

Supplemental Environmental Impact Statement for Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington - Draft



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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

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**Draft Supplemental Environmental Impact Statement (DSEIS):
Proposed Use of Imidacloprid for Burrowing Shrimp Control on Commercial
Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington**

September 18, 2017

Environmental Review. Notice of availability of this Draft Supplemental Environmental Impact Statement (DSEIS) is being sent to agencies, Tribes, organizations, land owners and lessees, and individuals who have expressed an interest in the Willapa-Grays Harbor Oyster Growers Association (WGHOGA) application to the Washington Department of Ecology (Ecology) for a permit under the National Pollutant Discharge Elimination System (NPDES) to use the insecticide imidacloprid for the control of ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*), collectively referred to as burrowing shrimp. The proposal is to apply imidacloprid on up to 500 acres per year of commercial shellfish beds within Willapa Bay (up to 485 acres per year) and Grays Harbor (up to 15 acres per year), between the tidal elevations of -2 feet mean lower low water (MLLW) and +4 feet MLLW.

Washington State Department of Ecology Action Required. There is no proposed action at this point. Ecology has not made a decision on whether or not to issue a NPDES State waste discharge permit or authorize Sediment Impact Zones.

Public Review and Comment Opportunities. Tribal, Agency, and public comments are invited on the DSEIS, which is available in electronic format on Ecology's website:
<http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid/index.html>

Printed copies of the DSEIS are available for review at the location indicated below.

Washington State Department of Ecology
Water Quality Program
300 Desmond Drive SE
Lacey, WA 98503

Comments are due to Derek Rockett of Ecology's Water Quality Program by 5 p.m. on November 01, 2017. All comments submitted within the 45-day comment period (September 18, 2017 through November 01, 2017) will receive a response in the SEIS. Please send written comments by mail or email to:

Derek Rockett, Permit Writer
Washington State Department of Ecology
Water Quality Program
PO Box 47775
Olympia, WA 98504-7775
<http://ws.ecology.commentinput.com/?id=acfUM>

Permits and Approvals Required. State and Federal permits and registrations required for the chemical control of burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor include: an NPDES Individual Permit/State Waste Discharge Permit, pesticide registration of the imidacloprid products to be issued by the Washington State Department of Agriculture, Federal registration of the imidacloprid products to be used (conditional registration issued by the U.S. Environmental Protection Agency, June 6, 2013), and applicators' licenses to be issued by the State. The EIS will be used by Ecology and other governmental agencies, along with other relevant considerations and documents, prior to taking action on the WGHOGA application.

Alternatives Considered. The DSEIS evaluates three alternatives for implementing the proposed action to control burrowing shrimp on oyster and clam beds in Willapa Bay and Grays Harbor: 1) No Action: No Permit for pesticide Applications, 2) Imidacloprid Applications with Integrated Pest Management (IPM) on up to 2,000 Acres per Year, 3) Imidacloprid Applications with Integrated Pest Management (IPM) on up to 500 Acres per Year.

No preferred alternative was identified.

Key Environmental Issues. Ecology's NPDES permit decision must comply with the regulations of the Washington State Surface Water Quality Standards. These standards were used to guide the selection of elements of the environment to be addressed in the Imidacloprid DSEIS: sediments, air quality, surface water, plants, animals, human health, land and shoreline use, recreation, and navigation. The DSEIS Table of Contents includes a detailed list of the plant and animal groups for which potential impacts and mitigation measures are evaluated. The DSEIS Chapter 1 includes a section that lists Areas of Controversy and Uncertainty, and Issues to be Resolved.

Ecology's Water Quality Program appreciates your interest in this proposal. If you would like more information about the burrowing shrimp control proposal and/or the environmental review that has been conducted, please contact Derek Rockett, Permit Writer, for whom contact information is provided above. Additional information regarding the environmental review process and public involvement opportunities is provided in Draft EIS Chapter 1, Section 1.3.

Thank you.



Heather R. Bartlett
Water Quality Program Manager

Date: 9/15/17

Fact Sheet

Project Title:

Proposed Use of Imidacloprid for Burrowing Shrimp Control on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington

Brief Description of the Proposed Action:

Two native species of burrowing shrimp (ghost shrimp, *Neotrypaea californiensis* and mud shrimp, *Upogebia pugettensis*) have caused impacts to Pacific Coast commercial clam and oyster production since at least the 1940s by disrupting the structure and composition of the substrate, causing these shellfish to sink and suffocate. Commercial shellfish growers in Willapa Bay and Grays Harbor, Washington used the N-methyl carbamate insecticide carbaryl for burrowing shrimp population control between 1963 and 2013. Ecology began to regulate carbaryl applications in the 1990s, and issued a NPDES permit for the use of carbaryl in 2002. This permit was terminated in May of 2015.

The Willapa Grays Harbor Oyster Growers Association (WHGOGA) and the Washington State University Long Beach Research and Extension Unit began testing imidacloprid (a neonicotinoid insecticide) in 1996 as an alternative to carbaryl for the control of burrowing shrimp populations. WGHOGA applied to Ecology in 2014 for a NPDES Individual Permit to authorize use of imidacloprid combined with Integrated Pest Management (IPM) practices to suppress burrowing shrimp populations on up to 2,000 acres per year (total) of commercial clam and oyster beds in Willapa Bay and Grays Harbor. Proposed application methods included aerial spraying from helicopters. Ecology issued a 5-year NPDES Individual Permit (WA0039781) on April 16, 2015, following a SEPA environmental review process. On May 3, 2015, WGHOGA asked Ecology to withdraw the permit in response to strong public concerns. Ecology agreed and cancelled the permit on May 4, 2015, prior to the close of the appeal period and before the permit was active.

This Supplemental EIS (SEIS) addresses a WGHOGA 2016 NPDES permit application to Ecology for a reduced-scope proposal for the use of imidacloprid to treat commercial clam and oyster beds on up to 500 acres per year (total) in Willapa Bay and Grays Harbor. The 2016 application also commits to making spray and granular applications from boats and/or ground equipment rather than aerial applications from helicopters.

This SEIS supplements the environmental review and analysis of alternatives in the 2015 FEIS. The FEIS is adopted and incorporated by reference in this SEIS, in accordance with WAC 197-11-600(4). The 2016 application is evaluated as Alternative 4, in the context of additional research that has been performed, and additional literature that has been published on the environmental effects of imidacloprid since the 2015 FEIS was issued.

Purpose and Objectives:

The WGHOGA 2016 application is a request for an Individual NPDES permit to authorize chemical applications of imidacloprid on up to approximately 485 acres *per year* of commercial clam and oyster beds within Willapa Bay, and up to 15 acres *per year* within Grays Harbor. The proposed action covers only these two geographic areas within Washington State, and only commercial shellfish beds on which oysters and clams are grown. While it is possible that over the 5-year term of the permit, the total acreage to be treated within Willapa Bay could range from 485 to 2,485 acres, and within Grays Harbor could range from 15 to 75 acres, growers would apply imidacloprid within the annual acreage limits in each bay based on shellfish grower plans for their seed beds, grow-out sites, and fattening grounds; the efficacy of prior treatments; and the density of burrowing shrimp populations.

Imidacloprid applications would be made using adaptive management principles, to be described in an IPM Plan and Annual Operations Plan subject to review and approval by Ecology. The objectives of the proposed action are to:

- Preserve and maintain the viability of shellfish commercially grown in Willapa Bay and Grays

Harbor by controlling populations of two species of burrowing shrimp on commercial oyster and clam beds.

- Preserve and restore selected commercial oyster and clam beds in Willapa Bay and Grays Harbor that are at risk of loss due to sediment destabilization caused by burrowing shrimp.

Principal Alternatives:

Commercial shellfish growers have been investigating mechanical means, alternative shellfish culture methods, various chemical applications, and biological controls for burrowing shrimp population control since the 1950s. Only pesticide applications of carbaryl and imidacloprid administered with adaptive management principles were found to be effective, reliable, and economical on a commercial scale, with sufficient species-specific efficacy.

The 2015 FEIS evaluated three alternatives for the control of burrowing shrimp populations:

ALTERNATIVE 1: No Action – No Permit for Pesticide Applications.

ALTERNATIVE 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management (IPM).

Note: Alternative 2 is no longer being considered as an alternative since Ecology denied the application for extension of the carbaryl NPDES permit (No. WA0040975) in May 2015.

ALTERNATIVE 3: Imidacloprid Applications with IPM on up to 2,000 acres per year in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

This SEIS evaluates a fourth alternative in the context of the current scientific understanding of imidacloprid effects in the environment:

ALTERNATIVE 4: Imidacloprid Applications with IPM on up to 500 acres per year in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

Both the 2015 FEIS and the 2017 Draft SEIS include a section that describes Alternatives

Considered and Eliminated from Detailed Evaluation.

Project Proponent: Willapa-Grays Harbor Oyster Growers Association
P.O. Box 3
Ocean Park, WA 98640

Schedule for Implementation: The target date for completion of the Supplemental EIS and Ecology's decision on the NPDES Individual Permit is Fall 2017.

Lead Agency: Washington Department of Ecology
Water Quality Program
300 Desmond Drive
P.O. Box 47775
Olympia, WA 98504-7775

SEPA Responsible Official: Heather Bartlett, *Program Manager*
Water Quality Program

**Project Information Contact Person,
And Person to Whom Comments are to
be Directed:** Derek Rockett, *Permit Writer*
360.407.6697
e-mail: droc461@ecy.wa.gov

Ecology File No. WA0039781

Permits and Registrations Required: The list below identifies State and Federal permits and registrations required for the chemical control of burrowing shrimp populations on commercial oyster and clam beds in Willapa Bay and Grays Harbor, Washington. Local government requirements may vary for a particular commercial shellfish site or operation.

Washington Department of Ecology NPDES Individual Permit/State waste discharge permit and Sediment Impact Zone authorization

Washington Department of Agriculture – State registration of the imidacloprid products Protector 0.5G (granular form) and Protector 2F (flowable form) under the requirements of the Washington Pesticide Control Act (RCW 15.58).
– Applicators' licenses for aquatic application of registered pesticides.

U.S. Environmental Protection Agency Federal registration of imidacloprid products Protector 0.5G (granular form) and Protector 2F

(flowable form) under the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Conditional FIFRA registrations issued June 6, 2013; see 2015 FEIS Appendix A.

Local Government(s):

Shoreline Permit (possible in some locations, though not usually required under local Shoreline Master Programs)

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DOWL

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Vicki Morris, *SEPA Specialist and Co-Author*

Draft SEIS Date of Issue:

September 18, 2017

Draft SEIS Comment Period:

September 18, 2017 through November 01, 2017

Date of Public Meeting:

Ecology intends to hold a public meeting in the local area in October. Notification of the meeting will be issued closer to that date.

Comments on the Draft SEIS Due:

5:00 PM, November 01, 2017

Availability of Copies of the Draft SEIS:

Everyone on the Distribution List was sent a Notice of Availability of the Draft SEIS. The document is posted on Ecology's website for review: <http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid>

Address Comments to:

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Ecology, Water Quality Program
P.O. Box 47775
Olympia, WA 98504-7775
e-mail: ECY RE WQ Burrowing Shrimp Permit
burrowingshrimp@ECY.WA.GOV

Next Steps in the SEIS Process:

Following the close of the Draft SEIS comment period, Ecology will review and respond to all comments received. Comments and responses will

be published in the Final SEIS. Everyone on the Draft SEIS Distribution List and persons who comment on the Draft SEIS will receive Notice of Availability of the Final SEIS.

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List of Symbols, Acronyms, and Units of Measure

>	greater than
<	less than
a.i./ac	active ingredient per acre
a.i./L	active ingredient per liter
AA-EQS	Annual Average Environmental Quality Standard
ALS	acetolactate synthesis
AOP	Annual Operations Plan
ATV	All-terrain vehicle
BMPs	Best Management Practices
cfm	cubic feet per meter
cm	centimeter
CSI	Compliance Services International
CWA	Clean Water Act
EC	Maximal Effective Concentration
ECY/Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FOIA	Freedom of Information Act
gpm	gallons per minute
HQ	hazard quotient
IPM	Integrated Pest Management
kg	kilogram
lbs/a.i./ac	pounds of active ingredient per acre
LC50	Median Lethal Dose
LOAEC	Lowest Observable Adverse Effects Concentration
LOC	Levels of Concern
m	meter
m ²	square meter

mg	milligram
µg	microgram
µg/L	micrograms per liter
MLLW	Mean Lower Low Water
MAC-EQS	Maximum Acceptable Concentration in Ecosystems
NAAQS	National Ambient Air Quality Standards
nAChR	nicotinerbic acetylcholine receptors
NOAEC	No Observed Adverse Effects Concentration
NOEC	No Observed Effects Concentration
NPDES	National Pollutant Discharge Elimination System
PMRA	Pesticide Management Regulatory Agency
ppb	parts per billion
PPE	personal protective equipment
psi	pounds per square inch
PVC	polyvinylchloride
RCW	Revised Code of Washington
RA	Risk Assessment
RQ	Risk Quotient
SAP	Sampling and Analysis Plan
SEIS	Supplemental Environmental Impact Statement
SEPA	Washington State Environmental Policy Act
SIZ	Sediment Impact Zone
SMS	Sediment Management Standards
SSD	species sensitivity distributions
TOC	total organic carbon
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WFD	Water Framework Directive
WGHOGA	Willapa-Grays Harbor Oyster Growers Association
WQC	Water Quality Certification
WQS	Water Quality Standards
WSU	Washington State University

1.0 Summary

1.1 Introduction and Problem Formulation

Since the 1940s, two native species of burrowing shrimp (ghost shrimp, *Neotrypaea californiensis*, and mud shrimp, *Upogebia pugettensis*) have caused impacts to Pacific Coast commercial clam and oyster production by disrupting the structure and composition of the substrate, causing these shellfish to sink and suffocate. The primary burrowing shrimp management practice used by Willapa Bay and Grays Harbor shellfish growers between 1963 and 2013 was chemical treatment with the n-methylcarbamate insecticide carbaryl. In 2014, the Willapa Grays Harbor Oyster Growers Association (WGHOGA) applied to Ecology for a NPDES Individual Permit to authorize use of the neonicotinoid pesticide imidacloprid¹ combined with IPM practices to suppress burrowing shrimp populations on up to 1,500 acres per year of commercial shellfish beds in Willapa Bay and up to 500 acres per year of commercial shellfish beds in Grays Harbor (up to 2,000 acres per year, total). Ecology reviewed the potential impacts of the proposed action in a Draft and Final Environmental Impact Statement in 2014 and 2015, respectively. The *Final EIS for Proposed Use of Imidacloprid for Burrowing Shrimp Control on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington* (Ecology 2015; hereafter referred to as the 2015 FEIS) was prepared based on scientific studies and information available at that time. Ecology issued a 5-year NPDES Individual Permit (WA0039781) on April 16, 2015, with an effective date of May 16, 2015. On May 3, 2015, WGHOGA asked Ecology to withdraw the permit in response to strong public concerns. Ecology agreed and cancelled the permit on May 4, 2015. The 2015 permit was cancelled prior to the close of the appeal period and before the permit was active.

On January 8, 2016, WGHOGA, on behalf of a group of about a dozen growers, applied to Ecology for a new pesticide permit for the use of imidacloprid to control burrowing shrimp on commercial clam and oyster beds in Willapa Bay and Grays Harbor. The 2016 proposal requests authorization to treat a reduced amount of commercial shellfish bed acreage (up to 500 acres per year, total, in the two estuaries), and commits to making spray and granular applications from boats and/or ground equipment rather than aerial applications from helicopters. The 2016 application for the use of imidacloprid, including the revised scope, is evaluated in this SEIS in the context of additional research that has been performed, and additional literature that has been published on the environmental effects of imidacloprid since the 2015 FEIS was issued. A summary of the Literature Review that was conducted for the SEIS is provided in Appendix A of this document.

¹ Neonicotinoids are a class of neuro-active insecticides chemically similar to nicotine. Neonicotinoids were developed in large part because they show reduced toxicity compared to previously used organophosphate and carbamate insecticides. Most neonicotinoids show much lower toxicity in birds and mammals than insects, but some breakdown products are toxic (e.g., Frew 2015, EPA 2017). However, there may be impacts to non-target invertebrates (e.g., Morrissey et al. 2015). The neonicotinoid imidacloprid is currently the most widely used pesticide in the world (Goulson et al. 2013 – EPA, van Dijk et al. 2013).

The history and background of commercial clam and oyster aquaculture in Willapa Bay and Grays Harbor was previously described in the 2015 Final EIS (Chapter 2, Section 2.4, pages 2-3 through 2-8). Also described in FEIS Chapter 2, Section 2.4 was the history of the impacts of the two burrowing shrimp species that are the subject of this SEIS, and treatment methods tested and used since the 1950s to attempt to control burrowing shrimp populations on commercial shellfish beds. The 2015 FEIS is incorporated by reference in the SEIS, in accordance with WAC 197-11-600 and -635.

1.2 Purpose and Objectives of the Proposed Action

The objectives of the 2016 proposed action are the same as those proposed in the prior WGHOGA permit application in 2014:

- Preserve and maintain the viability of clams and oysters commercially grown in Willapa Bay and Grays Harbor by controlling populations of two species of burrowing shrimp on commercial shellfish beds.
- Preserve and restore selected commercial shellfish beds in Willapa Bay and Grays Harbor that are at risk of loss due to sediment destabilization caused by burrowing shrimp.

1.3 SEPA Procedures and Public Involvement

As described above in Section 1.1, Ecology previously conducted environmental review of a 2014 WGHOGA application for use of the pesticide imidacloprid, under the regulations and guidelines of the Washington State Environmental Policy Act (SEPA). Ecology invited and received public and agency comments on the *Draft EIS for Proposed Use of Imidacloprid for Burrowing Shrimp Control on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington* (Ecology 2014), and on the 2015 draft permit between October 24 and December 8, 2014. Ecology responded to the comments in the *Final EIS for Proposed Use of Imidacloprid for Burrowing Shrimp Control on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington* (Ecology 2015), and issued a 5-year NPDES Individual Permit (WA0039781) on April 16, 2015, with an effective date of May 16, 2015. On May 3, 2015, WGHOGA asked Ecology to withdraw the permit in response to strong public concerns. Ecology agreed and cancelled the permit on May 4, 2015, effectively terminating commercial use of imidacloprid on shellfish beds in Willapa Bay and Grays Harbor. The 2015 permit was cancelled prior to the close of the appeal period and before the permit was active.

WGHOGA, on behalf of a group of about a dozen members, submitted an application to Ecology in 2016 for an Individual NPDES Permit and two Sediment Impact Zone (SIZ) authorizations to apply imidacloprid on a reduced acreage of tidelands in Willapa Bay and Grays Harbor (up to 500 acres per year, total), using ground-based methods that would not include aerial applications by helicopter. Ecology issued a public notice by e-mail to interested parties of record on June 23, 2017 to announce that it was evaluating this new application, and that a Supplemental EIS (SEIS) was being prepared. The purpose of the SEIS is to analyze the 2016 WGHOGA proposal for application of imidacloprid to commercial shellfish beds in Willapa Bay and Grays Harbor using both relevant information and analyses from the 2015 FEIS, and new research and information not previously available to the Department when the 2015 Final EIS was completed.

The June 23, 2017 announcement invited public comments during the SEIS process, and noted that a formal, 45-day public comment period would be offered on the Draft SEIS, when issued. The June 23, 2017 notice also indicated that several public meetings on the Draft SEIS will be held at key locations across western Washington (dates and times to be announced). Information obtained through public comments will be used by Ecology to finalize the SEIS prior to making its decision on the applications for an Individual NPDES permit and two SIZ authorizations.

1.4 Description of the Proposed Action

The 2016 WGHOGA proposal for the use of imidacloprid with Integrated Pest Management (IPM) practices to control burrowing shrimp on commercial shellfish beds² would occur on a limited number of acres in each estuary: up to 485 acres *per year* within Willapa Bay (1.1% of total tideland acres exposed at low tide), and up to 15 acres *per year* within Grays Harbor (0.04% of total tideland area exposed at low tide). Over the 5-year term of a potential permit, the total tideland acreage to be treated within Willapa Bay could range from 485 to 2,425 acres, and in Grays Harbor could range from 15 to 75 acres. Ecology would approve operations in any given year through its review of an Annual Operations Plan that WGHOGA would be required to submit. In addition, monitoring required by Ecology would be used to track the environmental effects of imidacloprid treatments, and to determine where applications would be allowed. It would be a condition of the permit, if issued, that authorization for the use of imidacloprid would include using adaptive management principles, to be described in an Integrated Pest Management (IPM) Plan.

The 2016 WGHOGA proposal requests flexibility in how the 485 acres per year are to be selected for treatment within Willapa Bay. In any given year, specific locations for imidacloprid treatment would be determined based on shellfish grower plans for their seed beds, grow-out sites, and fattening grounds; the efficacy of prior treatments; and the density of burrowing shrimp populations. The application also requests flexibility in being able to only partially spray some plots. WGHOGA would submit an Annual Operations Plan, and a Sampling and Analysis Plan (SAP), to Ecology each year for review, modification, and approval. It is anticipated that all applications would be made between the tidal elevations of -2 ft mean lower low water (MLLW) and +4 ft MLLW.

The 2016 application specifically excludes aerial applications of imidacloprid using helicopters. Rather, spray and granular applications would be made from boats and/or ground equipment, such as all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, and/or “belly grinders.” Applicators who may receive coverage under the Imidacloprid NPDES Individual Permit and SIZ authorizations (if issued) would need to comply with the terms and conditions of those permits.

² As used throughout this SEIS, the term “commercial shellfish beds” refers to a specified amount of tideland acreage within Willapa Bay and Grays Harbor on which oysters and clams are commercially grown. The requested NPDES permit would not extend to other geographical areas, and would not authorize treatment on other species of commercially-grown shellfish (e.g., geoducks or mussels).

1.5 Alternatives Considered

The 2015 FEIS evaluated the No Action Alternative, and two action alternatives for the control of burrowing shrimp: one using carbaryl with Integrated Pest Management (IPM) practices, and one using imidacloprid with IPM. These were identified as Alternative 1, 2 and 3, respectively. The 2015 FEIS alternatives analysis is incorporated by reference in this SEIS. Use of carbaryl for the control of burrowing shrimp populations on Willapa Bay and Grays Harbor commercial shellfish beds (FEIS Alternative 2) is no longer being considered by Ecology or other agencies. The Washington Special Local Need Registration was cancelled by the Department of Agriculture in January 2014, and Ecology denied the application for administrative extension of the NPDES permit for carbaryl applications (No. WA0040975) in May 2015. For these reasons, the potential effects of the 2016 WGHOGA proposal (Alternative 4) are not compared to FEIS Alternative 2 in SEIS Chapter 3.

The SEIS alternatives analysis in Chapter 3 compares the 2016 WGHOGA proposal (Alternative 4) to Alternatives 1 and 3 previously evaluated in the 2015 FEIS, in the context of additional field trial results and research that has been performed, and additional literature that has been published on the environmental effects of imidacloprid since the 2015 FEIS was issued. Ecology will use the SEIS to inform their decision regarding whether to issue the permit, and if so, appropriate conditions or mitigation requirements to impose.

1.5.1 Alternative 1, No Action: No Permit for Pesticide Applications

The 2015 FEIS evaluated a No Action Alternative in which there would be no permit authorizing pesticide applications to treat a limited acreage of commercial oyster beds in Willapa Bay and Grays Harbor for the control of burrowing shrimp populations. Commercial shellfish growers would only be able to utilize mechanical methods and alternative shellfish culture practices. Studies performed since the 1950s, and particularly from about the year 2000, have failed to find a non-chemical approach to controlling burrowing shrimp that was both effective, and economically feasible on a commercial scale. Some mechanical treatments also had large impacts on non-target animal species (e.g., dredging and deep harrowing). Off-bottom culture techniques, such as long-line or bag culture, are feasible in some areas with burrowing shrimp, such as areas protected from strong waves or currents. But these culture techniques would not support the shucked meat market that is the focus of most oyster culture in Willapa Bay and Grays Harbor, and would require large changes in the culture, harvest, processing, and marketing of oysters from these estuaries. Therefore, under Alternative 1, it was expected that most productive commercial clam and oyster grounds would decline over the subsequent 4- to 6-year period. The economic impacts of a decline in shellfish productivity on the order of 60 to 80 percent or more were discussed in FEIS Section 2.6 (pages 2-16 through 2-18). Ecosystem changes that would result from a significant increase in burrowing shrimp populations and significant reductions in shellfish (bivalve) populations were evaluated in FEIS Chapter 3. Reviewers interested in the analysis of the No Action Alternative are referred to the 2015 FEIS.

1.5.2 Alternative 3, Imidacloprid Applications with Integrated Pest Management (IPM) on Up to 2,000 Acres per Year in Willapa Bay and Grays Harbor

FEIS Alternative 3 described and evaluated the effects of a new NPDES Individual Permit that would authorize chemical applications of the neonicotinoid insecticide imidacloprid for burrowing shrimp population control on up to 2,000 acres total per year (1,500 acres per year in Willapa Bay³ and 500 acres per year in Grays Harbor⁴). It was possible over the 5-year term of the 2015 Imidacloprid NPDES Individual Permit that the total tideland acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and in Grays Harbor could range from 500 to 2,500 acres under Alternative 3.

WGHOGA would be required to prepare an Integrated Pest Management Plan for the use of imidacloprid, and to submit Annual Operations Plans, and Sampling and Analysis Plans, for proposed treatments, subject to review and approval by Ecology. The 2013 conditional Federal registrations for the imidacloprid products Protector 2F (flowable) and Protector 0.5G (granular) limited the application rate to 0.5 (one-half) pound of active ingredient per acre (a.i./ac), to be applied between April 15 and December 15 in any year for which all required permits and approvals were in-place. A favored method of application under Alternative 3 was aerial spraying using a helicopter. Reviewers interested in a more detailed description of Alternative 3 are referred to FEIS Chapter 2, Section 2.8.3 (pages 2-32 through 2-48). Analysis of the impacts of Alternative 3 compared to the No Action Alternative and Alternative 4 is provided throughout Chapter 3 of the 2015 FEIS.

1.5.3 Alternative 4, Imidacloprid Applications with Integrated Pest Management (IPM) on Up to 500 Acres per Year in Willapa Bay and Grays Harbor, with No Aerial Applications by Helicopter

The 2016 WGHOGA proposal for the use of imidacloprid combined with IPM practices to control burrowing shrimp on commercial clam and oyster beds would authorize chemical applications to up to 485 acres per year within Willapa Bay (1.1 percent of total tideland acres exposed at low tide), and up to 15 acres per year within Grays Harbor (0.04 percent of total tideland area exposed at low tide). It is possible over the 5-year term of the permit (if issued) that the total tideland acreage to be treated within Willapa Bay could range from 485 to 2,425 acres, and in Grays Harbor could range from 15 to 75 acres. This is a reduced-impact alternative compared to FEIS Alternative 3 in that the acreage that may be treated under the requested permit is approximately two-thirds less (64 percent) compared to the acreage of the 2014 WGHOGA proposal evaluated in the 2015 FEIS. The other distinguishing factor about Alternative 4 is the proposal to use equipment such as scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, belly grinders, and/or subsurface injectors. The 2016 WGHOGA proposal specifically excludes aerial applications using helicopters. This may result in smaller plot sizes for individual treatments.

³ Under Alternative 3, the imidacloprid treatment area would constitute approximately 3.3 percent of total tideland area exposed at low tide.

⁴ Under Alternative 3, the imidacloprid treatment area would constitute approximately 1.5 percent of total tideland area exposed at low tide.

The application rate of 0.5 pound a.i./acre for any treatment scenario is the same as the rate of application evaluated in FEIS Alternative 3.

The Imidacloprid NPDES Individual Permit and SIZ authorizations, if issued, would be subject to all applicable State and Federal regulations, and would require annual monitoring in application areas to record and document environmental effects. Applicable regulations administered by Ecology include Clean Water Act (CWA) water quality certification (WQC), regulation of aquatic pesticide applications under a NPDES waste discharge permit, and compliance with Washington State Sediment Management Standards (SMS). Permittees (including applicators) would also be required to comply with Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration requirements for the use of imidacloprid (provided in FEIS Appendix A). The NPDES permit (if issued) would have a duration of up to 5 years. Monitoring results would be reviewed during the 5-year term of the permit, with provisions for Ecology to alter permit conditions if necessary for the protection of the environment. Ecology does not yet have an approved final monitoring plan at the time of this writing.

1.5.4 Other Alternatives Considered and Eliminated from Detailed Evaluation

The 2015 FEIS Chapter 2, Section 2.8.4 (pages 2-48 through 2-56) description of Alternatives Considered and Eliminated from Detailed Evaluation was derived from personal communications with Dr. Kim Patten (Director, WSU Long Beach Research and Extension Unit), and from documents he provided of studies performed over several years on mechanical control methods, physical control methods, alternative culture methods, alternative chemical control methods, and biological controls. The 2016 WGHOGA application to Ecology includes *A Review of the Past Decade of Research on Non-Chemical Methods to Control Burrowing Shrimp* (Miller Nash Graham & Dunn, February 13, 2017, Exhibit C, prepared by Dr. Patten) that summarizes many of the same experiments. Additional methods not previously described in the 2015 FEIS, and results obtained with these methods, are described in Draft SEIS Chapter 2, Section 2.8.5.

A combined physical/mechanical method described by Dr. Patten in 2017 (Miller Nash Graham & Dunn, February 13, 2017, Exhibit C) demonstrated relatively high efficacy and could be considered on a commercial scale. Spikewheel injection of imidacloprid improves chemical contact at the sediment-water interface, particularly in areas where flowing water or heavy eelgrass is present. The 2016 WGHOGA application requests authorization under the NPDES permit (if issued) for small-scale, experimental use of subsurface injectors in order to continue to test the effectiveness of this adaptive management method of application. If small trials identify application methods that would increase efficacy, and/or that would reduce imidacloprid use for a given level of efficacy, WGHOGA may request a modification to the NPDES permit (if issued) to allow commercial-scale use of subsurface injectors in the latter part of the 5-year duration of this permit.

1.6 Summary of Impacts and Mitigation Measures

1.6.1 Literature Review

The 2015 FEIS included a review of more than 100 scientific reports and papers that evaluated the ecology of burrowing shrimp, physical and biological conditions in Grays Harbor and Willapa Bay, and effects of imidacloprid on invertebrate and vertebrate animals, including species listed under the Endangered Species Act (ESA). Information derived from that literature review was incorporated in a number of sections of the FEIS, and was the basis for much of the summary of expected effects of imidacloprid applications under the permit conditions analyzed in 2015. In general, the FEIS concluded that the application of imidacloprid would have minor to moderate effects on non-target invertebrates (e.g., polychaete worms, honey bees), minor effects on vertebrate species, including birds, and minor or insignificant effects on ESA-listed species.

Since the FEIS was published, a number of new studies on the effects of imidacloprid have been published. These new studies include three very large and comprehensive literature surveys. Health Canada (2016) conducted a comprehensive review of the toxicology literature on imidacloprid and published a report summarizing the expected effects of agricultural uses of imidacloprid on the environment based on that review, and on modeled and field data-based estimates of imidacloprid concentrations. The document included evaluation of toxicity to birds, mammals, and terrestrial and aquatic insects, and assessed exposure pathways and possible effects to humans. The U.S. Environmental Protection Agency (EPA) issued two large literature reviews. The EPA (2015) review assessed the effects of imidacloprid on pollinators, with some emphasis on honeybees. The EPA (2017) review was similar to the Health Canada study in that it included a comprehensive literature review and assessment of imidacloprid toxicity in the environment. The EPA (2017) literature review differed from the Health Canada study in that it only focused on aquatic ecosystems and species, and also used a different approach to estimating imidacloprid toxicity to various groups of animals.

Other published studies relevant to WGHOGA's proposed use of imidacloprid were reviewed for the SEIS. These included unpublished studies obtained from EPA through a Freedom of Information Act (FOIA) request. Most of these studies are also reviewed in the Health Canada and EPA documents described above. Many of the reviewed studies addressed potential impacts to freshwater ecosystems, particularly aquatic insects, while fewer focused on marine systems. Extrapolating the results of these studies to marine environments is therefore challenging. Several studies on vertebrates, and on food-web effects of imidacloprid are reviewed in the SEIS, but these areas have received less analysis in comparison to studies on invertebrates. Ecology is currently unaware of studies on the effects of imidacloprid on air quality, land use, recreation, or navigation.

Collectively, the studies considered in the SEIS literature review confirm and build on general conclusions of the literature review conducted for the 2015 FEIS. Most importantly, imidacloprid is highly toxic to many freshwater invertebrates, particularly insects, and reported concentrations of imidacloprid in surface waters are high enough to conclude that the chemical is negatively affecting invertebrate communities in many freshwater ecosystems, and may be impacting animals that feed on these communities. The more limited studies of imidacloprid in marine

environments, including the multiple field trials in Willapa Bay, document that imidacloprid is also toxic to marine invertebrates, but at higher concentrations or longer exposures compared to sensitive freshwater invertebrates. And with the exception of seed-eating birds that may be exposed to agriculturally-treated seeds, imidacloprid is expected to have low toxicity to humans, birds, mammals, fish, and aquatic amphibians.

The 2014 data from the field trials in Willapa Bay, when combined with prior field trials, provide a basis to evaluate probable effects to invertebrates from spraying of commercial shellfish beds with imidacloprid.

- *Water:* The surface water data indicate there will be localized short-term environmental impacts to surface waters, and a strong pattern of high on-plot (up to 1,600 parts per billion [ppb]) and off-plot concentrations during the first rising tide. Imidacloprid was detected at considerable distances off-plot (up to 1,640 feet), but the different sites demonstrated highly variable concentrations ranging from 0 ppb to 4200 ppb (in 2012). These varying results suggest that site-specific differences in how tidal waters advance and mix during a rising tide are important in determining both the distance traveled and concentration of imidacloprid off-plot. Flushing is expected to dilute imidacloprid to undetectable levels within 2 to 3 tidal cycles.
- *Sediment:* Imidacloprid concentrations in the sediment and sediment pore water indicate that there will be localized short-term environmental impacts to sediment and pore water that will decline rapidly following application. A subset of sites still had toxic concentrations after 14 days, but most sites showed undetectable or below the screening value levels at 28 days. Dilution rates were slower in some sediments, especially those with high organic carbon levels, with detectable concentrations still present in some samples at 56 days after treatment.
- *Animals:* Imidacloprid treatment will cause on-plot impacts to zooplankton and benthic invertebrates through either death or tetany (paralysis). These impacts could extend to adjacent off-plot areas, particularly those closest to the treated plot that would be exposed to the highest concentrations of imidacloprid as it is carried off-plot by the incoming tide. These impacts are expected to be localized and short-term, as the field trials have shown that benthic invertebrate populations recover quickly over 14 to 28 days following treatment. As with sediments, areas with high organic carbon levels showed limited invertebrate recovery or recolonization.

The literature review conducted for the SEIS provides new information on the potential toxicity to Dungeness crab of imidacloprid treatments in Willapa Bay and Grays Harbor. These studies support the conclusion that application of imidacloprid to control burrowing shrimp populations will result in death of planktonic and juvenile Dungeness crab on-plot. Dungeness crab in off-plot areas may also experience mortality, particularly in those areas closest to the sprayed plots where water concentrations of imidacloprid are highest. Monitoring has shown juvenile crab losses could range from 2 to 18 crab/acre sprayed depending on survey methods and crab densities. An unknown number of planktonic forms of Dungeness crab may be killed, but losses are expected to be minor, compared to the abundance of planktonic forms of the species estimated in the bays.

The literature review conducted for the SEIS supports the 2015 FEIS conclusion that imidacloprid spraying of commercial shellfish beds in Willapa Bay and Grays Harbor will have limited or no direct adverse effects on birds and fish. That conclusion extends to bird and fish species listed under the Endangered Species Act. Several new studies on green sturgeon, a species of concern in the FEIS, appear to demonstrate that this species would not be adversely affected by imidacloprid treatments. And additional studies on imidacloprid toxicity to birds confirm that under the potential exposure pathways in these estuaries, no direct impacts are expected. However, imidacloprid treatments will reduce invertebrate availability, at least in the short-term, in sprayed plots and in immediately surrounding areas. Indirect effects to birds and fish that feed on invertebrates are therefore possible, but are expected to be minor given both the small acreage that would be sprayed in comparison to the size of Willapa Bay and Grays Harbor, and due to the recovery of invertebrate populations on treated plots.

The SEIS literature review notes some scientific data gaps, including effects of imidacloprid to marine invertebrates from chronic exposure, the long-term persistence of imidacloprid in marine sediments, and indirect effects to species or food chains due to reductions in invertebrate numbers following imidacloprid exposure.

1.6.2 Summary of Impacts of and Mitigation Measures: Alternatives 1, 3 and 4

The full text of the Affected Environment, Potential Impacts, and Mitigation Measures analysis of the 2016 proposed action and alternatives is presented in Draft SEIS Chapter 3. A summary matrix of potential impacts and mitigation measures is provided in Table 1.6-2, below. In some cases, these descriptions are considerably abbreviated from the full discussion in Draft SEIS Chapter 3, and lack explanations of terminology and background information. Summary statements of potential impacts in the table also appear in the absence of the context of existing environmental conditions (the Affected Environment discussions in Draft SEIS Chapter 3). For these reasons, readers are encouraged to review the more comprehensive discussion of issues of interest in the Draft SEIS (and cross-references to the 2015 FEIS) to develop the most accurate understanding of potential impacts and mitigation measures for the 2016 proposed action and alternatives.

The potential impacts of Alternative 1: No Action, were previously described and evaluated in the 2015 FEIS. That information is unchanged at the time of this writing, and is incorporated by reference in this Supplemental EIS. Summary statements from FEIS Table 1.6-2 have been included in the table below for ease of reference.

The potential impacts of and mitigation measures for Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year with aerial applications by helicopter, were also previously described and evaluated in the 2015 FEIS (incorporated by reference). Because the types of impacts and mitigation measures would be very similar to those described in this SEIS for Alternative 4, cross-reference is made in Table 1.6-2 below to the summary of Alternative 4 impacts and mitigation, except where distinctions are noted between these two alternatives.

The SEIS impact analysis included identification of potential on-plot impacts, and localized short-term impacts. These are summarized in Table 1.6-2 below for Alternatives 3 and 4.

From a bay-wide, long-term perspective, no significant unavoidable adverse impacts of Alternative 4 were identified. Significant unavoidable adverse impacts are described in the SEPA Handbook (WAC 197-11, Section 8 – Definitions), as follows:

A significant adverse impact is “a reasonable likelihood of more than a moderate adverse impact on environmental quality.” The severity of an impact should be weighted along with the likelihood of its occurrence. An impact may be significant if its chance of occurrence is not great, but the resulting environmental impact would be severe if it occurred. The determination that a proposed action will (or may) have a significant adverse impact involves context and intensity, and does not lend itself to a formula or quantifiable test. Context may vary with the physical setting. Intensity depends on the magnitude and duration of an impact.

There are two contexts for imidacloprid applications on commercial shellfish beds in Willapa Bay and Grays Harbor. Overall (bay-wide), the proposal is to treat up to 485 acres per year in Willapa Bay (approximately 1.1% of total tideland area exposed at low tide), and up to 15 acres per year in Grays Harbor (approximately 0.04% of total tideland area exposed at low tide), in estuarine environments that experience two 10-ft+ tidal exchanges per day that would result in dilution and flushing following applications of imidacloprid. From a permitting perspective related to the request for Sediment Impact Zone authorizations, on-plot impacts are also taken into consideration by Ecology. Some of the on-plot impacts of imidacloprid applications would result in localized, short-term impacts. These are identified below and in SEIS Chapter 3.

Table 1.6-2. Summary of environmental impacts and mitigation measures associated with alternatives for burrowing shrimp population control in Willapa Bay and Grays Harbor, WA.

