1) Scope of the Problem and Charge to the Technical Committee
2) Chemical alternatives evaluation
3) Mechanical alternatives evaluation
4) Physical/Biological alternatives evaluation
5) Summary of alternatives evaluation and Report development process

The Technical Committee then prepared an oral report to the Advisory Committee, which was provided on November 19, 2019. After feedback from the Advisory Committee, the Technical Committee prepared this report. This report reflects the opinions of the Technical Committee and was not approved by County Public Works or the Advisory Committee.

TECHNICAL COMMITTEE OUTPUT

Comparison of Alternative Methods

The primary findings of the Technical Committee are summarized in Table 4. The Technical Committee used best professional judgement and their cumulative 100+ person-years of experience to rank each of the 12 methods for the 8 evaluation criteria. The rankings ranged from 1 to 5, with the following the rank definitions:

- 5 = Optimal
- 4 = Preferable
- 3 = Acceptable
- 2 = Poor
- 1 = Unacceptable

At the conclusion of ranking each method for each criteria, the Technical Committee provided some overarching interpretation:

- **Chemical methods are amongst the most effective, safest, and least expensive methods available**
  Despite being ranked the amongst safest and most effective methods for glyphosate replacement, all of the chemical methods require specific training and knowledge of when, where and how to apply each of these chemicals. There are clearly times and places where they are not the most effective method. Herbicide selection for the type of plant, time of year, application geography and landscape, presence of non-target organisms, application method, public notification system, and climate, all play an important role. Proper training and a well-developed Integrated Pest Management Control Plan is crucial for utilizing these methods.

- **Mechanical methods can be effective, but have their drawbacks**
  Mechanical methods, where feasible, can be very effective at vegetation management as a replacement for glyphosate. These methods are time-tested and generally have an easier training curriculum compared to chemical methods. Optimal applications include small areas, along fence lines, or weed management close to desirable sensitive plants. However, chemical methods are far more effective at eradication than mechanical methods, tend to be far less labor intensive, and typically are less expensive. For example, mowing is a non-selective destructive method, by definition damaging habitat and disrupting existing ecosystems. Moreover, mowing does not kill roots and plants will immediately begin the process of re-growing, necessitating the re-application of this method in a relatively short amount of time (hence, the increased costs). Finally, there is some modest risk of fire if mechanical methods like mowing strike a rock or exposed metal object causing sparks.

- **Physical methods are generally impractical**
  Hand removal methods were deemed generally impractical as a replacement for glyphosate because they are labor intensive. This is particularly true in an area as large as Los Angeles County. In addition to cumulative labor costs, work force development was also discussed as a factor. With this overarching finding in mind, the Technical Committee identified the advantages of physical methods including mulching, which

promotes moisture retention, reduces erosion, provides some habitat improvement, while minimizing surface area for weed germination.

- **Biological methods are infeasible at large scales**
  Biological methods were deemed infeasible as a replacement for glyphosate because of their limited applicability. Generally speaking, the challenges of grazing far outweigh the benefits. Similar to mowing, grazing does not kill roots and treated areas will re-grow. However, there are a variety of unintended consequences from grazing including contributions of fecal matter exacerbating bacteria pollution problems, increasing erosion, and compromising public safety when animals break free from the treatment area. With these limitations in mind, advantageous applications were identified, such as goats on steep hillsides where mowing is impractical.

Comparison of Chemical Methods

The Technical Committee spent additional time and effort evaluating the advantages and disadvantages of the various chemical methods provided by the County (tables 5-7). Since chemical methods were the most effective and efficient of all methods and, since glyphosate is likely to be replaced by another chemical method, the evaluation was worthy of additional time and effort.

Chemical methods were divided into one of three general alternatives:

- Post-emergent herbicides (Table 5): herbicides applied to plants that have already sprouted and are regulated by the US Environmental Protection Agency and the California Department of Pesticide Regulation. The County provided nine different post-emergent herbicides for evaluation
- Organic herbicides (Table 6): herbicides applied to plants that have already sprouted and may or may not be regulated by the US Environmental Protection Agency and the California Department of Pesticide Regulation depending on their ingredients. The County provided six different organic herbicides for evaluation
- Pre-emergent herbicides (Table 7): herbicides that are applied to the ground prior to seeds sprouting. The County provided nine different pre-emergent herbicides for evaluation

The advantages and disadvantages of all three groups of herbicides were compared based on seven different criteria. These criteria included:

- Label Signal Word: The US Environmental Protection Agency requires label signal words on all pesticides (including herbicides). Three label signal words exist (USEPA 2007). CAUTION means the pesticide product is slightly toxic if eaten, absorbed through the skin, inhaled, or it causes slight eye or skin irritation. WARNING indicates the pesticide product is moderately toxic if eaten, absorbed through the skin, inhaled, or it causes moderate eye or skin irritation. DANGER means that the pesticide product is highly toxic by at least one route of exposure. It may be corrosive, causing irreversible damage to the skin or eyes. Alternatively, it may be highly toxic if eaten, absorbed through the skin, or inhaled. If this is the case, then the word "POISON" must also be included in red letters on the front panel of the product label.
- On the Proposition 65 List: California Proposition 65 (Safe Drinking Water and Toxic Enforcement Act of 1986) legislatively mandates businesses to provide warnings to Californians about significant exposures to chemicals that cause cancer, birth defects or

other reproductive harm. The list currently contains 900 chemicals and is maintained by the California Office of Environmental Health and Hazard Assessment (https://oehha.ca.gov/proposition-65/proposition-65-list). Not all herbicides have been evaluated for the Proposition 65 list.

- Ecological Health – LC50: LC50 (sometimes called LD50) is the lethal concentration (or lethal dose) to 50% of the exposed organism population. LC50s were either obtained from the peer-reviewed literature or USEPA. Higher concentrations indicate this herbicide is less toxic while lower concentrations indicate this herbicide is more toxic. All findings are relative and an "allowable" LC50 does not exist.
- Ecological Health - Hazard Quotients: Hazard Quotients were determined by dividing measured or estimated environmental exposure concentrations by the LC50. For exposure, the highest globally observed measured concentration in water was used, obtained from either the peer-reviewed literature or from USEPA documentation. In general, Hazard Quotients greater than 1.0 indicate the potential for environmental risk. Hazard Quotients less than 1.0 indicate that environmental risk is unlikely.
- Human Health Hazard Threshold – ADI: ADI or Acceptable Daily Intake (sometimes called RfD or Reference Dose) estimates the amount of a substance, expressed on a body mass basis (usually mg/kg body weight), which can be ingested daily over a lifetime by humans without appreciable health risk. Effectively, this is considered a "safe Level" of this herbicide. The World Health Organization Joint Meeting on Pesticide Residues (JMPR) maintains the database that compiles the ADI for over 300 pesticides, as well as the available publications (reports and monographs) documenting the ADI for each compound (http://apps.who.int/pesticide-residues-jmpr-database) .
- Cost of Replacement relative to Glyphosate: This value estimates the cost for a single application of a common unit area for the proposed herbicide relative to the cost for glyphosate. Costs less than 1.0 are less expensive than glyphosate while costs greater than 1.0 are more expensive. Actual costs for each herbicide came from Los Angeles County. Application rates were standardized to one acre based on the product label highest recommended application rate. Costs do not include labor or additional equipment for application, nor does it include the cost for application frequency, which varies by location.
- Applicability: application labels describe locations where herbicide should not be used, which the Technical Committee addressed as parks and other areas with probability of public contact, Right of Way (RoW) such as streets or parking lots, water and other aquatic habitats, wildlands and associated wildlife, or restoration projects.

Table 4. Ranked scoring of different vegetation management alternatives for Los Angeles County based on best professional judgement by the Technical Committee.

	Hand Rem-oval	Mow-ing	Flam-ing	Steaming, Foaming	Graz-ing	Tillage	Soil Solariz-ation	Organic Mulch-ing	Weed mats	Post-Emergent Herbicides	Organic Chemicals	Pre-Emergent Herbicides
Worker Safety	3	2	2	3	NA	4	3	3	3	3	3	3
Public Safety	4	3	2	4	3	4	4	3	3	4	4	4
Environmental Safety	4	2	2	3	2	1	2	4	2	4	4	4
Fire Risk	4	3	1	3	4	3	5	3	5	5	5	5
Equipment and Training	4	3	2	2	NA	2	3	4	3	3	3	3
Ease of Implementation	3	4	1	2	2	2	2	4	1	4	4	3
Start up and Ongoing Costs	1	3	3	1	2	1	2	3	1	4	2	4
Efficacy	2	2	2	3	3	4	4	4	3	4	3	4

Scoring Definitions:
5 = Optimal
4 = Preferable
3 = Acceptable
2 = Poor
1 = Unacceptable

Table 5. Technical Committee Evaluation of Post Emergent Chemical Methods for Vegetation management in Los Angeles County

Herbicide	Label Signal Word (Caution, Warning, Danger)	On the Proposition 65 List (Yes, No)	Ecological Health		Human Health	Cost of Replacement Relative to Glyphosate	Applicability				
			Hazard Quotient	Hazard Threshold (LC50, mg/L)	Hazard Threshold (Acceptable Daily Intake, ADI, mg/kg)		Parks	Streets,	Water	Wildland	Restoration
Glyphosate	Caution	Yes	0.00062	86	0.3-1.75	1.0	✓	✓	✓	✓	✓
Diquat	Caution	No	0.02	67	0.008	2.0	✓	✓	✓	✓	✓
Glufosinate	Caution/Warning (depending on formulation)	No	0.00013	8	0.02	1.5	✓	✓	X	✓	✓
Fluazifop-P butyl	Caution	Yes	0.04	0.53	0.004	1.8	✓	✓	✓	✓	✓
Clethodim	Caution	No	0.0000041	56	0.01	0.7	✓	✓	✓	✓	✓
Triclopyr	Caution	No	0.142	45	0.03	0.7	✓	X	X	✓	✓
Aminopyralid	Caution	No	Insufficient data	>1,000	0.5	0.8	X	✓	X	✓	X
Clopyralid	Caution	No	0.00057	>1,000	0.15	1.4	X	✓	X	✓	X
Imazapyr	Caution	No	Insufficient data	>100	2.53	2.6	X	X	✓	X	X