Sediments

Alternative 1: No Action⁵

<p>No chemical control of burrowing shrimp populations. Attempts at mechanical control of burrowing shrimp populations are less effective than chemical treatments and would likely result in high density of shrimp and a benthic habitat on commercial shellfish beds that is lower in diversity and productivity than that found on shellfish beds with lower densities of shrimp (Ferraro and Cole 2007).</p>
<p>. The activities of burrowing shrimp may influence sediment biogeochemistry by increasing carbon and nitrogen cycling within the sediment-water interface (D’Andrea and DeWitt 2009). This can counter the effects of eutrophication by supplying nutrients necessary for primary and secondary production, and thus decrease the likelihood of the occurrence of hypoxic or anoxic conditions.</p>
<p>. Burrowing shrimp can re-suspend up to 50% of the sediment they occupy, creating a sediment character similar to quicksand (Posey 1985).</p>
<p>. Oysters and clams sink and suffocate in softened sediments created by the activity of burrowing shrimp (Dumbauld et al. 2001; DeFrancesco and Murray 2010; and personal communication with WGHOGA members, various dates).</p>

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

⁵ Under the No Action Alternative, there would be no permit application, and thus no mechanism for requiring mitigation measures.

Potential Impacts	Mitigation Measures
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters.</p>
<p>Localized Short-Term Impacts. Impacts to sediment and sediment porewater would be similar for Alternative 3 or 4. On-plot and adjacent sediments and sediment porewater would likely result in localized, short-term impacts of imidacloprid application.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to sediments with low TOC would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State Water Quality Standards [WQS] and Sediment Management Standards [SMS]). A new NPDES permit, if issued for Alternative 3, would include sediment monitoring requirements to confirm the effects of imidacloprid applications. Adjustments to permit conditions could be made during the 5-year term of the permit.</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

Potential Impacts	Mitigation Measures
<p>. Imidacloprid would be applied on up to 485 acres <i>per year</i> on commercial shellfish beds in Willapa Bay and up to 15 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 1.1% per year of total tideland acres within Willapa Bay and approximately 0.04% per year of total tideland acres within Grays Harbor.</p>	<p>. IPM practices would be implemented to continue experimenting with alternative physical, biological, or chemical control methods that are as species-specific as possible, economical, reliable, and environmentally responsible. An IPM Plan acceptable to Ecology would be a condition of the NPDES permit, if issued.</p> <p>NPDES PERMIT REQUIREMENTS:</p> <p>The proposed action would require authorization of two Sediment Impact Zones (SIZs) to comply with Washington State Water Quality Standards (WQS) and Sediment Management Standards (SMS). A NPDES permit may only be issued if the proposed use, as conditioned, would comply with all applicable SMS.</p> <p>. The SMS establish sediment quality standards for marine surface sediments, sediment source control standards with which point source discharges must comply, and an antidegradation policy (WAC 173-204-120, -300 through -350, and -400 through -450).</p> <p>. Sediment quality criteria for marine surface sediments include criteria establishing maximum concentrations of specified chemical pollutants, biological effects criteria, and criteria for benthic abundance (WAC 173-204-320).</p> <p>. Applicators would be required to follow all</p>

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
	<p>insecticide label instructions to prevent spills on unprotected soil.</p> <ul style="list-style-type: none"> . A potential NPDES Permit would include sediment monitoring requirements to confirm the effects of pesticide applications. That monitoring would include long-term sampling to evaluate and address any potential persistence of imidacloprid in sediments. Adjustments to permit conditions could be made during the 5-year term of the permit based on the results of that sampling. . A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases, and to describe the preventative measures and facilities that will avoid, contain, or treat spills of imidacloprid, oil, and other chemicals that may be used, processed or stored at the facility that could be spilled into State waters (if any). The Plan would be reviewed at least annually and updated as needed.
<ul style="list-style-type: none"> . Field trials conducted in 2012 and 2014 confirm that imidacloprid persists in sediment after application (Hart Crowser 2013 and 2016). Both the 2012 and 2014 results confirm that imidacloprid concentrations in sediment decline rapidly, remain above toxicity screening values after 14 days, and are generally undetectable or below screening values at 28 days. The 2012 results documented detectable concentrations of imidacloprid at 56 days for two of five sampled locations, both of which were below screening levels. 	<p>Same as above.</p>
<ul style="list-style-type: none"> . The 2016 WGHOGA permit application requests authorization to apply imidacloprid in both north and south Willapa Bay, locations known to contain sediments with higher organic carbon levels. Field and laboratory studies have documented that imidacloprid levels in sediments decline more slowly over time as organic carbon levels increase (Grue and Grassley 2013). This could lead to higher toxicity of benthic organisms than in sediments where imidacloprid dissipates quickly. 	<p>Same as above.</p>
<ul style="list-style-type: none"> . Measurable concentrations of imidacloprid in sediment pore water were generally undetectable or below toxicity screening levels by 28 days or less at a majority of the sites tested, but with slower levels of decline at sites with higher organic levels in the sediments (e.g., the Cedar River test plots). 	<p>Same as above.</p>
<ul style="list-style-type: none"> . Minor (if any) sediment disturbance would occur at the time of treatment with methods of application using land-based equipment suitable for the chemical formulation (i.e., liquid or granular imidacloprid), such as scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, and/or belly grinders. 	<p>No mitigation would be required for minor sediment disturbance during application.</p>
<p>Localized Short-Term Impacts. On-plot and adjacent sediments and sediment porewater would likely result in localized, short-term impacts of imidacloprid application under Alternative 4.</p>	
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and</p>	

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including the Washington State WQS and SMS), any potential significant unavoidable adverse impacts to sediments would be expected to be localized and short term as a result of implementing Alternative 4. The requested Ecology NPDES permit, if issued, would include sediment monitoring requirements to confirm the effects of pesticide applications. That monitoring would include long-term sampling to evaluate and address any potential persistence of imidacloprid in sediments. Adjustments to permit conditions could be made during the 5-year term of the permit based on the results of that sampling.	

Air Quality

Alternative 1: No Action

<ul style="list-style-type: none"> . There would be gasoline or diesel exhaust emissions to the air associated with the transport and operation of mechanical and shellfish culture equipment if these methods were used to attempt to control burrowing shrimp populations. . No significant adverse air quality impacts would be expected due to consistent wind circulation within Willapa Bay and Grays Harbor.
<ul style="list-style-type: none"> . There would be no insecticide applications to commercial shellfish beds under the No Action Alternative, and thus no risk of airborne dispersion.

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<ul style="list-style-type: none"> . Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor. . The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3. 	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters:</p> <p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . WGHOGA would be responsible for posting signs at least 2 days prior to aerial treatment [using helicopters], and maintain these signs in-place for at least 30 days after treatment.
<p>Localized, Short-Term Impacts. Impacts to air quality on or in the vicinity of plots treated with imidacloprid would be similar under Alternative 3 or 4, and these would likely be localized and short-term. Sources of emissions to the air would include vehicles (e.g., ATVs or boats) operating immediately over a plot during treatment. Under Alternative 3, helicopters could also be used to make aerial spray applications.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to air quality would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including disclosure of application dates and locations).</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<ul style="list-style-type: none"> . Emissions to the air under Alternative 4 would be lower than those projected to occur with Alternative 3, 	<ul style="list-style-type: none"> No mitigation measures would be required for vehicle or vessel exhaust emissions to the air.

Potential Impacts	Mitigation Measures
<p>which included the use of helicopters for aerial applications of imidacloprid. Alternative 4 specifically excludes aerial applications using helicopters. Imidacloprid may be applied using suitable vessels or land-based equipment, such as scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, and/or belly grinders.</p> <ul style="list-style-type: none"> . Vehicular and boat trips associated with imidacloprid applications would be added to existing trips for shellfish planting, rearing and harvest activities. Boat application of imidacloprid, if approved and used, would also contribute to emissions. . Emissions associated with Alternative 4 would not be expected to impair attainment of air quality standards in Pacific or Grays Harbor counties. 	
<ul style="list-style-type: none"> . The liquid formulation of imidacloprid (Protector 2F) is considered to be non-volatile, but slightly toxic by inhalation. . The granular formulation of imidacloprid (Protector 0.5G) is also considered to be non-volatile and is relatively non-toxic by inhalation. 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . It would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. . Average wind speed at the time of application shall not exceed 10 mph. . Persons handling the granular form of imidacloprid (Protector 0.5G) would be required to wear a respirator or dust mask.
<ul style="list-style-type: none"> . Applications of imidacloprid on commercial shellfish beds should pose little risk of exposure to the public or other bystanders due to lack of proximity to public gathering places. 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>WGHOGA would be responsible for implementing the public notification requirements listed below under Alternative 4, Human Health: Mitigation Measures.</p> <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <ul style="list-style-type: none"> . The WGHOGA IPM Coordinator would be responsible for posting, maintaining and removing public notice signs. . A website would be used in lieu of newspaper announcements for public notification of specific dates and locations of proposed imidacloprid applications within Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification.
<ul style="list-style-type: none"> . Both the liquid (Protector 2F) and granular (Protector 0.5G) forms of imidacloprid have only a slight odor, and most or all applications would be made away from the public and during periods of low wind. Therefore, it is unlikely that the odor would be detectable to off-site observers. 	<p>No mitigation measures would be required for odors associated with the use of imidacloprid.</p>
<p>Localized, Short-Term Impacts. Potential impacts to air quality for treated plots under Alternative 4 would likely be localized and short-term. Sources of emissions to the air would include vehicles (e.g., ATVs or boats) operating immediately over a plot during treatment. There would be no use of helicopters under Alternative 4.</p>	

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including disclosure of application dates and locations), no significant unavoidable adverse impacts to air quality would be expected as a result of implementing Alternative 4. Pesticide applications for burrowing shrimp population control would be implemented in compliance with FIFRA Registration restrictions and NPDES permit conditions that specify appropriate application equipment and spray drift management techniques to avoid or minimize off-target exposures. FIFRA Registration and NPDES permit conditions also include public notification requirements to inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided.</p>	

Surface Water

Alternative 1: No Action

<p>If mechanical means of burrowing shrimp population control were utilized, there would be localized occurrences of turbidity due to sediment destabilization. It is unlikely that any water quality exceedances would occur due to shallow water depth, naturally turbid water, and the fact that Willapa Bay and Grays Harbor are intertidal environments that often go dry.</p>
<p>If alternative shellfish culture methods were used, such as bag culture or long-line culture, potential impacts to surface water quality may include the introduction of anthropogenically-derived waste such as plastics, mesh bags, and ropes that may be dislodged during storm events.</p>
<p>No pesticides would be discharged to Willapa Bay or Grays Harbor under the No Action Alternative for the purpose of burrowing shrimp population control.</p>

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters:</p> <p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. Make aerial [i.e., helicopter] applications of imidacloprid on beds exposed at low tide [as opposed to other stages of the tidal cycle].</p>
<p>Localized, Short-Term Impacts. Impacts to surface water quality on plots treated with imidacloprid would be similar under Alternative 3 or 4, and these would likely be short-term. Experimental trials conducted in 2012 and 2014 confirm that imidacloprid dissolves in surface water and may persist in the water column during the first tidal cycle. See additional information in the description of localized, short-term impacts to surface water under Alternative 4, below.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to surface water quality would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State WQS and SMS). A new NPDES</p>	

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>permit, if issued for Alternative 3, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made during the 5-year term of the permit.</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<ul style="list-style-type: none"> . Imidacloprid and the degradation byproducts of imidacloprid would enter Willapa Bay and Grays Harbor following treatment of commercial shellfish beds. . The imidacloprid application rate authorized by the conditional FIFRA Registration for Protector 2F and Protector 0.5G (the liquid and granular forms of imidacloprid, respectively) is 0.5 (one-half) pound of active ingredient per acre (a.i./ac). . The application period authorized by the conditional FIFRA Registration for the liquid and granular forms of imidacloprid is April 15 through December 15. 	<p>NPDES PERMIT REQUIREMENTS:</p> <ul style="list-style-type: none"> . Alternative 4 would require issuance of a NPDES individual permit conditioned to ensure compliance with Washington State WQS and other applicable regulations, including USEPA registration requirements for the use of imidacloprid in the estuarine environment for the purpose of burrowing shrimp population control. . Discharge monitoring and data reporting would be required. . The imidacloprid water quality monitoring plan would take into account the treatment plan proposed, and current information regarding this proposal would be used to condition the permit (if issued). . The discharge of imidacloprid authorized by an NPDES permit (if issued) would be limited to waters of the State of Washington; specifically, to the waters of Willapa Bay and Grays Harbor for the purpose of burrowing shrimp population control on commercial shellfish beds. . A Spill Control Plan (SCP) would be required. . An NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made during the five-year term of the permit.
<ul style="list-style-type: none"> . The maximum annual treatment acreage proposed under Alternative 4 is 500 acres (up to 485 acres <i>per year</i> within Willapa Bay, and up to 15 acres <i>per year</i> within Grays Harbor); therefore, imidacloprid applications would occur on approximately 1.1% per year of total tideland acres within Willapa Bay and approximately 0.04% per year of total tideland acres within Grays Harbor. . It is possible that the total tideland acreage to be treated over the 5-year term of the NPDES permit could range from 485 to 2,425 acres within Willapa Bay, and from 15 to 75 acres within Grays Harbor. 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Restrict imidacloprid treatments so that the insecticide would not be applied on beds where shellfish are within 30 days of harvest. . Make aerial applications of imidacloprid [from vessels or land-based equipment] on beds exposed at low tide. Protector 0.5G applications made from a floating platform or boat may be applied to beds under water using a calibrated granular applicator. . Maintain buffer zones between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days: a 100-ft buffer for aerial applications, or a 25-ft buffer for applications made by hand. . It is recommended that a properly designed and maintained containment pad be used for mixing and loading imidacloprid into application equipment.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
	<ul style="list-style-type: none"> . If a containment pad is not used, a minimum distance of 25 feet should be maintained between mixing and loading areas and potential surface to groundwater conduits.
<ul style="list-style-type: none"> . Hydrolysis, photolysis, and microbial degradation would be the primary means of imidacloprid breakdown in the aquatic environment. Factors such as water chemistry, temperature, adsorption to sediment, water currents, and dilution can all have significant effects on the persistence of imidacloprid (CSI 2013). 	<p>Same as all entries in the Alternative 4, Surface Water: Mitigation Measures column above.</p>
<ul style="list-style-type: none"> . Data from studies conducted in Willapa Bay in 2012 and 2014 show that imidacloprid dissolves readily in surface water and moves off treated areas with incoming tides and in drainage channels. This may allow imidacloprid to impact non-treated areas through surface water conveyance, particularly as tidal waters first pass over off-plot areas. However, as tidal waters continue to flow onto off-site areas, imidacloprid is expected to dilute significantly and rapidly, a process that would continue through successive tidal cycles. Accordingly, imidacloprid in water is expected to have a low to moderate potential to cause ecological impacts in non-target areas. 	<p>Same as above.</p>
<ul style="list-style-type: none"> . Laboratory studies have shown that the half-life of imidacloprid at pH 5 and pH 7 can be greater than one year, while the half-life of imidacloprid at pH 9 is approximately one year (CSI 2013). (The pH of seawater is more alkaline, tending to range from 7.5 to 8.4.) . Other laboratory studies of photo-degradation of imidacloprid in water suggest that it has a half-life of approximately 4.2 hours in water and degrades under natural sunlight (CSI 2013). . Further laboratory experiments have shown varied results with a half-life ranging from 14 to 129 days (Spitteller 1993 and Henneböle 1998 as cited in CSI 2013). 	<ul style="list-style-type: none"> . Imidacloprid that is not degraded by environmental factors would be diluted by tidal flows in the Willapa Bay and Grays Harbor estuaries.
<p>Localized, Short-Term Impacts. Under Alternative 4, surface water on plots that have been treated with imidacloprid would likely show short-term impacts due to the application of imidacloprid. Experimental trials conducted in 2012 and 2014 confirm that imidacloprid dissolves in surface water and may persist in the water column during the first tidal cycle.</p> <p>Results of the 2012 commercial-scale experimental trials conducted in Willapa Bay (described in the 2015 FEIS, Chapter 3, Section 3.2.3, pages 3-23 through 3-24) documented that detectable concentrations of imidacloprid were observed, in some cases at up to 1,575 feet from the edge of the sprayed plots, on the leading edge of the rising tide. Results from the 2014 field trials in Willapa Bay documented detectable concentrations of imidacloprid at up to 2,316 feet from the edge of sprayed plots (SEIS Chapter 3, Section 3.3.3).</p>	
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to surface water quality would be expected as a result of implementing Alternative 4. The requested Ecology NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made during the five-year term of the permit.</p>	

Plants

Alternative 1: No Action

<ul style="list-style-type: none"> . Mechanical disturbance of oyster and clam beds for burrowing shrimp population control would temporarily affect flora within the treatment areas: microalgae, the upper elevations of eelgrass (both <i>Zostera marina</i> and <i>Z. japonica</i>), and saltmarsh species in their lower elevation locations.
<ul style="list-style-type: none"> . Since mechanical methods of burrowing shrimp control are less effective than chemical methods of control, untreated areas would be affected by burrowing shrimp over time. . Sediment disturbance caused by burrowing shrimp can inhibit eelgrass growth and density (Dumbauld and Wyllie-Echeverria 2003; Hosack et al. 2006).
<ul style="list-style-type: none"> . Mechanical methods of burrowing shrimp control (e.g., boats grounding on sand and mudflats, harrowing, raking and other activities) would have localized and temporary effects on marine and salt marsh vegetation. . Damaged plants would be suppressed for a period of time before re-growth; plant seeds may germinate during the same or following season; roots, rhizomes and seeds disrupted in one location may be distributed by the tide to other sites, potentially enhancing dispersion of affected plants.

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<ul style="list-style-type: none"> . Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor. . The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3. 	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters:</p> <p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Implementing spray drift management techniques (as described above under Alternative 4, Air Quality: Mitigation Measures) would be effective at avoiding potential impacts to off-site non-target plants.
<p>Localized, Short-Term Impacts. It is unlikely there would be any localized, short-term impacts to plants under Alternative 3, since plants lack the nervous system pathway through which imidacloprid impacts some organisms.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to plants would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State WQS and SMS). The FIFRA Registration specifies spray drift management techniques, and a new NPDES permit (if issued for Alternative 3), would include conditions that specify treatment methods; require buffers from sloughs and channels; and require discharge monitoring. Adjustments to permit conditions could be made during the 5-year term of the permit.</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<ul style="list-style-type: none"> . Imidacloprid applications may have localized, temporary, and negligible impacts on plants within Willapa Bay and Grays Harbor if the requested NPDES permit is issued. Imidacloprid is a systemic insecticide 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Implementing spray drift management techniques (as described below under Alternative 4, Animals

Potential Impacts	Mitigation Measures
<p>that is taken up from the soil (or sediments) by plants and is present in the foliage of plants.</p> <ul style="list-style-type: none"> . Rooted plants such as eelgrass and salt marsh plants could uptake the insecticide in these areas and small concentrations of imidacloprid have been found in eelgrass for limited periods of time (Grue & Grassley 2013; Hart Crowser 2013). Also, if applicators failed to employ effective spray drift management techniques, imidacloprid might stray from the application zone to adjacent aquatic or shoreline plants that are occasionally inundated by tidal waters. 	<p>[Pollinators]: Mitigation Measures) would be effective at avoiding potential impacts to off-site non-target plants.</p> <ul style="list-style-type: none"> . Maintaining buffers from sloughs and channels (as described above under Alternative 4, Surface Water: Mitigation Measures) would also be effective at avoiding potential impacts to off-site non-target plants. . Maintaining small application areas for short periods of time would be effective at minimizing potential impacts to plants. . Preparing and implementing a Spill Control Plan (as described above under Alternative 4, Surface Water: Mitigation Measures) would also be protective of plants. <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <ul style="list-style-type: none"> . WGHOGA would implement measures over time to minimize the frequency and quantity of imidacloprid applications necessary for the effective control of burrowing shrimp populations.
<ul style="list-style-type: none"> . The EPA (2017) reviewed for SEIS preparation notes that: “[a]quatic plants will not be assessed as available data for vascular and non-vascular aquatic plants indicate toxicity endpoints that are several orders of magnitude above the highest estimated environmental concentrations in surface waters.” Imidacloprid toxicity derives from its ability to bind to specific sites on nerves (nicotinic acetylcholine receptors – nAChRs), causing them to malfunction (e.g., excessive nervous stimulation, blockage of the receptor sites). Plants lack a nervous system, thus making it unlikely that imidacloprid would negatively affect marine plant species. 	<ul style="list-style-type: none"> . No additional mitigation measures for imidacloprid applications that may come into contact with plants are proposed beyond the FIFRA Registration requirements since plants lack a nervous system pathway through which imidacloprid impacts some organisms.
<p>Localized, Short-Term Impacts. It is unlikely there would be any localized, short-term impacts to plants under Alternative 4, since plants lack the nervous system pathway through which imidacloprid impacts some organisms.</p>	
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations, no significant unavoidable adverse impacts to estuarine or terrestrial plants would be expected as a result of implementing Alternative 4. FIFRA Registration specify spray drift management techniques and the requested Ecology NPDES permit, if issued, would include conditions that specify treatment methods; require buffers from sloughs and channels; and require discharge monitoring. Adjustments to permit conditions could be made during the 5-year term of the permit.</p>	

Animals

Alternative 1: No Action

<p>MARINE ZOOPLANKTON</p> <p>. Alternative 1 would be unlikely to adversely affect marine zooplankton because, in the absence of insecticide applications for the control of burrowing shrimp populations, there would be no potential insecticide effect to zooplankton from this source.</p>
<p>BENTHIC INVERTEBRATES (BURROWING SHRIMP, CLAMS AND OYSTERS, DUNGENESS CRAB)</p> <p>Due to the limited amount of tideland acreage proposed for treatment with imidacloprid, the No Action Alternative would be unlikely to have either a significant beneficial or adverse effect on benthic invertebrates, including burrowing shrimp, clams and oysters, and Dungeness crab (as described in Draft SEIS Chapter 2, Section 2.8.4.3).</p>
<p>FORAGE FISH AND GROUND FISH</p> <p>. The No Action Alternative would be unlikely to have a significant beneficial or adverse effect on forage fish or groundfish in Willapa Bay and Grays Harbor due to the relatively small proportion of tidelands within each estuary that have been or would be treated with an insecticide for the control of burrowing shrimp populations.</p>
<p>BIRDS</p> <p>. The No Action Alternative would be unlikely to have a significant beneficial or adverse effect on birds in Willapa Bay or Grays Harbor due to the relatively small proportion of tidelands within each estuary that have been or would be treated with an insecticide for the control of burrowing shrimp populations.</p>
<p>POLLINATORS</p> <p>. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on honey bees (or other pollinators) as no insecticides would be sprayed on commercial clam or oyster beds in Willapa Bay or Grays Harbor.</p> <p>. In addition, potential impacts from this alternative would be limited because honey bees are not attracted to sandflats or mudflats, and bumble bees and similar pollinators prefer terrestrial flowering plants that are not found in the bays (Macfarlane and Patten 1997).</p>
<p>MAMMALS</p> <p>. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on mammals in Willapa Bay or Grays Harbor due to the small size of these areas in relation to the total tideland area of Willapa Bay and Grays Harbor.</p>

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters:</p> <p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. Helicopters used to apply Protector 2F should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be</p>

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type.</p> <ul style="list-style-type: none"> . Application of the liquid form of imidacloprid (Protector 2F) by helicopter and hand-held equipment would tend to flush birds from the target area (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director). . Application events and flushing (i.e., scaring) birds from application sites would be short-term and temporary. . Aerial dispersal of imidacloprid limited by spray drift management techniques would minimize potential exposure to non-target species, and therefore would be unlikely to adversely affect bird populations within Willapa Bay or Grays Harbor. . Application methods and spray drift management techniques required by the conditional FIFRA Registrations would minimize the potential for direct exposure to migratory birds during the imidacloprid seasonal application period between April 15 and December 15. <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <ul style="list-style-type: none"> . The 2014 WGHOGA proposal to avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas would be protective of pollinators.
<p><i>Localized, Short-Term Impacts.</i> The localized short-term impacts of Alternative 3 on zooplankton and benthic invertebrates would be similar to those described below for Alternative 4. These impacts would be expected to occur within the boundaries of the treatment plots as imidacloprid is applied directly to the substrate or in shallow water, and could extend to adjacent off-plot areas, particularly those closest to the treated plot that would be exposed to the highest concentrations of imidacloprid as it is carried off-plot by the incoming tide. Field trials have shown that benthic invertebrate populations recover quickly (e.g., re-populate treated plots), although this recovery may be slower in sediments with high organic carbon levels.</p> <p>Dungeness crab juveniles and planktonic forms are likely to be killed by the application of imidacloprid on shellfish beds. Given the concentrations of imidacloprid required to produce tetany in crabs, and the limited exposure of off-plot areas due to the rapid dilution by rising tide waters, it is likely that most impacts to juvenile crab would be limited to on-plot areas, or areas adjacent to plots sprayed directly with imidacloprid during low tide conditions. Planktonic forms of Dungeness crab off-plot may also be impacted by rising tidewaters carrying imidacloprid. See additional information in the summary of localized short-term impacts to Animals of Alternative 4, below.</p>	
<p><i>Significant Unavoidable Adverse Impacts:</i> Similar to Alternative 4, only localized and short-term impacts to animals would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State WQS and SMS). A new NPDES Individual Permit (if issued for Alternative 3) would include conditions that limit the maximum annual tideland acreage for insecticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of pesticide applications. Adjustments to permit conditions could be made throughout the 5-year term of the permit based on the results of this monitoring.</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>MARINE ZOOPLANKTON</p> <p>Imidacloprid applications at the concentration being proposed (0.5 lb active ingredient per acre) would be expected to cause on-plot impacts to zooplankton through either death or paralysis. Off-plot (bay-wide) impacts are less likely to occur at the concentrations being proposed, primarily due to dilution of imidacloprid in surface water following tidal flow.</p>	<ul style="list-style-type: none"> . Imidacloprid would be applied in-water during outgoing tides or on the exposed sand or mudflats of commercial shellfish beds when densities of zooplankton would be low due to limited water depth. . Imidacloprid breaks down in water and has a low volatilization potential in air, minimizing any potential effects on zooplankton in Willapa Bay or Grays Harbor (Gervais et al. 2010).
<p>BENTHIC INVERTEBRATES (BURROWING SHRIMP, CLAMS AND OYSTERS, DUNGENESS CRAB)</p> <ul style="list-style-type: none"> . Imidacloprid applications at the concentration being proposed (0.5 lb active ingredient per acre) would be expected to cause on-plot impacts to benthic invertebrates through either death or paralysis. . Imidacloprid applications at the concentration being proposed would not decrease biodiversity other than to temporarily reduce burrowing shrimp populations within application areas (CSI 2013). . There is a potential for imidacloprid to persist in certain sediment types (Grue and Grassley 2013), and toxic effects to benthic infauna are likely in sediments with elevated organic carbon concentrations. . Studies have found that the use of imidacloprid at the proposed concentration would have some effects on polychaete worms or molluscs (bivalves, snails), including oysters and clams (Hart Crowser 2016). . Imidacloprid causes a temporary tetanus (paralysis) reaction in copepods (small crustaceans) and shrimp, creating an exposure pathway for predation by fish and birds that feed on copepods and shrimp flushed from their burrows. . Application of imidacloprid to control burrowing shrimp populations will result in tetany and death of planktonic and juvenile Dungeness crab on-plot, and adjacent to treated plots (Osterberg et al. 2012; Patten and Norelius 2017). 	<p>NPDES PERMIT REQUIREMENTS:</p> <ul style="list-style-type: none"> . NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made during the five-year term of the permit. <p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Spray drift management techniques and treatment site requirements specified in the conditional FIFRA Registrations for the liquid and granular forms of imidacloprid would be implemented under Alternative 4. These state that aerial applications must occur on beds exposed at low tide, and granular applications may be applied to beds under water using a calibrated granular applicator, operating from a floating platform or boat. . Application of the granular form of imidacloprid during periods of shallow standing water would limit the potential for crabs to be affected.
<p>FORAGE FISH AND GROUND FISH</p> <ul style="list-style-type: none"> . Imidacloprid has very low toxicity to vertebrates (CSI 2013). . It is unlikely that there would be adverse effects to forage fish or groundfish from imidacloprid in water (CSI 2013) due to dilution, adsorption of the chemical onto sediment, and due to applications being made during low tide conditions. 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Aerial dispersal of imidacloprid limited by spray drift management techniques (described below) would minimize the potential for exposure to non-target species, and therefore would be unlikely to adversely affect fish populations within Willapa Bay or Grays Harbor.
<p>BIRDS</p> <ul style="list-style-type: none"> . Concentrations of imidacloprid below 150 mg/kg are generally non-toxic to birds (Gervais et al. 2010), and CSI (2013) found that imidacloprid application was unlikely to adversely affect birds in Willapa Bay or Grays Harbor, based on an application concentration of 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Application of the liquid form of imidacloprid (Protector 2F) disperses quickly, and granular (Protector 0.5G) application dissolves readily in shallow water. In addition, application methods would tend to flush birds from the target area (personal communication with Dr.

Potential Impacts	Mitigation Measures
<p>approximately 3.34 mg/kg.⁶</p> <ul style="list-style-type: none"> . Although ingestion of imidacloprid pellets could lead to toxicity to birds (Health Canada 2016; Gibbons et al. 2015), the use of imidacloprid pellets in Willapa Bay or Grays Harbor is unlikely to impact birds because pellets would dissolve on contact with water from the incoming tide. . Although imidacloprid toxicity in birds is not likely, imidacloprid toxicity to invertebrates could have food chain effects that could indirectly affect birds. Reduction in invertebrates could reduce the levels of food for bird species, at least locally, particularly for shorebirds that feed exclusively on invertebrates. However, any such reductions are not expected to be significant because of the small area that would receive imidacloprid applications each year relative to the total area available for such foraging in Willapa Bay and Grays Harbor. 	<p>Kim Patten, WSU Pacific County Extension Director).</p> <ul style="list-style-type: none"> . Application events and flushing (i.e., scaring) birds from application sites would be short-term and temporary. . Aerial dispersal of imidacloprid limited by spray drift management techniques would minimize potential exposure to non-target species, and therefore would be unlikely to adversely affect bird populations within Willapa Bay or Grays Harbor. . Application methods and spray drift management techniques required by the conditional FIFRA Registrations would minimize the potential for direct exposure to migratory birds during the imidacloprid seasonal application period between April 15 and December 15. Peak abundance of red knot and many shorebirds occurs in April and May, in relation to the imidacloprid application period authorized by the conditional FIFRA Registration: April 15 through December 15.
<p>POLLINATORS</p> <ul style="list-style-type: none"> . Imidacloprid is toxic to bees in direct contact or as a residual on flowering plants (USEPA 2013b). . The proposed rate of application of imidacloprid (0.5 lb active ingredient per acre) would be below concentrations that would impact honey bees (USEPA 2013b). . The potential for direct exposure to pollinators or their associated plant species would be negligible since honey bees are not attracted to sandflats or mudflats; bumble bees and similar pollinators prefer terrestrial flowering plants that are not found in the bays; and neither are likely to be present over estuarine waters that cover commercial shellfish beds (CSI 2013). . In the professional opinion of the Washington State Department of Agriculture, Special Pesticide Registration Program Coordinator consulted during preparation of the 2015 FEIS, there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats due to the spray drift management techniques and buffers required by the FIFRA Registrations described in the Mitigation Measures column at right (personal communication with Erik Johansen, March 19, 2014). 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>FIFRA Registration spray drift management techniques would become conditions of the NPDES permit (if issued) for the use of imidacloprid:</p> <ul style="list-style-type: none"> . Average wind speed at the time of application shall not exceed 10 mph when either Protector 0.5G or 2F is applied by air. Further, aerial applications shall not occur during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning. . Applications of imidacloprid shall be made at the lowest possible height that is safe to operate ground equipment or barges, and that would reduce exposure of the granules to wind. . When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. . No direct treatment on blooming crops or weeds shall occur.
<p>MAMMALS</p> <ul style="list-style-type: none"> . Imidacloprid has very low toxicity to vertebrates (Health Canada 2016; CSI 2013). . Imidacloprid exposure for mammals would be related to direct ingestion. . Terrestrial mammals are unlikely to be present on shellfish beds during daylight hours when imidacloprid 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . Aerial dispersal of imidacloprid limited by spray drift management techniques (described above) would minimize the potential for exposure to non-target species, and therefore would be unlikely to adversely affect mammal populations within Willapa Bay or Grays Harbor.

⁶ Based on an assumption of imidacloprid being present in the top one centimeter of the sediment and a sediment density of 1.5 grams per cubic centimeter (g/cc).

Potential Impacts	Mitigation Measures
<p>would be applied. A reduction in invertebrates could reduce the level of prey items for these species, at least locally. However, any such reductions are not expected to be significant because of the small area that would be treated relative to the total area available in these estuaries for such foraging.</p> <p>. Harbor seals and gray whales are present in Willapa Bay and Grays Harbor, but generally do not use the high intertidal sand and mudflats where clam and oyster farming occurs. It is unlikely that any impacts to invertebrate prey species would be large enough to impact these marine mammals.</p>	<p>. No specific mitigation measures would be required for marine or terrestrial mammals.</p>
<p>Localized, Short-Term Impacts. Alternative 4 would be expected to cause on-plot impacts to zooplankton and benthic invertebrates through either death or paralysis. These impacts would be expected within the boundaries of the treatment plots as imidacloprid is applied directly to the substrate or in shallow water, and could extend to adjacent off-plot areas, particularly those closest to the treated plot that would be exposed to the highest concentrations of imidacloprid as it is carried off-plot by the incoming tide. These impacts are generally expected to be localized and short-term, as field trials have shown that benthic invertebrate populations recover (e.g., re-populate treated plots) within 14 to 28 days following treatment, although recovery may be delayed in sediments with high organic carbon levels.</p> <p>The two reviewed crab studies (Patten and Norelius 2017, Osterberg et al. 2012), and in particular the field observations of affected crab after field-spraying in Patten and Norelius, confirm that Dungeness crab juveniles and planktonic forms are likely to be killed by the proposed application of imidacloprid on shellfish beds. Given the concentrations of imidacloprid required to produce tetany in crabs, and the limited exposure of off-plot areas due to the rapid dilution by rising tide waters, it is likely that most impacts to juvenile crab would be limited to on-plot areas, or areas adjacent to plots sprayed directly with imidacloprid during low tide conditions (as shown in 2014 field trials). Planktonic forms of Dungeness crab off-plot may also be impacted by rising tidewaters carrying imidacloprid.</p>	
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations and regulations (including Washington State Water Quality Standards), any potential significant unavoidable adverse impacts to marine or terrestrial animal populations would likely be localized and short term.</p> <p>There is a low probability of adverse effects to birds, fish or other vertebrates. Invertebrates, including Dungeness crab would likely be killed or displaced from treatment areas, with recovery of these populations likely within 28 days or less on most treatment areas. Permit conditions and mitigation measures described below would be protective of surface water quality and for fish, including ESA-listed salmonids and green sturgeon. The NPDES Individual Permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of pesticide applications. Adjustments to permit conditions could be made throughout the 5-year term of the permit based on the results of this monitoring.</p>	

Threatened, Endangered and Protected Species

Alternative 1: No Action

<p>SALMONIDS INCLUDING BULL TROUT</p> <p>. The No Action Alternative would be unlikely to have either a significant beneficial or adverse effect on salmonids in Willapa Bay or Grays Harbor due to the small size of these areas in relation to the total tideland area of Willapa Bay and Grays Harbor.</p> <p>. To the extent that a reduction in eelgrass habitat and prey availability were to occur in untreated areas due to an increase in the density of burrowing shrimp, shelter and food sources could be reduced during the juvenile salmonid out-migration in these limited areas.</p>
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<p>. Increased turbidity due to mobilized sediments caused by mechanical control efforts and/or by the burrowing activity of shrimp could locally reduce foraging efficiency for short periods of time, resulting in reduced presence of juvenile salmon in untreated areas.</p>
<p>GREEN STURGEON</p> <p>. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on green sturgeon in Willapa Bay or Grays Harbor due to the relatively small proportion of tidelands within each estuary that have been or would be treated with pesticide for the control of burrowing shrimp.</p> <p>. The green sturgeon diet may seasonally consist of up to 50% burrowing shrimp (Dumbauld et al. 2008). Prey availability may increase on untreated commercial shellfish beds; however, this effect would be highly localized relative to the full extent of the bays.</p>
<p>MARBLED MURRELET</p> <p>. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on marbled murrelet, their habitat, or prey availability in Willapa Bay or Grays Harbor.</p> <p>. Marbled murrelet critical habitat is designated upland from these two bays.</p>
<p>WESTERN SNOWY PLOVER</p> <p>. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on western snowy plover in Willapa Bay or Grays Harbor. Most snowy plover use of the area is restricted to coastal beaches that are physically separated from proposed sites where imidacloprid would be used (see Figures 2.3-2 and 2.3-3 in SEIS Chapter 2).</p> <p>. Snowy plover prefer to forage on invertebrates in wet sand. Decreased prey diversity and softened substrate caused by increased burrowing shrimp activity on untreated commercial shellfish beds could indirectly affect snowy plover foraging success in limited areas as a result of less effective control measures; however, the area of affect would be small in relation to total tideland acreage in the two bays.</p>
<p>STREAKED HORN LARK</p> <p>. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on streaked horn lark because they do not forage on or near shellfish beds.</p> <p>. Streaked horned lark critical habitat is centered on nesting beaches along the coast. Nests are established on bare ground, well above MHHW.</p>

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

Potential Impacts	Mitigation Measures
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters.</p>
<p>Localized Short-Term Impacts. There would be no localized, short-term impacts to threatened, endangered, and protected species due to the application of imidacloprid under Alternative 3.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to threatened, endangered, or protected species would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with</p>	

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
the conditions of pesticide registrations, permits and regulations (including Washington State Department of Agriculture General Pesticide Rules). With the exception of some salmonid life stages, it is unlikely that these species would be present on treatment sites at the time of imidacloprid applications. There is a low probability of adverse effect to birds or other vertebrates. Permit conditions and mitigation measures protective of surface water quality would also be protective of salmonids. A new NPDES permit, if issued for Alternative 3, would require discharge monitoring to be conducted to evaluate the effects of imidacloprid applications. Adjustments to permit conditions could be made during the 5-year term of the permit.	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>SALMONIDS INCLUDING BULL TROUT</p> <ul style="list-style-type: none"> . Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat (CSI 2013). . Juvenile salmonids travel through the nearshore habitat during out-migration, feeding on copepods and zooplankton. Since crustaceans and molluscs do not bioaccumulate imidacloprid in their tissues, there would be no expectation of exposure to juvenile salmonids that consume these organisms. . No studies have been found that document the retention of imidacloprid in the tissue of burrowing shrimp. Therefore, no affect to salmonids would be expected if they were to consume some life stage of burrowing shrimp from a treatment site after an imidacloprid application. 	<ul style="list-style-type: none"> . Mitigation measures described above for Alternative 4: Surface Water would be protective of salmonids and their critical habitat within Willapa Bay and Grays Harbor. . Imidacloprid applications would occur during low and out-going tides, when salmon would not be present over commercial shellfish beds. This would limit the potential for salmon exposure during feeding. The granular form of imidacloprid (Protector 0.5G) dissolves before salmon could potentially return to treatment sites.
<p>GREEN STURGEON</p> <ul style="list-style-type: none"> . Imidacloprid has a limited effect on this species as documented in new studies from the University of Washington (reviewed in the SEIS). 	No specific mitigation measures would be required for green sturgeon.
<p>MARBLED MURRELET</p> <ul style="list-style-type: none"> . Marbled murrelet critical habitat and foraging habitat do not overlap with areas where imidacloprid applications would occur on commercial shellfish beds in Willapa Bay or Grays Harbor. These birds forage on the outer coast for forage fish, and are not well documented inside the bays. Therefore, imidacloprid would be unlikely to adversely affect marbled murrelet (CSI 2013). 	No specific mitigation measures would be required for marbled murrelet.
<p>WESTERN SNOWY PLOVER</p> <ul style="list-style-type: none"> . Imidacloprid applications under Alternative 4 would be unlikely to adversely affect western snowy plover because they are rare or absent on commercial shellfish beds within Willapa Bay or Grays Harbor. . The imidacloprid Risk Assessment (CSI 2013) found imidacloprid toxicity exposure for snowy plover to be "minimal acute," and "low likelihood of indirect effects." 	No specific mitigation measures would be required for western snowy plover.
<p>STREAKED HORN LARK</p> <p>Imidacloprid applications under Alternative 4 would be unlikely to adversely affect streaked horn lark or their</p>	No specific mitigation measures would be required for streaked horn lark.

nest sites because they do not occur on commercial shellfish beds within Willapa Bay or Grays Harbor.
Localized Short-Term Impacts. There would be no localized, short-term impacts to threatened, endangered, and protected species due to the application of imidacloprid under Alternative 4.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with pesticide registrations and regulations (including Washington State Department of Agriculture General Pesticide Rules), no significant unavoidable adverse impacts to threatened, endangered or protected species would be expected with Alternative 4. With the exception of some salmonid life stages, it is unlikely that these species would be present on treatment sites at the time of imidacloprid applications. There is a low probability of adverse effect to birds or other vertebrates. Permit conditions and mitigation measures protective of surface water quality would also be protective of salmonids. The NPDES Individual Permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of pesticide applications. The requested Ecology NPDES Permit, if issued, would require discharge monitoring to be conducted to evaluate the effects of imidacloprid applications. Adjustments to permit conditions could be made throughout the 5-year term of the permit.

Human Health

Alternative 1: No Action

. No human population would be exposed to insecticides in estuarine sediments or water under the No Action Alternative.
. Applicators and shellfish harvesters would have no potential exposures to imidacloprid under the No Action Alternative.

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters:</p> <p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. Application equipment specified for the liquid form of imidacloprid (Protector 2F) includes: helicopters equipped with a boom three-quarters as long as the rotor diameter, backpack sprayers, and ground-based vehicles with a boom.</p> <p>. Helicopter pilots must use an enclosed cockpit in a manner that is consistent with the WPS for Agricultural Pesticides.</p> <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <p>. A WGHOGA representative would be present at the time of application at each treatment site scheduled for aerial (i.e., helicopter) applications to provide line-of-sight supervision.</p>

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>Localized, Short-Term Impacts. Localized and short-term impacts to human health due to the application of imidacloprid would be similar under Alternative 3 or 4, and these would only apply to the small number of people who handle and apply the chemicals. Required safety measures for applicators, including personal protective equipment (e.g., gloves, long sleeved shirts), are expected to prevent adverse effects during application.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to human health would be expected with Alternative 3 (if a new NPDES permit were to be issued for Alternative 3), based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State Department of Agriculture General Pesticide Rules). Applicators and handlers would be required to use appropriate application equipment and wear specified Personal Protective Equipment. Public notification requirements would inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided. As a dietary precaution, avoidance and waiting periods are specified between dates of pesticide application and shellfish harvest for consumption.</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<ul style="list-style-type: none"> . Use of imidacloprid would potentially affect only a very small number of people, primarily pesticide handlers and applicators. . Imidacloprid is a systemic insecticide of the chemical class of chloronicotinyls-neonicotinoids; specifically, it is a chloronicotinyl nitroguanidine. The compound acts on the nicotinic acetylcholine receptors (nAChR) in the nervous system of insects, blocking the transmission of nervous signals in the post-synaptic region, resulting in paralysis and death. Vertebrates, including humans, are much less sensitive to imidacloprid than certain aquatic invertebrates because of differences in the nAChR receptors in vertebrates. . Imidacloprid is not considered acutely toxic to humans via dermal or inhalation exposure routes even though it is designated an acute oral toxicant. The 2015 FEIS discusses in detail potential impacts to humans (Chapter 3, Section 3.2.6, pages 3-58 through 3-60). . Health Canada (2016) reviewed case reports of attempted suicides through ingestion of imidacloprid. Based on this work they identified that imidacloprid toxicity “<i>symptoms in humans consist of nausea, vomiting, headache, dizziness, abdominal pain, and diarrhea.</i>” Of 56 attempted suicides, “<i>recovery was seen in all 56 patients reported.</i>” 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <ul style="list-style-type: none"> . To mitigate potential exposure for persons applying imidacloprid, applicators, mixers, loaders, and handlers are advised to wear approved Personal Protective Equipment (PPE), and would be trained in pesticide applications. The following PPE would be required of all imidacloprid applicators and handlers: <ul style="list-style-type: none"> . Long-sleeved shirt and long pants; . Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or Viton; . Shoes and socks; . Protective eyewear; and . Dust masks when using Protector 0.5 G, the granular formulation of imidacloprid. . Manufacturer's instructions must be followed for cleaning and maintaining PPE. . As a dietary precaution, the conditional FIFRA Registration for imidacloprid specifies that no commercial shellfish bed may be treated with this pesticide if the crop is within 30 days of harvest. <p>WASHINGTON STATE DEPARTMENT OF AGRICULTURE GENERAL PESTICIDE RULES (WAC 16-228-1231[1]):</p> <ul style="list-style-type: none"> . Applications would be made by a State-licensed applicator with an aquatic endorsement.
<ul style="list-style-type: none"> . The maximum annual treatment acreage proposed under Alternative 4 is 500 acres (up to 485 <i>per year</i> acres within Willapa Bay, and up to 15 acres <i>per year</i> within Grays Harbor); therefore, imidacloprid applications would occur on approximately 1.1% per year of total tideland acres within Willapa Bay and 	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>WGHOGA would be responsible for implementing the following public notification requirements:</p> <ul style="list-style-type: none"> . Notify the public prior to imidacloprid applications through signs, website postings, and e-mail to interested

Potential Impacts	Mitigation Measures
<p>approximately 0.04% per year of total tideland acres within Grays Harbor.</p>	<p>parties.</p> <ul style="list-style-type: none"> . Post public access areas within 0.25 mile and all public boat launches within a 0.25-mile radius of any bed scheduled for treatment with imidacloprid. Signs shall say "<i>Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not Fish, Crab or Clam within one-quarter mile of the treated area.</i>" Include the location of the treatment area on the sign. . Post signs at 500-ft intervals, at least 2 days prior to aerial treatments [using vessels or land-based equipment], and maintain signs in-place for at least 30 days after treatment. . Do not treat a commercial clam or oyster bed if it contains shellfish within 30 days of harvest. . Maintain buffer zones between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days: a 100-ft buffer for aerial applications, or a 25-ft buffer for applications made by hand. . Do not apply imidacloprid on commercial shellfish beds during Federal holiday weekends. . It would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions. [Boats would need to use a hopper, hopper loaders, and possibly a large barge to hold additional chemical, equipment and personnel.] <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <ul style="list-style-type: none"> . Public notification procedures proposed by WGHOGA would be implemented as described above under Air Quality (Alternative 4): Mitigation Measures.
<p>Localized, Short-Term Impacts. Localized and short-term impacts to human health due to the application of imidacloprid under Alternative 4 would only apply to the small number of people who handle and apply the chemicals. Required safety measures for applicators, including personal protective equipment (e.g., gloves, long sleeved shirts) are expected to prevent adverse effects during application.</p>	
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with pesticide registrations and regulations (including Washington State Department of Agriculture General Pesticide Rules), no significant unavoidable adverse impacts to human health would be expected as a result of implementing Alternative 4. Applicators and handlers would be required to use appropriate application equipment and wear specified Personal Protective Equipment. Public notification requirements would inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided. As a dietary precaution, avoidance and waiting periods are specified between dates of pesticide application and shellfish harvest for consumption.</p>	

Land Use

Alternative 1: No Action
 There would be no direct or indirect impact to upland land uses from the use of mechanical methods of burrowing

shrimp population control or alternative shellfish culture practices on commercial clam and oyster beds in Willapa Bay and Grays Harbor.

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters:</p> <p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. Helicopters used to apply Protector 2F should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type.</p> <p>. When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.</p> <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <p>. Avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas.</p>
<p>Localized, Short-Term Impacts. There would be no localized, short-term impacts to land or shoreline use due to the application of imidacloprid under Alternative 3.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to land or shoreline use would be expected with Alternative 3, based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations.</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>There would be no direct or indirect impact to upland land uses from implementation of Alternative 4.</p>	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. Public notification requirements at public and private shoreline access sites would be the same as those described above for Human Health (Alternative 4): Mitigation Measures.</p>
<p>Due to the distance between existing cranberry farms and the nearest commercial clam and oyster beds adjacent to Willapa Bay and Grays Harbor, and the proposal under Alternative 4 to apply spray applications only at ground level (i.e., no use of helicopters) it is</p>	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. FIFRA Registration spray drift management techniques (described above under Alternative 4, Animals [Pollinators]; Mitigation Measures) would become conditions of the NPDES permit (if issued) for</p>

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
expected that spray drift management requirements for imidacloprid applications would avoid risk of exposure to pollinators present at these farms during the approximate period of April 15 through December 15 each year.	the use of imidacloprid.
Localized, Short-Term Impacts. There would be no localized, short-term impacts to land or shoreline use due to the application of imidacloprid under Alternative 4.	
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations and regulations, no significant unavoidable adverse impacts to land or shoreline use would be expected as a result of implementing Alternative 4.	

Recreation

Alternative 1: No Action Alternative

. Under the No Action Alternative, persons engaged in recreation in Willapa Bay and Grays Harbor would have no risk of exposure to chemical applications for the purpose of burrowing shrimp population control.
. Ongoing attempts at mechanical control of burrowing shrimp populations, and alternative shellfish culture practices would likely constitute no detectable change from existing conditions to persons using Willapa Bay and Grays Harbor for recreational purposes due to the small size of these areas in relation to the total tideland area of Willapa Bay and Grays Harbor.

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% per year of total tideland acres within Willapa Bay and approximately 1.5% per year of total tideland acres within Grays Harbor. . The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be sprayed, and application methods that could include aerial spraying from helicopters under Alternative 3.	Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4, except as distinguished for aerial applications of imidacloprid using helicopters: 2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . Avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas.
Localized, Short-Term Impacts. There would be no localized, short-term impacts to recreation due to the application of imidacloprid under Alternative 3.	
Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to recreation would be expected with Alternative 3 (if a new NPDES permit were to be issued for Alternative 3), based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations.	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
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Potential Impacts	Mitigation Measures
<p>. The maximum annual treatment acreage proposed under Alternative 4 is 500 acres (up to 485 acres <i>per year</i> within Willapa Bay, and up to 15 acres <i>per year</i> within Grays Harbor); therefore, imidacloprid applications would occur on approximately 1.1% per year of total tideland acres within Willapa Bay and approximately 0.04% per year of total tideland acres within Grays Harbor. These small areas of application each year would minimize the potential for exposure of persons using exposed tide flats for recreation in Willapa Bay or Grays Harbor.</p> <p>. As described above in the Human Health section, based on the relatively low acute toxicity and short half-life of imidacloprid in sediment and surface water, there is a very low likelihood of possible human health impacts from imidacloprid exposure to the general population engaging in recreational activities (e.g., shellfish gathering, fishing, swimming). Further, imidacloprid is classified as a “Group E” carcinogen indicating “<i>no evidence of carcinogenicity in humans</i>” (USEPA 1999a, 1999b, 2003).</p> <p>. As discussed in the Animals section above, impacts to birds, fish, and mammals (vertebrates) from imidacloprid applications are not expected, and therefore no impacts to recreation involving these animal groups are expected.</p> <p>. Although Dungeness crab are expected to be affected on-plot, and in some off-plot areas, the number of animals involved is small compared to the bay-wide populations of this species. Thus, no negative impacts to recreational crabbing are expected.</p>	<p>FIFRA REGISTRATION REQUIREMENTS:</p> <p>. Public notification requirements at public and private shoreline access sites would be the same as those described above under Alternative 4, Human Health: Mitigation Measures.</p> <p>. Imidacloprid would not be applied to commercial clam or oyster beds during Federal holiday weekends.</p> <p>2014 WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID:</p> <p>. Public notification procedures proposed by WGHOGA would be implemented as described above under Air Quality (Alternative 4): Mitigation Measures.</p>
<p>. Most commercial shellfish beds are distant from public access areas. The potential for exposure of recreationists to imidacloprid in Willapa Bay and Grays Harbor would be limited by proximity and by the maximum annual treatment area.</p>	<p>Same as above.</p>
<p>Localized, Short-Term Impacts. There would be no localized, short-term impacts to recreation due to the application of imidacloprid under Alternative 4.</p>	
<p>Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, regulations, and public notification requirements, no significant unavoidable adverse impacts to recreation would be expected as a result of implementing Alternative 4.</p>	

Navigation

Alternative 1: No Action

There would be no significant impacts to navigation as a result of mechanical methods of burrowing shrimp population control or alternative shellfish culture practices on commercial clam and oyster beds in Willapa Bay and Grays Harbor.

Alternative 3: Imidacloprid with IPM on up to 2,000 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>. Imidacloprid would be applied on up to 1,500 acres <i>per year</i> of commercial shellfish beds in Willapa Bay and up to 500 acres <i>per year</i> of commercial shellfish beds in Grays Harbor between April 15 and December 15 each year. These areas would constitute approximately 3.3% <i>per year</i> of total tideland acres within Willapa Bay and approximately 1.5% <i>per year</i> of total tideland acres within Grays Harbor.</p> <p>. The impacts of Alternative 3 were previously described in the 2015 FEIS, and would be similar to those described below for Alternative 4. The distinguishing factors between Alternatives 3 and 4 are the number of tideland acres that could be treated, and application methods that could include aerial spraying from helicopters under Alternative 3.</p>	<p>Mitigation measures for Alternative 3 were previously described in the 2015 FEIS and would be the same as those described below for Alternative 4.</p>
<p>Localized, Short-Term Impacts. There would be no localized, short-term impacts to navigation due to the application of imidacloprid under Alternative 3.</p>	
<p>Significant Unavoidable Adverse Impacts: Similar to Alternative 4, no significant unavoidable adverse impacts to navigation would be expected with Alternative 3 (if a new NPDES permit were to be issued for Alternative 3).</p>	

Alternative 4: Imidacloprid Applications with IPM on up to 500 acres per year of commercial shellfish beds in Willapa Bay and Grays Harbor, with no aerial applications by helicopter.

<i>Potential Impacts</i>	<i>Mitigation Measures</i>
<p>There would be no significant impacts to navigation as a result of imidacloprid treatments for burrowing shrimp population control. Commercial shellfish beds are staked for various purposes at various times of the year. For this reason, stakes placed to identify beds for applications of imidacloprid under Alternative 4 would not constitute a new or different obstruction to watercraft that navigate the shallow areas of Willapa Bay or Grays Harbor where these shellfish beds are located. No stakes or obstructions would be placed in the main navigation channels of either bay.</p>	<p>Public notification requirements at marinas and boat launch sites would be the same as those described above under Alternative 4, Human Health: Mitigation Measures.</p>
<p>Localized, Short-Term Impacts. There would be no localized, short-term impacts to navigation due to the application of imidacloprid under Alternative 4.</p>	
<p>Significant Unavoidable Adverse Impacts: No significant unavoidable adverse impacts to navigation would be expected as a result of implementing Alternative 4.</p>	

1.7 Areas of Controversy and Uncertainty, and Issues to be Resolved

Chapter 1, Section 1.7 of the 2015 FEIS (pages 1-34 through 1-37) described areas of controversy and uncertainty about the use of imidacloprid for burrowing shrimp population control in the marine aquatic environment of Willapa Bay and Grays Harbor. This SEIS section updates those issues, and describes new information identified by Ecology during preparation of the SEIS.

Areas of Controversy. Imidacloprid is a neonicotinoid pesticide. There is controversy over the use of neonicotinoid pesticides in the environment. Much of this controversy is likely due to the widespread distribution (e.g., newspaper and magazine articles) of the results of studies examining the impacts of this class of pesticides on honey bees, other pollinators, and freshwater

aquatic insects. Consequently, a number of countries, states, and local municipalities have banned or significantly restricted the use of neonicotinoid pesticides. A segment of the public is also opposed to the use of chemical pesticides, particularly on food crops, including oysters. Conservation groups are often concerned with the use of pesticides which may have impacts to mammals, birds and fish, or the ecosystems on which these animals depend. Conversely, many oyster growers and public and business members of the communities in which they operate feel strongly that chemical control of burrowing shrimp is essential to the long-term operational and economic survival of the industry. Some growers report feeling they are being unfairly targeted, or that the public does not recognize that they have used chemical control of burrowing shrimp since at least the 1960s without, from their perspective, adverse human or environmental effects. For these and other reasons, consideration by Ecology of a potential permit to apply imidacloprid to commercial shellfish grounds in Willapa Bay and Grays Harbor will be controversial, as the Department learned when it reviewed and approved a 2015 permit (since terminated at the request of WGHOGA).

Another area of controversy involves whether enough scientific information is available to adequately address the potential effects of a proposed permit to apply imidacloprid to commercial shellfish grounds. Neonicotinoid pesticides, and imidacloprid specifically, have been the focus of hundreds of scientific studies, and more recently (e.g., EPA 2017) risk assessments based on reviews of those studies. The majority of data regarding the effects of imidacloprid have been obtained from dose-response studies performed within laboratory settings to determine toxicity over periods ranging from 24 hours to 28 days, or longer. Other published studies have focused on freshwater ecosystems, particularly potential impacts to sensitive freshwater insects. Elements of these studies may not be directly transferrable to aquatic organisms in an estuarine environment where imidacloprid would be directly applied to sediments, and benthic invertebrates, where tidal exchange and dilution would occur within a few hours of application. Helpfully, a number of field studies of imidacloprid and its effects in these specific estuarine environments have been conducted, and they inform much of the analysis of effects in this SEIS. As a condition of the permit, if issued, Ecology would require that these monitoring studies continue. Ecology would review the results of these new studies and consider their applicability to the proposed use of imidacloprid to treat burrowing shrimp populations on commercial shellfish beds in Willapa Bay and Grays Harbor.

During public review of the DEIS for the 2015 permit, some commenters raised concerns about how eradication of burrowing shrimp would affect the ecosystems where these animals are present. However, the WGHOGA application for the permit is not a proposal to eradicate burrowing shrimp in Willapa Bay and Grays Harbor. The proposal is for the control of burrowing shrimp populations on a limited acreage of commercial shellfish beds that have historically been used and dedicated to growing shellfish in these two estuaries. Not all of the tideland acres owned, leased, or currently farmed for commercial clams and oysters would be treated with imidacloprid over the term of the permit. Permit conditions would limit imidacloprid applications to individual treatment sites, not to exceed one application per year. Burrowing shrimp populations in the vast majority of tidelands in Willapa Bay and Grays Harbor would not be treated with imidacloprid, and are expected to continue functioning normally as components of the ecosystems within these estuaries.

Areas of Uncertainty and Issues to be Resolved. The Toxicology Review that accompanies the WSDA registration of the granular and liquid forms of imidacloprid (Protector 0.5G and Protector 2F, respectively) identified the following areas of uncertainty based on WSDA's assessment of the preliminary nature of the environmental fate and effects data presented in the studies submitted with the application (Tuttle 2014):

The results of multi-year studies (> 2 years) are not yet available to affirm whether imidacloprid accumulates in sediments, and if so, the "worst-case" scenario of such accumulation.

- Long-term data on sediment and sediment pore-water concentrations of imidacloprid after treatment are still absent.
- Previous field trials with imidacloprid in Willapa Bay indicate that imidacloprid concentrations decrease following treatment, with concentrations in sediments falling below laboratory detection limits in most samples within 28 days. However, these data also demonstrate that imidacloprid remained at detectable levels in some samples on the last sampling date of the trials (28 days or 56 days), particularly in sediments with higher organic carbon levels (e.g., the 2011 Cedar River trials).
- It is possible that imidacloprid residues may remain in some treatment areas at the time that imidacloprid is again applied to the site. Such a circumstance would constitute a cumulative effect, over time, such that imidacloprid concentrations could occur at higher levels than those expected where no residual imidacloprid remains.
- To test for this possibility, Ecology would (if the permit is issued) require that WGHOGA, as part of its mandatory Monitoring Plan, conduct long-term persistence monitoring of imidacloprid in sediments. This sampling would continue through time to determine when no imidacloprid is detectable in sediment pore water or whole sediments, and to confirm whether a cumulative buildup of imidacloprid would occur over time.

Due to the preliminary nature of research data available at the time of this writing, there is uncertainty regarding whether imidacloprid may have potential long-term sediment toxicity effects on benthic and free-swimming invertebrate communities, the species that utilize them as food sources, and the ability of the Willapa Bay and Grays Harbor estuary ecosystems to maintain homeostasis, as a whole.

- This SEIS includes a review of additional field studies of the effects of imidacloprid on invertebrate communities conducted in 2014. These studies confirmed previous work that showed that invertebrate communities on treatment and control plots were generally similar within 14 to 28 days after treatment. They also demonstrated that imidacloprid is carried for long distances off-plot, by rising tides and could pose some impact, particularly to sensitive species, or in those areas closest to the treatment plots that are most likely to experience high concentrations of imidacloprid.
- This SEIS also includes results from new scientific studies, including studies of possible impacts to Dungeness crab. This work documents that Dungeness crab would be killed or immobilized on-plot, and may also be impacted off-plot. However, the magnitude of the losses is expected to be a minor impact compared to bay-wide populations of Dungeness

crab, and hence would not have a population-level effect on this species within Willapa Bay or Grays Harbor.

- As with potential sediment impacts, Ecology would (if the permit is issued) require that WGHOGA continue monitoring the effects of imidacloprid applications on invertebrates, including Dungeness crab.

Uncertainty has been expressed as to whether the results of experimental trials using imidacloprid on treatment plots up to ten acres in size can be assumed to correlate directly when the spatial extent of the treatment area is increased under the NPDES permit.

- This concern applied to the 2014 permit application, which requested permission to treat up to 1,500 acres *per year* in Willapa Bay, and up to 500 acres *per year* in Grays Harbor, on plots up to 120 acres in size. The 2016 WGHOGA application requests authorization to treat up to 485 acres *per year* in Willapa Bay, and up to 15 acres *per year* in Grays Harbor. Given the reduced acreage, and the elimination of aerial spraying from helicopters from the 2016 WGHOGA application, treated plots are now expected to be 10 acres or less in size, consistent with most of the prior field studies.
- In addition, the 2014 field trial examined the effects of spraying imidacloprid on large parcels, specifically two adjacent 45-acre parcels (for 90 acres total). Results were consistent with those of prior field trials on small plots: rapid recovery of invertebrate populations within 14 to 28 days of treatment.

A well-defined method for determining the treatment threshold to ensure efficacy of the product on the target species of burrowing shrimp (*Neotrypaea californiensis* and *Upogebia pugettensis*) has not yet been formulated from the preliminary research data on imidacloprid.

It is not yet known whether the target species of burrowing shrimp may become resistant to the effects of imidacloprid over time.

Other areas of uncertainty were identified during the original EIS scoping process, in subsequent meetings and communications with Ecology, and during preparation of the FEIS. These are listed below.

Research on the effects of burrowing shrimp on commercial shellfish beds has been done where oysters are the primary crop. Field research data are lacking regarding how burrowing shrimp affect clams, and the threshold for damage to clam beds.

- WGHOGA growers have provided information that indicates, based on their field observations, there is no biological basis for making a distinction between the effects of burrowing shrimp on tidelands primarily used for the production of commercial clams versus areas primarily used for the production of commercial oysters. The adverse effect is on the substrate, not the crop (see FEIS Chapter 2, Section 2.8.3, page 2-34).

The proposed permit would allow imidacloprid treatments from April to December. Some studies have documented seasonal or temperature related effects on imidacloprid toxicity,

specifically that the pesticide has greater efficacy at higher temperatures. There is uncertainty whether imidacloprid treatments during periods of low water temperature will have successfully reduced burrowing shrimp populations.

The effects of imidacloprid on zooplankton species are largely unstudied.

- Under the proposed action, imidacloprid would be applied on selected commercial shellfish beds under low tide conditions when large numbers of zooplankton would not be present (see FEIS Chapter 3, Section 3.2.5). However, those communities on the leading edge of the incoming tide could be exposed to imidacloprid during the first flood tide.
- The SEIS reviews two recent scientific studies that examined the effects of imidacloprid on crab megalopae (the last planktonic stage before settlement to the sediments). Both documented that imidacloprid can cause death or tetany at concentrations that are likely to exist on-plot immediately following treatment, and that may occur off-plot, particularly in those areas closest to the treatment plots that are most likely to experience high concentrations of imidacloprid. By extrapolation, impacts to other planktonic species appears likely. However, given the abundance of zooplankton, effects are expected to be localized and temporary.

Limited information in marine environments is available regarding the possible sub-lethal effects of imidacloprid on non-target aquatic organisms. Ultimately, burrowing shrimp are controlled through sub-lethal effects.

- The SEIS reviews a number of studies that recorded sub-lethal effects, including tetany, reduced feeding, impaired movement, and behavioral changes. Laboratory studies document that these sub-lethal effects are reversed once imidacloprid has been removed.
- Sub-lethal impacts are likely to occur due to exposure to imidacloprid, but they are very difficult to document or measure outside of laboratory conditions. This may remain an area of uncertainty into the future.

Limited information is available regarding imidacloprid impacts to marine vegetation.

- The results of field studies conducted during one season to evaluate uptake in eelgrass tissues showed limited uptake by eelgrass, and imidacloprid was undetectable after 14 days.
- Imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that imidacloprid would adversely affect eelgrass or other marine vegetation (see FEIS Chapter 3, Section 3.2.4).

Limited field verification data are available at the time of this writing regarding the toxicity and persistence of imidacloprid degradation products.

- Some laboratory studies have been conducted using marine waters. The results of these

studies showed that the imidacloprid degradation products have toxicity levels that are equal to or less than the toxicity of the parent compound (SERA 2005) (see FEIS Chapter 3, Section 3.2.3).

A limited number of field studies have been conducted in the estuarine environment to confirm the off-plot movement of imidacloprid following applications of the flowable and granular forms on commercial shellfish beds.

- The SEIS evaluates field data from both 2012 and 2014 trials in Willapa Bay in which off-plot movement of imidacloprid was evaluated. These data showed a strong pattern of high on-plot and low off-plot concentrations during the first rising tide. Imidacloprid was detected at considerable distances off-plot, but at highly variable concentrations (e.g., 0.55 ppb to 1300 ppb). These varying results suggest that site-specific differences in how tidal waters advance and mix during a rising tide are important in determining both the distance traveled and concentration of imidacloprid off-plot.

It is not possible to quantify the total acreage of commercial shellfish beds to be treated with imidacloprid over the five-year term of the NPDES permit.

- The maximum possible acreage is known. If the growers apply imidacloprid to every acre allowed under the permit, and every such acre is sprayed only once, then the maximum acreage to be treated under the potential permit would be 2,425 acres in Willapa Bay (485 acres *per year* times five years), and 75 acres in Grays Harbor (15 acres *per year* times five years).
- In practice, WGHOGA growers may end up not spraying the maximum acreage each year, and/or some acres may be sprayed more than one time in the five-year period. Because this decision is up to WGHOGA growers, subject to Ecology's approval of their Annual Operations Plan, the exact acreage cannot be known for certain at this time.

2.0 Description of the Proposed Action and Alternatives

2.1 Project Proponent

Willapa Grays Harbor Oyster Growers Association (WGHOGA) has applied to the Washington State Department of Ecology (Ecology) for issuance of a new National Pollutant Discharge Elimination System (NPDES) Individual Permit and two Sediment Impact Zone (SIZ) authorizations in Willapa Bay and Grays Harbor for burrowing shrimp¹ control. The 2016 WGHOGA proposal for the use of imidacloprid with Integrated Pest Management (IPM) practices to control burrowing shrimp on commercial shellfish beds² would occur on a limited number of acres in each estuary: up to 485 acres *per year* within Willapa Bay (1.1% of total tideland acres exposed at low tide), and up to 15 acres *per year* within Grays Harbor (0.04% of total tideland area exposed at low tide). Over the 5-year term of a potential permit, the total acreage to be treated within Willapa Bay could be 2,485 acres, and 75 acres in Grays Harbor. Monitoring required by Ecology would establish where applications would be allowed. It would be a condition of the permit, if issued, that authorization for the use of imidacloprid would include using adaptive management principles, to be described in an Integrated Pest Management (IPM) Plan.³ Applicators who may receive coverage under the Imidacloprid NPDES Individual Permit and SIZ permits would need to comply with the terms and conditions of those permits.

2.2 Purpose and Objectives of the Proposed Action

The objectives of the 2016 proposed action are the same as those proposed in a prior permit application in 2014:

- Preserve and maintain the viability of clams and oysters commercially grown in Willapa Bay and Grays Harbor by controlling populations of two species of burrowing shrimp on commercial shellfish beds.
- Preserve and restore selected commercial shellfish beds in Willapa Bay and Grays Harbor that are at risk of loss due to sediment destabilization caused by burrowing shrimp.

¹ The two species of burrowing shrimp to be controlled are the ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*). These are the same species for which chemical control with integrated pest management (IPM) under the provisions of an NPDES Individual Permit was sought in 2015.

² As used throughout this Supplemental Environmental Impact Statement (SEIS) in the context of alternatives to implement the proposed action, the term “commercial shellfish beds” refers to a specified amount of tideland acreage within Willapa Bay and Grays Harbor on which oysters and clams are commercially grown. The requested NPDES permit would not extend to other geographical areas, and would not authorize treatment on other species of commercially-grown shellfish (e.g., geoducks or mussels).

³ An IPM Plan acceptable to Ecology will be a condition of the NPDES permit, if issued.

2.3 Location

The proposed action would be implemented on commercial shellfish beds in Willapa Bay⁴ and Grays Harbor,⁵ Washington. These large estuaries are located in Pacific County and Grays Harbor County, respectively, on the Pacific Ocean coast in southwest Washington (see Figure 2.3-1).



Figure 2.3-1. Willapa Bay and Grays Harbor Location Map

⁴ Willapa Bay is located at Latitude 46.37 through 46.75, and Longitude -124.05 through -123.84.

⁵ Grays Harbor is located at Latitude 47.86 through 47.04, and Longitude -124.16 through -123.84.

In any given year, specific locations for imidacloprid treatment would be determined based on shellfish grower plans for their seed beds, grow-out sites, and fattening grounds; the efficacy of prior treatments; and the density of burrowing shrimp populations. WGHOGA would submit an Annual Operations Plan to Ecology each year for review, modification, and approval. It is anticipated that all applications would be made between the tidal elevations of -2 ft mean lower low water (MLLW) and +4 ft MLLW.

The 2016 WGHOGA proposal requests flexibility in how the 485 acres per year are selected for treatment within Willapa Bay. WGHOGA proposes to commit to maximum levels of treatment within a given year of 125 acres, 485 acres, and 50 acres of the North, Central, and South portions of Willapa Bay, respectively (see Figure 2.3-2). These areas represent the maximum acreage per year that would be treated in each of these areas of Willapa Bay. If 125 acres are treated in the North portion of the bay and 15 acres in the south, only the net difference of 345 acres could be treated in the same year in the Central portion of Willapa Bay.

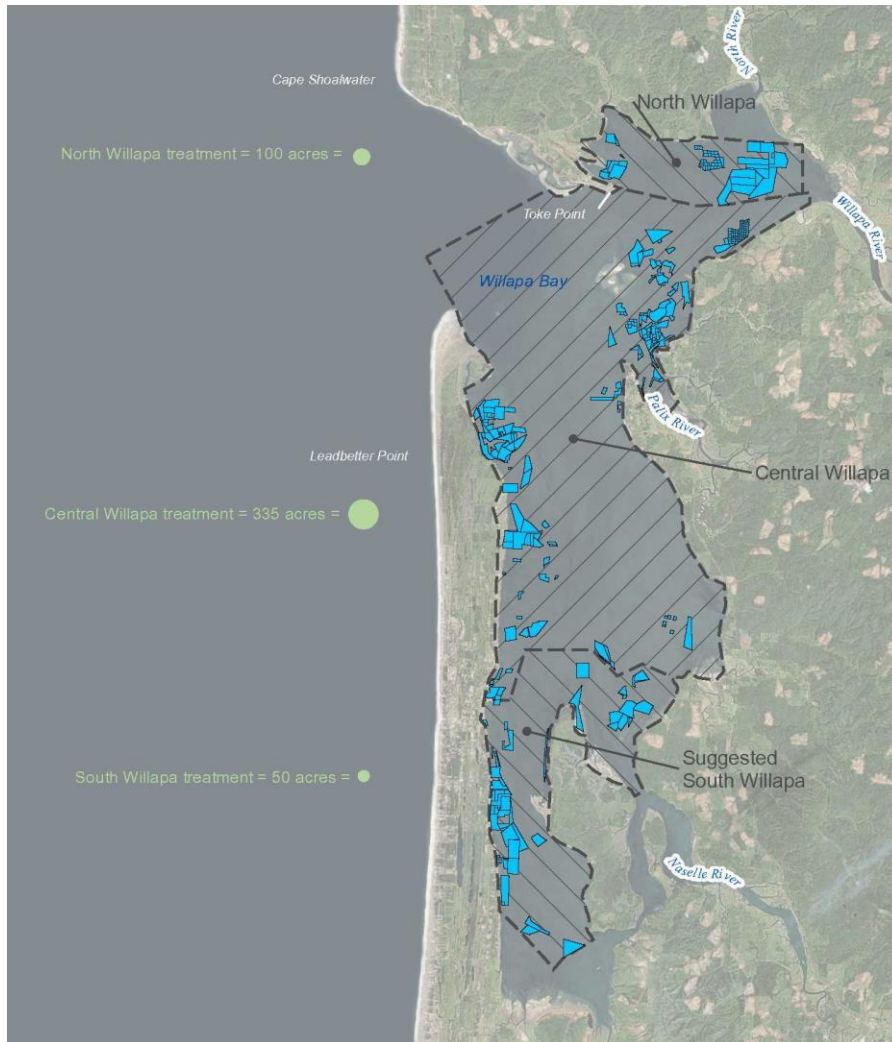


Figure 2.3-2. Willapa Bay Oyster Beds that May be Treated with Imidacloprid under the NPDES Permit (if issued).

Within Grays Harbor, the treatment area (not to exceed 15 acres per year) would be within the South Bay area (see Figure 2.3-3).

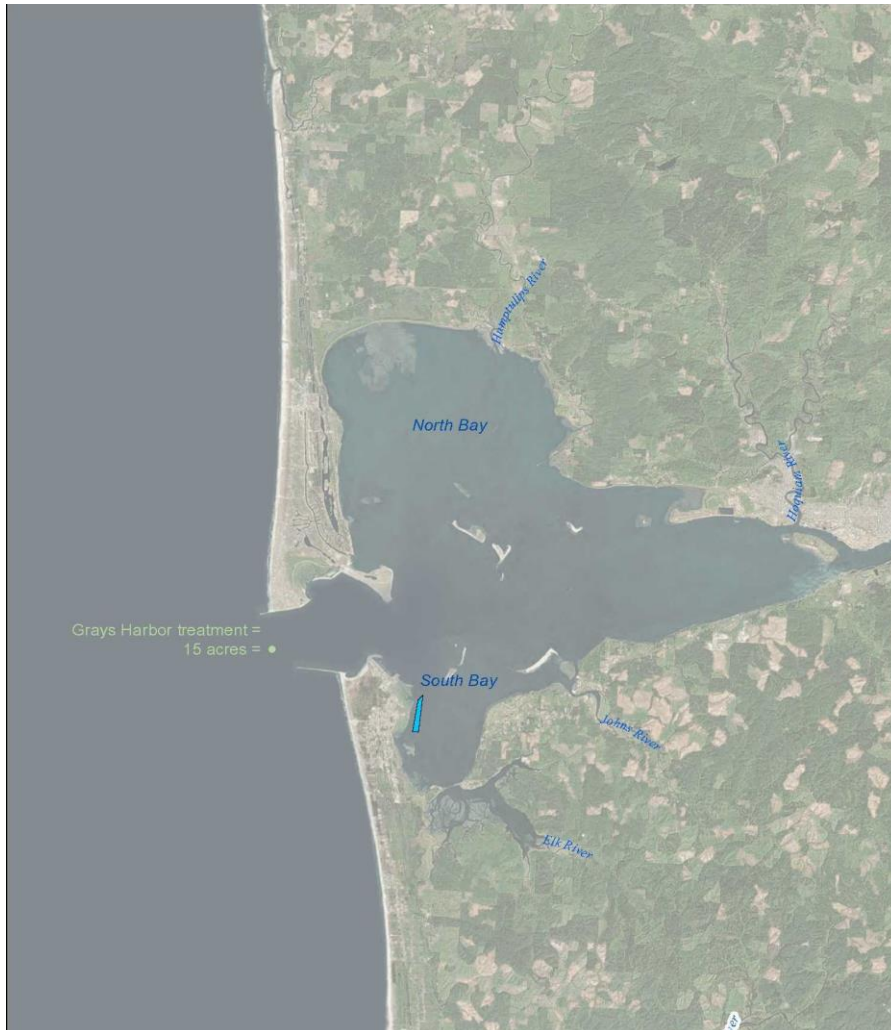


Figure 2.3-3. Grays Harbor Oyster Beds that May be Treated with Imidacloprid under the NPDES Permit (if issued).

2.4 History and Background

The history and background of commercial clam and oyster aquaculture in Willapa Bay and Grays Harbor was previously described in the 2015 Final EIS (Chapter 2, Section 2.4, pages 2-3 through 2-8). Also described in FEIS Chapter 2, Section 2.4 was the history of the impacts of the two burrowing shrimp species that are the subject of this SEIS, and treatment methods tested and used since the 1950s to attempt to control burrowing shrimp populations on commercial shellfish beds. The 2015 FEIS is adopted by reference for inclusion in the SEIS. The history of burrowing shrimp control in Willapa Bay and Grays Harbor is briefly summarized below.

The factors controlling burrowing shrimp populations are not well known, in part because long-term data on burrowing shrimp numbers in Willapa Bay and Grays Harbor are not available. Several authors (e.g., Stevens 1929, Feldman et al. 2000, Sanford 2012), have hypothesized that human-related impacts may have contributed to changes in Willapa Bay which led to increased burrowing shrimp populations. These potentially include excessive harvest of native *Olympia* oysters during the 1900s, land use changes in the watersheds (e.g. logging, farming), disturbance associated with current shellfish farming (including chemical and physical efforts to reduce burrowing shrimp), and other human activities. Changes in climate and oceanic conditions may also have altered conditions in ways that are favorable for burrowing shrimp.

The primary burrowing shrimp management practice used by Willapa Bay and Grays Harbor shellfish growers between 1963 and 2013 was chemical treatment with the n-methyl carbamate insecticide carbaryl. As Ecology gained increased understanding of pesticide impacts, it began to regulate carbaryl applications (under the trade name Sevin brand 4F)⁶ in the 1990s, via both a Temporary Water Quality Modification Order, and a FIFRA Section 24 (c) Special Local Needs registration issued by the Washington State Department of Agriculture. Ecology issued a National Discharge Elimination System (NPDES) permit for the use of carbaryl in 2002. This permit was terminated in May of 2015. Under the permit provisions, carbaryl was applied annually on up to 600 acres (1.3 percent of total tideland acres) in Willapa Bay, and up to 200 acres (approximately 0.6 percent of total tideland acres) in Grays Harbor⁷, predominantly in the form of liquid spray dispersed on exposed mudflats by helicopter over 5 to 10 days on extreme low tides during July and August of each year. Once a bed was treated with carbaryl, it typically did not need to be treated again for another 3 to 7 years, depending on the level of shrimp larvae recruitment and lateral movement of adults from neighboring tide flats to the treated bed area (2015 FEIS Chapter 2, Section 2.8.2, page 2-28).

WGHOGA and the Washington State University Long Beach Research and Extension Unit began testing imidacloprid in 1996 as an alternative to carbaryl for the control of burrowing shrimp on areas primarily grown for commercial oysters in Willapa Bay.⁸ With the carbaryl registration due to expire, WGHOGA applied to Ecology in 2014 for a NPDES Individual Permit to authorize use of imidacloprid combined with Integrated Pest Management (IPM) practices to suppress burrowing shrimp populations on up to 1,500 acres per year of commercial shellfish beds in Willapa Bay and up to 500 acres per year of commercial shellfish beds in Grays Harbor (up to 2,000 acres per year, total). Clarification was requested in the 2014 application to allow imidacloprid applications on tidelands primarily grown with commercial clams as well as

⁶ The FIFRA Section 24(c) Special Local Need registration (SLN Reg. No. WA-120013) for the trade name Sevin brand 4F expired on December 31, 2013 (NovaSource 2012). Regulatory action would be required to continue the use of this insecticide (clarified in the description of FEIS Alternative 2).

⁷ Shellfish growers reduced the carbaryl treatment area by 10 percent (down to 720 acres) in 2003, by another 10 percent (20 percent total) in 2004, and by an additional 10 percent (30 percent total) to 560 acres in 2005. The annual treatment area remained approximately 560 acres through 2013. These actions were taken to comply with a Settlement Agreement entered into by WGHOGA, the Washington Toxics Coalition, and the Ad Hoc Coalition for Willapa Bay. Ecology was not a party to this Agreement.