- Label Signal Word is defined by OSHA's Hazard Communication Standard (29 CFR 1910.1200).
- Proposition 65 legislatively mandates the state to maintain a list of chemicals known to cause cancer or reproductive toxicity.
- LC50 is the lethal concentration at which 50% of the most sensitive species survives, Lower concentrations are more toxic than higher concentrations, See Appendix B for data sources.
- Hazard quotient is the ambient concentration divided by the hazard threshold, Hazard quotients $\geq$1 indicate potential for environmental impact, See Appendix B for data sources.
- Acceptable Daily Intake is the amount of substance in food or drinking water that can be ingested on a daily basis over a lifetime without an appreciable health risk, Lower concentrations are more toxic than higher concentrations, See Appendix C for data sources.
- Cost relative to Glyphosate: 1 is the same as Glyphosate, >1 is more expensive than Glyphosate, <1 is less expensive than Glyphosate, See Appendix D for application rates and actual costs.

Table 6. Technical Committee Evaluation of Organic Chemical Methods for Vegetation management in Los Angeles County

Herbicide	Label Signal Word (Caution, Warning, Danger)	On the Proposition 65 List (Yes, No)	Ecological Health		Human Health	Cost of Replacement Relative to Glyphosate	Applicability				
			Hazard Quotient	Hazard Threshold (LC50, mg/L)	Hazard Threshold (Acceptable Daily Intake, ADI, mg/kg)		Parks	Streets, RoW	Water	Wildland	Restoration
Mix of Caprylic and Capric Acids	Warning	No	Insufficient data	No data	No data	26.8	✓	✓	X	✓	✓
Pelargonic Acid	Warning	No	Insufficient data	>5	No data	65.0	✓	✓	X	✓	✓
Acetic Acid	Danger	No	Insufficient data	No data	No data	44.5	✓	✓	X	✓	✓
d-Limonene	Caution	No	Insufficient data	No data	No data	26.5	✓	✓	X	✓	✓
Clove Oil-Cinnamon Oil	Exempt	No	Insufficient data	No data	No data	30.8	✓	✓	X	✓	✓
Clove Oil-Citric Acid	Danger	No	Insufficient data	No data	No data	77.6	✓	✓	X	✓	✓

- Label Signal Word is defined by OSHA's Hazard Communication Standard (29 CFR 1910.1200).
- Proposition 65 legislatively mandates the state to maintain a list of chemicals known to cause cancer or reproductive toxicity.
- LC50 is the lethal concentration at which 50% of the most sensitive species survives, Lower concentrations are more toxic than higher concentrations, See Appendix B for data sources.
- Hazard quotient is the ambient concentration divided by the hazard threshold, Hazard quotients $\geq$1 indicate potential for environmental impact, See Appendix B for data sources.
- Acceptable Daily Intake is the amount of substance in food or drinking water that can be ingested on a daily basis over a lifetime without an appreciable health risk, Lower concentrations are more toxic than higher concentrations, See Appendix C for data sources.
- Cost relative to Glyphosate: 1 is the same as Glyphosate, >1 is more expensive than Glyphosate, <1 is less expensive than Glyphosate, See Appendix D for application rates and actual costs.

Table 7. Technical Committee Evaluation of Pre-Emergent Chemical Methods for Vegetation management in Los Angeles County

Herbicide	Label Signal Word (Caution, Warning, Danger)	On the Proposition 65 List (Yes, No)	Ecological Health		Human Health	Cost of Replacement Relative to Glyphosate	Applicability				
			Hazard Quotient	Hazard Threshold (LC50, mg/L)	Hazard Threshold (Acceptable Daily Intake, ADI, mg/kg)		Parks	Streets, ROW	Water	Wildland	Restoration
Aminopyralid	Caution	No	Insufficient data	>1,000	0.05	0.8	✓	✓	X	✓	✓
Indaziflam	Caution	No	Insufficient data	0.1-1.0	0.02	8.7	✓	✓	X	✓	✓
Isoxaben	Caution	No	Insufficient data	>11	0.05	1.4	✓	✓	X	✓	✓
Chlorsulfuron	Caution	No	Insufficient data	>250	0.2	1.8	✓	✓	X	✓	✓
Dithiopyr	Warning	No	Insufficient data	0.5-0.7	0.004	2.8	X[E]	✓	X	✓	✓
Oryzalin	Caution	Yes	Insufficient data	>1.4	0.05	0.7	X[E]	✓	X	✓	✓
Prodiamine	Caution	No	Insufficient data	0.52	0.05	1.6	✓	✓	X	✓	✓
Pendimethalin	Caution	No	Insufficient data	0.14	0.01	0.6	✓	✓	X	✓	✓
Sulfometuron-Methyl	Caution	No	Insufficient data	>12.5	0.22	0.8	✓	✓	X	✓	✓

- Label Signal is defined by OSHA's Hazard Communication Standard (29 CFR 1910.1200).
- Proposition 65 legislatively mandates the state to maintain a list of chemicals known to cause cancer or reproductive toxicity.
- LC50 is the lethal concentration at which 50% of the most sensitive species survives, Lower concentrations are more toxic than higher concentrations, See Appendix B for data sources.
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- Acceptable Daily Intake is the amount of substance in food or drinking water that can be ingested on a daily basis over a lifetime without an appreciable health risk, Lower concentrations are more toxic than higher concentrations, See Appendix C for data sources.
- Cost relative to Glyphosate: 1 is the same as Glyphosate, >1 is more expensive than Glyphosate, <1 is less expensive than Glyphosate, See Appendix D for application rates and actual costs.
- E=limited exemption for specific uses or application types

Post-Emergent Herbicides

The Technical Committee identified a series findings for post-emergent herbicides including:

- **All of the post-emergent herbicides are registered and approved by US Environmental Protection Agency and the California Department of Pesticide Regulation.**
  The use of any registered pesticide (including glyphosate) requires proper training to minimize exposure to workers, the public, and wildlife.
- **All of the post-emergent herbicides proposed by the County have relatively low-risk thresholds and extremely low Risk Quotients.**
  Based on existing data, low-risk thresholds and low risk quotients indicates that these chemicals are likely low risk to workers, the public, and wildlife.
- **Some of the post-emergent herbicides proposed by the County have limited application**
  About half of the proposed post-emergent herbicides should not be used near water and about one-third should not be used near parks.
- **The costs of the proposed post-emergent herbicides vary relative to glyphosate**
  While some of the proposed post-emergent herbicides were up to one-third less expensive than glyphosate for a standard application, the majority were more expensive, with some more than twice the cost of glyphosate for a standard application. However, even for the less expensive methods, the frequency of application could be greater than for glyphosate eliminating any assumed cost savings.

Organic Herbicides

The Technical Committee identified a series findings for organic herbicides including:

- **"Organic" is often misinterpreted**
  For many people, the term "organic" implies "safe", but many of these herbicides are not safer than glyphosate. In fact, two of the six organic herbicides had DANGER label signals words, the only such label signal word of all chemicals evaluated by the Technical Committee. These chemicals can cause acute harm to workers if not used safely with proper training.
- **Organic herbicides can be effective**
  Some organic chemical treatment have effectively been used as post-emergent herbicides without known harm to the environment, particularly for spot treatment. For the most part, these chemicals use natural ingredients and low pH to kill plants.
- **Organic herbicides are typically exempt from US Environmental Protection Agency California Department of Regulation registration and evaluation**
  Because organic herbicides occur in nature, these chemicals may not be subject to the same pesticide registration process that researches and documents human and ecological toxicity. Hence, these chemicals are not typically evaluated for California's Proposition 65 list and data to calculate human health or ecological hazard thresholds or risk quotients are missing.
- **Organic herbicides are substantially more expensive than glyphosate**
  Cost estimates were more than an order of magnitude more expensive compared to glyphosate. Actual expenses are likely even greater based on the need for more frequent application since organic herbicides are non-translocating.

- **Organic herbicides should not be used near water**
  Organic herbicides are almost all soluble in water, which means they will not adsorb to aquatic plants for treatment and the dissolution will present a risk to wildlife who live in or use the water.

Pre-Emergent Herbicides

The Technical Committee identified a series findings for pre-emergent herbicides including:

- **Pre-emergent herbicides proposed by the County of Los Angeles are generally safe to use for workers**
  Label signals for nearly all of the selected pre-emergent herbicides were at their lowest (least dangerous) state and none were on the Proposition 65 list of chemicals.
- **Pre-emergent herbicides are designed to be broadcast applied, preventing most weeds from germinating over large areas**
  The necessary application method limits pre-emergent herbicide use both in time and locations. However, these chemicals can persist for long periods of time, which enhances their effectiveness.
- **Pre-emergent herbicides generally lack environmental (ambient) monitoring data for evaluating environmental risk**
  While these chemicals require toxicity information for federal and state pesticide registration, there have been few measurements of these chemicals in the environment. Overall, ecological risk thresholds are greater (less risky) than post-emergent herbicides, but there are almost no data on environmental occurrence. As a result, the Technical Committee could not calculate risk quotients.

SYNTHESIS AND CONCLUSIONS

The Technical Committee synthesized a set of conclusions after undergoing the evaluation of advantages and disadvantages of alternatives for glyphosate. These conclusions include:

- **A diversity of methods is required for effective vegetation management**
  There is no "magic bullet" when it comes to vegetation management. Hence, a variety of methods is necessary for combating invasive plants, preventing infrastructure damage, minimizing wildfires, and protecting public health. Los Angeles County's Vegetation Control Plan, and the County Public Works use survey, indicate the County is aware of this fact and appear prepared to tackle challenges associated with any single method.

- **Even the best scoring methods have their limitations**
  Based on the scoring system developed by the Technical Committee for ranking the advantages and disadvantages of alternatives, chemical methods scored best. They were the most effective at the least expense, while being safe for workers, the public, and wildlife. However, these methods could not be used everywhere. Some had limited applications while others had timing challenges (time of year or frequency).

- **Even the worst scoring methods have an appropriate application**
  Based on the scoring system developed by the Technical Committee for ranking the advantages and disadvantages of alternatives, biological methods scored lowest. Despite the low ranking, biological methods have their application when mechanical access is difficult and chemicals applications won't work.