⁸ See the description of Imidacloprid Efficacy Trials in FEIS Chapter 2, Section 2.8.3.4.

tidelands primarily grown with commercial oysters.⁹ Ecology invited and received public and agency comments on both the Draft EIS and the 2015 draft permit between October 24 and December 8, 2014. Ecology responded to the comments in the Final EIS, and issued a 5-year NPDES Individual Permit (WA0039781) on April 16, 2015, with an effective date of May 16, 2015. On May 3, 2015, WGHOGA asked Ecology to withdraw the permit in response to strong public concerns. Ecology agreed and cancelled the permit on May 4, 2015, effectively terminating commercial use of imidacloprid on shellfish beds in Willapa Bay and Grays Harbor. The 2015 permit was cancelled prior to the close of the appeal period and before the permit was active.

The 2015 permit authorized the establishment of two Sediment Impact Zones (SIZs), one in Willapa Bay and one in Grays Harbor, as mapped in Appendix C of that permit. The SIZ in the Cedar River Area (northern Willapa Bay) and Grays Harbor were identified as “conditional,” authorized under special conditions, and subject to modification or rescission of the permit and SIZ in these two areas, dependent on the results of field studies that were to have been completed in the calendar years 2015 and 2017. South Willapa Bay was excluded from the SIZ established by the 2015 permit, due to field study data that indicated imidacloprid binds more readily and appears to be more persistent in sediments that have a higher level of total organic carbon (TOC) than in sediments with lower concentrations of TOC. Field study results that caused Ecology to exclude South Willapa Bay are described in Section 2.8.3.5 of the 2015 FEIS (pages 2-40 through 2-47). This exclusion did not modify the 2014 WGHOGA proposal for Alternative 3 evaluated in the FEIS, which requested authorization for imidacloprid treatments on up to 1,500 acres throughout Willapa Bay (north, central and south). For this reason, the SEIS analysis of Alternative 4 (Imidacloprid Applications with IPM on up to 485 acres within Willapa Bay) and comparison to Alternative 3 does not distinguish South Willapa Bay as a new treatment area under Alternative 4, as this area was subject to prior environmental review in the 2015 FEIS.

On January 8, 2016, a group of about a dozen growers from WGHOGA applied to Ecology for a new pesticide permit for the use of imidacloprid to control burrowing shrimp on commercial clam and oyster beds in Willapa Bay and Grays Harbor. The 2016 proposal requests authorization to treat up to 500 acres per year in the two estuaries (compared to up to 2,000 acres per year in the 2014 application), and commits to making spray and granular applications from boats and/or ground equipment rather than aerial applications from helicopters. Ground application equipment will include all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, and/or “belly grinders”. Similar to the 2014 application, the 2016 WGHOGA proposal requests approval to apply imidacloprid to commercial shellfish lands in north, middle and south Willapa Bay, and to a smaller group of commercial shellfish acreage in the western portion of Grays Harbor. The revised scope of the 2016 application for the use of imidacloprid is being evaluated in this SEIS in the context of additional research that has been performed, and additional literature that has been published on the environmental effects of imidacloprid since the 2015 FEIS was issued.

⁹ The request to authorize use of imidacloprid on tidelands primarily grown with commercial clams as well as tidelands primarily grown with commercial oysters is described in more detail in FEIS Chapter 2, Section 2.8.3 (page 2-34). This request is also an element of the 2016 WGHOGA application.

2.5 Description of Shellfish Aquaculture

Methods of clam and oyster culture are described in detail in FEIS Chapter 2, Section 2.5 (pages 2-8 through 2-16). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

2.6 Economics

FEIS Chapter 2, Section 2.6 (pages 2-16 through 2-18) described the economic, employment, and tax base significance of the clam and oyster aquaculture industry in Pacific County, Grays Harbor County, Washington State, and the nation. It also described the value of ecological services that are beneficial effects of shellfish aquaculture – things like carbon sequestration, nutrient filtration, and nitrogen removal. Reviewers interested in these subjects are encouraged to review the 2015 FEIS section on these subjects (adopted in the SEIS by reference).

With regard to direct economic impacts to growers in Willapa Bay and Grays Harbor in the absence of burrowing shrimp population control, the FEIS cited the growers' estimate at that time that they would anticipate a 60 to 80 percent reduction in oyster production. The bay-wide loss of clams and oysters in Willapa Bay without pesticide treatments for burrowing shrimp population control was estimated at a higher level by the Washington State University Pacific County Extension Director – on the order of 80 to 90 percent.

Information provided with the 2016 WGHOGA NPDES permit application responds to a question from Ecology and others about the estimated economic consequences of not being able to control burrowing shrimp on commercial clam and oyster beds in Willapa Bay and Grays Harbor. WGHOGA members were surveyed and asked to project their bed losses over the next 5 years (2017 through 2022).¹⁰ WGHOGA growers estimated cumulative losses of approximately 500 acres of seed or nursery ground, 575 acres of fattening beds, and more than 530 acres of clam beds by 2022 (Miller Nash Graham & Dunn, February 13, 2017). Based on growers' estimates of the dollar value of productivity per acre of these commercial shellfish beds, cumulative production losses by 2022 are projected to be just under \$50 million without chemical control of burrowing shrimp populations on selected tideland acreage. Not included in this estimate are indirect economic impacts to the communities that surround Willapa Bay and Grays Harbor; the economic value of lost habitat associated with the conversion of ecologically diverse oyster or clam beds into less diverse mudflats containing predominantly burrowing shrimp¹¹; and indirect or induced economic consequences to others associated with employment, the consumption of shellfish, regional recreation and tourist resources. For additional information on these subjects, the *Economic Analysis to Support Marine Spatial Planning in Washington* prepared for the Washington Coastal Marine Advisory Council (Cascade

¹⁰ Losses projected over the next 5 years do not include losses already experienced by WGHOGA's growers due to not being able to control burrowing shrimp over the past three years (2015-2017), and do not take into account the possibility that these growers may have to close farms due to increased burrowing shrimp activity. As with economic impact information published in the 2015 FEIS, information provided by WGHOGA with the 2016 application has not been independently verified by Ecology.

¹¹ However, approval of the permit will reduce the acreage of habitat containing dense populations of burrowing shrimp, which would reduce the availability to those species that prefer such habitats.

Economics, June 30, 2015) includes estimates of income and expenditures for WGHOGA as a whole in Pacific and Grays Harbor counties.¹²

Approval of the proposed NPDES permit, and subsequent use of imidacloprid to control burrowing shrimp could have negative economic consequences. For example, some tourists and recreationalists might choose to avoid Willapa Bay and Grays Harbor due to the use of chemical controls. Prices for shellfish from these estuaries could also fall due to negative perceptions about the use of imidacloprid.

In the interim since the FEIS was published, a number of shellfish producers, including Taylor Shellfish and Coast (Pacific Seafoods), have announced that they will not use imidacloprid to treat their commercial shellfish grounds in Willapa Bay. Taylor Shellfish has separately indicated it will continue the process of moving much of its shellfish production in Willapa Bay to off-bottom culture. Ecology expects that during public comment on the SEIS, public and agency stakeholders will ask whether treatment of tidelands with imidacloprid is needed to support the shellfish industry in Willapa Bay and Grays Harbor. Ecology contacted representatives of Taylor Shellfish to obtain information on their current operations, and more generally to seek their input on the feasibility of shifting much or most of the oyster culture in Willapa Bay and Grays Harbor to off-bottom production. The following points were derived from that discussion:¹³

- Burrowing shrimp are constraining production of ground-based oysters on Taylor Shellfish lands in Willapa Bay. Two 20-acre shellfish beds, one at Cedar River and one on North River, and another 50-acre bed near Goose Point can no longer be bottom-planted with cultched seed for shucked oyster meat production due to heavy populations of burrowing shrimp. A 30-acre bed at Stoney Point traditionally treated and used for bottom culture of oysters is currently threatened for continued bottom-culture use.
- Taylor Shellfish is developing custom equipment and their own methods of off-bottom oyster culture in Willapa Bay for beds lost to burrowing shrimp. These methods include line cultures with larger and longer posts and different types of anchors to prevent sinking in soft sediments, as well as harrowing of some bottom-culture beds, and a faster rotation to decrease loss of oysters due to the effects of burrowing shrimp populations. While some of the methods Taylor Shellfish is experimenting with seem to be working for them, these methods are still in experimental stages.
- Bottom-cultured oysters grown for the shucked meat market have historically been and continue to be the predominant crop of the shellfish industry in Willapa Bay and Grays Harbor. Single-oyster production for the half-shell market is an entirely different, more specialized industry, requiring different farming, processing, and marketing approaches than shucked oyster meat production. It is an expensive process to convert from bottom culture to off-bottom systems of shellfish farming. Taylor Shellfish Farms' representative shared that in their opinion, it is not appropriate to compare single-oyster production for live sales to cluster production for shucked meat sales. "It is not apples to apples. They are entirely different products, culture systems, processing and markets."

¹² http://www.msp.wa.gov/wp-content/uploads/2014/02/WMSP_2015_small.pdf.

¹³ Bill Dewey, Director of Public Affairs, Taylor Shellfish, personal communication, July 28 and August 22, 2017.

- Taylor Shellfish does not believe it would be feasible for all of the growers in Willapa Bay and Grays Harbor to convert to off-bottom oyster culture to supply the half-shell market. It would be infeasible to cultivate enough single oyster seed stock in the appropriate nursery setting to provide stock for this many growers or this much tideland acreage. A significant shift to half-shell cultivation in Willapa Bay and Grays Harbor would also result in saturation of the half-shell market, thus dropping prices, making it economically infeasible and unsustainable for growers. In addition, Willapa Bay and Grays Harbor contribute significantly to the entire U.S. shucked-meat industry. If shucked oysters were to be lost or significantly reduced in Washington, this would create a large void (up to 25% by some accounts) in the national supply of shucked oyster meats, and there would be secondary impacts to on-shore processing facilities, and related support services for this industry.
- Although Taylor Shellfish has chosen not to treat its shellfish beds in Willapa Bay with imidacloprid, the company believes that burrowing shrimp control is necessary to maintain a healthy and viable bottom-culture, shucked-meat oyster industry in Willapa Bay and Grays Harbor.

2.7 Regulatory Status, Regulatory Control, and Policy Background

A comprehensive section describing the regulatory status, regulatory control, and policy background that applies to commercial shellfish aquaculture and to the use of pesticides in the aquatic environment is provided in FEIS Chapter 2, Section 2.7 (pages 2-18 through 2-24). The Federal Registrations for imidacloprid were provided in FEIS Appendix A. All of this information is still applicable in the SEIS, has not changed, and is adopted by reference.

Since the 2015 FEIS was published, the U.S. Environmental Protection Agency (EPA) issued two large literature reviews. The EPA (2015) review assessed the effects of imidacloprid on pollinators, with some emphasis on honeybees. The EPA (2017) review included a comprehensive literature review and assessment of imidacloprid toxicity in the environment, focusing on aquatic ecosystems and species. These more recent EPA risk assessments, along with study results reported in other literature sources published since the 2015 FEIS was issued, are described in SEIS Chapter 3, Section 3.2. EPA (2017) makes three broad conclusions: 1) aquatic insect species have a relatively high response to imidacloprid toxicity compared to other classes of arthropods or other phyla; 2) imidacloprid concentrations present in many freshwater bodies of the U.S. would result in toxicity to sensitive aquatic insects and crustaceans; and, 3) there is low risk of direct imidacloprid toxicity to fish or aquatic-phase amphibians, although indirect effects by reducing invertebrate prey are possible. There are limited available data on imidacloprid concentrations in estuaries and saltwater bodies; however, EPA concluded that chronic toxicity to crustaceans in saltwater environments is possible. EPA's assessment is discussed in SEIS Chapter 3, Section 3.2, and in Appendix A.

Compliance with Chapter 173-204 Washington Administrative Code (Sediment Management Standards)

WAC 173-204-110 – Applicability

WAC 173-204-110 (6): Nothing in this chapter shall constrain the department’s authority to make appropriate sediment management decisions on a case-specific basis using best professional judgement and latest scientific knowledge for cases whether the standards of this chapter are reserved or standards are not available.

WAC 173-204-420 (3(c)(iii)) –

For Willapa Bay and Grays Harbors, the sediment impact zone maximum biological effects level is established as benthic abundance in which test sediments have, “less than fifty percent of the reference sediment mean abundance of any two of the following major taxa: Class Crustacea, Phylum Mollusca or Class Polychaeta and the test sediment abundances are statistically different (t test, $p \leq 0.05$) from the reference sediment abundances.”

WAC 173-204-420 (5) –

Puget Sound marine sediment impact zone maximum other toxic, radioactive, biological, or deleterious substances criteria. Other toxic, radioactive, biological or deleterious substances in, or on, sediments shall be below levels which cause minor adverse effects in marine biological resources, or which correspond to a significant health risk to humans, as determined by the department. The department shall determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of this chapter.

2.8 The Proposed Action and Alternatives

Guidelines for the Analysis of Alternatives

Washington State Environmental Policy Act (SEPA). The SEPA Rules (Chapter 197-11 WAC) that implement the State Environmental Policy Act (Chapter 43.21C RCW) require an EIS to describe and evaluate the proposal (or preferred alternative, if one exists) and reasonable alternative courses of action. Reasonable alternatives are actions that could feasibly attain or approximate the objectives of the proposal, but at a lower environmental cost or decreased level of environmental degradation. The word “reasonable” is intended to limit the number and range of alternatives, as well as the amount of detailed analysis for each alternative. The level of detail is to be tailored to the significance of environmental impacts, and one alternative may be used as a benchmark against which to compare the other alternatives. The EIS may indicate reasons for eliminating some alternatives from detailed study (WAC 197-11-440[5]).

Washington State Surface Water Quality Standards and the Water Pollution Control Act. Washington State surface water quality regulations and standards (Chapter 173-201A WAC) provide authority to Ecology to establish criteria for waters of the State and to regulate various activities. These standards protect public health and maintain the beneficial uses of surface water, which are defined in the statute to include:

- Recreational activities such as swimming, SCUBA diving, water skiing, boating, fishing, and aesthetic enjoyment;
- Public water supply;
- Stock watering;
- Fish and shellfish rearing, spawning, and harvesting;
- Wildlife habitat; and
- Commerce and navigation.

Introduction to the Alternatives Analysis

The 2015 FEIS evaluated the No Action Alternative, and two action alternatives for the control of burrowing shrimp: one using carbaryl with Integrated Pest Management (IPM) practices, and one using imidacloprid with IPM. Development of an IPM Plan was required by the Memorandum of Agreement (Washington Department of Ecology et al., January 30, 2001) that accompanied the 2001 NPDES permit; however, an IPM Plan for the carbaryl permit was never finalized and accepted by Ecology. Similarly, no IPM plan was submitted by WGHOGA as part of the 2016 NPDES permit application for the use of imidacloprid. Because the FEIS is adopted by reference in the SEIS, the 2016 WGHOGA proposal is evaluated in the SEIS as a fourth action alternative, with cross-reference to the 2015 FEIS alternatives as appropriate. Carbaryl with IPM (Alternative 2) is not considered in this SEIS because of the expiration of authorizations required for its use (see SEIS Section 2.8.2, below).

The 2015 FEIS also described Alternatives Considered and Eliminated from Detailed Evaluation (Chapter 2, Section 2.8.4, pages 2-48 through 2-56). These included mechanical control methods, physical control methods, alternative culture methods, alternative chemical control methods, and biological controls. Although some methods were at least partially effective (e.g., graveling or oyster shell pavement), at this time none have been determined by WGHOGA to be economically feasible on the scale of commercial shellfish operations. The SEIS includes updated information on alternative control methods in Chapter 2, Section 2.8.5 (below).

Consistent with its responsibility to maintain beneficial uses of State waters and protect the environment, Ecology will consider the 2016 WGHOGA application (Alternative 4) in the context of:

- Probable adverse environmental or human health impacts;
- Economic viability of the shellfish industry;
- Effectiveness in controlling burrowing shrimp (*Neotrypaea californiensis* and *Upogebia pugettensis*); and
- Other possible indirect or cumulative effects of the proposed application on beneficial uses of Willapa Bay and/or Grays Harbor.

The potential effects of the 2016 WGHOGA proposal on recreational activities, fish and shellfish, wildlife habitat, and navigation are discussed in SEIS Chapter 3. Other beneficial uses listed in Chapter 173-201A WAC (i.e., public water supply and stock watering) would not be affected by the proposed action since the affected environment encompasses the saltwater estuaries of Willapa Bay and Grays Harbor.

2.8.1 Alternative 1, No Action: No Permit for Pesticide Applications

The 2015 FEIS evaluated a No Action Alternative in which there would be no permit authorizing insecticide applications to treat a limited acreage of commercial oyster beds in Willapa Bay and Grays Harbor for the control of burrowing shrimp. Commercial shellfish growers would only be able to utilize mechanical methods and alternative shellfish culture practices. Studies performed since the 1950s, and particularly from about the year 2000, have failed to find a non-chemical approach to controlling burrowing shrimp that was both effective, and economically feasible on a commercial scale. Some mechanical treatments also had large impacts on non-target animal species (e.g., dredging, deep harrowing, etc.). Off-bottom culture techniques, such as long-line or bag culture, are feasible in some areas with burrowing shrimp, such as areas protected from strong waves or currents. But these culture techniques would not support the shucked meat market that is the focus of most oyster culture in Willapa Bay and Grays Harbor, and would require large changes in the culture, harvest, processing, and marketing of oysters from these estuaries. Therefore, under Alternative 1, it was expected that most productive commercial clam and oyster grounds would decline over the subsequent 4- to 6-year period if no permit was issued to authorize pesticide applications to treat burrowing shrimp populations. The economic impacts of a decline in shellfish productivity on the order of 60 to 80 percent or more were discussed in FEIS Section 2.6 (pages 2-16 through 2-18). Ecosystem changes that would result from a significant increase in burrowing shrimp populations and significant reductions in shellfish (bivalve) populations were evaluated in FEIS Chapter 3. Reviewers interested in the analysis of the No Action Alternative are referred to the 2015 FEIS.

2.8.2 Alternative 2, Continue Historical Management Practices: Carbaryl Applications with Integrated Pest Management (IPM)

The primary burrowing shrimp management practice used by Willapa Bay and Grays Harbor shellfish growers between 1963 and 2013 was chemical treatment with the n-methyl carbamate insecticide, carbaryl. Use of carbaryl for the control of burrowing shrimp populations on Willapa Bay and Grays Harbor commercial shellfish beds is no longer considered by Ecology and other agencies to be a viable alternative. The Washington Special Local Need Registration was cancelled by the Department of Agriculture in January 2014, and Ecology denied the application for administrative extension of the NPDES permit for carbaryl applications (No. WA0040975) in May 2015. For these reasons, the potential effects of the 2016 WGHOGA proposal (Alternative 4) are not compared to FEIS Alternative 2 in SEIS Chapter 3.

2.8.3 Alternative 3, Imidacloprid Applications with Integrated Pest Management (IPM) – 2015 Alternative

FEIS Alternative 3 described and evaluated the effects of a new NPDES Individual Permit that would authorize chemical applications of the neonicotinoid insecticide imidacloprid for burrowing shrimp control on up to 2,000 acres total per year (1,500 acres per year in Willapa Bay¹⁴ and 500 acres per year in Grays Harbor¹⁵). It was possible over the 5-year term of the 2015 Imidacloprid NPDES Individual Permit that the total tideland acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and in Grays Harbor could range from 500 to 2,500 acres under Alternative 3.

WGHOGA would be required to prepare an Integrated Pest Management Plan for the use of imidacloprid, and to submit Annual Operations Plans for proposed treatments, subject to review and approval by Ecology. The IPM Plan and the Annual Operations Plan for implementing Alternative 3 had not been finalized at the time the 2015 FEIS was prepared and the permit was requested to be withdrawn by WGHOGA. Both these documents would have to be submitted and approved by Ecology as part of Alternative 3. The 2013 conditional Federal registrations for the imidacloprid products Protector 2F (flowable) and Protector 0.5G (granular) limited the application rate to 0.5 (one-half) pound a.i./ac, to be applied between April 15 and December 15 in any year for which all required permits and approvals were in-place. A preferred method of application under Alternative 3 was aerial spraying using a helicopter. Reviewers interested in a more detailed description of Alternative 3 are referred to FEIS Chapter 2, Section 2.8.3 (pages 2-32 through 2-48). Analysis of the impacts of Alternative 3 compared to the No Action Alternative and Alternative 2 is provided throughout Chapter 3 of the 2015 FEIS.

2.8.4 Alternative 4, Imidacloprid Applications with Integrated Pest Management (IPM) – 2016 WGHOGA Proposal

The 2016 WGHOGA proposal for the use of imidacloprid combined with IPM practices to control burrowing shrimp on commercial clam and oyster beds would limit chemical applications to up to 485 acres per year within Willapa Bay (1.1 percent of total tideland acres exposed at low tide), and up to 15 acres per year within Grays Harbor (0.04 percent of total tideland area exposed at low tide). This is a reduced-impact alternative compared to FEIS Alternative 3 in that the acreage that may be treated under the currently requested permit is approximately two-thirds less (64 percent) compared to the acreage of the 2014 WGHOGA proposal evaluated in the FEIS as Alternative 3 (Willapa Bay: 485 acres compared to 1,500 acres), and approximately 97 percent less in Grays Harbor (15 acres compared to 500 acres).

The 2016 WGHOGA application (Alternative 4) requests flexibility in how treatment acres are allocated, but proposes to commit to maximum levels of treatment within any given year of 125 acres in North Willapa Bay, 485 acres in Central Willapa Bay, and 50 acres in South Willapa Bay. These acreages are the maximum for each geographical area of Willapa Bay in any one

¹⁴ Under Alternative 3, the imidacloprid treatment area would constitute approximately 3.3 percent of total tideland area exposed at low tide.

¹⁵ Under Alternative 3, the imidacloprid treatment area would constitute approximately 1.5 percent of total tideland area exposed at low tide.

treatment season; in no case would the total acreage treated within Willapa Bay exceed 485 acres per year. Under Alternative 4, the flexibility requested by growers includes only partially treating some commercial shellfish parcels, to avoid areas where burrowing shrimp population control is not needed; e.g., shallow channels with flowing water, transportation corridors, eelgrass beds, and areas that may be more suitable to alternative methods like subsurface injection of imidacloprid (see SEIS Section 2.8.5.3, below). However, treatment is still expected to consist of contiguous blocks in most cases, rather than a more dispersed pattern such as a “checkerboard” or “shotgun” approach¹⁶. Figure 2.3-2 in SEIS Chapter 2 shows the tideland parcel locations where imidacloprid may be applied in Willapa Bay under Alternative 4. Within Grays Harbor, the 15 acres of commercial clam and oyster beds proposed for inclusion in the potential permit would be located in South Bay (see Figure 2.3-3).

Over the 5-year term of the permit (if issued), the total tideland acreage to be treated under Alternative 4 within Willapa Bay could be up to 2,485 acres, and up to 75 acres within Grays Harbor.

The pesticide to be applied under Alternative 4 is the same as that described in FEIS Alternative 3: Protector 2F (21.4 percent Nuprid, flowable), and Protector 0.5G (0.5 percent Mallet, granular), both known by the common name imidacloprid. Protector 2F would be applied using ground methods over exposed tide-flat clam and oyster beds during very low tides. Protector 0.5G would be applied to shallow standing water over commercial clam and oyster beds. Both formulations may be applied using suitable equipment, such as scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, belly grinders, and/or subsurface injectors. The WGHOGA application for the 2016 permit (if issued) specifically excludes aerial applications using helicopters. The application rate of 0.5 pound a.i./acre for any treatment scenario is the same as the rate of application evaluated in FEIS Alternative 3. The reduction in total tideland acreage to be treated (from 2,000 acres per year total in Willapa Bay and Grays Harbor to 500 acres total per year in the two estuaries), and the elimination of aerial spraying from helicopters may result in smaller plot sizes for individual treatments (WGHOGA 2017a).

If the NPDES permit and Sediment Impact Zones are authorized by Ecology, imidacloprid applications would occur between the tidal elevations of -2 feet mean lower low water (MLLW) and +4 feet MLLW. In any given year, the specific discharge locations would be determined based on shellfish grower plans for the seed beds, grow-out sites, and fattening grounds; the efficacy of prior treatments; and the density of burrowing shrimp populations on their commercial shellfish beds.

¹⁶ The location of proposed treatment blocks could affect the likelihood of off-plot impacts to water, sediment, and animals. For example, a “checkerboard” arrangement of many adjacent treatment blocks would be more likely to produce off-plot impacts than a similar level of treatment of blocks that are physically distant from one another. Ecology will evaluate the proposed distribution of treatment blocks on a year to year basis through its review of the Annual Operations Plan (discussed below) that WGHOGA would be required to submit under the permit. Ecology may require changes in the proposed distribution of treatment blocks, the timing of treatment, or the water quality monitoring following treatment to address this concern.

The WGHOGA proposal for treatment sites would be presented to Ecology in an Annual Operations Plan (AOP), subject to Ecology's review and approval prior to commencing treatment with imidacloprid. Information provided in the AOP would identify potential shellfish beds to be treated that year, including legal descriptions of potential treatment beds, total acreage, type of application (liquid or granular formulation, method of application – by ground or boat), the legal owner and (if applicable) the lessee, and the bed identification name. The AOP would also specify the location and type of non-chemical controls to be used during the year as part of WGHOGA's IPM Plan. Research plans designed to improve the efficacy of imidacloprid treatments and of non-chemical controls would also be specified.

The proposed permit, if issued, would be subject to all applicable State and Federal regulations, and would require annual monitoring in application areas to record and document environmental effects. Applicable regulations administered by Ecology include Clean Water Act (CWA) water quality certification (WQC), regulation of aquatic pesticide applications under a NPDES waste discharge permit, and compliance with Washington State Sediment Management Standards (SMS). The NPDES Individual Permit, if issued, would list discharge limitations, monitoring requirements, reporting and recordkeeping requirements; and would require preparation of an Annual Operations Plan, compliance schedule, Spill Control Plan, and Best Management Practices (BMPs) to ensure that the regulated action complies with the CWA. The NPDES permit could have a duration of up to 5 years. Monitoring results would be reviewed during the 5-year term of the permit, with provisions for Ecology to alter permit conditions if necessary for the protection of the environment. Although a monitoring plan has been proposed as a condition of the applications by the WGHOGA, Ecology had not yet finalized or approved the monitoring plan at the time of this writing.

2.8.4.1 Proposed Monitoring Plan

The proposed *Monitoring Plan for WGHOGA SIZ Application: Willapa Bay and Grays Harbor, Washington* (GeoEngineers, March 20, 2017) is in draft form at the time of this writing. Monitoring will be required if the NPDES Individual Permit is issued for Alternative 4, Imidacloprid Applications with IPM – the 2016 WGHOGA proposal. The purpose for monitoring will be to characterize potential impacts of imidacloprid to surface water, sediments, and benthic invertebrates within the Sediment Impact Zone (SIZ); i.e., on commercial clam and oyster plots and adjacent areas within Willapa Bay and Grays Harbor, up to the annual treatment acreage limits.

The draft Monitoring Plan describes a proposed schedule, location, and methods for collecting water column samples; whole sediment, sediment porewater, and sediment persistence monitoring; and benthic and epibenthic organism samples from within a series of treatment and control plots. Ecology will review the draft Monitoring Plan in relation to the conditions and intent of Washington State Sediment Management Standards (SMS), and may request modifications as appropriate.

A Sampling and Analysis Plan (SAP) would also be submitted to Ecology for review and approval each year, as part of the Annual Operations Plan (AOP) required by the NPDES permit (if issued). The SAP would describe detailed procedures to be followed; for example, methods

for handling samples, sample storage requirements, chain of custody procedures, and statistical methods to be used to analyze invertebrates. Specific sampling dates, the location of treatment sites and any required corresponding control site locations would be identified in the AOP each year.

A Water Column and Sediment Monitoring Report would be submitted to Ecology each sampling year. A summary report on the taxonomic identification of benthic invertebrates within the SIZ, and the statistical analysis of abundance, may take 6 months or more following sample collection. Ecology would review monitoring results in relation to the SMS, for which representative requirements include:

Existing beneficial uses shall be maintained and protected, and no further degradation which would interfere with or become injurious to existing sediment beneficial uses shall be allowed (Antidegradation and Designated Use Policies, WAC 173-204-120[1][a]).

The sediment quality standards of this section shall correspond to a sediment quality that will result in no adverse effects, including no acute or chronic adverse effects on biological resources and no significant health risk to humans (Puget Sound Marine Sediment Quality Standards, WAC 173-204-320[1][a]).

[Adverse effects are inferred if the] test sediment has less than fifty percent of the reference sediment mean abundance of any two of the following major taxa: Class Crustacea, Phylum Mollusca or Class Polychaeta and the test sediment abundance are statistically different (t test, $p \leq 0.05$) from the reference sediment abundances (Puget Sound Marine Sediment Zone Benthic Abundance Criteria, WAC 173-204-420[3][c][iii]).¹⁷

2.8.4.2 Imidacloprid Efficacy and Environmental Impact Trials

The FEIS Chapter 2, Section 2.8.3.4 (pages 2-39 through 2-40) describes the results of imidacloprid efficacy trials conducted between 2010 and 2014. At the time the FEIS was written, the complete results of the 2014 efficacy trials were not available; therefore, they are presented in this SEIS.

The 2014 field trials indicated a range of results using imidacloprid to control burrowing shrimp on shellfish beds, depending on site conditions. Efficacy was variable, ranging from 20 to 97 percent, with most sites showing efficacy levels in excess of 60 percent in assessments conducted by WGHOGA and the Washington State University (WSU) Long Beach Research and Extension Unit. Low levels of efficacy were noted in areas with flowing water, high eelgrass densities, or both. WGHOGA members also observed this variable efficacy on their grounds

¹⁷ WAC 173-204-320 and -420 state that the Department (of Ecology) shall determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of the SMS for non-Puget Sound marine sediment impact zones (such as Willapa Bay and Grays Harbor). Ecology's *Sediment Cleanup Users' Manual II* (SCUM II) is used as a guidance document by Ecology sediment specialists, site managers, potentially liable persons, and technical consultants for how to implement Part V provisions of the SMS rule. Ecology applies the Puget Sound criteria to all marine environments in the State, as guidance not as a codified rule.

following spraying in 2014, but were able to plant oysters on many of the beds they sprayed in 2014, and subsequently were successful in raising crops on them (Douglas Steding, Miller Nash Graham and Dunn, personal communication via e-mail to Derek Rockett, July 31, 2017). For those habitat types where treatment efficacy is low, WGHOGA may not be successful in controlling burrowing shrimp populations with imidacloprid.

Trials in the laboratory have shown that burrowing shrimp are not typically killed at imidacloprid concentrations proposed for use by WGHOGA (Dr. Chris Grue, University of Washington, personal communication). Efficacy of imidacloprid on burrowing shrimp during field trials may be due to their tunneling behavior: on exposure to imidacloprid, any resulting tetany would prevent them from circulating water through their burrows, or burrow maintenance, resulting in burrow collapse and eventual suffocation.

Effects of Imidacloprid on Epibenthic and Benthic Invertebrates. Epibenthic and benthic invertebrate samples were collected both within and adjacent to the treatment plots, using a grid-based sampling approach. Epibenthic and benthic invertebrates were sampled prior to the application of imidacloprid and at 14 and 28 days post-treatment. Imidacloprid effects were assessed for three criteria (absolute abundance, taxonomic richness, and Shannon diversity index) for each of three primary taxonomic groups: (polychaetes, molluscs, and crustaceans) by comparing invertebrate numbers in the treated plots to those in the control plots at each post-treatment sampling date.

As in prior years, the invertebrate results showed high variability, both within individual plots over time, and when plots were compared to one another. Thus, the primary finding of the 2014 invertebrate trials, that estuarine epibenthic and benthic invertebrates were similar on control plots as compared to treatment plots, may be due to weak statistical power to detect differences.

Differences in epibenthic or benthic invertebrates between control and treatment plots fell within the permissible range of Ecology's SIZ standards, a result noted in most trials from prior years as well. The SAP Field Report proposed that this lack of significant differences between treatment and control plots may be due to imidacloprid having a limited effect on non-target epibenthic or benthic species, rapid recolonization following treatment, or some combination of these factors.

A detailed explanation of the results of the 2014 field studies is provided below.

2.8.4.3 2014 Field Studies

The 2014 field trials were designed to assess the magnitude, extent, and duration of impacts from commercial use of imidacloprid for the control of burrowing shrimp on tidelands used for clam and oyster aquaculture. Whereas the previous year's studies had focused on smaller plots (i.e., 10 acres or less), the 2014 field trials were designed to assess these potential effects when imidacloprid is applied to larger (>50-acre) plots. Commercial treatment of plots of this size is most likely only feasible using aerial spraying by helicopter, which is not proposed under the 2016 WGHOGA NPDES permit application. The 2014 field trials provide data on the potential effects of imidacloprid spraying over larger areas, including clusters of smaller plots that are located in proximity to one another. It also indirectly allowed a test of whether post-spraying

recruitment of invertebrates from unsprayed areas to the sprayed plots would be impeded when larger blocks and clusters are sprayed (e.g., due to the greater distance to be traveled, and the smaller amount of unsprayed area available as potential sources of recruitment). The results of the 2014 field trials are described in detail in Hart Crowser (2015), which is available through Ecology.

The 2014 field trials involved two trial plots (the “Coast plot” and the “Taylor plot”), immediately adjacent to one another, collectively covering approximately 90 acres, located near Stony Point in Willapa Bay. Both sites had high levels of burrowing shrimp, and were owned by members of WGHOGA. The beds were selected both for their larger size, and because they were in close proximity to other beds scheduled for commercial treatment. A total of 90 acres were treated by helicopter with liquid imidacloprid, Protector 2F, at 0.5 lb a.i./acre on July 26, 2014. The control site was matched to the treatment plots, to the extent feasible, to have similar elevation, vegetation and substrate as the treatment plots. The control plot was located near Bay Center, approximately five miles from the treatment plots, to ensure no imidacloprid was carried there from the treatment plots by the rising tide. In addition, two sites (the “Nisbet plot” and the “Coast plot”) were located in the Cedar River area. These plots were selected to allow collection of water samples over long distances from the treatment plots in order to better understand how imidacloprid in surface waters is diluted by tidal inflow.

The 2014 field trials were intended to assess:

- Pre- and post-application water column concentrations of imidacloprid;
- Whole sediment imidacloprid concentrations after treatment and over time;
- Whole sediment characteristics (texture, total organic carbon, dissolved organic carbon);
- Sediment porewater imidacloprid concentrations after treatment and over time;
- The efficacy of imidacloprid in controlling burrowing shrimp on larger treatment areas;
- The impact of large-scale imidacloprid application on megafauna (e.g., Dungeness crab); and
- The impact of large-scale imidacloprid application on benthic invertebrate communities.

Overall, the SAP Field Report found that the 2014 field trials produced results comparable to those of the prior trials: imidacloprid was widely detected in water and sediments shortly after treatment, concentrations diminished quickly with increasing distance from the treatment plots (water) or over 14 to 28 days following treatment (on-plot sediments), and impacts to epibenthic and benthic invertebrate communities did not exceed minor adverse effects.

Screening values were used to determine when levels of imidacloprid in various sample types were high enough to potentially result in environmental consequences. These values were used to determine which samples were analyzed and reported on in the SAP field report.

- Surface water – 3.7 ppb (screening value);
- Sediment – 6.7 ppb (laboratory quantitation limit); and

- Sediment porewater – 0.6 ppb (screening value).

Water Column Sampling and Analysis. Water column samples were collected from the leading edge of the rising tide, typically about 2 hours after treatment. On-plot water sampling followed the same protocols as in prior year trials. For off-plot samples (taken at the Cedar River sites only), the primary goal of water quality sampling was to determine the maximum distance, off-plot, that imidacloprid could be detected in surface water. Accordingly, off-plot sampling design focused on long, linear transects, rather than the extensive network of off-plot samples used in the 2012 trials. Imidacloprid concentrations in surface water at the Taylor and Coast sites (on-plot samples) ranged from 180 to 1,600 ppb, with an average value of 796 ppb. At the first Cedar River site (a second Coast plot), the on-plot concentration of imidacloprid was 230 ppb. At approximately 731 meters from the plot (about 2,400 feet) the concentration was 0.054 ppb. At the second Cedar River site (Nisbet plot), samples were taken on-plot, and at distances of 62 meters (203 feet), 125 meters (410 feet), 250 meters (820 feet), 500 meters (1,640 feet), and on the shoreline (approximately 706 meters or 2,316 feet). This set of samples documented a decrease in imidacloprid concentrations with distance as follows: on-plot = 290 ppb, 62 meters (203 feet) = 0.55 ppb, 125 meters (410 feet) = 0.14 ppb, 250 meters (820 feet) = not detectable, 500 meters (1,640 feet) = 0.066 ppb, and shoreline (2,316 feet) = not detectable. The 2014 Cedar River samples confirmed results in 2012 that detectable concentrations of imidacloprid are present on the leading edge of the incoming tide at considerable distances from the treated plots.

Overall, the surface water data collected during the 2014 trials indicate a strong pattern of high on-plot and lower off-plot concentrations during the first rising tide, a result also noted in prior trials. For the Cedar River sites, on plot locations had concentrations up to 1,600 ppb, with an average value of approximately half this amount. Imidacloprid was detected at considerable distances off-plot, but at low concentrations of 0.55 ppb to 0 ppb. Thus, although the 2014 data confirm a greater distance off-plot for movement of imidacloprid (up to 500 meters), the concentrations were much lower than those observed in the off-plot data from 2012. These varying results suggest that site-specific differences in how tidal waters advance and mix during a rising tide are important in determining both the distance traveled and concentration of imidacloprid off-plot. To ensure consistent results, a potential permit would require more rigorous water quality monitoring and analysis.

Sediment and Sediment Porewater Sampling and Analysis. The 2014 field trials confirmed prior studies that demonstrate a rapid, negative-exponential decline in imidacloprid concentrations in whole sediment and pore water after treatment. All but one sampling site declined to below detection limits in whole sediment by 28 days after treatment, with the one sample (12 ppb) exceeding the 6.7 ppb screening level established for whole sediment. Sediment porewater demonstrated a similar rapid decline of imidacloprid concentrations, with all sediment porewater samples except one below the screening level of 0.6 ppb by day 28. The single sample that was above that screening level at day 28 exceeded that level, with a concentration of 1.2 ppb.

Megafauna Sampling and Analysis. The 2014 trials differed from prior trials in that they focused on the edges of the plots in surveying effects on crabs, both because it was infeasible to survey the entire plot area sprayed due to its size, and because past trials had found that the edges often had higher numbers of Dungeness crab due to tidal depths (Dr. Kim Patten, WSU Long Beach

Research and Extension Unit, personal communication). The monitored areas along the edge of the treated area were generally deeper and contained more eelgrass (*Zostera marina*) than the plots as a whole. Monitoring in 2014 found 137 out of 141 Dungeness crabs either dead or exhibiting tetany. Crabs in tetany would be unable to eat, move or avoid predators, and therefore would be at high risk of subsequent mortality. Based on their size, these were juvenile crabs. On a density basis, the 2014 field trials found that an average of 2 crabs/acre were affected, of which about two out of three were reported dead, and one out of three were in tetany. This compares to 0.87 to 3.8 crab/acre reported dead or in tetany during field trials in 2011 and 2012. When the number of affected crab was divided using only the actual acreage examined, an average of more than 18 crab/acre is calculated. The first calculation (2 crabs/acre) underestimates the density of affected crab because crab in unsurveyed portions of the sprayed plot were not counted. And the second calculation (18 crabs/acre) overestimates the density of affected crab because the surveyed area was selected because it had the highest density of affected crab. Another complication in interpreting these results is that most of the dead crab were either eaten by birds or were crushed by the field equipment used to conduct the experimental trials (Dr. Kim Patten, personal communication). It is not clear whether these crab were already dead due to imidacloprid exposure, or if they were in tetany, thereby making them vulnerable to predation and crushing. Regardless, the 2014 results confirm prior work that imidacloprid treatments result in impacts to juvenile Dungeness crab in the treated plots and immediately surrounding areas.

2.8.5 Alternatives Considered and Eliminated from Detailed Evaluation

The 2015 FEIS Chapter 2, Section 2.8.4 (pages 2-48 through 2-56) description of Alternatives Considered and Eliminated from Detailed Evaluation was derived from personal communications with Dr. Kim Patten (Director, WSU Long Beach Research and Extension Unit), and from documents he provided of studies performed over the years on mechanical control methods, physical control methods, alternative culture methods, alternative chemical control methods, and biological controls. The 2016 WGHOGA application to Ecology includes *A Review of the Past Decade of Research on Non-Chemical Methods to Control Burrowing Shrimp* (Miller Nash Graham & Dunn, February 13, 2017, Exhibit C, prepared by Dr. Patten) that summarizes many of the same experiments. Additional methods not previously described in the 2015 FEIS, and results obtained with these methods, are described below from that source.

2.8.5.1 Mechanical Control Methods

Suction Harvesting. Several suction head devices were designed and connected to water pumps. The premise was to create enough suction to selectively evacuate shrimp from their burrows, without removing sediment. Plastic barrels 33 gallons in size were cut longitudinally and attached to a sharp-edged plywood platform. It was possible to apply enough suction to collapse the barrels and selectively pull large volumes of water out of burrows; however, few shrimp were removed from their burrows. The conclusion was that suction is not a feasible method for shrimp control. Not only did it fail to remove a significant number of adult shrimp, it was destructive to the benthic environment.

Subsurface Air Bubble Harvester. The premise of an air bubble harvester was to introduce enough air below the shrimp to force them up out of their burrows into the water column where

they could be trapped in a net or other harvest device. Two devices were constructed. One used compressed air at 10.7 cubic feet per minute (cfm) @ 125 psi applied through the six-wheel spikewheel unit previously described in FEIS Chapter 2, Section 2.8.4.4 (page 2-55). The other used 185.5 cfm @ 100 psi applied through a large shank system constructed by oysterman Leonard Bennett. The first system was tested using the WSU spikewheel barge. The second system was tested using a commercial shellfish barge. Based on data obtained from underwater cameras, there was no evidence that any shrimp were raised from the substrate. Burrow counts post-treatment were temporarily reduced by 39 percent with the high-volume air bubble method (to 60 vs. 98 burrows/m²), but this level was still well above what would be considered successful control (i.e., less than 10 burrows/m²).

Behavioral Weak Links. Assessments were made to find weak links in the biology of burrowing shrimp that could help focus mechanical control efforts. Individuals were pit-tagged, as well as filmed under the surface in their burrows to determine if there is a time when they come closer to the surface. Shrimp maintained a fairly constant depth within their burrows, at approximately 10 to 13 inches (25 to 30 cm), regardless of the conditions. Adult burrow depth, 24 to 40 inches (60 to 100 cm), is deep enough to preclude most types of mechanical control. The depths of new recruits were sampled as a function of time and size. New recruits were also often found at depths too deep to facilitate mechanical or physical control.

2.8.5.2 Physical Control Methods

Heat. Surface areas of shrimp-infested sediment were heated with a propane torch for 2 minutes/m². The sediment temperatures at 4- to 8-inch (10 cm and 20 cm) depths did not change sufficiently to affect burrowing shrimp. Therefore, there was no effect on adult shrimp below the heated area.

Water Injection. The traditional method to harvest shrimp is by pumping water into the sediment along a drainage channel bank, causing shrimp to float out. This method is destructive to the sediment, and is only effective on channel banks, not flat commercial shellfish beds. A method was devised to extract shrimp from small areas on flat ground by pumping water into an 8-inch diameter aluminum pipe sunk approximately 1 yard (1 meter) deep into the sediment. This proved to be effective for sampling, but not practical for controlling burrowing shrimp on large areas.

High Pressure, Low-Volume Water Injection. A shanking system was designed to inject water at 1,500 psi while being dragged through the sediment. Penetration of the water jet into the sediment was not deep enough to reach the burrowing shrimp, and therefore did not reduce shrimp densities.

Low Pressure, High-Volume Water Injection. Taylor Shellfish designed a tow sled (previously described in FEIS Chapter 2, Section 2.8.4.2 [page 2-52]) that was capable of injecting water into tideland sediment at approximately 10,000 gallons per minute (gpm). This large injection sled was very difficult to tow in a straight line; the barge was not able to maintain the plotted course of direction. An assessment of post-treatment efficacy indicated good shrimp control in affected areas, but the entire sediment profile, vegetation, and invertebrate population

was also destroyed. Overall, this method was not practical to implement and extremely destructive to the habitat.

Trapping. Scents were tested for their attractiveness to burrowing shrimp. Several were found to be effective. Scent lures were then used in crawfish traps on the sediment surface to trap adult burrowing shrimp. Although a few large male shrimp were trapped, this method had no impact on the density of shrimp in the immediate vicinity.

Dr. Patten concluded his review of research on non-chemical methods to control burrowing shrimp by stating:

No suitable biological control method has yet been found to suppress the population of ghost shrimp. None of the mechanical methods assessed provided viable options for management of burrowing shrimp populations. They all failed to permanently reduce shrimp populations below the economic threshold (10 burrows/m²). Most of the methods tested were also very destructive to the habitat, as well as to any shellfish that would be present at the time of treatment. At present, the only commercial production of oysters in shrimp-infested ground in Willapa Bay and Grays Harbor is in the small areas of the bays that are protected from exposure to major winter storms and have low enough shrimp densities to provide for secure anchoring for off-bottom culture. None of these production methods, however, are viable for large-scale production across the major growing regions of these estuaries (Miller Nash Graham & Dunn, February 13, 2017, Exhibit C, page 5).

2.8.5.3 A Combined Mechanical/Physical Control Method: Use of Subsurface Injectors

Dr. Patten also prepared *A Summary of Ten Years of Research (2006 to 2015) on the Efficacy of Imidacloprid for Management of Burrowing Shrimp Infestations on Shellfish Grounds* (Miller Nash Graham & Dunn, February 13, 2017, Exhibit B). In this document, Dr. Patten documents site-specific methods used to increase the efficacy of imidacloprid by ensuring chemical contact with the sediment-water interface, particularly in areas where flowing water or heavy eelgrass is present. A wide range of efficacy (from 40 percent to 80 percent) was achieved using a granular, pelletized version of imidacloprid under “normal” tidal conditions. Somewhat less efficacy was achieved (from 30 percent to 70 percent) under “moderate to thick densities of eelgrass” (see Table 2.8-1). Under these conditions, spikewheel injection of the flowable form of imidacloprid (Protector 2F) resulted in the most efficacy.

Table 2.8-1. Efficacy of broadcast-applied imidacloprid at ≤ 0.5 lbs ai/ac in locations that do not fully dewater (K. Patten, undated; Miller Nash Graham & Dunn, February 13, 2017, Exhibit B).

Condition	Imidcaloprid Formulation	Application conditions	Expected range of control found under experimental conditions
Sand	2F	Broadcast, tide out, no standing water	60 to 80% ¹
Sand	0.5G	Broadcast, tide out, no standing water	40 to 70% ²
Sand	2F	Broadcast, tide out, shallow standing water with no outflow	60% ³
Sand	2F	Broadcast, tide out or going out, shallow or deep swale with constant flow of water	0% ⁴
Sand	0.5G	Broadcast, tide out, shallow standing water with no outflow	70%
Sand	0.5G	Broadcast, applied in shallow water 3 to 60 inches as tide was going out	30 to 80% ⁵
Sand	2F	Injected via spikewheel 4 to 6 inches deep, shallow or deep swale with constant water flow	70 to 90%

¹ Lower if applied to dry beds, higher if applied just as tidal water is going off the bed.

² Much lower if applied to beds, higher if applied in shallow water just as tidal water is going off the bed.

³ WSU data from small pools, not large sites. Results have not been provided in any progress report.

⁴ WSU observations and data not contained in any progress report.

⁵ Lower efficacy in deeper water.

Given that a relatively high level of efficacy was achieved with spikewheel injection, the 2016 WGHOGA application requests small-scale, experimental use of subsurface injectors in order to continue to test the effectiveness of this adaptive management method of application. If small trials identify application methods that would increase efficacy, and/or that would reduce imidacloprid use for a given level of efficacy, WGHOGA may request a modification to the potential permit to allow commercial-scale use of subsurface injectors in the latter part of the 5-year duration of the NPDES Individual Permit (if issued).

2.9 Comparison of the Environmental Impacts of the Alternatives

The SEIS Alternative 4 impact analysis in Chapter 3 of this document was conducted for two areas of effect: 1) on-plot where imidacloprid applications would be allowed by the NPDES Individual Permit (if issued) for imidacloprid applications with Integrated Pest Management (IPM) –(2016 WGHOGA proposal); and 2) bay-wide within Willapa Bay and Grays Harbor, in the context of applying imidacloprid with IPM on up to 485 acres per year on commercial shellfish beds in Willapa Bay, and on up to 15 acres per year of commercial shellfish beds in

Grays Harbor. For comparison between Alternative 4 and the 2015 FEIS alternatives, an on-plot impact analysis is also provided in Chapter 3 for Alternative 3, Imidacloprid Applications with IPM on up to 1,500 acres per year of commercial shellfish beds in Willapa Bay, and up to 500 acres per year of commercial shellfish beds in Grays Harbor.¹⁸

The on-plot and bay-wide impact analyses are summarized in this SEIS text section, and in a summary table in SEIS Chapter 1, to compare the potential effects of the alternatives evaluated by Ecology for the use of pesticides to control burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor. The imidacloprid application rate would be the same under Alternative 3 or 4 (0.5 lb a.i./ac). The substantive difference between these two action alternatives would be the number of commercial shellfish bed acres per year that could be treated with the pesticide,¹⁹ and the method of application. Under Alternative 4, there would be no aerial applications by helicopter.

2.9.1 Comparison of On-Plot Impacts

The 2015 FEIS Chapter 3 impact analysis evaluated potential effects throughout Willapa Bay and Grays Harbor, but did not consider the potential effects of imidacloprid application on specific commercial clam and oyster plots. SEIS Chapter 3 (this document) describes and compares on-plot impacts for Alternative 3 and Alternative 4 – the 2016 WGHOGA proposal. Those impact analyses are summarized here. The purpose for the on-plot impact analyses is to evaluate potential impacts of chemical applications within the Sediment Impact Zone (SIZ) that would be authorized by the NPDES Individual Permit (if issued).

Sediment and Sediment Porewater. On-plot sediment and sediment porewater would likely see short-term impacts of either Alternative 3 or Alternative 4 imidacloprid applications. Field trials conducted in 2012 and 2014 confirm that imidacloprid persists in sediment after application (Hart Crowser 2013 and 2016). Both the 2012 and 2014 results confirm that imidacloprid concentrations in the sediment decline, with concentrations often above screening values after 14 days but generally undetectable or below screening values at 28 days. The 2012 results documented detectable concentrations of imidacloprid at 56 days for two of five sampled locations, both of which were below screening levels. Imidacloprid is known to bind to organic materials in sediments, which delays the rate of decline in imidacloprid concentrations compared to sediments low in organic materials (Grue and Grassley 2013). Similar results are seen for sediment porewater, with measurable concentrations of imidacloprid generally undetectable or falling below 2014 screening levels by 28 days or less at a majority of the sites tested, but with slower levels of decline at sites with higher organic levels in the sediments (e.g., the Cedar River test plots).

¹⁸ FEIS Alternative 2 is not included in the SEIS comparative analysis of impacts, as it is no longer considered a viable alternative at the time of this writing (see SEIS Section 2.8.2, above).

¹⁹ Under Alternative 3, up to 2,000 tideland acres per year (up to 1,500 acres per year within Willapa Bay, and up to 500 acres per year within Grays Harbor) could be treated with imidacloprid. Under Alternative 4, up to 500 tideland acres per year (up to 485 acres per year within Willapa Bay, and up to 15 acres per year within Grays Harbor) could be treated with imidacloprid.

Air Quality. Potential impacts to air quality for treated plots under Alternative 3 or 4 would likely be minor and short-term. Sources of emissions to the air would be vehicles (e.g., ATVs or boats under either alternative, or from a helicopter under Alternative 3) operating immediately over a plot during treatment. Under Alternative 4, there would be no aerial applications, and thus no use of helicopters.

Surface Water. Under Alternative 3 or 4, surface water on plots that have been treated with imidacloprid would be likely to show short-term impacts due to the application. Experimental trials conducted in 2012 and 2014 confirm that imidacloprid dissolves in surface water and may persist in the water column during the first tidal cycle. The highest concentrations of imidacloprid would occur during the first rising tide after application, and would dilute and flow off-plot during consecutive tidal cycles (Hart Crowser 2016).

Plants. Under Alternative 3 or 4, it is unlikely that imidacloprid would impact plants present on treated plots immediately after treatment since plants lack the nervous system pathway through which imidacloprid impacts some organisms.

Animals. Alternative 3 or 4 would be expected to cause on-plot impacts to zooplankton and benthic invertebrates through either death or paralysis. These impacts would be expected within the boundaries of the treatment plots as imidacloprid is applied directly to the substrate or in shallow water. These on-plot impacts are generally expected to be short-term, as field trials have shown that benthic invertebrate populations recover (e.g., repopulate treated plots). For example, trials with imidacloprid have demonstrated invertebrate recovery within 14 days of chemical applications (Hart Crowser 2013 and 2016). However, one set of studies in an area of sediments containing higher organic carbon levels (Cedar River), found incomplete recovery for several invertebrate organisms, after 28 days. Imidacloprid binds to organic carbon, so these results for the Cedar River area may have been due to longer retention of imidacloprid in the sediments, with an accompanying increase in toxicity to invertebrates. In such areas, on-plot recovery may be delayed compared to other areas with lower sediment organic carbon levels.

Under Alternative 3 or 4, forage fish and groundfish may be impacted by treatment with imidacloprid, but these would be short-term impacts. There would also be a potential for fish to be impacted by imidacloprid if they were to enter a treated area immediately after application and prior to dissipation of imidacloprid from the on-plot area. Indirect impacts may occur to fish due to potential impacts to their food base.

Under Alternative 3 or 4, birds, pollinators, and mammals may be affected by imidacloprid applications. It is possible for a minor effect to occur due to the potential short-term reduction in prey items present on treated areas. This would also be true for threatened, endangered, and protected species in the vicinity of treated plots. They are not likely to be present on-plot during the time of application, but may see a minor and temporary loss in prey items. Pollinators are highly susceptible to imidacloprid; however, there are no flowering plants present on the commercial shellfish beds where this pesticide would be applied; therefore, it is highly unlikely that pollinators would be present on treated plots.

Human Health. Under Alternative 3 or 4, the on-plot risk to human health due to application of imidacloprid would only apply to the small number of people that handle and apply the chemical. Applicators would need to be covered under a pesticide license. This risk is discussed further in Chapter 3 of this document.

Land Use, Recreation, and Navigation. None of these elements of the environment would be impacted by on-plot application of imidacloprid under Alternative 3 or Alternative 4.

2.9.2 Comparison of Bay-Wide Impacts

The 2015 FEIS Chapter 3 impact analysis evaluated potential effects throughout Willapa Bay and Grays Harbor of no permit for pesticide applications (Alternative 1), carbaryl applications with IPM (Alternative 2),²⁰ or imidacloprid applications with IPM (Alternative 3) for burrowing shrimp control on up to 1,500 acres per year of total tideland acreage exposed at low tide within Willapa Bay, and up to 500 acres per year of total tideland acreage exposed at low tide within Grays Harbor (Alternative 4). SEIS Chapter 3 (in this document) includes bay-wide environmental impact analyses for Alternative 4.

The 2015 FEIS concluded that the No Action Alternative (Alternative 1) would result in neither significantly beneficial nor significantly adverse ecological impacts to either estuary as a whole, due to the relatively small area of each bay that would be affected by the cessation of chemical treatments.²¹ Reviewers are referred to FEIS Chapter 2, Section 2.9 for additional discussion (pages 2-57 and 2-58). However, it is the position of WGHOGA that the adverse effect of the No Action Alternative would be larger for them than the loss of the annual treatment acreage in Willapa Bay and Grays Harbor. WGHOGA growers believe that if progress is not made each year to stay ahead of, or keep pace, with burrowing shrimp recruitment on commercial shellfish beds that experience the most damage, it would take years to restore these beds if insecticide treatments became available in the future. WGHOGA's growers report that efforts to attempt to control burrowing shrimp populations using only mechanical means results in temporary increases in turbidity, damage to benthic communities, and damage to or displacement of marine and salt marsh vegetation, with no significant control of burrowing shrimp. Additional information on alternative methods that have been tried for burrowing shrimp control is provided above in SEIS Section 2.8.5, and in FEIS Chapter 2, Section 2.8.4 (pages 2-48 through 2-56).

Analysis of the 2015 FEIS action alternatives took into account the dilution factor of two tidal exchanges per day in these estuaries, the life cycle and feeding habitats of potentially affected species, biochemical pathways of effect for the pesticides evaluated in various species, and the mitigating effects of complying with all applicable pesticide registrations, permits and regulations that govern pesticide applications. From the bay-wide perspective, no significant

²⁰ Alternative 2 is no longer considered a viable alternative (see SEIS Section 2.8.2, above).

²¹ The total area of tide flats exposed on low tide in Willapa Bay is approximately 45,000 acres. Of this acreage, up to 600 acres (1.3 percent) per year could be treated with carbaryl under Alternative 2, or up to 1,500 acres (3.3 percent) per year could be treated with imidacloprid under Alternative 3, if the 2015 permit had gone into effect. The total area of tide flats exposed on low tide in Grays Harbor is approximately 34,460 acres. Of this acreage, up to 200 acres (approximately 0.6 percent) per year could be treated with carbaryl under Alternative 2, or up to 500 acres (1.5 percent) per year could be treated with imidacloprid under Alternative 3, if the 2015 permit had gone into effect.

unavoidable adverse impacts were identified in the 2015 FEIS for the action alternatives. The same conclusion is drawn in this SEIS for Alternative 4, under which there would be no aerial applications of imidacloprid by helicopter, and the total acreage over which imidacloprid applications could occur would be significantly less under Alternative 4 compared to Alternative 3.²²

2.10 Cumulative Impacts and Potential Interactions

The SEPA Rules specifically define only direct and indirect impacts, as follows: those effects resulting from growth caused by a proposal (direct impacts), and the likelihood that the present proposal will serve as a precedent for future actions (indirect impacts) (WAC 197-11-060[4][d]). Cumulative impacts are those that could result from the combined incremental impacts of multiple actions over time.

2.10.1 Summary of the 2015 FEIS Cumulative Impact Analysis

The 2015 FEIS is incorporated by reference in the SEIS. There is no change to the bay-wide cumulative impact analysis provided in that document, summarized below.

The FEIS cumulative impacts analysis considered the potential additive effects of the presence of imazamox and imazapyr in Willapa Bay for the control of non-native eelgrass (*Zostera japonica*) and *Spartina*, respectively, if imidacloprid were to be applied on up to 1,500 acres of commercial shellfish beds in Willapa Bay under Alternative 3 (FEIS Chapter 2, Section 2.10.1, pages 2-60 through 2-62). There currently are no known studies that address additive or synergistic effects between imidacloprid and imazamox or imazapyr. However, imidacloprid has a completely different toxic mode of action compared to these two chemicals. Imidacloprid is a neonicotinoid insecticide that affects neural transmission in animals. Imazamox and imazapyr are both acetolactate synthesis (ALS) inhibitors that act on a biochemical pathway that occurs in plants but not in animals. Therefore, there is no reason to expect that there would be additive or synergistic effects between these chemical applications. Further, Willapa Bay is a large estuary that experiences tidal flushing twice per day, and only limited quantities of any of these chemicals would be applied over a limited amount of acreage within the estuary in any year. As a cautionary approach, the FEIS suggested that Ecology could consider utilizing different treatment periods for imidacloprid targeting burrowing shrimp, and imazamox or imazapyr targeting invasive species of marine plants. Additional information is provided in the FEIS chapter and section referenced above.

The 2015 FEIS cumulative impact analysis also identified (but did not analyze in detail) potential additive effects within Willapa Bay and Grays Harbor of other shellfish pests, like the oyster drill (*Ceratostoma inornatum*), crab, moon snails (*Euspira lewisii*), starfish, and some polychaetes.

²² The 2016 WGHOGA proposal for Alternative 4 is a request to apply imidacloprid on up to 485 acres per year within Willapa Bay (1.1% percent of total tideland acreage exposed at low tide), and up to 15 acres per year within Grays Harbor (0.04 percent of total tideland acreage exposed at low tide). These areas constitute approximately two-thirds (64 percent) less treatment acreage within Willapa Bay, and approximately 97 percent less treatment acreage within Grays Harbor compared to FEIS (2015) Alternative 3.

Not considered in the 2015 FEIS cumulative impact analysis was the potential expansion of NPDES permit authority to other aquatic lands (e.g., Puget Sound) for the use of imidacloprid or other pesticides to control burrowing shrimp. No such proposals have been submitted to Ecology, and the Department does not know at this time whether expansion would be considered in other water bodies of the State. For this reason, this scenario is considered speculative and outside the scope of the FEIS or SEIS.

2.10.2 SEIS (2017) Cumulative Impact Analysis

With the addition of an on-plot impact analysis in SEIS Chapter 3, and the comparison of the potential on-plot effects of Alternative 4 with FEIS Alternative 3 (summarized above in SEIS Chapter 2, Section 2.9.1), the potential for on-plot cumulative impacts from pesticide applications to control burrowing shrimp is described in this section. Ecology has previously identified three types of cumulative effects that could occur based on the location and type of imidacloprid applications proposed by WGHOGA: cumulative effects to sediment quality, cumulative effects to water quality, and cumulative effects to marine invertebrates.

Sediment. Previous field trials with imidacloprid in Willapa Bay (reviewed in the 2015 FEIS, and in Chapter 3 of this document) have examined the persistence of imidacloprid in the porewater of sediments, and in whole sediments. These data indicate that imidacloprid concentrations decrease rapidly following treatment, with concentrations in sediments falling below laboratory detection limits in most samples within 28 days. However, these data also demonstrate that imidacloprid remained at detectable levels in some samples on the last sampling date of the trials (28 days or 56 days), particularly in sediments with higher organic carbon levels (e.g., the 2012 Cedar River trials). Thus, data demonstrating that imidacloprid will not persist for long periods in some sediment types (e.g., those with high silt or organic carbon levels) is not available. By extension, it is possible that imidacloprid residues may remain in some treatment areas at the time that imidacloprid could again be applied to the site. Such a circumstance would constitute a cumulative effect, over time, such that imidacloprid levels could occur at higher levels than those expected where no residual imidacloprid remains. To test for this possibility, Ecology would (if the permit is issued) require that WGHOGA, as part of its mandatory Monitoring Plan, conduct long-term persistence monitoring of imidacloprid in sediments. This sampling would continue through time to determine when no imidacloprid is detectable in sediment pore water or whole sediments, and to confirm whether a cumulative buildup of imidacloprid would occur over time.

Water Quality. Previous trials with imidacloprid applications in Willapa Bay (reviewed in the 2015 FEIS, and in Chapter 3 of this document) have examined the water concentration of imidacloprid with distance from the area of treatment. These data clearly demonstrate that imidacloprid concentrations, as measured on the leading edge of the incoming tide, are diluted by that tide compared to on-plot concentrations. However, field data indicate that the amount of dilution has been highly variable, likely due in large part to site-specific differences in how tidal waters rise and mix on the incoming tide. As the tide continues to rise, dilution would increase. Both Willapa Bay and Grays Harbor have large tidal prisms, that is, the amount of water that enters and exits these bays on each tidal cycle is large. Accordingly, both field data and a simple analysis of dilution indicate that water quality concentrations of imidacloprid will be reduced to non-detectable, and biologically inert concentrations in the short term. Similarly, EPA (2017)

and others have documented that imidacloprid is subject to relatively rapid photolysis (molecular deactivation by light), and so the diluted imidacloprid is expected to break down within days to weeks into inert compounds. In total, therefore, no cumulative effects of imidacloprid applications on water quality are expected.

Marine Invertebrates. Both the scientific literature (e.g., Health Canada 2016, EPA 2017) and imidacloprid field trials in Willapa Bay (reviewed in the 2015 FEIS, and in Chapter 3 of this document) lead to the conclusion that imidacloprid exposure leads to death, and paralysis (“tetany”) in marine invertebrates. Field trials, in particular, have documented that some types of animals show a decline in abundance or diversity on the treatment plots compared to pre-treatment levels or to animal abundance on untreated control plots. The plots that WGHOGA proposes to treat would have biologically toxic concentrations in water of a few hours, and in sediment, toxic concentrations may persist for a period of days to weeks. Thus, long-term toxicity is not expected. In addition, field trials have demonstrated that even where invertebrate numbers and diversity fall after treatment, rapid recolonization occurs for many types of invertebrates, so that within 14 to 28 days, treatment plots have invertebrate communities similar to those of unsprayed control plots. Based on this information, no cumulative effect of imidacloprid spraying on invertebrates is expected. To confirm this as the potential permit is implemented over time and in various locations, Ecology would (if the permit is issued) require that WGHOGA, as part of its mandatory Monitoring Plan, conduct repeated trials in which invertebrate abundance and diversity are tracked from before treatment to 28 days after treatment on both sprayed and control plots. These trials would be required in areas that have not previously been tested (i.e., Grays Harbor, south Willapa Bay), and in north Willapa Bay where a previous trial suggested invertebrate recovery, post-application, was delayed or absent for a number of polychaete and crustacean invertebrate species. These trials would also likely occur again in other areas that were previously tested.

Cumulative effects to mud shrimp and ghost shrimp would occur for those areas sprayed with imidacloprid. By design, the proposed permit is meant to reduce numbers of these species over time. However, cumulative effects to the populations of these species within Willapa Bay and Grays Harbor are not expected because of the relatively small area of these estuaries proposed for treatment with imidacloprid. Both species would retain tens of thousands of acres of suitable habitat that would not be treated with or impacted by imidacloprid. For the same reason, animals that feed on burrowing shrimp are not expected to experience cumulative effects from reduced availability of this prey type.

Impacts to Dungeness crab have been noted following treatment of plots with imidacloprid. Both mortality of crab from crushing by application equipment and bird predation have been noted, as well as tetany in remaining crab. It is likely that all plots sprayed under a potential permit would result in mortality of Dungeness crab. However, no cumulative effect is expected because: 1) the number of crab killed on the plots is a very small proportion of the entire population, 2) the large majority of Willapa Bay and Grays Harbor tidelands would not be treated with imidacloprid, and would therefore remain as nursery and foraging habitat for the species, and 3) for planktonic forms, any impact would be offset by the very high fecundity of females of this species (approximately 2 million eggs/individual). In addition, juvenile crab are known to preferentially forage and shelter in oyster beds in comparison to burrowing shrimp dominated habitat.

2.11 Benefits and Disadvantages of Reserving the Proposed Action for Some Future Time

The benefits and disadvantages of postponing burrowing shrimp control using imidacloprid applications on a limited number of acres of commercial shellfish beds in Willapa Bay and Grays Harbor are essentially the same as previously described in FEIS Chapter 2, Section 2.11 (page 2-62), restated here.

Opinions vary regarding the benefits and disadvantages of reserving until some future time applications of imidacloprid to control burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor. For those who are opposed to the use of insecticides in these estuaries, the benefit would be that no additional chemicals would be discharged into Willapa Bay or Grays Harbor. The disadvantage would be that the two species of burrowing shrimp would proliferate unmanaged, which would likely cause unrecoverable damage to commercial shellfish beds, and significant alterations to the bay-wide ecosystem.²³ Even during the 50+ years of the carbaryl control program, methods have often not been enough to protect commercial shellfish beds, causing the industry to shrink over time (testimony of WGHOGA members at the Imidacloprid EIS Scoping meeting, February 1, 2014, and at public hearing to receive comments on the Draft EIS, December 2, 2014). WGHOGA therefore expect that elimination or delay of approval of imidacloprid as a chemical control for burrowing shrimp would have serious negative effects on shellfish aquaculture in Grays Harbor and Willapa Bay.

Burrowing shrimp recruitment is monitored by Dr. Brett Dumbauld, Ecologist, U.S. Department of Agriculture, Agriculture Research Service, and by Dr. Kim Patten, Director, WSU Long Beach Research and Extension Unit. FEIS Chapter 2, Section 3.1 (page 3-1) cites a November 28, 2014 memo from Dr. Dumbauld in which he concludes that conditions were favorable for ghost shrimp larval recruitment to Willapa Bay and Grays Harbor during the period 2010 through 2013, with a combined density that may be significant, after what appeared to have been a period of very low or no recruitment and declining adult populations prior to that since the mid-1990s. Dr. Patten and Scott Norelius (2017 report to WDFW) monitored the density of ghost shrimp larvae recruiting into Willapa Bay at seven locations between mid-August and mid-September 2016. They found very high recruitment in the north end of the bay: 543 ghost shrimp per square meter (m²) near the entrance to the estuary at Tokeland. The mean density of new 2016 recruits declined at sampling locations further away from the estuary mouth, to 14/m² at Middle Island Sands. The bay-wide average for 2015-2016 recruits was 152/m², indicating an overall robust population of new ghost shrimp recruits in 2015 and 2016 in Willapa Bay. Dr. Patten concludes from this study that:

When these population cohorts become large enough to cause significant bioturbation, their numbers, on top of the currently existing population of adults, represent a severe threat to the Willapa Bay shellfish industry.

²³ See FEIS (2015) Chapter 3, Section 3.1, Biological Background Information (pages 3-1 through 3-6).

At the time this SEIS was prepared, WGHOGA growers were three years into a period of time with no pesticide control of burrowing shrimp, coinciding with the spike in recruitment between 2010 and 2016. Some commercial shellfish beds are crossing the threshold into non-productivity, causing them to be abandoned by the WGHOGA growers (personal communication with Douglas Steding, Miller Nash Graham and Dunn). Economic losses due to burrowing shrimp impacts to commercial shellfish beds in Willapa Bay and Grays Harbor are described above in Section 2.6.

3.0 Affected Environment, Potential Impacts, and Mitigation Measures

3.1 Biological Background Information

The biological background information on the history, characteristics, and interactions of burrowing shrimp with the intertidal community was previously described in the 2015 FEIS (Chapter 3, Section 3.1, pages 3-1 through 3-6). The 2015 FEIS is adopted by reference for inclusion in the SEIS.

3.2 Literature Review

The 2015 FEIS included a review of more than 100 scientific reports and papers that evaluated the ecology of burrowing shrimp, physical and biological conditions in Grays Harbor and Willapa Bay, and effects of imidacloprid on invertebrate and vertebrate animals, including species listed under the Endangered Species Act (ESA). Information derived from that literature review is incorporated in a number of sections of the FEIS, and is the basis for much of the summary of imidacloprid's expected effects under the permit conditions analyzed in 2015. In general, the FEIS concluded that the application of imidacloprid would have minor to moderate effects on non-target invertebrates (e.g., polychaete worms, honey bees), minor effects on vertebrate species, including birds, and minor or insignificant effects on ESA-listed species.

Since the FEIS was published, a number of new studies on the effects of imidacloprid have been published. These new studies include three very large and comprehensive literature surveys. Health Canada (2016) conducted a comprehensive review of the toxicology literature on imidacloprid and published a report summarizing the expected effects of agricultural uses of imidacloprid on the environment based on that review, and on modeled and field data-based estimates of imidacloprid concentrations. The document included evaluation of toxicity to birds, mammals, and terrestrial and aquatic insects, and assessed exposure pathways and possible effects to humans. The U.S. Environmental Protection Agency (EPA) issued two large literature reviews. The EPA (2015) review assessed the effects of imidacloprid on pollinators, with some emphasis on honeybees. The EPA (2017) review was similar to the Health Canada study in that it included a comprehensive literature review and assessment of imidacloprid toxicity in the environment. The EPA (2017) literature review differed from the Health Canada study in that it only focused on aquatic ecosystems and species, and also used a different approach to estimating imidacloprid toxicity to various groups of animals.

Other published studies relevant to WGHOGA's proposed use of imidacloprid are available, some published since the 2015 FEIS was issued. Most of these studies are reviewed in the Health Canada and EPA documents described above. Multiple studies address potential impacts to freshwater ecosystems, particularly aquatic insects, while fewer have focused on marine systems. Extrapolating the results of these studies to marine environments is therefore challenging. The studies reviewed demonstrate a very wide range of toxicity of imidacloprid, depending on the environment and the animals involved. In general, this new scientific literature continues to document that imidacloprid is acutely toxic to many types of freshwater invertebrates. Measured

concentrations of imidacloprid in the environment often exceed these toxicity thresholds. Consequently, imidacloprid is widely viewed as having actual or potential effects on freshwater invertebrates, and through food chain effects, potential impacts on vertebrate species that depend upon these freshwater invertebrate species as prey items. Conversely, the majority of this newly published literature provides further support for the conclusion that imidacloprid has relatively little effect on vertebrates, with birds, mammals, and fish having little to no risk from imidacloprid except in specialized circumstances (e.g., bird consumption of treated agricultural seeds).

Finally, the EPA (2017) analysis of the effects of imidacloprid to marine invertebrates was based, in-part, on unpublished scientific studies. Ecology used a Freedom of Information Act (FOIA) request to the EPA to obtain these studies.

A literature review of studies published since 2015, the studies obtained through the FOIA request, and some older studies relevant to the proposed permit is presented in Appendix A to this SEIS. Findings from this literature review are incorporated in many of the elements of the environment analyzed below, including sediments, surface water, animals, and human health. There were no literature sources describing the effects of imidacloprid on air quality, land use, recreation, or navigation.

3.3 Elements of the Environment

This section is organized by elements of the environment to be reviewed by the Washington State Department of Ecology (Ecology) when making the NPDES permit decision regarding the proposed action to control burrowing shrimp populations on commercial shellfish beds in Willapa Bay and Grays Harbor using chemical applications of imidacloprid combined with Integrated Pest Management (IPM) practices. Existing environmental conditions are described for each of these elements, followed by a description of potential impacts that could result from Alternative 4.¹ The impact analysis presents two different contexts: bay-wide impacts within Willapa Bay and Grays Harbor, and potential impacts on treatment plots (i.e., on-plot impacts). The analysis of the potential impacts of Alternative 4 is followed by a description of proposed (i.e., WGHOGA growers will voluntarily conduct those actions), required, and other recommended mitigation measures that could be implemented to avoid or minimize potential adverse impacts of Alternative 4.

Ecology's (Water Quality Program) review of the 2016 WGHOGA NPDES permit application must ensure that the proposed discharge of imidacloprid will comply with Washington State Water Quality Standards (Chapter 173-201A WAC; see also 33 U.S.C. § 1313; 40 C.F.R. Part 131, §§ 131.6, 131.10 through .12), State Sediment Management Standards (WAC 173-204-120, -300 through -350, and -400 through -450), and other applicable laws and regulations. The permit, if issued, would be conditioned to protect State resources. Before requiring additional

¹ Alternative 4 is the 2016 WGHOGA proposal, described in SEIS Chapter 2, Section 2.8.4. Additional alternatives were described and evaluated in the 2015 FEIS, adopted by reference (see FEIS Chapter 2, Section 2.8, pages 2-24 through 2-56).

mitigation measures through the SEPA process, Ecology is required to consider whether local, State, or Federal requirements and enforcement would adequately mitigate any identified significant adverse impact. The SEPA Rules with regard to imposing mitigation measures are as follows (WAC 197.11.660[1][a through e]):

(1) Any governmental action on public or private proposals that are not exempt may be conditioned or denied under SEPA to mitigate the environmental impact subject to the following limitations:

(a) Mitigation measures or denials shall be based on policies, plans, rules, or regulations formally designated by the agency (or appropriate legislative body, in the case of local government) as a basis for the exercise of substantive authority in effect when the DNS or FSEIS is issued.

(b) Mitigation measures shall be related to specific, adverse environmental impacts clearly identified in an environmental document on the proposal and shall be stated in writing by the decision maker. The decision maker shall cite the agency SEPA policy that is the basis of any condition or denial under this chapter (for proposals of applicants). After its decision, each agency shall make available to the public a document that states the decision. The document shall state the mitigation measures, if any, that will be implemented as part of the decision, including any monitoring of environmental impacts. Such a document may be the license itself, or may be combined with other agency documents, or may reference relevant portions of environmental documents.

(c) Mitigation measures shall be reasonable and capable of being accomplished.

(d) Responsibility for implementing mitigation measures may be imposed upon an applicant only to the extent attributable to the identified adverse impacts of its proposal. Voluntary additional mitigation may occur.

(e) Before requiring mitigation measures, agencies shall consider whether local, state, or federal requirements and enforcement would mitigate an identified significant impact.

3.3.1 Sediments

AFFECTED ENVIRONMENT

3.3.1.1 Willapa Bay

Information regarding the sediments of Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.1, page 3-7). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. Information obtained since the 2015 FEIS was published is presented here.

As discussed in the 2015 FEIS, Willapa Bay sediments range from low-organic to high-organic sediments and vary throughout the bay. Sediments containing higher percentages of clays, silts, and organic matter are more prevalent in the northern and southern ends of the bay, with sand

dominating in other areas (Brett Dumbauld, unpublished data). The 2016 WGHOGA application proposes to apply imidacloprid at locations throughout the bay. As discussed in the 2015 FEIS, imidacloprid binds to organic materials in the sediments, and persists there for a longer time than in low-organic sediments. So sediment type could affect imidacloprid persistence and effects.

3.3.1.2 Grays Harbor

Information regarding the sediments of Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.1, pages 3-8 through 3-9). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to sediments of Alternative 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.1, pages 3-9 through 3-11). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

The 2016 WGHOGA permit application requests authorization to apply imidacloprid in both north and south Willapa Bay, locations known to contain sediments with higher organic carbon levels. Field and laboratory studies have documented that imidacloprid levels in sediments decline more slowly over time as organic carbon levels increase (Grue and Grassley 2013). This could lead to higher toxicity of benthic organisms than in sediments where imidacloprid dissipates quickly. Only one field trial in Willapa Bay has been conducted in areas with high organic carbon to test this possibility, the 2011 test in Cedar River. Results in this area did find greater persistence of imidacloprid in sediments, and greater impacts to benthic invertebrates than those noted in other trials (see Section 3.3.5 below for discussion of invertebrate results).

Under Alternative 4, imidacloprid would be applied (if the permit is issued) on up to 485 acres of commercial shellfish beds per year within Willapa Bay, and up to 15 acres of commercial shellfish beds within Grays Harbor per year (see SEIS Chapter 2, Section 2.8.4). This is a reduced-impact alternative compared to FEIS Alternative 3 in that the acreage that may be treated under the requested permit is approximately two-thirds less (64 percent) compared to the acreage of the 2014 WGHOGA proposal evaluated in the FEIS (Willapa Bay: 485 acres compared to 1,500 acres), and approximately 97 percent less in Grays Harbor (15 acres compared to 500 acres).

IPM practices would be implemented to continue experimenting with alternative physical, biological, or chemical control methods that are as species-specific as possible, economical, reliable, and environmentally responsible. Preparation of an IPM Plan acceptable to Ecology would be a condition of the NPDES permit, if issued. Applications of imidacloprid to shellfish

beds are proposed to occur on low tides from April through December each year. Minor (if any) sediment disturbance would occur at the time of treatment with methods of application suitable for the chemical formulation (i.e., “flowable” or granular): scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, back pack reservoirs with hand-held sprayers and/or belly grinders. Sediment disruption that occurs during shellfish harvest would continue to occur, as would disruptions concurrent with any mechanical controls implemented through IPM strategies.

The 2015 FEIS discusses the interactions of imidacloprid with water and sediments, including site-specific studies conducted to clarify the persistence of imidacloprid in estuarine environments (Chapter 3, Section 3.2.1, pages 3-9 through 3-11). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. Results of the 2014 field trials in Willapa Bay were not available at the time the 2015 FEIS was written. The results of the 2014 sediment studies are presented here.