- **Keeping a well-stocked toolbox as part of your vegetation management plan will be important for future success**
  Since no method is perfect, and every method has its optimal application, the Technical Committee recognized that the County needs a toolbox approach. The key is to ensure that the County managers know when and where each method is best applied, and that staff is well-trained on executing each method to protect themselves and their co-workers, the public, and wildlife. Updates to the County's Vegetation Control Plan and Integrated Pest Management Plan are likely outcomes.

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APPENDIX A: SURVEY OF GLYPHOSATE ALTERNATIVE METHODS BY LOS ANGELES COUNTY

Reference: Los Angeles County Weed Management Area BMP Manual

#	Method	Applicable Areas	Pro	Con
1	**Hand removal/Hoeing** Pulling weeds by hand, or cutting weeds with a hoe.	• All sites except large holdings of land and transportation corridors • Sites not accessible with large equipment • Highly-visible sites	• Effective on seasonal and some year-round weed species • Does not require skilled labor but does require some initial education to differentiate weeds from desirable plants	• Not effective on many year-round weed species, as they can recover from hoeing (many can be killed by repeated hoeing) • Labor intensive • Safety risk for workers along transportation corridors • Creates significant soil disturbance, which can lead to opportunities for new weed infestations and the risk of soil erosion • Does not prevent weed regrowth of species that are able to re-sprout from roots or fragments remaining in the soil • Poorly-trained workers or volunteers can damage desirable vegetation by mistake
2	**Mowing (hand power tool)** Cutting and/or shredding weeds with motorized equipment or hand-operated tools such as string trimmers, chainsaws, brush cutters and slope mowers.	• Sites accessible to motorized equipment or individuals using portable tools	• Aesthetically pleasing and more efficient than manual removal • Reduces fuel for fires, seed production, and water use • Can be used on dense vegetation without disturbing the soil surface	• Effectiveness of this method varies for different weed species • Safety risks to operators and bystanders (flying debris, fire hazard, visibility problems with dust) • Equipment is expensive to purchase and maintain and requires skilled labor • Noise concern for local residents or wildlife • Can encourage weeds if improperly timed • May not be as cost-effective as chemical application • Weeds with seeds (especially invasive weeds) must be mowed before seed matures or removed by hand before mowing takes place
3	**Flaming** Using intense heat (2000°F) from a propane or butane torch (handheld or tractor-drawn) to “boil” rather than burn weeds, selectively killing unwanted weeds (withering within minutes) without harming desirable plants.	• Small sites under close control such as private property, schools, and urban areas • Appropriate for use on gravel, paving stones, pathways, and parking areas	• Effective on small succulent annuals and the young woody plants • Potential to be more cost-effective compared to hand removal • Quick, safe, easy to utilize, and avoids soil disturbance (when used properly) • Popular alternative to herbicide use on cropland	• Not effective on year-round plants or grasses • Repeated flaming may be necessary for weedy grass control • Risk of ignition to standing vegetation and require close coordination with the local fire department • Cost potentially greater than herbicides • Increases burn injury risk to workers and pressurized propane tanks can be hazardous if improperly handled • Not appropriate in areas with organic mulch, which often ignites

#	Method	Applicable Areas	Pro	Con
4	**Steaming** Using steam (handheld or tractor-drawn equipment) to scald weed's root system selectively to kill young succulent weeds without harming desirable plants.	• Small sites under close control, such as private property, schools, urban and agricultural areas. • Areas accessible to tractor-drawn equipment	• Effective on young annual plants under 6-inches tall • Kill weeds without damaging other vegetation except where the weeds and desirable plants are closely mixed • Does not cause soil disturbance • No risk of inadvertently starting fires • Does not require permits or licenses	• Does not control year-round plants, large grasses, or plants with extensive underground roots • Amount of time required is equivalent to hand removal, but cost is slightly higher due to the initial cost and maintenance of the equipment • May place workers at risk for burn injuries from equipment and backsplash from extremely hot mud; full safety gear is necessary, including hearing protection
5	**Foaming** Using pressurized application (handheld or tractor-drawn equipment) of hot biodegradable foam that comprises a mixture of corn and coconut sugar extracts and superheated steam to kill unwanted vegetation.	• Small sites under close control, such as private property, schools, and urban areas where complete vegetation removal is sought • Roadside application feasible with truck-mounted mechanical boom delivery system	• Effective weed control for small seedlings, annual plants and some perennials • Can be a very selective method, only killing weeds and not damaging other vegetation unless the weeds and desirable plants are closely mixed • No soil disturbance • No risk of inadvertently starting fires • Can be used in varying weather conditions, including light wind and rain, without fear of pesticide drift or residue • No permits or licenses required (Mixture considered an "organic," naturally-occurring compound; thus, it is not regulated as an herbicide by U.S. EPA or pesticide by CalDPR)	• Systems are only available by lease (currently) • Some perennials, especially plants with extensive underground roots or rhizomes, may require more than one application to attain full control • Amount of time required is equivalent to hand labor, but cost is slightly higher due to the equipment lease and cost of foam • Requires a nearby water source due to water use • Requires eye and hearing protections for workers • Foam cannot be used near surface water (concentration of 3 mg/liter can be toxic to fish) • Effects of foam need to be fully studied
6	**Chemical Methods** (non-glyphosate products) Application of herbicides to kill weeds or invasive plants. Cal-IPC's herbicide BMP manual presents proper use of this method. http://www.cal-ipc.org/	• Sites of private or public entities that can control access during and after herbicide application	• Can minimize exposure of workers to vehicle traffic, exposure of the public to equipment and traffic diversions that might be required for mowing or burning • Herbicides can selectively control undesirable vegetation without harming desirable vegetation • Relatively inexpensive and effective compared to many other methods	• Can harm the environment, humans and wildlife with inappropriate application of herbicides (e.g., during excessive winds that move the herbicide off the target area, during periods of the day when people are normally present, having faulty equipment that results in leaks or spills) • Proximity to habitats for protected animal and plant species must be considered