The 2014 field trials were designed to assess the magnitude, extent, and duration of impacts from imidacloprid that could be associated with commercial use of imidacloprid for population control of burrowing shrimp on tidelands used for commercial clam and oyster aquaculture. Whereas the previous year’s studies had focused on smaller plots (i.e., 10 acres or less), the 2014 field trials were designed to assess these potential effects when imidacloprid is applied to larger (>50 acre) plots. Commercial treatment of plots of this size is most likely only feasible using aerial spraying from helicopters, which is not proposed under the 2016 WGHOGA NPDES application. Nonetheless, the 2014 field trials provide data on the potential effects of imidacloprid spraying over larger areas, including clusters of smaller plots that are located in proximity to one another. It also indirectly allowed a test of whether post-spraying recruitment of invertebrates from unsprayed areas to the sprayed plots would be impeded when larger blocks and clusters are sprayed (e.g., due to the greater distance to be traveled, and the smaller amount of unsprayed area available as potential sources of recruitment). The results of the 2014 field trials are described in detail in Hart Crowser (2016), which is available through Ecology.

The 2014 field trials involved two trial plots (the “Coast plot,” and the “Taylor plot”), immediately adjacent to one another, collectively covering approximately 90 acres, located near Stony Point in Willapa Bay. Both sites had high populations of burrowing shrimp, and were owned by members of WGHOGA. The beds were selected both for their larger size, and because they were in close proximity to other beds scheduled for commercial treatment. A total of 90 acres were sprayed by helicopter with liquid imidacloprid, Protector 2F, at 0.5 lb a.i./acre on July 26, 2014. The control site was matched to the treatment plots, to the extent feasible, to have similar elevation, vegetation and substrate as the treatment plots. The control plot was located near Bay Center, approximately five miles from the treatment plots, to ensure no imidacloprid was carried there from the treatment plots by the rising tide. Screening values of 6.7 and 0.6 ppb were used for whole sediment and sediment porewater, respectively.

The 2014 field trials confirmed prior studies that demonstrate a rapid, negative-exponential decline in imidacloprid concentrations in whole sediment and pore water after treatment. At 14 days, 4 of 8 sites had concentrations ranging from 6.8 µg a.i./L to 18 µg a.i./L, but imidacloprid

was below detection limits at the other four locations. All but one sampling site declined to below detection limits in whole sediment by 28 days after treatment, with one sample (12 ppb) exceeding the 6.7 ppb screening level established for whole sediment. Sediment porewater demonstrated a similar rapid decline of imidacloprid concentrations, with all sediment porewater samples except one below the screening level of 0.6 ppb by day 28. The single sample that was above that screening level at day 28 exceeded that level, with a concentration of 1.2 ppb.

Potential On-plot Impacts

Potential impacts to sediment and sediment porewater would be similar for Alternatives 3 and 4. On-plot sediment and sediment porewater would likely result in short-term impacts from imidacloprid application. Field trials conducted in 2012 and 2014 confirm that imidacloprid does persist in the sediment after application (Hart Crowser 2013 and 2016). Both the 2012 and 2014 results confirm that imidacloprid concentrations in the sediment decline, remain above screening values after 14 days, and are generally undetectable or below screening values at 28 days. The 2012 results documented detectable concentrations of imidacloprid at 56 days for two of five sampled locations, both of which were below screening levels. Imidacloprid is known to bind to organic materials in sediments, which delays the rate of decline in imidacloprid concentrations compared to sediments low in organic materials (Grue and Grassley 2013). Similar results are seen for sediment porewater, with measurable concentrations of imidacloprid generally undetectable or falling below 2014 screening levels by 28 days or less at a majority of the sites tested, but with slower levels of decline at sites with higher organic levels in the sediments (e.g., the Cedar River test plots).

MITIGATION MEASURES

Prior to issuing a NPDES permit for the discharge of a pesticide to waters of the State, Ecology must determine whether the proposed action will comply with Washington's Water Quality Standards (WQS), Sediment Management Standards (SMS), and other applicable laws and regulations. Washington's SMS establish sediment quality standards for marine surface sediments, sediment source control standards with which point source discharges must comply, and an antidegradation policy (WAC 173-204-120, -300 through -350, and -400 through -450). Sediment quality criteria for marine surface sediments include criteria establishing maximum concentrations of specified chemical pollutants, biological effects criteria, and criteria for benthic abundance (WAC 173-204-320).

Under Alternative 4, the NPDES Individual Permit for the use of imidacloprid would only be issued if appropriate conditions were imposed to achieve compliance with the Washington State WQS and SMS. These conditions would likely mitigate potential significant adverse impacts on sediments and benthic organisms.

Applicators would be required to follow all pesticide label instructions to prevent spills on unprotected soil. If the NPDES permit is issued, a Spill Control Plan would be prepared to implement Alternative 4 that would address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that would avoid,

contain, or treat spills of imidacloprid. It would also list all oil and chemicals used, processed, or stored at the facility which may be spilled into State waters (if any). The plan would be reviewed at least annually and updated as needed. In the event of a spill, applicators would be required to follow spill response procedures outlined in the NPDES Individual Permit and Spill Control Plan.

LOCALIZED, SHORT-TERM IMPACTS

Impacts to sediment and sediment porewater would be similar for Alternatives 3 and 4. On-plot and adjacent sediments and sediment porewater would likely result in localized, short-term impacts of imidacloprid application.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS²

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including the Washington State WQS and SMS), any significant unavoidable adverse impacts to sediments would be expected to be localized and short term as a result of implementing Alternative 4. The requested Ecology NPDES permit, if issued, would include sediment monitoring requirements to confirm the effects of pesticide applications. That monitoring would include long-term sampling to evaluate and address any potential persistence of imidacloprid in sediments. Adjustments to permit conditions could be made during the 5-year term of the permit based on the results of that sampling.

3.3.2 Air Quality

AFFECTED ENVIRONMENT

Information regarding regulations applicable to air emissions is described in the 2015 FEIS (Chapter 3, Section 3.2.2, pages 3-12 through 3-13). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.2.1 Willapa Bay

² According to The SEPA Handbook, Section Eight – Definitions (SEPA Rules, WAC 197-11), a significant adverse impact is “a reasonable likelihood of more than a moderate adverse impact on environmental quality.” The severity of an impact should be weighted along with the likelihood of its occurrence. An impact may be significant if its chance of occurrence is not great, but the resulting environmental impact would be severe if it occurred. The determination that a proposed action will (or may) have a significant adverse impact involves context and intensity, and does not lend itself to a formula or quantifiable test. Context may vary with the physical setting. Intensity depends on the magnitude and duration of an impact. Context for imidacloprid applications on commercial shellfish beds in Willapa Bay and Grays Harbor includes the fact that the proposal is to treat up to 485 acres per year in Willapa Bay (approximately 1.1% of total tideland area exposed at low tide), and up to 15 acres per year in Grays Harbor (approximately 0.04% of total tideland area exposed at low tide), in estuarine environments that experience two 10-ft+ tidal exchanges per day that result in dilution and flushing.

Information regarding the air quality of Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.2, page 3-13). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. Willapa Bay meets all National Ambient Air Quality Standards (NAAQS), as well as the more stringent State standards set for total suspended solids and sulfur dioxide.

3.3.1.2 Grays Harbor

Information regarding the air quality of Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.2, page 3-13). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. Grays Harbor meets all NAAQS, as well as the more stringent State standards set for total suspended solids and sulfur dioxide.

POTENTIAL IMPACTS

The potential impacts of Alternative 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.2, pages 3-13 through 3-14). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

Emissions to the air under Alternative 4 would be lower than those projected to occur with Alternative 3, which were discussed and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.2, page 3-14). Alternative 3 considered the use of helicopters for aerial applications of imidacloprid. Alternative 4 specifically excludes from the permit application aerial applications using helicopters. Imidacloprid may be applied using suitable vessels or land-based equipment, such as scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, backpack reservoirs with hand-held sprayers, and/or belly grinders. Vehicular and boat trips associated with imidacloprid applications would be added to existing trips for shellfish planting, rearing and harvest activities. Boat application of imidacloprid, if approved and used, would also contribute to emissions. Emissions associated with Alternative 4 would not be expected to impair attainment of air quality standards in Pacific or Grays Harbor counties.

Both the flowable (Protector 2F) and granular (Protector 0.5G) forms of imidacloprid have only a slight odor and most or all applications would be made away from the public and during periods of low wind. Therefore, it is unlikely that the odor would be detectable to off-site observers. This effect would be the same with Alternative 4 as that previously described for Alternative 3.

Protector 2F is considered to be non-volatile, but slightly toxic by inhalation. Protector 0.5G is also considered to be non-volatile and is relatively non-toxic by inhalation. There should be little to no inhalation exposure to the applicator during aquatic applications of either formulation under Alternative 4. The pesticide label requires the following personal protective gear: a long-

sleeved shirt and long pants, shoes and socks, protective eyewear, dust mask (Protector 0.5G only), and chemical-resistant gloves when applying Protector 0.5G and Protector 2F. Imidacloprid would be applied on private tidelands normally located well away from public gathering locations; therefore, there should be little to no risk of air-based exposure to the public or other bystanders. These effects would be the same with Alternative 4 as those previously described for Alternative 3.

Potential On-plot Impacts

Potential impacts to air quality for treated plots under Alternative 3 or 4 would likely be minor and short-term. Sources of emissions to the air would be vehicles (e.g., ATVs or boats) operating immediately over a plot during treatment. Under Alternative 4, there would be no aerial applications, and thus no use of helicopters.

MITIGATION MEASURES

Under Alternative 4, it would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. The FIFRA Registrations for Protector 0.5G and 2F (No. 88867-1 and 88867-2, the granular and flowable forms of imidacloprid, respectively) state that average wind speed at the time of application is not to exceed 10 mph (USEPA 2013a and USEPA 2013b). In addition, the FIFRA Registration for Protector 0.5G requires the use of a dust mask by all handlers of imidacloprid. It would be a violation of the FIFRA label and the proposed NPDES individual permit for the applicator to not follow label directions.

To help prevent human exposure, the NPDES Individual Permit, if issued to implement Alternative 4, would require public notification measures that are the same as or similar to the measures listed in the FIFRA Registrations for Protector 2F and 0.5G (USEPA 2013a and 2013b). All public access areas within a one-quarter mile radius of any bed scheduled for treatment would be posted with a sign, or signs would be located at 500-foot intervals at those access areas more than 500 feet wide. Signs would be posted at least 2 days prior to treatment and would remain for at least 30 days after treatment (USEPA 2013a and 2013b). In addition, WGHOGA would use a website for public notification of specific dates of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The WGHOGA Integrated Pest Management (IPM) Coordinator would send e-mail notification to registered interested parties, as needed.³

³ If a SIZ is defined to implement Alternative 4, prior to authorization of the SIZ Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees affected by the SIZ in accordance with WAC 173-204-415(2)(e). This notification would also include an opportunity for affected landowners, adjacent landowners, and lessees to comment on the proposed SIZ. This notification is separate from the public notice requirements for chemical applications for which WGHOGA would be responsible under a potential NPDES permit.

LOCALIZED, SHORT-TERM IMPACTS

Potential impacts to air quality for treated plots under Alternative 3 or 4 would likely be localized and short-term. Sources of emissions to the air would be vehicles (e.g., ATVs or boats) operating immediately over a plot during treatment. Under Alternative 4, there would be no aerial applications, and thus no use of helicopters.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including disclosure of application dates and locations), no significant unavoidable adverse impacts to air quality would be expected as a result of implementing Alternative 4. Pesticide applications for burrowing shrimp population control would be implemented in compliance with FIFRA Registration restrictions and NPDES permit conditions that specify appropriate application equipment and spray drift management techniques to avoid or minimize off-target exposures. FIFRA Registration and NPDES permit conditions also include public notification requirements to inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided.

3.3.3 Surface Water

AFFECTED ENVIRONMENT

3.3.3.1 *Willapa Bay*

Information regarding the surface water characteristics of Willapa Bay is included in the 2015 FEIS (Chapter 3, Section 3.2.3, pages 3-16 through 3-18). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.3.2 *Grays Harbor*

Information regarding the surface water characteristics of Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.3, pages 3-18 through 3-21). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to surface water of Alternative 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and

Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.3 pages 3-21 through 3-24). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

Under Alternative 4 (imidacloprid applications with IPM – the 2016 WGHOGA proposal), imidacloprid and the degradation byproducts of imidacloprid would enter Willapa Bay and Grays Harbor following treatments of commercial shellfish beds on approximately 485 acres per year within Willapa Bay, and approximately 15 acres per year within Grays Harbor. These applications are proposed to occur between April 15 through December 15 (see SEIS Chapter 2, Section 2.8.4). Hydrolysis, photolysis, and microbial degradation would be the primary means of imidacloprid breakdown in aquatic environments. Factors such as water chemistry, temperature, adsorption to the sediment, water currents, and dilution can all have significant effects on the persistence of imidacloprid (CSI 2013). Laboratory studies have shown that the half-life of imidacloprid at pH 5 and 7 can be greater than one year, while the half-life of imidacloprid at pH 9 is approximately one year (CSI 2013). Other laboratory studies of photodegradation of imidacloprid in freshwater suggest that imidacloprid has a half-life of approximately 4.2 hours in water and quickly degrades under natural sunlight (CSI 2013). Further laboratory experiments have had varied results, with one showing a half-life of 129 days (Spiteller 1993 as cited in CSI 2013) and the other 14 days (Henneböle 1998, cited in CSI 2013). Imidacloprid that is not degraded by environmental factors would be subject to dilution through tidal flows into and out of the estuaries.

Studies have shown that imidacloprid has eight degradation products as a result of hydrolysis, photolysis, and soil and microbial degradation. These degradation products include: imidacloprid-olefin, 5-hydroxy- imidacloprid, imidacloprid-nitrosimine, imidacloprid-guanidine, imidacloprid-urea, 6-chloronicotinic acid, imidacloprid-guanidine-olefin, and acyclic derivative. The toxicity levels of all the degradation products are equal to or lower than the toxicity of the parent compound (SERA 2005).

Site-specific studies have been conducted to assess the transport and persistence of imidacloprid in surface water. Studies were conducted in Willapa Bay in 2012 and 2014 (Grue and Grassley 2013; Hart Crowser 2013 and 2016) to quantify the concentrations of imidacloprid in the water column, sediment, and sediment porewater. The scope of these trials was to describe the SIZ that could be associated with the commercial use of imidacloprid for burrowing shrimp population control. A SIZ is the area where the applicable State sediment quality standards of WAC 173-204-320 through 173-204-340 are exceeded due to ongoing permitted or otherwise authorized wastewater, storm water, or nonpoint source discharges (WAC 173- 204-200). One of the studies was also designed to measure one of the degradation products of imidacloprid: imidacloprid-olefin.

Results of the 2012 commercial-scale experimental trials conducted in Willapa Bay were described in the 2015 FEIS (Chapter 3, Section 3.2.3, pages 3-23 through 3-24). These trials documented that detectable concentrations of imidacloprid were observed at up to 1,575 feet from the edge of the sprayed plots, on the leading edge of the rising tide. Overall, imidacloprid

was frequently detected off-site in drainage channels and areas covered by the rising tide, especially in those areas located closest to the treatment plots. Off-plot concentrations were highly variable, ranging from non-detection up to concentrations of 4,200 µg a.i./L. All remaining information on the 2012 trials is unchanged at the time of this writing, and the FEIS discussion is incorporated by reference in the SEIS.

The 2014 field trials were designed to assess the magnitude, extent, and duration of impacts from imidacloprid that could be associated with commercial use of imidacloprid for burrowing shrimp population control on tidelands used for commercial clam and oyster aquaculture. Whereas the previous year's studies had focused on smaller plots (i.e., 10 acres or less), the 2014 field trials were designed to assess these potential effects when imidacloprid is applied to larger (>50 acre) plots. Commercial treatment of plots of this size is most likely only feasible using aerial spraying from helicopters, which is not proposed under the 2016 WGHOGA application. Nonetheless, the 2014 field trials provide data on the potential effects of imidacloprid spraying over larger areas, including clusters of smaller plots that are located in proximity to one another. It also indirectly allowed a test of whether post-spraying recruitment of invertebrates from unsprayed areas to the sprayed plots would be impeded when larger blocks and clusters are sprayed (e.g., due to the greater distance to be traveled, and the smaller amount of unsprayed area available as potential sources of recruitment). The results of the 2014 field trials are described in detail in Hart Crowser (2016), which is available through Ecology. A total of 90 acres were sprayed by helicopter with liquid imidacloprid, Protector 2F, at 0.5 lb active ingredient per acre (a.i./ac) on July 26, 2014 ("Taylor and Coast Sites"). A screening criterion of 3.7 ppb was used to determine when surface water samples indicated a potential for negative biological effects. Liquid formulation was also sprayed (0.5 lb a.i./ac) at two smaller sites (<10 acres) in the Cedar River area ("Coast and Nisbet Plots") to specifically test on-plot and off-plot concentrations of imidacloprid in water. All flowable imidacloprid was sprayed on treatment plots that were exposed by an outgoing tide.

Water column samples were collected from the leading edge of the rising tide, typically about 2 hours after treatment. Imidacloprid concentrations in surface water at the Taylor and Coast sites (on-plot samples) ranged from 180 to 1,600 ppb, with an average value of 796 ppb. The Cedar River sites were designed to test the linear extent to which imidacloprid concentrations are diminished with distance from the sprayed plots (e.g., due to dilution by the incoming tide) and to determine the maximum distance of detectability. At the Coast plot, the on-plot concentration of imidacloprid was 230 ppb. At approximately 731 meters from the plot (about 2,400 feet), the concentration was 0.054 ppb. For the Nisbet plot, samples were taken on-plot, and at distances of 62 meters (203 feet), 125 meters (410 feet), 250 meters (820 feet), 500 meters (1,640 feet), and on the shoreline (approximately 706 meters or 2,316 feet). This set of samples documented a decrease in imidacloprid concentrations with distance as follows: on-plot = 290 ppb, 62 meters = 0.55 ppb, 125 meters = 0.14 ppb, 250 meters = not detectable, 500 meters = 0.066 ppb, and shoreline = not detectable.

Overall, the surface water data collected during the 2014 trials indicate a strong pattern of high on-plot and low off-plot concentrations during the first rising tide, a result also noted in prior trials. For the Cedar River sites, on plot locations had concentrations up to 1,600 ppb, with an

average value of approximately half this amount. Imidacloprid was detected at considerable distances off-plot, but at low concentrations of 0.55 ppb to 0 ppb. Thus, although the 2014 data confirm a greater distance off-plot for movement of imidacloprid (up to 500 meters), the concentrations were much lower than those observed in the off-plot data from 2012. These varying results suggest that site-specific differences in how tidal waters advance and mix during a rising tide are important in determining both the distance traveled and concentration of imidacloprid off-plot.

Imidacloprid dissolves readily in surface water and moves off treated areas with incoming tides and in drainage channels. As the data above show, this may allow imidacloprid to impact non-treated areas through surface water conveyance, particularly as tide waters first pass over off-plot areas. However, as tide waters continue to flow onto off-site areas, imidacloprid is expected to dilute significantly, a process that would continue through successive tidal cycles. Accordingly, imidacloprid in water is expected to have a low to moderate potential to cause ecological impacts in non-target areas (see Section 3.3.5 for analysis of potential effects on off-plot invertebrates).

Potential On-plot Impacts

Under Alternative 3 or 4, surface water on plots that have been treated with imidacloprid would likely show short-term impacts due to the application. Experimental trials conducted in 2012 and 2014 confirm that imidacloprid dissolves in surface water and may persist in the water column during the first tidal cycle. The highest concentrations of imidacloprid would occur during the first rising tide after application, and would dilute and flow off-plot during consecutive tidal cycles (Hart Crowser 2016).

MITIGATION MEASURES

Under Alternative 4, a NPDES Individual Permit for the use of imidacloprid, if issued, would contain conditions and restrictions to ensure compliance with all applicable laws and regulations protecting water quality. Additional guidance on mitigation measures can be obtained from the EPA registration requirements for the use of imidacloprid. If the NPDES permit requested by WGHOGA is issued by Ecology, it would include appropriate conditions and restrictions to ensure compliance with applicable regulatory standards to address water quality impacts. The discharge of imidacloprid authorized by an NPDES permit would be limited to waters of the State of Washington; specifically, to the waters of Willapa Bay and Grays Harbor, for the purpose of burrowing shrimp population control on commercial shellfish beds. If issued, this permit would not allow application to tidelands on the Shoalwater Indian Reservation.

Discharge monitoring and data reporting would be required under the NPDES Individual Permit for the use of imidacloprid, if issued (USEPA 2013a and 2013b). The imidacloprid water quality monitoring plan would take into account the treatment plan proposed, and current information regarding this proposal would be used to condition the permit.

Applicators would be required to follow all pesticide label instructions for the use of imidacloprid to prevent spills where applications are not permitted. If the NPDES permit is

issued, a Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that would prevent, contain, or treat spills of imidacloprid. It would also list all oil and chemicals used, processed, or stored at the facility that may be spilled into State waters. The plan would be reviewed at least annually and updated as needed. In the event of a spill, applicators would be required to follow spill response procedures outlined in the NPDES Individual Permit and the Spill Control Plan. The FIFRA Registrations for the flowable and granular formulations of imidacloprid (Protector 2F and Protector 0.5G, respectively) recommend that a properly designed and maintained containment pad be used for mixing and loading imidacloprid into application equipment. If a containment pad is not used, a minimum distance of 25 feet should be maintained between mixing and loading areas and potential surface to groundwater conduits (USEPA 2013a and 2013b).

If issued, the NPDES permit would include FIFRA Registration conditions requiring that a 25-foot buffer for treatment by hand spray if an adjacent shellfish bed is to be harvested within 30 days. Protector 0.5G applications made from a floating platform or boat may be applied to beds under water using a calibrated granular applicator (USEPA 2013a and 2013b).

LOCALIZED, SHORT-TERM IMPACTS

Under Alternative 3 or 4, surface water on plots that have been treated with imidacloprid would likely show short-term impacts due to the application of imidacloprid. Experimental trials conducted in 2012 and 2014 confirm that imidacloprid dissolves in surface water and may persist in the water column during the first tidal cycle.

Results of the 2012 commercial-scale experimental trials conducted in Willapa Bay were described in the 2015 FEIS (Chapter 3, Section 3.2.3, pages 3-23 through 3-24). These trials documented that detectable concentrations of imidacloprid were observed, in some cases at up to 1,575 feet from the edge of the sprayed plots, on the leading edge of the rising tide.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to surface water quality would be expected as a result of implementing Alternative 4. The requested Ecology NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made during the five-year term of the permit.

3.3.4 Plants

AFFECTED ENVIRONMENT

3.3.4.1 Willapa Bay

Information regarding the plant communities of Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.4, pages 3-25 through 3-27). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.3.2 Grays Harbor

Information regarding the plant communities of Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.4, pages 3-27 through 3-28). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to plants of Alternative 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.4, pages 3-28 through 3-31). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

Under Alternative 4 (imidacloprid applications with IPM – the 2016 WGHOGA proposal), the application of imidacloprid may have localized, temporary, and negligible impacts on plants within Willapa Bay and Grays Harbor if the NPDES permit is issued. Imidacloprid is a systemic insecticide that is taken up from the soil (or sediments) by plants and is present in the foliage of plants. There is limited information available regarding imidacloprid impacts to marine vegetation, as discussed below.

While imidacloprid would, if the permit is issued, be applied to areas with high populations of burrowing shrimp on commercial shellfish beds only, research also indicates that imidacloprid can move off-site rapidly in surface water and can be detected at least 480 meters (1,575 feet) away from the application site. Earlier research conducted by Felsot and Ruppert (2002) showed that imidacloprid dissipated rapidly in marine waters, but was detectable in sediments for longer periods of time. Sediment porewater concentrations of imidacloprid were also examined and researchers found that imidacloprid was almost undetectable 56 days after application (Grue and Grassley 2013). Rooted plants such as eelgrass and salt marsh plants could uptake the insecticide in these areas and small concentrations of imidacloprid have been found in eelgrass for limited periods of time (Grue & Grassley 2013; Hart Crowser 2013).. Also, if applicators failed to employ effective spray drift management techniques, imidacloprid might stray from the

application zone to adjacent aquatic or shoreline plants that are occasionally inundated by tidal waters.

The 2015 FEIS discusses the potential impacts of imidacloprid on marine plants including marine algae (Chapter 3, Section 3.2.4, pages 3-28 through 3-31), and is incorporated by reference in the SEIS. The results of more recent studies on the effects of imidacloprid on plants are presented below.

EPA (2017) provides a comprehensive review of imidacloprid risks to the environment. A detailed review of this Risk Assessment is provided in SEIS Appendix A. For plants, EPA noted “[a]quatic plants will not be assessed as available data for vascular and non-vascular aquatic plants indicate toxicity endpoints that are several orders of magnitude above the highest estimated environmental concentrations in surface waters.” Imidacloprid toxicity derives from its ability to bind to specific sites on nerves (nicotinic acetylcholine receptors – nAChRs), causing them to malfunction (e.g., excessive nervous stimulation, blockage of the receptor sites). Plants lack a nervous system, thus making it unlikely that imidacloprid would negatively affect marine plant species.

Potential On-plot Impacts

Under Alternative 3 or 4, it is unlikely that imidacloprid would impact plants present on treated plots immediately after treatment since plants lack the nervous system pathway through which imidacloprid impacts some organisms.

MITIGATION MEASURES

Under Alternative 4, if the NPDES permit is issued, imidacloprid application would be administered off-shore during periods of low wind, and during outgoing tides or over water, thus exposure to flowering plants would also be minimized.

Under Alternative 4, applicators would be required to follow all pesticide label instructions for the use of imidacloprid to prevent spills on unprotected soil and vegetation. FIFRA Registration restrictions (USEPA 2013a and 2013b) would restrict the aerial application of imidacloprid to conditions when the wind speed is 10 mph or less, but may allow application to beds covered by an outgoing tide (i.e., with a granular form of imidacloprid). Further, imidacloprid could only be used pursuant to a NPDES permit, which would contain terms and conditions to ensure compliance with all applicable regulatory standards.

If the NPDES permit is issued, a Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases, and would describe the preventative measures and facilities that would prevent, contain, or treat spills of imidacloprid.

The FIFRA Registrations (USEPA 2013a and 2013b) establish a series of application methods and spray drift management techniques that would minimize the risk of exposure of imidacloprid to non-target species and plants. For the granular form of imidacloprid (Protector 0.5G), average

wind speed at the time of application would not exceed 10 mph to minimize drift to adjacent shellfish beds and water areas when applied by spray. This would minimize the potential for exposure to terrestrial habitats and plants, as would the avoidance of aerial applications. Applications would also not occur during temperature inversions. Applications would be made at the lowest possible height (scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, back pack reservoirs with hand-held sprayers and/or belly grinders) that is safe to operate, and that would reduce exposure of the granules to wind. When applications of the granular form of imidacloprid (Protector 0.5G) are made crosswind, the applicator would compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. For the flowable form of imidacloprid (Protector 2F), applicators would avoid and minimize spray drift by following detailed instructions on the FIFRA Registration label, including measures to control droplet size, making applications at the lowest possible height (scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, back pack reservoirs with hand-held sprayers and/or belly grinders) that is safe and practical and reduces exposure of droplets to evaporation and wind, applying during appropriate wind speeds and avoiding temperature inversions, and using authorized application methods and equipment.

LOCALIZED, SHORT-TERM IMPACTS

It is unlikely there would be any localized, short-term impacts to plants under Alternative 3 or 4, since plants lack the nervous system pathway through which imidacloprid impacts some organisms.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, permits and regulations, no significant unavoidable adverse impacts to estuarine or terrestrial plants would be expected as a result of implementing Alternative 4. FIFRA Registration specify spray drift management techniques and the requested Ecology NPDES permit, if issued, would include conditions that specify treatment methods; require buffers from sloughs and channels; and require discharge monitoring. Adjustments to permit conditions could be made during the 5-year term of the permit.

3.3.5 Animals

AFFECTED ENVIRONMENT

3.3.5.1 Willapa Bay

Information regarding the animal communities of Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.5, pages 3-32 through 3-38). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.5.2 Grays Harbor

Information regarding the animal communities of Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.5, pages 3-38 through 3-47). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to animals of Alternative 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.5, pages 3-47 through 3-54). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

Under Alternative 4, imidacloprid applications occurring on up to 485 acres each year within Willapa Bay could affect approximately 1.1 percent of total exposed tideland acreage within the bay annually. Imidacloprid applications occurring on up to 15 acres within Grays Harbor each year could affect approximately 0.04 percent of total exposed tideland acreage within the harbor annually (see SEIS Chapter 2, Section 2.8.4).

Statements of potential impact below are made in the context of the areas of affect described above.

Zooplankton, and Benthic Invertebrates (Burrowing Shrimp, Clams and Oysters, Dungeness Crab). Alternative 4 would provide burrowing shrimp control on commercial shellfish beds with potentially reduced environmental side effects, compared to Alternative 3 (2015 FEIS). Information on the potential impacts of imidacloprid on zooplankton and benthic invertebrates is presented in the 2015 FEIS (Chapter 3, Section 3.2.5, pages 3-48 through 3-49).

Most field trials of imidacloprid in Willapa Bay have been conducted in or near the middle of the bay where sand sediments have predominated and organic carbon levels are generally low. In these areas, as discussed in the FEIS, impacts to invertebrates from spraying imidacloprid have generally been limited in either extent or duration. For example, on-plot invertebrate measurements have generally not been more than 50 percent different than those on control plots after 14 or 28 days, although reaching appropriate statistical power has been difficult to achieve. In part, this may be due to high recolonization rates of invertebrates following treatment, survival of organisms on-plot despite treatment, or both. The proposed permit (if issued) will require additional field trials in mid-Willapa Bay and other approved locations, to maintain compliance with NPDES and SIZ requirements.

The 2016 WGHOGA permit application requests authorization to spray in both north and south Willapa Bay, locations known to contain sediments with higher organic carbon levels. Field and

laboratory studies have documented that imidacloprid levels in sediments decline more slowly over time as organic carbon levels increase (Grue and Grassley 2013). This could lead to higher toxicity to benthic organisms than in sediments where imidacloprid dissipates more quickly. Only one field trial in Willapa Bay has been conducted in areas with high organic carbon to test this possibility, the 2011 test in Cedar River. Results in this area did find greater impacts to benthic invertebrates than those noted in other trials. As discussed in the FEIS:

Before imidacloprid application, invertebrates on the control and treatment plots at the Cedar River site were statistically different for five of the nine endpoints that were examined. Polychaetes and crustaceans, in particular, were far more abundant on the treatment plot than at the control plot. In part, this was likely due to differences in vegetation levels and tidal elevations between the control and treatment plots. The differences between the plots were great enough to make any interpretation of invertebrate numbers after imidacloprid application difficult. Results of the analyses showed a decrease in abundance for most crustacean and polychaete species on the treatment plot, while a general increase was seen in the control plot. These differences were seen at both 14 and 28 days after treatment. While not conclusive, these results are consistent with an interpretation that imidacloprid reduced the number of polychaetes and crustaceans on the treatment plot, and that the decline lasted for at least 28 days following treatment, at least for some species. However, the data also show that the abundances of some species increased 28 days after treatment. Subtle differences in temperature, tidal elevation, and vegetation accounted for some differences between the treated and control site as well. A treatment effect was not evident for the three endpoints for molluscs (abundance, taxonomic richness, and Shannon diversity), or for richness and diversity in polychaetes or crustaceans.

During evaluation of the original WGHOGA permit application, Ecology determined that these results exceeded the “minor adverse effects” standard of the SIZ regulations (TCP memo dated April 7, 2015) . Ultimately, Ecology granted provisional approval to apply imidacloprid in north Willapa Bay, but removed south Willapa Bay from the permit. The provisional approval in north Willapa Bay was linked to a requirement to conduct additional field trials in this area as part of the permit’s monitoring and reporting plan. The NPDES permit (if issued) would also require additional field trials in north Willapa Bay, as well as the first field trials in south Willapa Bay. Ecology will retain the ability to modify the permit, including revocation of authorization to apply imidacloprid in north or south Willapa Bay, based on these monitoring results.

Information on zooplankton and invertebrates not available at the time the 2015 FEIS was written or obtained since the FEIS is presented below.

Several studies have been published since the 2015 FEIS was issued, including risk assessments prepared by both Health Canada (2016) and EPA (2017). EPA (2017) examined the effects of imidacloprid on 15 species of freshwater crustaceans and seven species of estuarine or marine invertebrates. The freshwater crustaceans included water fleas (Branchiopoda), amphipods and isopods (Malacostraca), and seed shrimp (Ostracoda). Seed shrimp appeared to be the most

sensitive group of freshwater crustaceans (EPA found some freshwater insects to be the most sensitive invertebrates), while water fleas were found to be more resistant to imidacloprid toxicity. Ostracods are “widely distributed in freshwater and saltwater ecosystems” and are “considered important components of the aquatic food web.” A detailed discussion of the toxicity values associated with these invertebrates is presented in SEIS Appendix A. EPA concludes that the concentrations of imidacloprid measured in many freshwater habitats exceed the toxicity thresholds for sensitive freshwater invertebrates, and therefore that imidacloprid is likely impacting these animals.

For saltwater invertebrates, EPA (2017) found only a limited number of studies covering seven estuarine or marine species, five of which were crustaceans. Acute toxicity values ranged widely, from a low LC₅₀⁴ of 10 micrograms of active ingredient per liter (µg a.i./L) for blue crab megalopae (a planktonic stage), to an LC₅₀ of 361,000 µg a.i./L for brine shrimp. The blue crab study (Osterberg et al.) is of particular interest given its possible relevance to imidacloprid effects on Dungeness crab in Grays Harbor and Willapa Bay, and so is reviewed separately below. However, for EPA (2017), the study was deemed “qualitative,” so EPA chose to use “the lowest acceptable (quantitative) acute toxicity value of 33 µg a.i./L ...for estimating risks to saltwater aquatic invertebrates.” The value of 33 µg a.i./L is the 96-hour LC₅₀ for a species of mysid shrimp (*Americamysis bahia*). EPA notes that this value is “42X less sensitive than that for freshwater invertebrates” EPA then applied a Level of Concern of 0.5 (i.e., a factor of safety) to this value, resulting in an acute toxicity standard for marine invertebrates of 16.5 µg a.i./L. (i.e., 33 µg a.i./L /0.5 LOC = 16.5 µg a.i./L). Given selection of this toxicity standard by EPA (2017), Ecology has chosen to utilize 16.5 µg a.i./L as the imidacloprid acute toxicity criterion for marine invertebrates.

For chronic toxicity of saltwater invertebrates, EPA (2017) again used data on *A. bahia* to develop a 28-day No Observable Adverse Effects Concentration (NOAEC) value of 0.163 µg a.i./L and a Lowest Observable Adverse Effects Concentration (LOAEC) of 0.326 µg a.i./L based on “significant reductions in length and weight.” EPA (2017) includes only two chronic studies of imidacloprid effects on saltwater invertebrates. If a larger database had been available, it seems likely that lower values for chronic toxicity would have been noted for one or more invertebrate types, especially given the consistent pattern of wide variation in imidacloprid toxicity among species. See the literature review in SEIS Appendix A for further details. These selected values for saltwater invertebrate toxicity were used by EPA to evaluate potential environmental effects from runoff of imidacloprid from upland areas. For its modeled imidacloprid exposures (based on different uses of imidacloprid in agriculture), EPA found only one acute risk to saltwater invertebrates in any of its modeled scenarios. For chronic exposures, it found that foliar spraying of imidacloprid (e.g., on fruit trees) could lead to runoff that would produce toxicity, and obtained a similar result in three of its eight modeled scenarios of agricultural use of imidacloprid-treated seed. EPA’s comparison of field data on imidacloprid concentrations in estuarine and marine environments to its chosen toxicity values was limited, probably because it notes that field data were limited. Based on this review, EPA concluded that

⁴ LC₅₀ is the concentration of imidacloprid that killed 50 percent of the test organisms in the allotted test time (e.g., 48-hours, 96-hours, etc.).

chronic toxicity to crustaceans in saltwater environments is possible from existing levels of imidacloprid in marine waters.

Using EPA's (2017) acute toxicity criterion of 16.5 µg a.i./L, Ecology modeled potential impacts of imidacloprid on marine invertebrates as it is carried off-plot by rising tidal waters.

Specifically, the Department calculated the off-plot area that could be exposed to acutely toxic levels of imidacloprid as it was carried by the rising tide. Purposely, this modeling was "worst case" due to incorporation of several assumptions:

- EPA's acute toxicity criterion was based on scientific literature showing toxicity at 33 µg a.i./L. EPA used a level of concern (i.e., a factor of safety) of 0.5 to lower this toxicity criterion to 16.5 µg a.i./L even though the underlying scientific study did not find toxicity at this lower level. Ecology retained EPA's level of concern in its analysis.
- EPA's acute toxicity criterion of 16.5 µg a.i./L was based on a 96-hour exposure. For Ecology's modeling scenario, it was assumed that toxicity would occur at any location where the instantaneous concentration equaled or exceeded this level, regardless of the duration of exposure.
- Previous water quality monitoring following field applications has documented widely varying concentrations of imidacloprid as it travels off-plot. The single greatest distance where imidacloprid was ever measured at or above 16.5 µg a.i./L (1,575 feet during the 2012 field trial at Palix site) was assumed to occur on all plots where imidacloprid would be applied.
- It was assumed that one-half of the edge of each treated plot would experience off-plot flow⁵, and that in all locations with off-plot flow, imidacloprid levels would exceed 16.5 µg a.i./L the full 1,575-foot distance outward from the plot edge.

Ecology evaluated a rectangular spray plot, 5 acres in size.⁶ The area exposed to acutely toxic levels of imidacloprid off-plot with these modeling assumptions would be 10.6 acres (463,050 square feet). That is, it was assumed that invertebrates in off-plot areas approximately double the size of the modeled spray plot would experience imidacloprid levels above the acute toxicity criterion of 16.5 µg a.i./L.

Actual toxicity to off-plot invertebrates is expected to be less than this given greater tidal dilutions, and non-instantaneous toxicity that would be associated with field exposures. Additionally, this modeling of imidacloprid off-plot is simple and a more complex model might yield different results.

Two studies particularly relevant to the potential impacts of imidacloprid on Dungeness crab were reviewed. The first, Patten and Norelius (2017) summarizes nine sets of experiments on the effects of imidacloprid on Dungeness crab. Seven of the studies looked at the onset of and recovery from tetany in crab under laboratory conditions exposed to varying levels and durations

⁵ As the tide rises some edges of the plot have tidewater sweep onto the plot. For these edges off-plot effects would not occur as imidacloprid is carried further onto the plot, not to off-plot areas.

⁶ Plots of different sizes or geometry would produce different results.

of imidacloprid. Two studies assessed the number of crab affected following field applications of imidacloprid to commercial shellfish grounds in Willapa Bay. Based on the results of water quality monitoring during field applications of imidacloprid, the authors report an average imidacloprid concentration of 170 µg/L in the “leading edge” of the rising tide that carries imidacloprid off treated plots, and 2.2 µg/L on-plot during high tide on the day of application, although variability is high as imidacloprid 10 times higher has been recorded both on- and off-plot during monitoring. In the lab, they found that Dungeness crab megalopae (the last planktonic form before crabs settle to the bottom) did not develop tetany at imidacloprid concentrations up to 100 µg/L for 2 hours exposure; however, significant tetany was observed at 500 µg/L within 20 minutes. Dungeness crab juveniles also did not develop tetany at imidacloprid concentrations up to 100 µg/L (6 hours exposure). In studies designed to mimic the rate of dilution of imidacloprid from rising tidal waters following field applications (i.e., dilution by approximately 50% every 4 minutes) they did not observe tetany of juvenile Dungeness crab at starting concentrations of either 250 µg/L or 500 µg/L (highest concentration tested), although their surveys following field applications consistently found affected Dungeness crab in the spray plots. Across surveys, the authors found an average of 3.2 affected crab/acre sprayed, but numbers up to 29 crab/acre were observed. The authors noted both crabs crushed by the ATVs used to spread imidacloprid on the plots, and widespread predation by gulls on Dungeness crab following field spraying. Considering all their results, the authors concluded that some level of Dungeness crab megalopae and juvenile crab mortality from treatment of shellfish beds is “likely..” Similar lab studies of burrowing shrimp subjected to high concentrations of imidacloprid showed similar low mortality and eventual recovery from tetany (Grue, pers. comm.)

The second study relevant to Dungeness crab is Osterberg et al. (2012), who studied blue crab, a species common on the U.S. Gulf and East coasts. The authors exposed blue crab megalopae and juveniles to acute, 24-hour, static concentrations of various pesticides, including both laboratory-grade (i.e., pure) and commercial grade (formulated and sold as Trimax™) imidacloprid. They recorded mortality, and for megalopae, effects on metamorphosis and subsequent juvenile survival. The authors found a significant difference in the toxicity of laboratory and commercial-grade imidacloprid on megalopae toxicity, with estimated LC₅₀ values of 10.04 µg/L and 312.7 µg/L, respectively. This difference was reversed for juveniles, with LC₅₀ values for the laboratory and commercial grades of 1,112 µg/L and 816.7 µg/L, respectively. No explanation was offered for these observed differences in toxicity. Imidacloprid exposure did not delay the onset of metamorphosis in megalopae, but did result in lower molting rates and higher mortality in newly metamorphosed juveniles compared to controls. The authors included a short literature review on imidacloprid toxicity in crustaceans, and also conducted a simplified dilution study which led them to conclude that “*direct overspray of Trimax or imidacloprid has a good chance to be acutely toxic to any blue crabs there [in shallow estuarine waters].*”

Based on these two studies, and particularly the field results reported in Patten and Norelius (2017), application of imidacloprid to control burrowing shrimp populations will result in tetany and death of planktonic and juvenile Dungeness crab on-plot. Whether through crushing by application equipment, predation on individual animals in tetany, or direct mortality, the result will be a reduction in Dungeness crab in the imidacloprid application areas. Dungeness crab in

off-plot areas may also experience tetany and mortality, particularly in those areas closest to the sprayed plots where water concentrations of imidacloprid being moved off-plot are highest due to lower levels of dilution. Given average juvenile mortality levels of 2.3 crab/acre, as reported in Patten and Norelius (2017), impacts to juvenile Dungeness crab are not expected to have a significant effect on total crab populations in either Willapa Bay or Grays Harbor due to the large overall size of these populations⁷ and the limited area that would be treated each year under the permit (if issued). Impacts to planktonic life stages of Dungeness crab will also occur, but other than longer duration laboratory studies, there is little scientific basis for quantifying such impacts. Conservatively, if all planktonic forms of Dungeness crab on plot, and those in off-plot areas exposed to 500 µg/l or more imidacloprid in the water column for even short periods are assumed to be lost, the effects on-plot would be substantial, and off-plot losses would add to this impact. However, planktonic forms of Dungeness crab are extremely abundant compared to juvenile forms. For example, a single Dungeness crab female can produce up to 2 million eggs per year (https://www.nwrc.usgs.gov/wdb/pub/species_profiles/82_11-063.pdf). Thus, no significant bay-wide impact on Dungeness crab from imidacloprid effects on planktonic forms of this species is expected.

Forage Fish and Groundfish. It is unlikely that there would be direct adverse effects to forage fish or groundfish from imidacloprid in water (Alternative 4), according to EPA's Risk Assessment (2017). Although EPA identified a data gap for chronic effects of imidacloprid on saltwater fish, they used the ratio of acute to chronic toxicity values to estimate a chronic NOAEC, which served as a basis for its conclusion of no direct chronic effects on saltwater fish. The estimated chronic NOAEC for saltwater fish was 6,420 µg a.i./L; by comparison, the highest concentration of imidacloprid in the water column was measured at 4,200 µg a.i./L during the 2012 field studies, and was associated with a rising tide that likely resulted in rapid dilution to much lower levels.⁸ The Health Canada (2016) literature review did not analyze in detail the toxicity of imidacloprid to freshwater and marine fish; however, it did list tabular data documenting LC₅₀ values that were consistently greater than 1,000 µg/L, indicating low potential for imidacloprid toxicity. Similarly, based on a review of 150 published studies, Gibbons et al. (2015) report LC₅₀ values for fish of 1,200 to 241,000 µg/L (various exposure durations). They note that reported concentrations of imidacloprid in surface waters are “*except in the most extreme cases...2 to 7 orders of magnitude lower than the LC₅₀ measurements for fish,*” and therefore direct mortality in these groups is unlikely. The authors also reviewed literature to show that imidacloprid can cause sub-lethal effects (e.g., reduced growth or reproductive success) in fish at 30 to 320,000 µg/L (duration of exposure unknown). The authors conclude that “*the possibility of sub-lethal effects [in fish]...cannot be ruled out.*” Other authors have raised concerns about potential sublethal effects (e.g. Hayasaka et al. 2012, Sanchez-Bayo et al. 2016).

⁷ For example, the commercial harvest in Pacific County, in which Willapa Bay is located, averages 2 to 6 million pounds of adult crabs/year (<http://msp.wa.gov/wp-content/uploads/2014/03/FishingSectorAnalysis.pdf>). At an average weight of 1 pound, this is equal to 2 to 6 million adult crabs. When this catch is combined with adult crabs not captured in the fishery (e.g., all females) and with the numbers of juvenile crabs not sampled by the fishery, the total population of Dungeness crabs in Pacific County likely exceeds 10 to 20 million animals or more.

⁸ Field protocols require that water samples be taken on the leading edge of the rising tide. Samples taken at the sprayed plots on the first high tide after treatment averaged 2.2 µg/l imidacloprid (Patten and Norelius 2016).

Birds. Marbled murrelet, Western snowy plover, and streaked horned lark are individually discussed below in the Threatened, Endangered, and Protected Species section. The 2015 FEIS provides a discussion of the potential impacts to birds from imidacloprid exposure (Chapter 3, Section 3.2.5, page 3-20 through 3-51). Information not available or reviewed before the 2015 FEIS was issued is presented here.

As with other vertebrates, high concentrations of imidacloprid are required to produce toxicity in birds. The Health Canada (2016) risk assessment includes an extensive review of imidacloprid toxicity to different bird species, as well as modeling to compare likely environmental exposure levels (e.g., from eating imidacloprid-containing seed or invertebrates). Health Canada noted a wide range of reported acute and chronic toxicity levels for different bird species, and modes of exposure. It concluded that imidacloprid is “*not expected to pose a risk to birds*” due to low toxicity relative to exposure, and the reality that “*birds are unlikely to feed solely on imidacloprid-contaminated foodstuffs.*” The modeled toxicity to small and insectivorous birds concluded that imidacloprid is “*not expected to pose a risk to birds,*” again based on an inherent high toxicity threshold, and because imidacloprid is expected to decline in their prey organisms following treatment with imidacloprid. Similarly, Health Canada concluded that the “*risk to small and medium sized birds is considered to be relatively low.*” Health Canada did find that consumption of agricultural seeds treated with imidacloprid could lead to toxicity if ingested by seed-eating birds. Health Canada also evaluated anecdotal reports of birds that had fallen ill, or were dead or dying, following turf treatments of imidacloprid. Health Canada concluded that these reports demonstrate a potential for impacts from pellet applications of imidacloprid, but indicated that this risk could be mitigated by prompt exposure of the pellets to water following application. The use of imidacloprid pellets in Willapa Bay or Grays Harbor is unlikely to impact birds because pellets will dissolve on contact with water from the incoming tide.

Although Health Canada (2016) did not conclude that imidacloprid toxicity in birds is likely, it noted that imidacloprid toxicity to invertebrates could have food chain effects that could indirectly affect birds. Birds that eat invertebrates would be particularly susceptible. Reduction in invertebrates could reduce the levels of food for these species, at least locally, particularly for shorebirds that feed exclusively on invertebrates. However, any such reductions are not expected to be significant because of the small area that would receive imidacloprid applications each year relative to the total area available for such foraging in Willapa Bay and Grays Harbor.

Granular-form applications of imidacloprid on commercial shellfish beds (sand or mudflats) could result in an opportunity for birds to be exposed to this chemical through ingestion of the solid form, but direct exposure would be limited since application techniques flush birds from the site, and imidacloprid dissolves readily in water. In addition, the granular form of imidacloprid uses clay pellets, which presumably are not sought as a prey item by foraging birds. Even if the pellets were readily eaten, the period for birds to ingest the granular form of imidacloprid would be a few hours or less due to rising tides that would inundate treated plots. Similar to potential impacts that may be associated with birds eating invertebrate prey organisms that have been exposed to imidacloprid, the risk of birds ingesting the granular form of

imidacloprid is not expected to be significant because of the small area that would be treated relative to the total area available for such foraging in Willapa Bay and Grays Harbor.

Another study containing an extensive review of imidacloprid effect on birds is Gibbons et al. (2015). They reviewed 150 previously published studies on the effects of pesticides on vertebrate wildlife, including fish, birds, and mammals. Common to many studies, they found widely varying toxicity of imidacloprid to different species. For birds, they report LC₅₀ values ranging from 13,900 to 283,000 µg/L. The authors also reviewed literature to show that imidacloprid can cause sub-lethal effects (e.g., reduced reproductive success) in birds at doses (in food) of 1,000 to 53,400 µg/kg animal weight per day. The authors noted that one of the greatest potential impacts of imidacloprid is from imidacloprid-treated agricultural seeds, where “*ingestion of even a few treated seeds could cause mortality and reproductive impairment to sensitive bird species.*” The authors also concluded that sub-lethal effects can occur in birds, particularly those exposed to imidacloprid-treated seeds. Finally, the authors noted the rarity of studies looking at potential indirect effects, in particular how reductions in invertebrates caused by pesticide treatments may reduce the prey available to vertebrate consumers of these animals.

Pollinators. Pesticide exposure to honey bees is the primary concern for pollinators in Willapa Bay and Grays Harbor. Additional information not presented in the 2015 FEIS is presented below.

In 2016, EPA conducted an assessment of the potential risks of imidacloprid to terrestrial pollinators, focusing on honey bees (*Apis mellifera*). Overall, EPA (2016) concludes that most modeled agricultural uses of imidacloprid are at low or uncertain risk of impacting bee hives, that many uses pose risks to individual bees (i.e., can kill or impair individual animals), and a few modeled scenarios indicate risks to both individual bees and bee hives. Although imidacloprid was deemed by EPA to be “*highly toxic*” to honey bees, their modeled concentrations were also deemed “*conservative*” because they exceeded the levels measured in field studies. In general, scenarios that do not involve direct, on-field exposure by honey bees to imidacloprid did not exceed EPA’s toxicity thresholds for the majority of agricultural uses modeled. But EPA (2016) concluded that some agricultural uses pose significant environmental risks to bees and bee colonies. Many other published studies have also concluded that imidacloprid can cause both mortality and sub-lethal effects in bees and other pollinators. This body of literature, and documentation of increasing levels of bee colony collapse, has combined to raise many concerns about the effects of imidacloprid on pollinators. This remains an active area of scientific research.

In Willapa Bay and Grays Harbor, imidacloprid would be applied on tidelands that are located approximately 0.5 mile or more from the nearest bee hive colonies. Imidacloprid would not be applied on any shoreline or upland vegetation. Therefore, it is unlikely that this use of imidacloprid would impact pollinators in the area. In addition, the 2016 WGHOGA NPDES permit application specifically excludes aerial spraying of imidacloprid from helicopters, which further decreases the likelihood of impacts to pollinators due to spray drift.

Mammals. Imidacloprid (Alternative 4) exposure to mammals would be related to direct ingestion. The Health Canada risk assessment (2016) concludes that mammals would likely have little to no risk from imidacloprid toxicity at the concentrations expected in the field. There could, however, be secondary effects to mammals from a potential reduction in their invertebrate prey. For Willapa Bay and Grays Harbor, terrestrial mammals, such as raccoons and coyotes, would be expected to forage along the shoreline and intertidal areas at times. Reduction in invertebrates could reduce the levels of food for these species, at least locally. However, any such reductions are not expected to be significant because of the small area that would be treated relative to the total area available in these estuaries for such foraging.

Although marine mammals such as harbor seals and gray whales are present in Willapa Bay and Grays Harbor, few use the high intertidal mudflats where clam and oyster farming generally occurs. It is unlikely that any impacts to invertebrate prey species would be large enough to consequently impact these marine mammals.

Threatened, Endangered and Protected Species.

Salmonids including Bull Trout. Imidacloprid (Alternative 4) would be unlikely to adversely affect adult salmonids, bull trout, or their critical habitat (CSI 2013). As discussed in the 2015 FEIS, juvenile salmonids travel through the nearshore habitat during out-migration, feeding on copepods and zooplankton. Although there may be short-term effects on crustacean zooplankton populations during imidacloprid application, the impacted area would be small in relation to the total tideland area of Willapa Bay and Grays Harbor.⁹ Imidacloprid does not bioaccumulate in invertebrates, and uptake through contaminated prey would be no greater than environmental exposure. In addition, EPA (2017) and Health Canada (2016) both indicate that there is low potential for imidacloprid toxicity to fish species.

Green Sturgeon. Imidacloprid (Alternative 4) has a limited effect on large vertebrates, and only when high concentrations are ingested directly. Imidacloprid applications would occur in shallow water or on exposed sand or mudflats, when sturgeon are unlikely to be present over commercial shellfish beds. Studies have been conducted in an attempt to determine the effects of imidacloprid on green sturgeon. Frew (2013) used white sturgeon as a surrogate for green sturgeon and found the 96-hour LC₅₀ was 124,000 µg/L, indicating that sturgeon do not possess high sensitivity to imidacloprid. An exposure model was used to estimate the ingestion of imidacloprid by green sturgeon following treatment to reduce burrowing shrimp in Willapa Bay (Frew et al. 2015). The exposure model included four components: ingestion of imidacloprid-exposed shrimp, uptake from water containing imidacloprid within shrimp burrows by swallowing, uptake from water passing across the gills, and uptake from ingestion of sediment containing imidacloprid. Conservative assumptions were used throughout the exposure model, the three most important of which were that green sturgeon ate a large volume of exposed shrimp, that uptake of imidacloprid from such shrimp had a 10 percent efficiency (i.e., 10 percent of the imidacloprid in the shrimp was assimilated by the sturgeon), and that sturgeon were exposed to porewater concentrations of imidacloprid for the entire feeding session modeled

⁹ See SEIS Chapter 2, Section 2.8.4.

(4 hours). The authors acknowledge that their conservative assumptions likely result in an overestimation of actual imidacloprid uptake by green sturgeon. Their results indicate that uptake from porewater was 9.5 and 7.5 times greater (at 6 and 30 hours post-exposure, respectively) than estimated uptake from ingestion of exposed shrimp. The authors estimated total imidacloprid uptake, from all four sources, of 196.7 µg/L at 6 hours and 113.2 µg/L at 30 hours post-exposure. The authors cite the Frew (2013) LC₅₀ of imidacloprid for white sturgeon of 124,000 µg/L, which is 630 times higher than their maximum modeled uptake, to conclude “*Imidacloprid concentrations and durations of exposure following chemical application in Willapa Bay would be lower than the levels expected to elicit direct acute toxic effects in green sturgeon. Furthermore, no chronic toxic effects would be expected following unforeseen extended periods of exposure.*”

Marbled Murrelet. Marbled murrelet critical habitat and foraging habitat do not overlap with areas where imidacloprid applications (Alternative 4) would occur on commercial shellfish beds in Willapa Bay or Grays Harbor; therefore, it would be unlikely to adversely affect marbled murrelet (CSI 2013). Were murrelets to forage in areas where imidacloprid is applied, such use would be at higher tide levels because murrelets are diving birds, ensuring any imidacloprid from treatment would have been diluted to below toxic levels. Potential uptake from consumption of contaminated fish is possible, but such uptake would be minimal given the limited exposure pathways for prey fish species to ingest imidacloprid and the fact that imidacloprid does not bioaccumulate (i.e., it would not persist in fish that were exposed). In addition, fish are highly mobile, so murrelet foraging would be on the larger population of fish in Willapa Bay and Grays Harbor, the vast majority of which would not have been exposed to imidacloprid.

Western Snowy Plover. Granular-form applications of imidacloprid (Alternative 4) on commercial shellfish beds (sand and mudflats) could result in an opportunity for birds to be exposed to this chemical through ingestion of the solid form, but direct exposure would be limited since application techniques flush birds from the site, imidacloprid dissolves readily in water, and only small percentages of total tidelands within Willapa Bay and Grays Harbor would receive imidacloprid applications in any given year. This limited period of potential exposure would be interrupted when the sand or mudflats became inundated by the incoming tide. CSI (2013) found imidacloprid toxicity exposure for snowy plover to have a low likelihood of indirect effects (e.g., through effect on food chains), and concluded that it would be unlikely to have adverse effects. “Flowable”-form applications of imidacloprid would result in minimal exposure times for birds (Giddings et al. 2012). Plovers are also generally found only on the ocean beaches on the west side of Willapa Bay and Grays Harbor, not in the bays themselves; therefore, it is unlikely they would be found in the vicinity of the commercial oyster and clam beds. See the 2015 FEIS (Chapter 3, Section 3.2.5.3, pages 3-45 through 3-46) for further discussion on western snowy plover habitat.

Streaked Horned Lark. Streaked horned lark critical habitat is centered on nesting beaches along the coast. Nests are established on bare ground, well above MHHW, and the birds do not forage on or near shellfish beds (Pearson and Hopey 2004 and 2005). Application of imidacloprid (Alternative 4) would be unlikely to adversely affect streaked horned lark or their nest sites because they do not occur on commercial shellfish beds within Willapa Bay or Grays Harbor.

Potential On-plot Impacts

Alternative 3 or 4 would be expected to cause on-plot impacts to zooplankton and benthic invertebrates through either death or paralysis. These impacts would be expected within the boundaries of the treatment plots as imidacloprid is applied directly to the substrate or in shallow water. These on-plot impacts are generally expected to be short-term, as field trials have shown that benthic invertebrate populations recover (e.g., repopulate treated plots). For example, trials with imidacloprid have demonstrated invertebrate recovery within 14 days of chemical applications (Hart Crowser 2013 and 2016). However, one set of studies in an area of sediments containing higher organic carbon levels (Cedar River), found incomplete recovery for several invertebrate organisms, after 28 days. Imidacloprid binds to organic carbon, so these results for the Cedar River area may have been due to longer retention of imidacloprid in the sediments, with an accompanying increase in toxicity to invertebrates. In such areas, on-plot recovery may be delayed compared to other areas with lower sediment organic carbon levels.

The two reviewed crab studies (Patten and Norelius 2017, Osterberg et al. 2012), and in particular the field observations of affected crab after field-spraying in Patten and Norelius, confirm that some Dungeness crab juveniles and planktonic forms are likely to be killed by the proposed application of imidacloprid on shellfish beds. Given the concentrations of imidacloprid required to produce tetany in crabs, and the limited exposure of off-plot areas due to the rapid dilution by rising tide waters, it is likely that most impacts to juvenile crab would be limited to on-plot, and immediately adjacent areas directly sprayed with imidacloprid during low tide conditions. Planktonic forms of Dungeness crab off-plot may be impacted by rising tidewaters carrying imidacloprid. Given the small area that would receive imidacloprid applications each year (if the permit is issued), compared to the total size of Willapa Bay and Grays Harbor, and the small number of animals that would be affected compared to the total number of animals present in these estuaries and surrounding areas, imidacloprid effects are not expected to impact bay-wide populations of Dungeness crab in these estuaries.

Under Alternative 3 or 4, forage fish and groundfish may be impacted by shellfish bed treatment with imidacloprid, but these would be short-term impacts. The lower toxicity of imidacloprid to fish indicates that there is only a small potential for fish to be impacted by imidacloprid on-plot. Fish that enter a treated area immediately after application or those that feed extensively on imidacloprid-treated invertebrates may be exposed to high enough concentrations of imidacloprid to experience effects. In addition, reductions in invertebrate numbers on-plot would reduce the availability of prey items for fish that feed on these animals, and this effect would persist until on-plot recovery was complete.

It is highly unlikely that there would be on-plot effects to pollinators because bees and other pollinators are rare or absent from the intertidal, salt-water areas that would be treated. This absence is likely because there are no flowering plants present on the commercial shellfish beds to attract such pollinators. If pollinator use of such areas is assumed to occur, then under Alternative 3 or 4 on-plot impacts would be likely to occur when such use occurs in the interval between chemical spraying and the first rising tide to inundate the sprayed plots. Imidacloprid is

acutely toxic to bees that are directly exposed to these chemicals. So it is reasonable to assume that any pollinators that were so exposed would die.

Direct toxicity to birds and mammals as a result of Alternative 3 or 4 is not expected on-plot given the low toxicity of imidacloprid to vertebrates. There could be minor effects to birds and mammals due to the potential short-term reduction in prey items present on treated areas. This would also be true for threatened, endangered, and protected species that occur or forage in the vicinity of treated plots. They are not likely to be present on-plot during the time of application, but may see a minor and temporary loss in prey items.

MITIGATION MEASURES

Mitigation measures for the use of imidacloprid (Alternative 4) would be imposed pursuant to a new NPDES permit (if issued), as necessary to ensure compliance with all applicable NPDES approval criteria, including Washington State Water Quality Standards that protect water quality, fish and wildlife. Compliance with these laws would likely avoid and minimize significant adverse impacts to animals. Specific mitigation measures would likely require imidacloprid to be administered on commercial shellfish beds in a manner consistent with the spray drift management techniques and treatment site requirements specified in the FIFRA Registrations for the flowable and granular formulations of imidacloprid. These state that applications must occur on beds exposed at low tide, and granular applications may be applied to beds under water using a calibrated granular applicator, operating from a floating platform or boat. Liquid applications from boats or ATVs would be limited by spray drift management measures to minimize or prevent exposure of imidacloprid to non-target terrestrial species or flowering terrestrial plants, and therefore would be unlikely to adversely affect local honey bee, bumble bee, butterfly, fish, mammal, or bird populations.

To avoid and minimize potential exposure to bees, the spray drift management requirements indicated in the FIFRA Registrations for the granular and flowable formulations of imidacloprid (Protector 0.5G and Protector 2F, respectively) would be employed (USEPA 2013a and 2013b). Imidacloprid would be applied either to exposed mudflats at low tide or to shallow water covering shellfish beds during an out-going tide. Drift management techniques include, among other things, a controlled nozzle applicator used during low wind speeds, and drift to blooming crops or weeds is a violation of the label. Additional spray drift management requirements are described below.

With regard to Alternative 4, the WSDA Special Pesticide Registration Program Coordinator stated during preparation of the 2015 FEIS that, in his professional opinion, there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats despite proposed aerial applications using a helicopter. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, or maintaining an adequate buffer between the imidacloprid treatment areas and blooming plants, would mitigate potential risk to bees (personal communication with Erik Johansen, Policy Assistant, Washington State Department of Agriculture, March 19, 2014). The current permit application does not

include aerial applications from helicopters, further reducing potential spray drift and effects to bees or other pollinators.

The FIFRA Registrations limit the application of imidacloprid to the period between April 15 and December 15. This application window would limit exposure to herring and sand lance during their peak spawning periods, and would avoid the late winter migration of birds.

Application of imidacloprid between April 15 and July 15 would overlap with the window of juvenile salmon out-migration, and with spring and fall bird migrations; however, application methods would minimize the potential for direct exposure to juvenile salmonids and migrating birds, and studies discussed above have determined that it is unlikely there would be adverse effects to these species.

Imidacloprid would not be applied to any areas with shellfish to be harvested within 30 days of treatment (FIFRA Registrations 88867-1 and 88867-2; USEPA 2013a and 2013b). In addition, a 25-foot buffer zone would be maintained when treatment is by hand spray. All shellfish beds to be treated would be properly staked and flagged to protect adjacent shellfish and water areas.

The FIFRA Registrations for the flowable and granular formulations of imidacloprid (USEPA 2013a and 2013b) establish a series of application methods for spray drift management that would minimize the risk of exposure to non-target species. Granular applications would be made at the lowest possible height (scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, back pack reservoirs with hand-held sprayers and/or belly grinders) that is safe to operate and reduce exposure of the granules to wind. When applications are made crosswind, FIFRA Registration conditions would require the applicator to compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. For the flowable form of imidacloprid (Protector 2F), applicators would avoid and minimize spray drift by following detailed instructions in the FIFRA Registration, including measures to control droplet size, making applications at the lowest possible height (scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, back pack reservoirs with hand-held sprayers and/or belly grinders) that is safe and practical and reduces exposure of droplets to evaporation and wind, applying during appropriate wind speeds, avoiding temperature inversions, and using authorized application methods and equipment.

LOCALIZED, SHORT-TERM IMPACTS

Alternative 3 or 4 would be expected to cause on-plot impacts to zooplankton and benthic invertebrates through either death or paralysis. These impacts would be expected within the boundaries of the treatment plots as imidacloprid is applied directly to the substrate or in shallow water, and could extend to adjacent off-plot areas, particularly those closest to the treated plot that would be exposed to the highest concentrations of imidacloprid as it is carried off-plot by the incoming tide. These impacts are generally expected to be localized and short-term, as field trials have shown that benthic invertebrate populations recover (e.g., re-populate treated plots), although high variability confounds this. For example, trials with imidacloprid have demonstrated invertebrate recovery within 14 days of chemical applications (Hart Crowser 2013

and 2016). However, one set of studies in an area of sediments containing higher organic carbon levels (Cedar River), found incomplete recovery for several invertebrate organisms after 28 days.

The two reviewed crab studies (Patten and Norelius 2017, Osterberg et al. 2012), and in particular the field observations of affected crab after field-spraying in Patten and Norelius, confirm that some Dungeness crab juveniles and planktonic forms are likely to be killed by the proposed application of imidacloprid on shellfish beds. Given the concentrations of imidacloprid required to produce tetany in crabs, and the limited exposure of off-plot areas due to the rapid dilution by rising tide waters, it is likely that most impacts to juvenile crab would be limited to on-plot areas, or areas adjacent to plots sprayed directly with imidacloprid during low tide conditions (as shown in 2014 field trials). Planktonic forms of Dungeness crab off-plot may also be impacted by rising tidewaters carrying imidacloprid.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations and regulations (including Washington State Water Quality Standards), any significant unavoidable adverse impacts to marine or terrestrial animal populations would likely be localized and short term.

No significant unavoidable adverse impacts to threatened, endangered or protected species would be expected as a result of implementing Alternative 4. There is a low probability of adverse effects to birds, fish or other vertebrates. Invertebrates, including Dungeness crab would likely be killed or displaced from treatment areas, with recovery of these populations likely within 28 days or less on most treatment areas. Permit conditions and mitigation measures protective of surface water quality would also be protective for fish, including ESA-listed salmonids and green sturgeon. The NPDES Individual Permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of pesticide applications. Adjustments to permit conditions could be made throughout the 5-year term of the permit based on the results of this monitoring.

3.3.6 Human Health

AFFECTED ENVIRONMENT

3.3.6.1 Willapa Bay

Information regarding human health in the Willapa Bay area is described in the 2015 FEIS (Chapter 3, Section 3.2.6, pages 3-55 through 3-56). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.6.2 Grays Harbor

Information regarding human health in the Grays Harbor area is described in the 2015 FEIS (Chapter 3, Section 3.2.6, page 3-56). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to human health of Alternatives 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.6, pages 3-58 through 3-60). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

Alternative 4 would likely have no effect on human health or potentially affect only a very small number of people (primarily pesticide handlers and applicators) in Willapa Bay and Grays Harbor.

There would be a risk of exposure to a small number of people who would handle and apply imidacloprid. Up to 500 acres would be treated per year: up to 485 acres within Willapa Bay and up to 15 acres per year within Grays Harbor on commercial clam and oyster beds (see SEIS Chapter 2, Section 2.8.4). Imidacloprid is a systemic insecticide of the chemical class of chloronicotinyls-neonicotinoids; specifically, it is a chloronicotinyl nitroguanidine. The compound acts on the nicotinic acetylcholine receptors (nAChR) in the nervous system of insects, blocking the transmission of nervous signals in the post-synaptic region, resulting in paralysis and death. Mammals, birds, fish, and amphibians, are much less sensitive to imidacloprid than certain aquatic invertebrates because of differences in the nAChR receptors in vertebrates. Imidacloprid is not considered acutely toxic to humans via dermal or inhalation exposure routes even though it is designated an acute oral toxicant. The 2015 FEIS discusses in detail potential impacts to humans (Chapter 3, Section 3.2.6, pages 3-58 through 3-60).

The Health Canada (2016) risk assessment evaluated the effects of imidacloprid on humans, using an analysis largely based on studies of other mammals, as well as an extensive review of potential exposure pathways (e.g., ingestion or adsorption in agricultural workers using imidacloprid). There is no direct analysis of the likelihood of imidacloprid toxicity in humans, but the general discussion indicates a low risk, as for other vertebrates. Health Canada (2016) reviewed case reports of attempted suicides through ingestion of imidacloprid. Based on this work they identified that imidacloprid toxicity *“symptoms in humans consist of nausea, vomiting, headache, dizziness, abdominal pain, and diarrhea.”* Of 56 attempted suicides, *“recovery was seen in all 56 patients reported.”*

Potential On-plot Impacts

The on-plot risk to human health due to the application of imidacloprid under either of the action alternatives would only apply to the small number of people that handle and apply the chemicals. Required safety measures for applicators, including personal protective equipment (e.g., gloves, long sleeved shirts) are expected to prevent adverse effects during application (discussed further below).

MITIGATION MEASURES

While no mitigation for potential impacts to human health with implementation of Alternative 4 are indicated by the results of testing imidacloprid, Federal and State laws require various measures to be implemented to protect human health. These measures would mitigate potential significant adverse impacts. The following conditions imposed by the imidacloprid FIFRA Registrations (USEPA 2013a and 2013b) would be protective of human health:

- The public would be notified prior to imidacloprid applications through signs, website postings, and e-mail to interested parties.
- All public access areas within one-quarter mile and all public boat launches within one-quarter mile radius of any bed scheduled for treatment with imidacloprid would be posted. Public access areas would be posted at 500-foot intervals at those access areas more than 500 feet wide.
- Signs would be posted at least 2 days prior to aerial treatment and will remain for at least 30 days after treatment. Signs shall say “Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not Fish, Crab or Clam within one-quarter mile of the treated area.” The location of the treatment area would be included on the sign. The WGHOGA IPM Coordinator would be responsible for posting, maintaining, and removing these signs.
- No bed would be treated with imidacloprid if it contains shellfish within 30 days of harvest.
- A 25-foot buffer zone would be maintained between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days when treatment is by hand.
- Imidacloprid would not be applied during Federal holiday weekends.

Under Alternative 4, WGHOGA proposes to also use a website in lieu of newspaper announcements for public notification of specific dates of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The WGHOGA IPM Coordinator would send e-mail notifications to registered interested parties, as needed.

Washington State law requires that imidacloprid be used and applied only by certified applicators or persons under the direct supervision of a certified applicator.

To mitigate potential exposure for persons applying imidacloprid, applicators would be required to wear approved Personal Protective Equipment (PPE), and would be trained in pesticide applications. The following PPE would be required of all imidacloprid applicators and handlers, as required by the FIFRA labels (i.e., required pursuant to Federal law) and would mitigate potential significant impacts:

- Long-sleeved shirt and long pants;
- Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or Viton;
- Shoes and socks;
- Protective eyewear; and
- Dust mask when using Protector 0.5G, the granular formulation of imidacloprid.

Manufacturer's instructions must be followed for cleaning/maintaining PPE. If instructions for washables do not exist, detergent and hot water would be used. PPE should be kept and washed separately from other laundry.

Boats would also need to use a hopper, hopper loaders, and possibly a barge to hold additional chemical, equipment and personnel.

Alternative 4 specifically excludes aerial (helicopter) applications of imidacloprid from the permit application, which would decrease the potential for drift compared to Alternative 3.

LOCALIZED, SHORT-TERM IMPACTS

Localized and short-term impacts to human health due to the application of imidacloprid under either of the action alternatives would only apply to the small number of people that handle and apply the chemicals. Required safety measures for applicators, including personal protective equipment (e.g., gloves, long sleeved shirts) are expected to prevent adverse effects during application (discussed further below).

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with pesticide registrations and regulations (including Washington State Department of Agriculture General Pesticide Rules), no significant unavoidable adverse impacts to human health would be expected as a result of implementing Alternative 4. Applicators and handlers would be required to use appropriate application equipment and wear specified Personal Protective Equipment. Public notification requirements would inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct

exposure could be avoided. As a dietary precaution, avoidance and waiting periods are specified between dates of pesticide application and shellfish harvest for consumption.

3.3.7 Land Use

AFFECTED ENVIRONMENT

3.3.7.1 Willapa Bay

Information regarding land use around Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.7, pages 3-64 through 3-65). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.7.2 Grays Harbor

Information regarding land use around Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.7, pages 3-66 through 3-67). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts of Alternatives 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.7, page 3-68). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

There would be no direct or indirect impact to upland land uses from Alternative 4.

Due to the distance between existing cranberry farms and the nearest commercial shellfish beds adjacent to Willapa Bay and Grays Harbor, and the proposal under Alternative 4 to apply spray applications only at ground level (i.e., no use of helicopters), it is expected that spray drift management requirements for the use of imidacloprid under Alternative 4 would avoid risk of exposure to pollinators present at these farms during the approximate period of April 15 through December 15 each year.

Potential On-plot Impacts

There would be no on-plot risk to land use due to the application of imidacloprid under either of the action alternatives.

MITIGATION MEASURES

The NPDES permit for Alternative 4, if issued, would include public notification requirements at public and private shoreline access sites that would be the same as those described above under mitigation measures for Human Health (SEIS Section 3.2.6), or below under mitigation measures for Recreation (SEIS Section 3.2.8).

Federal and State regulations contain measures to mitigate potential significant impacts to land and shoreline use. The FIFRA Registrations for the use of imidacloprid with IPM techniques (Alternative 4) include precautions and spray drift management practices for the use of either the granular or flowable forms of imidacloprid on commercial clam or oyster tidelands. Primarily, no direct treatment on terrestrial blooming crops or weeds, or drift to blooming crops or weeds, would be allowed. This would avoid the potential for impacts to pollinators.

The WSDA Special Pesticide Registration Program Coordinator stated during preparation of the 2015 FEIS that, in his professional opinion, there is no risk to bees from the application of imidacloprid (either the granular or flowable formulation) to tidal flats. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, or maintaining an adequate buffer between the imidacloprid treatment area and blooming plants would mitigate potential risk to bees (personal communication with Erik Johansen, Policy Assistant, Washington State Department of Agriculture March 19, 2014). Alternative 4 specifically excludes aerial applications of imidacloprid by helicopter from the permit application.

LOCALIZED, SHORT-TERM IMPACTS

There would be no localized, short-term impacts to land use due to the application of imidacloprid under either of the action alternatives.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations and regulations, no significant unavoidable adverse impacts to land or shoreline use would be expected as a result of implementing Alternative 4.

3.3.8 Recreation

AFFECTED ENVIRONMENT

Ecology will review the 2016 WGHOGA application for NPDES permit coverage for the use of imidacloprid for burrowing shrimp population control on commercial clam and oyster beds in Willapa Bay and Grays Harbor for potential effects on beneficial uses of surface waters, which include recreational activities such as swimming, SCUBA diving, water skiing, boating, fishing and aesthetic enjoyment. Washington State surface water quality regulations and standards

(RCW 90.48; Chapter 173-201A WAC) authorize Ecology to establish criteria for waters of the State and to regulate impacts to water quality.

3.3.8.1 Willapa Bay

Information regarding recreation in Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.8, pages 3-69 through 3-72). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.8.2 Grays Harbor

Information regarding recreation in Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.8, pages 3-72 through 3-75). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to Recreation of Alternative 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.8, page 3-76). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

Under Alternative 4, imidacloprid applications on up to 485 acres per year in Willapa Bay could affect approximately 1.1 percent of total exposed tideland acreage within the bay per year (see SEIS Chapter 2, Section 2.8.3). Imidacloprid applications on up to 15 acres in Grays Harbor per year could affect approximately 0.04 percent of total exposed tideland acreage within the harbor per year (see SEIS Chapter 2, Section 2.8.4). These small areas of application each year would minimize the potential for exposure of persons using exposed tide flats for recreation in Willapa Bay or Grays Harbor. Further, as described above in the Human Health section, based on the relatively low acute toxicity and short half-life of imidacloprid in sediment and surface water, there is a very low likelihood of possible human health impacts from imidacloprid exposure to the general population engaging in recreational activities (e.g., shellfish gathering, fishing, swimming). Imidacloprid is classified as a “Group E” carcinogen indicating “*no evidence of carcinogenicity in humans*” (USEPA 1999a, 1999b, 2003). As discussed in SEIS Section 3.3.5, impacts to birds, fish, and mammals from imidacloprid applications are not expected, and therefore no impacts to recreation involving these animal groups are expected. Short-term impacts to invertebrates are expected on the sprayed plots, including to Dungeness crab that are subject to an active fishery by the public. But the small areas being sprayed compared to the overall size of the Willapa Bay and Grays Harbor estuaries are expected to result in no population-level effects to this species, and therefore no significant impacts to recreational or commercial harvest (see Section 3.3.5 for additional analysis of impacts to Dungeness crab).

Potential On-plot Impacts

Chemical applications would be small-scale activities that occur on privately-owned or leased tidelands designated for commercial shellfish aquaculture. These areas are normally located well away from public gathering areas. People do not tend to walk on the commercial shellfish beds as most are remote and are private farm lands. Therefore, recreational swimmers, fishers, and shellfish gatherers are unlikely to be present at the treatment sites, and potential exposure to the public would be from more distant locations. For these reasons, there would be no expectation of on-plot risk to recreation due to the application of imidacloprid under either of the action alternatives.

MITIGATION MEASURES

Federal and State regulations would mitigate potential impacts to recreational users of Willapa Bay and Grays Harbor. The FIFRA Registrations would require public access points within a one-quarter-mile (1,320-foot) radius of any commercial shellfish bed scheduled for applications of either Protector 0.5G or Protector 2F to be posted with a “WARNING” OR “CAUTION” sign that states *“Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not fish, crab or clam within one-quarter mile of the treated area.”* The location of the treatment area would be included on the sign. If the public access area at any of these locations is more than 500 feet wide, additional signs would be posted at 500-foot intervals. The WGHOGA IPM Coordinator would be responsible for posting, maintaining and removing these signs.

Under Alternative 4, WGHOGA proposes to also use a website in lieu of newspaper announcements for public notification of specific dates of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The WGHOGA IPM Coordinator would send e-mail notifications to registered interested parties, as needed.

Further, the 2016 WGHOGA proposal for the use of imidacloprid (Alternative 4) specifically excludes aerial (helicopter) applications from the permit.

LOCALIZED, SHORT-TERM IMPACTS

There would be no localized, short-term impacts to recreation due to the application of imidacloprid under either of the action alternatives.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and with full and successful implementation of all applicable requirements to comply with the conditions of pesticide registrations, regulations, and public notification requirements, no significant unavoidable adverse impacts to recreation would be expected as a result of implementing Alternative 4.

3.3.9 Navigation

AFFECTED ENVIRONMENT

3.3.9.1 Willapa Bay

Information regarding navigation in Willapa Bay is described in the 2015 FEIS (Chapter 3, Section 3.2.9, pages 3-77 through 3-78). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

3.3.8.2 Grays Harbor

Information regarding recreation in Grays Harbor is described in the 2015 FEIS (Chapter 3, Section 3.2.9, pages 3-78 through 3-79). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS.

POTENTIAL IMPACTS

The potential impacts to navigation of Alternatives 1 (No Action: No Permit for Pesticide Applications, Continue Historical Management Practices) and Alternative 3 (Imidacloprid Applications with Integrated Pest Management, on up to 2,000 acres per year in Willapa Bay and Grays Harbor) were described and evaluated in the 2015 FEIS (Chapter 3, Section 3.2.9, page 3-79). That information is unchanged at the time of this writing, and is incorporated by reference in the SEIS. A comparison of the impacts of the alternatives is provided in SEIS Chapter 2, Section 2.9, and in the SEIS Chapter 1 Summary.

As with each of the previously-evaluated alternatives, there would be no significant adverse impacts to navigation as a result of Alternative 4. The tidelands where commercial shellfish beds are located are staked for various purposes at various times of the year. For this reason, stakes placed to identify beds for applications of imidacloprid under Alternative 4 would not constitute a new or different obstruction to watercraft that navigate the shallow areas of Willapa Bay or Grays Harbor where these shellfish beds are located. There would be no stakes or obstructions placed in the main navigation channels of either bay.

Potential On-plot Impacts

There would be no on-plot risk to navigation due to the application of imidacloprid under either of the action alternatives.

MITIGATION MEASURES

No mitigation measures for impacts to navigation would be required with the No Action Alternative.

If Alternative 3 or Alternative 4 were selected for implementation, public notification requirements at marinas and boat launch sites would be the same as those described above under mitigation measures for Recreation (FEIS Section 3.2.8). These measures would mitigate potential significant adverse impacts.