#	Method	Applicable Areas	Pro	Con
7	**Organic Chemical Methods (OMRI products)** Controlling weeds using non-synthetic pesticides, derived from natural sources not synthetically manufactured, (plastic mulch, weak acids, mined minerals, plant extract derivatives, coconut fiber, biocontrol).	• Projects installed with stormwater infiltration systems (LID) • Communities with chemical sensitivity issues that require the use of non-synthetic herbicides or organic methods of weed control	• Products are non-synthetic pesticides derived from natural sources • Does not require a written recommendation from a Pest Control Advisor (PCA)	• Effectiveness of organic products is unknown and needs further research • Products are not registered or reviewed by the EPA for impacts to humans and environmental health; thus, there is a potential for chemicals to cause harm to the environment, humans and wildlife when used improperly • Decisions should be made by a certified PCA, especially when applying in public situations, and trained applicators are recommended
8	**Grazing, and other forms of herbivory** Using herbivores, generally sheep, goats, or cattle to feed on land covered by weeds, typically only removing the top portion of plants but not roots or rhizomes.	• Limited to sites that are accessible to animals and where they can be fenced or managed	• Cheap and effective for control of annual plants and to suppress seed production • Grazing is analogous to mowing for perennial weed control	• Animals must be managed for effective control and to prevent them from eating desired vegetation • May damage desired vegetation • Need protection from predators and dogs • Safety concern on or near highways • Nutrient addition from feces can make the site more hospitable to non-native species • Must be managed to ensure they do not transport non-native species from other areas, either in feces or on fur • Does not prevent weed regrowth of species that are able to re-sprout from roots or fragments remaining in the soil
9	**Tillage (cultivation)** Practices that disturb the soil where plants are cut off at the soil line, uprooted, or smothered, such as roto-tilling, disking, and plowing.	• Sites accessible to motorized equipment (tractors, roto-tillers)	• Effective, quick, and can be less expensive than other methods that have similar results • Potential to kill perennial plants if done routinely	• Requires skilled or semiskilled labor and supervision • Equipment is expensive to purchase and maintain • Potential for significant source of erosion • Dust can create a vision hazard along highways • Horizontal tillage can bring buried weed seed to the soil surface where it can germinate • Rhizomes of perennial weeds can be cut up, which can lead to more individual plants and these pieces can be spread on equipment • Heavy discs can damage underground water and gas pipes, etc. • Repeated disturbance may be more environmentally damaging long-term

#	Method	Applicable Areas	Pro	Con
10	**Soil Solarization** Using clear plastic to trap heat energy from the sun to bring about physical, chemical, and biological changes in the soil that will kill soil pathogens and weed seed.	• Variety of sites, especially with little wind or cloud cover	• Provides safe and effective control of weed seed and plant pathogens to a depth of 6-inches if done correctly with sufficient radiant heat energy from the sun	• Labor intensive to install and maintain • Does not work well on perennial species, and in coastal areas of LA County • Ultraviolet resistant plastic must be used, which is not readily available • Kills beneficial microbes and insects as well as any native seeds in the seed bank • Effective only at warm times of the year
11	**Mulching** Controlling weeds by spreading a protective layer of organic (compost, bark chips, straw, pine needles, etc.) or inorganic (rocks, plastic sheeting, landscape fabrics, ground rubber tires, etc.) material on the ground that reduces weed growth by excluding light from the soil. Organic mulches can tie up available nitrogen through decomposition and starve weed seedlings. To be effective, mulch should be at least 3 to 4 inches thick.	• Can be used in a variety of sites, but different sites will limit the mulch material that can be used. • Timing for application is important and depends on the objective.	• Generally very effective on annual weeds • Can use recycled materials as mulch (tires, plastics, papers, wood chips, and compost) • Can conserve soil moisture, maintain even soil temperature, reduce soil compaction, and add nutrients • Potential to add a "finished" look to the landscape • Mulch such as pine needles can increase the acidity of soil around acid-loving plants such as rhododendron or azaleas • Stabilizes the soil temperature throughout different seasons by providing an insulating barrier between the soil and the air • Potential to delay soil drying and subsequent root growth that is dependent upon sufficient oxygen content in soil and reasonably warm temperature in the root zone	• Does not work well on perennial species • Organic materials can ignite • Improper placement or site selection can result in clogged water runoff conveyances or drains • Labor-intensive to install and maintain • Materials can be expensive • Mulches, such as hay and straw, work well but may harbor weed seeds. Unless mulch is weed-free, it can introduce new invasive weeds to an area • Moister, cooler environment from mulches can attract other pests, such as earwigs, slugs and sow bugs • Excess mulch, particularly if applied right against the stem or trunk of landscape plants, leads to root crown death, conditions favorable for disease development and plant death • Organic mulches can change the soil structure and enrich soil to the detriment of native species • When possible in restoration projects, inorganic mulches should be given serious consideration

#	Method	Applicable Areas	Pro	Con
12	**Weed Mats** Using specialized mulch or ground cover, usually porous plastic, that covers the soil to stop weed growth without chemical use but allows water to move through the soil. Weed mats vary in thickness and durability. Some resistant to UV radiation with life spans of at least 15 years.	• Under guardrails along highways, fences, signs, utility poles, hydrants or anywhere the normal weed control method would be weed-whipping or spraying herbicides • Low impact development projects that transition from developed hardscaped areas to green spaces	• Can control weeds, reduce runoff, long-lasting • Can be maintenance free, pesticide free • Can conform to any shape • Can be fire-resistant • Can be cost effective over time	• High initial cost • If weed mat fabric is too thin, it may require replacement in several years, and fabric will end up in landfill

APPENDIX B: SUPPORTING DATA FOR ECOLOGICAL HEALTH OUTCOMES

Pesticide	Ecological Health	
	Hazard Quotient (Ambient concentration/LC50)	Hazard Threshold (LC50, mg/L)
Post-Emergent Herbicides		
Glyphosate	53[b]/97,000=0.00079	97[a]
Diquat	400[c]/21000=0.019	21[d]
Glufosinate	0.17[f]/8000=0.00002	8[e]
Fluazifop-P butyl	71[g]/530=0.133	0.53[d]
Clethodim	0.230[h]/56000=0.000004	56[db]
Triclopyr	6.4[b]/45 = 0.142	45[d]
Aminopyralid	Insufficient data	>100[i]
Clopyralid	55[j]/103500=0.00053	103.5[j]
Imazapyr	Insufficient data	>100
Organic Herbicides		
Mix of Caprylic and Capric Acids	Insufficient data	Insufficient data
Pelargonic Acid	Insufficient data	>5[k]
Acetic Acid	Insufficient data	Insufficient data
d-Limonene	Insufficient data	<1.0[l]
Clove Oil-Cinnamon Oil	Insufficient data	Insufficient data
Clove Oil-Citric Acid	Insufficient data	Insufficient data
Pre-Emergent Herbicides		
Aminopyralid	Insufficient data	>100
Indaziflam	Insufficient data	0.1[d]
Isoxaben	Insufficient data	>11[d]
Chlorsulfuron	Insufficient data	>250[d]
Dithiopyr	Insufficient data	0.5[d]
Oryzalin	Insufficient data	>1.4[d]
Prodiamine	Insufficient data	0.52[d]
Pendimethalin	Insufficient data	0.14
Sulfometuron-Methyl	Insufficient data	>12.5[d]

[a] http://npic.orst.edu/factsheets/archive/glyphotech.html

[b] Tran-Thi, Nhu-Trang; Do, Minh-Huy; Truong, Lam Son Hai; Nguyen, Thien-Thao; Nguyen, T. Thu-Thao; Chau, Quoc Hung; Tran, Lam Thanh Thien; Orange, Didier; Behra, Philippe 2017. Analyses of polar pesticides and glyphosate in Mekong Delta. Abstracts of Papers, 253rd ACS National Meeting & Exposition, San Francisco, CA, United States, April 2-6.

[c] https://www.cdpr.ca.gov/docs/whs/active_ingredient/diquat-dibromide.htm

[e] https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+6666

[d] Tomlin C. (2000) The Pesticide manual (12th Edition); British Crop Protection Council. Publisher: Farnham, Surrey, UK : British Crop Protection Council.

[f] Masiol M; Gianni B; Prete M (2018) Herbicides in river water across the northeastern Italy: occurrence and spatial patterns of glyphosate, aminomethylphosphonic acid, and glufosinate ammonium. Environmental science and pollution research international 25:24368-24378.

[g] Spliid NH, Helweg A, Heinrichson K (2006) Leaching and degradation of 21 pesticides in a full-scale model biobed. Chemosphere 65: 2223-2232.

[h]Gaillard, Juliette; Thomas, Marielle; Iuretig, Alain; Pallez, Christelle; Feidt, Cyril; Dauchy, Xavier; Banas, Damien (2016) Barrage fishponds: Reduction of pesticide concentration peaks and associated risk of adverse ecological effects in headwater streams. Journal of Environmental Management 169:261-271.

[i]USEPA 2005 Aminopyralid Pesticide Fact Sheet (https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_PC-005100_10-Aug-05.pdf)

[j] https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+6593

[k] Techer, Didier; Milla, Sylvain; Fontaine, Pascal; Viot, Sandrine; Thomas, Marielle (2017) Influence of waterborne gallic and pelargonic acid exposures on biochemical and reproductive parameters in the zebrafish (Danio rerio). Environmental Toxicology 32: 227-240.

APPENDIX C: SUPPORTING DATA FOR HUMAN HEALTH OUTCOMES

Human Health Hazard Threshold (Acceptable Daily Intake, ADI, mg per kg body weight)
https://www.epa.gov/sites/production/files/2014-11/documents/guidelines_exp_assessment.pdf

Broad Spectrum/Non – Translocating

Diquat – Reward (0.008 mg/kg; WHO 1977)

Glufosinate – Cheetah (0.02; WHO)

Selective – Grasses

Fluazifop-P – Fusilade (0.004; WHO; 0.005 PMRA) https://apps.who.int/pesticideresidues-jmpr-database/pesticide?name=FLUAZIFOP-p-BUTYL

Clethodim – Vaquero (0.01; WHO1994) https://apps.who.int/pesticide-residues-jmprdatabase/pesticide?name=CLETHODIM

Translocated Selective – Broad leaves

Triclopyr – Vastlan (0.03; European Food Safety Authority)
https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2006.56r

Aminopyralid - Milestone (0.5; PMRA)

Clopyralid – Transline (0.15; NLM /EU)
https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2018.5389

Translocated Broad Spectrum

Imazapyr – Polaris, Habitat (2.53; PMRA 2011) https://www.canada.ca/en/health-canada/services/consumer-product-safety/reportspublications/pesticides-pest-management/decisions-updates/reevaluationnote/2016/rev2016-02-special-review-decision-imazapyr.html

Organics

Caprylic Acid - no data

Pelargonic Acid - no data

Acetic Acid - no data

Limonene - no data

Clove Oil-Cinnamon Oil - no data

Clove Oil-Citric Acid - no data

Common Pre-Emergent Herbicides

Aminopyralid see above

Indaziflam (0.02; PMRA 2011)

Isoxaben (0.05; NLM 2011) https://pubchem.ncbi.nlm.nih.gov/compound/Isoxaben

Chlorsulfuron* (0.2; EFSA 2008)
https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2009.201r

Dithiopyr (0.004; PMRA 2009)

Oryzalin (0.05; NLM) https://pubchem.ncbi.nlm.nih.gov/compound/Oryzalin

Prodiamine (0.05; AUS 2010) https://www.google.com/search?client=firefox-b-d&q=adi+for+prodiamine

Pendimethalin (0.01; WHO 2016)

Sulfometuron-methyl (0.22 ; NLM) https://pubchem.ncbi.nlm.nih.gov/compound/Sulfometuron-methyl

DEFINITIONS:

NLM – National Library of Medicine

PMRA – Pest Management Regulatory Agency (Canada)

AUS – Australian Dept of Pesticides and Veterinary Drugs

EFSA – European Food Safety Authority

WHO – World Health Organization

APPENDIX D: COST CALCULATIONS RELATIVE TO GLYPHOSATE

Pesticide	Example Trade Name	Cost per gallon	Application Rate (gallons per acre) [4]	Cost ($ per acre, herbicide only)	Cost Relative to Glyphosate[5]
Post-Emergent Herbicides					
Glyphosate	Roundup Pro	20.18[1]	1.00	20.18	1.0
Diquat	Reward	79.00[1]	0.50	39.50	2.0
Glufosinate	Cheetah Pro	46.40[1]	0.64	29.70	1.5
Fluazifop-P butyl	Fusilade II	190.72[1]	0.19	36.24	1.8
Clethodim	Grassout Max	105.00[1]	0.125	13.13	0.7
Triclopyr	Turflon Ester Ultra	115.56[1]	0.125	14.45	0.7
Aminopyralid	Milestone	307.20[1]	0.05	15.36	0.8
Clopyralid	Transline	345.60[1]	0.08	27.65	1.4
Imazapyr	Polaris	70.40[1]	0.75	52.80	2.6
Organic Herbicides					
Mix of Caprylic and Capric Acids	Suppress	60.00[1]	9.0	540.00	26.8
Pelargonic Acid	Scythe	65.54[1]	20	1310.80	65.0
Acetic Acid	Vinagreen Vinegar 20%	30.00[1]	30	898.50	44.5
d-Limonene	Avenger	62.90[1]	8.5	534.65	26.5
Clove Oil-Cinnamon Oil	Weed Zap	124.35[1]	5	621.75	30.8
Clove Oil-Citric Acid	Burnout	54.00[1]	29	1566.00	77.6
Post-Emergent Herbicides					
Aminopyralid	Milestone	556.00[2]	0.05	27.80	1.4
Indaziflam	Morengo	2600.00[2]	0.12	312.00	15.5
Isoxaben	Gallery-75D	4.69[2]	43.56	204.45	10.1
Chlorsulfuron	Telar XP	2480.00[3]	0.02	49.60	2.5
Dithiopyr	Dimension 2EW	258.00[2]	0.25	64.50	3.2
Oryzalin	Surflan Pro	100.00[2]	1	100.00	5.0
Prodiamine	Barricade 4FL	167.00[2]	0.16	26.72	1.3
Pendimethalin	Pendulum Aquacap	74.80[2]	0.79	59.09	2.9
Sulfometuron-Methyl	Oust XP	525.33[2]	0.04	21.01	1.0

[1]Cost from Los Angeles County Dept of Public Works
[2]Cost from DoMyOwn.com
[3]Cost from KeystonePestSolutions.com
[4]Highest application rate from label
[5]Relative cost = Herbicide cost per acre / Glyphosate cost per acre