LOCALIZED, SHORT-TERM IMPACTS

There would be no localized, short-term impacts to navigation due to the application of imidacloprid under either of the action alternatives.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

No significant unavoidable adverse impacts to navigation would be expected as a result of implementing Alternative 4.

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Appendix A

Literature Review

The Final Environmental Impact Statement (FEIS; Ecology 2015) included a review of more than 100 scientific reports and papers that evaluated the ecology of burrowing shrimp, physical and biological conditions in Grays Harbor and Willapa Bay, and effects of imidacloprid on invertebrate and vertebrate animals, including species listed under the Endangered Species Act (ESA). That literature review is incorporated in a number of sections of the FEIS, and is the basis for much of the summary of imidacloprid's expected effects under the permit conditions analyzed in the 2015 FEIS that is presented in Chapter 1, Section 1.6 of that document. In general, the FEIS concluded that the application of imidacloprid would have minor to moderate effects on non-target invertebrates (e.g., polychaete worms, honey bees), minor effects on vertebrate species, including birds, and minor or insignificant effects on ESA-listed species.

Since the FEIS was published, a number of new studies on the effects of imidacloprid have been published. These new studies include three very large and comprehensive literature surveys and numerous peer reviewed journal articles. Health Canada (2016), also known as PMRA, conducted a comprehensive review of the toxicology literature on imidacloprid and published a report summarizing the expected effects of agricultural uses of imidacloprid on the environment based on that review, and on modeled and field data-based estimates of imidacloprid concentrations. The document included evaluation of toxicity to humans; fish, birds and mammals; terrestrial and aquatic invertebrates, both freshwater and marine; and, assessed exposure pathways and possible effects to humans. The U.S. Environmental Protection Agency (EPA) issued two large literature reviews. The EPA (2015) review assessed the effects of imidacloprid on pollinators, with some emphasis on honeybees. The EPA (2017) review was similar to the Health Canada study in that it included a comprehensive literature review and assessment of imidacloprid toxicity in the environment, and both addressed aquatic ecosystems and species. Although both reviews used similar data sets, each used a different approach to estimating imidacloprid toxicity to various groups of animals. Ultimately, EPA (2017) concluded that it's "risk findings...were comparable" to those from the Health Canada study. Each of these studies is described in some detail below.

Other published studies relevant to WGHOGA's proposed use of imidacloprid are available, some published since the 2015 FEIS was published. Most of these studies are covered in the Health Canada and EPA reviews noted above. Numerous studies address potential impacts to freshwater ecosystems, particularly aquatic insects. Marine studies are limited, perhaps because most imidacloprid applications are for terrestrial croplands that drain to freshwater habitats. The absence of direct spraying to marine environments, other than the field trials in Willapa Bay, also limits the availability of studies on marine environments. Extrapolating the results of freshwater studies to marine environments is challenging. Some freshwater studies have reported results for crustacean and mollusk species, which tend to dominate marine in marine systems (i.e., as opposed to insects). These results are emphasized in the literature review.

Finally, the EPA (2017) analysis of the effects of imidacloprid to marine invertebrates was based, in-part, on unpublished scientific studies. Ecology used a Freedom of Information Act (FOIA) request to the EPA to obtain these studies, which are also reviewed below.

EPA. 2017. Preliminary aquatic risk assessment to support the registration review of imidacloprid. PC Code 129099. DP Barcode 429937. USEPA, Office of Chemical Safety and Pollution Prevention, Washington DC. Prepared by USEPA Office of Pesticide Programs, Environmental Fate and Effects Division, Washington DC.

Many regulators and scientists were awaiting publication of the EPA Risk Assessment, both because it promised to be a comprehensive review of imidacloprid risks to the environment, and because its source, EPA, has broad jurisdiction to regulate pesticides under a variety of statutes, including the Clean Water Act. Additionally, EPA has registered imidacloprid for the control of burrowing shrimp in Willapa Bay and Grays Harbor. The EPA Risk Assessment contains an extensive review of the scientific literature on the toxicity of imidacloprid to aquatic life forms, including fish and amphibians. The approach involves: review of the toxicity literature to determine appropriate toxicity thresholds, modeling of agricultural uses of imidacloprid to estimate concentrations of imidacloprid that could be released to the environment, and a comparison of the two metrics to determine the potential environmental risks. EPA (2017) also includes an extensive review of field data on imidacloprid concentrations in surface waters of the U.S., and then compares those levels to its selected toxicity thresholds to establish whether toxic concentrations of imidacloprid are present in the environment.

EPA's analysis uses several metrics: the Risk Quotient (RQ) is the ratio of modeled or measured imidacloprid concentrations divided by the concentration known to cause toxicity. RQs, in turn, are compared to EPA's selected Levels of Concern (LOC), which is the multiple of the RQ at which the agency assumes imidacloprid is having a negative effect. RQs are calculated for groups of animals (e.g., freshwater insects, marine invertebrates), and for two different exposure types: acute, which is typically applied to exposure periods of 96-hours or less, and chronic, which applies to longer-term exposures (e.g., 21-days, 28-days, etc.).¹ Criteria chosen to represent acute and chronic toxicity were selected by EPA using results for the most sensitive animal types from among those studies that met its criteria for data quality. Calculating RQs using the most sensitive animals is a standard approach in risk assessment of toxicants in order to protect all species present in that system and to cover other sensitive species which may not have been tested yet. This turns out to be particularly true for imidacloprid, which shows widely varying levels of toxicity among different groups of animals, and among species within each group. In most cases, the toxicity data EPA used were either LC₅₀ (Median Lethal Dose) or EC₅₀ (Maximal Effective Concentration) values. LC₅₀ is the concentration of imidacloprid that killed 50 percent of the test organisms in the allotted test time (e.g., 24-hours, 48-hours, 96-hours, etc.). The EC₅₀ is the concentration of imidacloprid that produces 50 percent of the maximum response (i.e., halfway between the baseline and the maximum response). EC₅₀ values are used where less than 100 percent of the test organisms are killed, or where the metric of interest is something

¹ Most such studies are "static", meaning a known concentration of imidacloprid is established at the start of the test and no more imidacloprid is added during the length of the trial. In a static test it is possible that the actual concentration of imidacloprid will fall below the initial value over time due to degradation, particularly over long trials (e.g., 14 or 28 day chronic tests).

other than mortality (e.g., paralysis, reduced growth). Both LC₅₀ and EC₅₀ values were typically expressed as µg a.i./L (micrograms active ingredient per liter). A value of 1 µg a.i./L is the same as saying one part per billion of imidacloprid per liter of water.

EPA (2017) makes three broad conclusions. First, there is little or no direct risk of imidacloprid toxicity for groups other than invertebrates. *“No direct risk to fish or aquatic phase amphibians is indicated...since all acute and chronic RQs were well below their respective LOCs.”*² EPA estimated an acute LC₅₀ for freshwater fish of 229,000 µg a.i./L, an acute LC₅₀ of 163,000 µg a.i./L for saltwater fish, and a chronic No Observed Adverse Effects Concentration (NOAEC) of 6,420 µg a.i./L for saltwater fish. For plants, EPA noted *“[a]quatic plants will not be assessed as available data for vascular and non-vascular aquatic plants indicate toxicity endpoints that are several orders of magnitude above the highest estimated environmental concentrations in surface waters.”* Imidacloprid toxicity derives from its ability to bind to specific sites on nerves (nicotinic acetylcholine receptors – nAChRs), causing them to malfunction (e.g., excessive nervous stimulation, blockage of the receptor sites). Nerves in vertebrates are different from those in invertebrates (i.e., differences in receptor sites and associated neurochemicals), and these differences make vertebrates broadly resistant to imidacloprid toxicity. Plants lack a nervous system. EPA (2017) did not analyze toxicity to birds or mammals, but states it plans to do so in a future version of its risk assessment.

Despite concluding that direct effects of imidacloprid on vertebrates are unlikely, EPA (2017) noted that animal groups could be indirectly affected by reductions in invertebrate prey that are susceptible to imidacloprid; The RA states, **“the potential exists for indirect risks to fish and aquatic-phase amphibians indirectly** through reduction in aquatic invertebrates that comprise their prey base” (EPA bolded). Impacts to vertebrate consumers would be expected to increase in severity where reductions in their prey are extensive or chronic. Several authors, some reviewed here or by EPA (2017), have also raised concerns over indirect impacts to food webs from imidacloprid or other neonicotinoid pesticides (e.g., Gouslon 2013, Gibbons et al. 2014, Hallman et al. 2014, van der Sluijs et al. 2014, Chagnon et al. 2015, Sanchez-Bayo et al. 2016).

The second broad conclusion is the *“relatively high sensitivity of aquatic insect species compared to other classes of arthropods or other phyla”* to imidacloprid toxicity. For the most sensitive mayflies, EPA found acute EC₅₀ values as low as 0.77 µg a.i./L, and chronic NOAEC values as low as 0.01 µg a.i./L. In more than 50 percent of its modeled imidacloprid scenarios (i.e., for various types of agricultural uses of imidacloprid), EPA found potential for acute toxicity to the most sensitive aquatic insects (e.g., mayflies). Extensive evidence of chronic toxicity was also found (e.g., toxicity in the “vast majority” of modeled scenarios for soil applications).

The final broad conclusion is that imidacloprid is present in many freshwater bodies of the U.S. in concentrations that would result in toxicity to sensitive aquatic insects and crustaceans (e.g., seed shrimp). Its analysis of estuaries and saltwater bodies was limited by the available data on

² EPA noted “one aquatic effects data gap was identified for chronic effects of imidacloprid on saltwater fish”. Given this, EPA used the ratio of acute to chronic toxicity values to estimate a chronic NOAEC (No Observed Adverse Effects Concentration), which served as its basis for concluding no chronic effects are expected for saltwater fish.

imidacloprid concentrations in these habitats, but EPA concluded that chronic toxicity to crustaceans in saltwater environments is possible (e.g., toxicity in 39 percent of their modeled soil applications).

EPA (2017) noted that, “imidacloprid is classified as very highly toxic to both freshwater and saltwater invertebrates on an acute exposure basis.” In its review of the literature EPA (2017) confirmed that status for many groups of animals, but also documented a very wide range of toxicities to imidacloprid.” Within groups (e.g., among aquatic insects), the range of toxicity could vary over four orders of magnitude or more (i.e., the difference between a value of 1 and a value of 10,000), while between groups (e.g., vertebrates compared to aquatic insects) the range of toxicity could vary over five orders of magnitude (i.e., the difference between 1 and 100,000).

Because the majority of the invertebrates in Willapa Bay and Grays Harbor are crustaceans, two sections of EPA (2017) are particularly relevant to the proposed NPDES permit for WGHOGA: its analysis of freshwater crustaceans, and its analysis of saltwater crustaceans. For freshwater crustaceans, EPA examined 15 species including water fleas (Branchiopoda), amphipods and isopods (Malacostraca), and seed shrimp (Ostracoda). They found that seed shrimp were the most sensitive group, with acute EC₅₀ values of 1–3 µg a.i./L. EPA noted that this group is “widely distributed in freshwater and saltwater ecosystems” and are “considered important components of the aquatic food web.” Thus, impacts to ostracods could have broader effects on aquatic food chains. One reviewed study found that *Ceriodaphnia dubia* (a species of water flea) had a 48-hour LC₅₀ of 2.1 µg a.i./L, making it the second most sensitive freshwater crustacean examined by EPA. EPA found that other water fleas were resistant to imidacloprid toxicity, with acute LC₅₀ values of 5,000 µg a.i./L or more. Finally, EPA’s literature review found freshwater amphipods and isopods had acute LC₅₀ and EC₅₀ values of 17–74 µg a.i./L. Data on chronic effects to freshwater crustaceans were limited. EPA reported 28-day NOAEC values of 1–3.4 µg a.i./L for two amphipods and one isopod, and an 8-day Lowest Observable Adverse Effect Concentration (LOAEC) of 0.3 µg a.i./L for a species of water flea. EPA also noted a report of runoff from treated grass that resulted in “(e)xtensive mortality of crawfish.”

For saltwater invertebrates, EPA (2017) found only a limited number of studies covering seven estuarine or marine species, five of which were crustaceans. Acute toxicity values ranged widely, from a low LC₅₀ of 10 µg a.i./L for blue crab megalopae (a planktonic stage), to an LC₅₀ of 361,000 µg a.i./L for brine shrimp. The blue crab study (Osterberg et al. 2012) is of particular interest given its possible relevance to imidacloprid effects on Dungeness crab in Grays Harbor and Willapa Bay, and so is reviewed separately below. The study was deemed “qualitative,” so EPA chose to use “the lowest acceptable (quantitative) acute toxicity value of 33 µg a.i./L ...for estimating risks to saltwater aquatic invertebrates.” The value of 33 µg a.i./L is the 96-hour LC₅₀ for a species of mysid shrimp (*Americamysis bahia*)³. EPA notes that this value is “42X less sensitive than that for freshwater invertebrates.” For chronic toxicity of saltwater invertebrates, EPA (2017) again used data on *A. bahia* to develop a 28-day NOAEC value of 0.163 µg a.i./L and a LOAEC of 0.326 µg a.i./L based on “significant reductions in length and

³ Given EPA’s use of a LOC of 0.5, this translates into a toxicity screening criterion for saltwater invertebrates of 33/0.5= 16.5 µg/l. Later, this literature review covers results for the 2014 Field Trials of imidacloprid in Willapa Bay. Both in that analysis, and in the field trials reviewed in the FEIS, a toxicity screening threshold of 3.7 µg/l was used, based on 1/10th the acute LC₅₀ value obtained in a separate study of imidacloprid’s effects on mysid shrimp.

weight.” EPA (2017) includes only two chronic studies of imidacloprid effects on saltwater invertebrates. If a larger database had been available, it seems likely lower values for chronic toxicity would have been noted for one or more invertebrate types, especially given the consistent pattern of wide variation in imidacloprid toxicity among species.

EPA provides useful information on both acute and chronic endpoints. The EPA’s preliminary risk assessment proposes acute (peak exposure concentrations) and chronic (21-day exposure for invertebrates) marine surface water criteria (Table A-1) which are then compared to other recent risk assessments conducted by other regulating entities. The chronic endpoint of 0.16 µg a.i./L is designed to protect sensitive invertebrates at a level low enough to not affect reproduction, therefore taking into account non-lethal impacts to imidacloprid that would not be measured solely through benthic abundance surveys. The EPA saltwater toxicity endpoint is higher than the Health Canada endpoint based upon differing analysis methods (lowest endpoint used by EPA vs. HC₅ used by Health Canada); although EPA also notes that this may in combination to “limited data available for saltwater invertebrates.”

Table A-1 – Comparison of Recent Regulatory and Non-Regulatory Aquatic Risk Assessments for Imidacloprid (copied from EPA 2017).

Endpoint Description	USEPA 2016	PMRA 2016	EFSA 2014	BCS 2016
Freshwater Invertebrates (µg ai/L)				
Acute Endpoint (Basis)	0.39 (Lowest EC ₅₀ of 0.77/2)	0.36 (Acute HC ₅)	0.098 (Acute HC ₅ of 0.49/5)	1.73 (Acute HC ₅)
Chronic Endpoint (Basis)	0.01 (Lowest NOAEC)	0.021 (Chronic HC ₅ /2)	0.009 (Chronic HC ₅ of 0.027/3)	0.039 (Chronic HC ₅)
Saltwater Invertebrates (µg ai/L)				
Acute Endpoint (Basis)	16.5 (Lowest EC ₅₀ /2)	1.37 (Acute HC ₅)	n.d.	n.d.
Chronic Endpoint (Basis)	0.16 (Lowest NOAEC)	0.33 (Lowest NOAEC)	n.d.	n.d.
Risk Findings				
RQ range	<0.01-2,130	54-1,790 (select scenario)	High acute and chronic risk (select representative scenarios)	Screening: 0.3-296 (Tier 1) 0.5-11.4 (Tier 2) Refined: = low risk

Note – PMRA refers to Health Canada (2016), EFSA refers to Smit et al. 2014, both reviewed below, and BCS refers to Bayer Crop Sciences, not reviewed below as Ecology was unable to obtain a copy for this review and marine biologic endpoints were not estimated.

These selected values for saltwater invertebrate toxicity were used by EPA to evaluate potential environmental effects. EPA modeled imidacloprid exposures based on different terrestrial uses of imidacloprid in agriculture and the projected runoff from those uses into marine systems (i.e., did not model direct spraying to marine systems). EPA found only one acute risk to saltwater invertebrates in any of its modeled scenarios.⁴ For chronic exposures, it found that foliar

⁴ Note: the LOC used in these analyses was 0.5, that is one-half of the calculated RQ that was assumed to produce toxicity. One acute test exceeded this level. However, EPA used a separate LOC of 0.05 for any

spraying of imidacloprid (e.g., on fruit trees) could lead to runoff that would produce toxicity, and obtained a similar result in three of its eight modeled scenarios of agricultural use of imidacloprid-treated seed. EPA's comparison of field data on imidacloprid concentrations in estuarine and marine environments to its chosen toxicity values was limited, probably because it notes that field data were limited. Based on this review, EPA concluded that chronic toxicity to crustaceans in saltwater environments is possible from existing levels of imidacloprid in marine waters. Because it did not evaluate direct application of imidacloprid to marine sediments, as proposed by WGHOGA, EPA's conclusions regarding marine toxicity of imidacloprid provide indirect information on the likely effects of spraying in Willapa Bay and Grays Harbor.

J.S. Osterberg, K.M. Darnell, T.M. Blickley, J.A. Romano, and D. Rittschof. 2012. Acute toxicity and sub-lethal effects of common pesticides in post-larval and juvenile blue crabs, *Callinectes sapidus*. J. Exper. Marine Bio. and Ecol. 424-425: 5-14.

These authors exposed blue crab megalopae (the last planktonic stage before crabs settle to the substrate) and juveniles to acute, 24-hour, static concentrations of various pesticides, including both laboratory grade (i.e., pure) and commercial grade (formulated and sold as Trimax™) imidacloprid. They recorded mortality, and for megalopae, effects on metamorphosis and subsequent juvenile survival. Sample sizes for toxicity tests ranged from 2–4 assays, which limited the precision of the subsequent toxicity curves. The authors found a significant difference in the toxicity of laboratory and commercial grade imidacloprid on megalopae toxicity, with estimated LC₅₀ values of 10.04 µg/L and 312.7 µg/L, respectively. This difference was reversed for juveniles, with LC₅₀ values for the laboratory and commercial grades of 1,112 µg/L and 816.7 µg/L, respectively. No explanation was offered for these observed differences in toxicity. Imidacloprid exposure did not delay the onset of metamorphosis in megalopae, but did result in lower molting rates and higher mortality in newly metamorphosed juveniles compared to controls. The authors include a short literature review on imidacloprid toxicity in crustaceans, and also conduct a simplified dilution study which leads them to conclude that “*direct overspray of Trimax or imidacloprid has a good chance to be acutely toxic to any blue crabs there [in shallow estuarine waters]*” and that “*lethal and sub-lethal effects here could have serious implications for the broader estuarine ecosystem.*”

Health Canada. 2016. Proposed re-evaluation decision, Imidacloprid. Document PRVD2016-20. Health Canada Pest Management Regulatory Agency, Ottawa, Canada.

Broadly, the Health Canada assessment is very similar to EPA (2017). It is a risk assessment, it includes a review of the scientific literature to establish toxicity thresholds, it models aquatic concentrations of imidacloprid from various types of agricultural uses of that chemical, and it compares thresholds to exposure to determine if environmental impacts are likely. And, as with EPA (2017), Health Canada includes a review of imidacloprid concentrations in surface bodies of freshwater to determine whether these field data indicate imidacloprid toxicity is occurring.

invertebrate species listed under the ESA, a decrease by a factor of 10 selected to provide a higher level of protection for listed species. Under a LOC of 0.05, additional acute tests exceeded levels predicted to produce toxicity. There are no ESA listed marine or estuarine invertebrates in Willapa Bay or Grays Harbor, making this result irrelevant with respect to WGHOGA's proposed permit.

Unlike EPA (2017), Health Canada includes an analysis of imidacloprid toxicity to birds and mammals, and an analysis of potential human exposure from a variety of imidacloprid uses.

The Health Canada literature review discussed many of the same studies as EPA (2017); however, the Health Canada review did not use data for the most sensitive species or study to set toxicity thresholds. It instead used a mathematical process to develop “species sensitivity distributions” (SSDs). SSDs are plots of species-specific toxicity versus imidacloprid toxicity. These curves are arranged so that the species are listed from the most sensitive to the least sensitive. A statistical approach is used on all data to estimate the hazardous concentration assumed to be protective of 95 percent of all species in the distribution, the so called “HC₅” value. Although this sounds similar to EPA (2017) use of the most sensitive taxon, in practice the HC₅ can be, and in the Health Canada study often is, a lower value than the lowest toxicity actually noted in experiments (i.e., because the HC₅ is statistically derived). Thus, in practice, Health Canada used a more conservative approach to assessing potential environmental effects of imidacloprid than EPA (2017).

One example that is relevant to WGHOGA’s proposed application involved the use of the blue crab data from Osterberg et al. (2012). Unlike EPA (2017), Health Canada used data from this study in developing its toxicity thresholds for saltwater invertebrates, specifically the 10.04 µg/L LC₅₀ observed in blue crab megalopae using laboratory grade imidacloprid. This was the most sensitive result in the studies reviewed by Health Canada. Once Health Canada constructed its SSD for saltwater invertebrates, it derived an estimate of the HC₅ of 1.37 µg/L, a result 8.7 µg/L lower than the lowest research-based value. Health Canada used the 1.37 µg/L as its toxicity threshold for all its subsequent analyses. By contrast, EPA (2017) used 33 µg/L times a LOC of 0.5 to produce an acute toxicity threshold of 16.5 µg/L for saltwater invertebrates in its analysis.

Major findings of the Health Canada study overlap some of those in EPA (2017). Health Canada concluded that aquatic insects are the most sensitive to imidacloprid, and both their modeled scenarios and their review of field data on imidacloprid support a conclusion that widespread impacts to sensitive freshwater species are likely occurring. Their analysis also documented the wide range of toxicities to imidacloprid present among groups (e.g., birds versus invertebrates) and among species within groups (e.g., within aquatic insects). They also found that vertebrate species, including the birds and mammals analyzed, were not predicted to experience toxicity from imidacloprid for the majority of their modeled field concentrations. A notable exception to this was the conclusion that direct ingestion of imidacloprid-treated seeds could lead to toxicity in birds and small mammals. Like EPA (2017), Health Canada identified potential secondary effects to insectivorous birds and mammals from a potential reduction in their invertebrate prey.

With respect to imidacloprid effects on humans, Health Canada used an analysis largely based on studies of other mammals, as well as an extensive review of potential exposure pathways (e.g., ingestion or adsorption in agricultural workers using imidacloprid). There is no direct analysis of the likelihood of imidacloprid toxicity in humans, but the general discussion indicates a low risk, as for other vertebrates. Health Canada reviewed case reports of attempted suicides through ingestion of imidacloprid. Based on this work they identified that imidacloprid toxicity “*symptoms in humans consist of nausea, vomiting, headache, dizziness, abdominal pain, and diarrhea.*” Of 56 attempted suicides, “*recovery was seen in all 56 patients reported.*”

Specific findings of the Health Canada study include:

- For marine invertebrates, the acute HC₅ value used to assess potential toxicity was 1.37 µg/L. The reviewed studies showed acute LC₅₀ values ranging from 10 µg/L to 313 µg/L (both values are for blue crab megalopae). Too few data were available to develop an HC₅ value for chronic exposure. A NOEC value of 0.33 µg/L was used based on a single study of mysid shrimp. Health Canada concluded that “[i]midacloprid may pose an acute and chronic risk to marine/estuarine invertebrates based on water modelling results. The monitoring data for imidacloprid in marine/estuarine environments are not robust enough to exclude risks to marine/estuarine invertebrates.”
- For freshwater invertebrates, the acute and chronic HC₅ values used to assess potential toxicity were 0.36 and 0.041 µg/L, respectively. Based on its analysis of monitoring data, Health Canada concluded that imidacloprid levels found in surface waters that receive agricultural runoff frequently exceed these concentrations, and thus would be expected to affect the most sensitive species of freshwater invertebrates.
- Freshwater crustaceans were analyzed and the results include acute LC₅₀ estimates for the amphipod *Hyalella azteca* of 17.4–526 µg/L (96-hour test), for seed shrimp (Ostracods) a 6-day LC₅₀ of 1.5 µg/L, and growth inhibition at 1–1.5 µg/L, and for the amphipod *Gammarus* sp. a 96-hour LC₅₀ of 111–263 µg/L, with immobility noted at 18.3 µg/L. Results for chronic toxicity tests include 28-day LC₅₀ values of 7.08 µg/L, 1.26 µg/L, and 2.03 µg/L, for the amphipods *H. azteca* and *Gammarus* sp., and the isopod *Asellus aquaticus*, respectively. For *H. Azteca* a No Observed Effects Concentration (NOEC) of 3.44 µg/L was reported (96-hour test).
- Table 29 specifically compares marine aquatic organisms exposed to imidacloprid from indirect applications (i.e. not spraying sediments directly) for curcubit vegetables at a rate of 587 g a.i. / hectare (which converts to 0.5 lbs. a.i. / acre) and determined that both acute and chronic levels of concern (LOCs) were exceeded.
- Toxicity to freshwater and marine fish was not analyzed in detail, but the tabular data listed by Health Canada for its review documented LC₅₀ values that were consistently greater than 1,000 µg/L, indicating low potential for imidacloprid toxicity to this animal group.
- Low toxicity or no toxicity to birds. Their model of potential toxicity to large birds concludes that imidacloprid is “not expected to pose a risk to birds” due to low toxicity relative to exposure, and the reality that “birds are unlikely to feed solely on imidacloprid-contaminated foodstuffs.” The modeled toxicity to small and insectivorous birds concluded that imidacloprid is “not expected to pose a risk to birds,” again based on an inherent high toxicity threshold, and because imidacloprid is expected to decline in their prey organisms following treatment with imidacloprid. Similarly, Health Canada concluded that the “risk to small and medium sized birds is considered to be relatively low.” The selected HC₅ for imidacloprid toxicity to birds was 8,070 µg/L.
- Low toxicity to mammals for many of the same reasons as those noted above for birds.
- Toxicity to birds and mammals is possible under special circumstances. Modeled ingestion of imidacloprid-treated seeds (animals assumed to be able to eat as much treated seed as they wanted) resulted in predictions of toxicity for all bird sizes (20,100 and 1,000-gram bird categories) and all seed types that were modeled. Also, Health

Canada analyzed reports of birds that had fallen ill, or were dead and dying, following turf treatments (e.g., on golf courses) with imidacloprid or a mixture of pesticides that included imidacloprid. The data were considered anecdotal, but indicative of a potential for impacts from turf applications of imidacloprid. The report concluded that pellet applications of imidacloprid to turf could be mitigated by prompt exposure to water following application (i.e., because pellets quickly dissolve on contact with water).

- Health Canada had as one of its goals the development of recommendations for the continued use of imidacloprid for agricultural uses. Based on their results for freshwater invertebrates the review “*propos[ed] continued registration of certain uses of imidacloprid and removal of others based on environmental risks of concern.*” Elsewhere in the document the recommendations were more strongly negative: “The environmental assessment showed that, in aquatic environments in Canada, imidacloprid is being measured at levels that are harmful to aquatic insects,” and that the continued “use of imidacloprid in agricultural areas is not sustainable.” Health Canada’s key finding was, “For the protection of the environment, PMRA is proposing to phase-out all the agricultural and a majority of other outdoor uses of imidacloprid over three to five years.”

EPA. 2016. Preliminary pollinator review to support the registration review of imidacloprid. PC Code 129099. DP Barcode 435477. USEPA, Office of Chemical Safety and Pollution Prevention, Washington DC. Prepared by USEPA Office of Pesticide Programs, Environmental Fate and Effects Division, Washington DC.

EPA (2016) is an assessment of whether imidacloprid poses a risk to terrestrial pollinators, with a focus on honey bees (*Apis mellifera*). As with the other risk assessments reviewed above (EPA 2017, Health Canada 2016), the EPA 2016 assessment involves modeling of different agricultural uses of imidacloprid to develop potential exposure concentrations, as well as review of published literature, which for this document is centered on environmental measurements of imidacloprid in field crops, and studies of honey bee toxicity from such exposures. The EPA 2016 document has no analysis of potential effects to either freshwater or saltwater invertebrates. Overall, although “highly toxic” to honey bees, EPA 2016 concludes that most modeled agricultural uses of imidacloprid are at low or uncertain risk of impacting bee hives, many uses pose risks to individual bees, and a few modeled scenarios indicate risks to both individual bees and bee hives. Specific findings include:

- Honey bees are most likely to be exposed to agricultural uses of imidacloprid from direct contact with foliar sprays and oral ingestion (e.g., through consumption of contaminated pollen and nectar).
- Imidacloprid does not appear to “*carryover*” from one year to the next in plants (e.g., is not persistent).
- Adult mortality thresholds were selected for both acute (96-hour) contact exposure (0.043 µg a.i./L) and acute (48-hour) oral toxicity (0.0039 µg a.i./L). The adult chronic (10-day) oral toxicity value selected was 0.00016 µg a.i./L. Based on these values, EPA deemed imidacloprid as “*highly toxic*” to honey bees.
- EPA’s modeled imidacloprid concentrations were deemed “*conservative*” because they exceeded the levels measured in field studies.

- Some on-field exposure scenarios (e.g., direct exposure to foliar spray applications in citrus crops) exceed EPA’s selected toxicity thresholds (i.e., honey bees are predicted to experience toxicity).
- Scenarios that do not involve direct, on-field exposure (e.g., ingestion of contaminated pollen and nectar) did not exceed EPA’s toxicity thresholds for the majority of agricultural uses modeled.
- For direct, on-field exposure, EPA (2016) contains a “red grouping” of agricultural uses of imidacloprid that are predicted to impact both individual honey bees and bee hives. These uses are foliar applications in citrus crops, and foliar, soil, soil + foliar, and seed treatment + foliar applications in cotton. Remaining modeled agricultural uses were either deemed “*green grouping*” (i.e., low risk of toxicity) or “*yellow grouping*” (i.e., toxic effects may occur in individual bees but there is scientific uncertainty whether any effect on hives would occur).

Patten, K. 2016. A summary of ten years of research (2006-2015) on the efficacy of imidacloprid for management of burrowing shrimp infestations on shrimp grounds. Memorandum included in WGHOGA’s 2017 SIZ application to Ecology. 23 p.

Dr. Patten led most of the studies of the effectiveness of imidacloprid in reducing burrowing shrimp densities in Willapa Bay, Washington. The experimental work included efficacy measurements as part of the formal imidacloprid field trials in 2011, 2012, and 2014, as well as a large number of smaller studies designed to test approaches to increasing efficacy, reducing imidacloprid concentrations necessary for shrimp control, or both. Given the wide variation in study types, he reports efficacy levels that range from 0 to 100 percent. Most of his reported efficacy levels exceed 40 percent, and average 80 percent or more. But Dr. Patten reports that where flowing water or heavy eelgrass are present at the time of treatment, imidacloprid efficacy can decline below 40 percent unless site-specific approaches to ensure chemical contact with the sediment-water interface can be enhanced (e.g., hand spraying, sediment injectors). For difficult treatment areas he suggests that use of pelletized forms of imidacloprid, reduction in eelgrass densities before treatment, or spot treatments may be effective strategies to boost efficacy. Dr. Patten also recommends continued investigation of approaches to improve the efficacy of imidacloprid in reducing burrowing shrimp densities, as part of an integrated pest management plan by WGHOGA.

Patten, K., and S Norelius. 2017. Response of Dungeness crab megalopae and juveniles to short-term exposure to imidacloprid. 2017 Report to Washington Department of Fish and Wildlife. Washington State University, Long Beach Research and Extension Unit, Long Beach, WA. 21 p.

This is a report summarizing nine different sets of experiments on the effects of imidacloprid on Dungeness crab. Five of the studies were conducted in 2017, and the remaining four, which are included in appendices, were conducted in prior years. The specific methods, imidacloprid concentrations, and exposure pathways (e.g., lab studies versus field trials) tested vary considerably and sample numbers in some cases were limited. Seven of the studies brought crab from Willapa Bay into the laboratory where a variety of experiments were conducted to look at the onset of tetany in crab exposed to varying levels and durations of imidacloprid. Most of these

laboratory studies also tracked recovery from tetany over time using clean salt water. The two field studies were both assessments of the number of crab affected following applications of imidacloprid to commercial shellfish grounds in Willapa Bay. Potentially relevant highlights from these studies include:

- Water quality data from field trials in Willapa Bay indicate an average imidacloprid concentration of 170 µg/L in the “leading edge” of the rising tide that carries imidacloprid off treated plots, and 2.2 µg/L on-plot during high tide on the day of application. Methods for how this was calculated were not provided. On- and adjacent off-plot monitoring (ex. see 2012 monitoring report) have shown exceedances of this average by more than 5 times.
- Dungeness crab showed “no short-term tetany response of megalopae to imidacloprid up to 100 µg/L for 2 hours [exposure]; however significant tetany was observed at 500 µg/L within 20 minutes.”
- Dungeness crab juveniles exposed to imidacloprid at concentrations up to 100 µg/L for 6 hours did not experience tetany.
- Studies designed to mimic the rate of dilution of imidacloprid from rising tidal waters following field applications (i.e., dilution by approximately 50% every 4 minutes) did not result in tetany of juvenile Dungeness crab at starting concentrations of either 250 µg/L or 500 µg/L.
- Surveys following field applications consistently found affected Dungeness crab in the spray plots. Across surveys the authors found an average of 3.2 affected crab/acre sprayed, but numbers up to 29 crab/acre were observed. The authors noted widespread predation by gulls on Dungeness crab in the plots following field spraying.
- Tetany reversal, i.e. resumption of motion, was observed in both megalopae and juveniles under lab conditions, generally within 10-24 hours. This would correspond to one to two tidal cycles in the field.
- The authors conclude: “there will likely be some mortality of Dungeness megalopae and juvenile crab resulting from commercial treatment of tide flats with imidacloprid. This mortality will result from mechanical damage from being run over by ATVs during application (Patten 2012) and the result of tetany and subsequent predation following exposure to high doses of imidacloprid in the wetting front [i.e., leading edge].

This study has not undergone rigorous scientific peer review. Some areas of concern are;

- Lack of detailed study methodologies
- Tidal dilution studies are incomplete models of actual tidal cycles
- 2014 studies show Dungeness crab tetany and mortality
- The study underestimates mortality in the field as it does not include tetany as leading to mortality

Patten, K., and S Norelius. 2016. 2016 Progress report to Washington Department of Fish and Wildlife – burrowing shrimp recruitment survey for Willapa Bay late summer 2016. Washington State University, Long Beach Research and Extension Unit, Long Beach, WA. 8 p.

This is an annual report on the results of WSU research that was funded by WDFW. Sediment samples were taken from seven locations across Willapa Bay and then screened to obtain samples of juvenile ghost shrimp (*Neotrypaea californiensis*) that recruited into the bay in 2015 (as determined by a carapace length greater than 3.5 mm or about 0.14 inches), or 2016 (carapace length less than 3.5 mm). Recruitment was “*very high*” at the north end of Willapa Bay (543 recruits per square meter or 50.4 per square foot), and “*progressively declined towards the south end of the bay*” (down to 14 recruits/meter squared or 1.3 per square foot). Across all sites the average number of juvenile shrimp estimated to have recruited in 2015 and 2016 was 152 animals/meter squared (14.1 per square foot). The number of individuals in each size class (greater than 3.5 mm, and less than 3.5 mm) indicates that recruitment was higher in 2015 than in 2016. The authors note that recruitment in Willapa Bay since 2000 “*has been relatively minor,*” but that recruitment over the past two years has been “*robust.*” The authors raise concerns that as these juveniles reach adulthood they will “*represent a severe threat to the Willapa Bay shellfish industry.*”

Gibbons, D., C. Morrissey, and P. Mineau. 2015. A review of direct and indirect effects of neonicotinoids and fibronil on vertebrate wildlife. Environmental Science and Pollution Research 22: 103-118

The authors conducted a literature review on 150 previously published studies on the effects of pesticides on vertebrate wildlife, including fish, birds, and mammals. Based on the relative abundance of published studies, the authors focused on three pesticides, imidacloprid, clothianidin, and fibronil. Most (91%) of the studies they reviewed were laboratory-based toxicity studies, but a few were based on field work. Common to many studies, they found widely varying toxicity of imidacloprid to different species. For mammals they report LC₅₀ values ranging from 131,000 – 475,000 µg/L, for birds 13,900 – 283,000 µg/L, for fish 1,200-241,000 µg/L, and for amphibians 82,000 – 366,000 µg/L. Even the lowest of these LC₅₀ values is orders of magnitude higher than reported LC₅₀ values for sensitive marine and freshwater invertebrates, confirming the much lower toxicity of imidacloprid to vertebrates than to invertebrate groups. The authors note that one of the greatest potential impacts of imidacloprid is from imidacloprid treated agricultural seeds, where “*ingestion of even a few treated seeds could cause mortality and reproductive impairment to sensitive bird species.*” They note that reported concentrations of imidacloprid in surface waters are “*except in the most extreme cases...2 to 7 orders of magnitude lower than the LC₅₀ measurements for fish and amphibians,*” and therefore direct mortality in these groups is unlikely. Their tables include a study for rainbow trout fry that reported an LC₅₀ of 1.2 ppm (1,200 ug/L). Gibbons et al. concluded that although concentrations were too low to exert a direct effect on the fish, they were deemed sufficiently high to reduce prey abundance. The authors also review literature to show that imidacloprid can cause sub-lethal effects (e.g., reduced reproductive success) in birds at doses (in food) of 1,000 to 53,400 µg per kilogram animal weight per day, and in fish at 30 – 320,000 µg/L (duration of exposure unknown). For example, the authors cite a study by Sanchez-Bayo and Goka (2005) which noted fish became physiologically stressed following exposure to imidacloprid and subsequently

became susceptible to parasites. The authors conclude that sub-lethal effects can occur in birds, particularly those exposed to imidacloprid treated seeds, and that for fish and amphibians “*the possibility of sub-lethal effects...cannot be ruled out.*” Finally, the authors note the rarity of studies looking at potential indirect effects, in particular how reductions in invertebrates by pesticides may reduce the prey available to vertebrate consumers of these animals. They raise concerns about this impact pathway, and call for more study in this area.

Lintott, D. R. 1992. NTN 33893 (240 FS Formulation): Acute Toxicity to the Mysid, *Mysidopsis bahia* under Flow-through Conditions: Lab Project Number: J9202001: 103845. Unpublished study prepared by Toxikon Environmental Sciences. 43 p.

Lintott (1992) exposed mysid shrimp to imidacloprid over 96 hours (i.e., an acute test) and found an LC₅₀ of 36 µg a.i./L, with 95 percent confidence limits (CL) of 31 and 42 µg a.i./L. The NOEC was 21 µg a.i./L based on the lack of mortality observed at this concentration.

Wheat, J. and S. Ward. 1991. NTN 33893 Technical: Acute Effect on New Shell Growth of the Eastern Oyster, *Crassostrea virginica*: Lab Project Number: J9008023D: J9107005. Unpublished data by Toxikon Environmental Sciences. 54 p.

Wheat and Ward (1991) conducted two acute exposure tests evaluating the effects of imidacloprid on new shell growth in the Eastern oyster (*Crassostrea virginica*). Specifically, they compared new shell growth in oysters exposed to imidacloprid to control oysters. In the first study, the effective concentration to produce a 50 percent reduction in new shell growth of Eastern oysters was very high, greater than 23,300 µg a.i./L. At 2,930 µg a.i./L, new shell growth was reduced by only 5 percent relative to the controls. The second test found that new shell growth of exposed oysters was reduced by 22 percent relative to the controls at the highest concentrations tested. Survival of oysters was 100 percent in all treatments. The authors state that evaluation of new shell growth data from the second exposure study found the 96-hour EC₅₀ was greater than 145,000 µg a.i./L.

Gagliano, G. G. 1991. Growth and Survival of the Midge (*Chironomus tentans*⁵) Exposed to NTN 33893 Technical Under Static Renewal Conditions: Lab Project Number: N3881401: 101985. Unpublished study prepared by Mobay Corp. 43 p.

Gagliano (1991) studied the growth and survival of a freshwater midge exposed to imidacloprid under static conditions. The study found a 10-day (i.e., chronic) LC₅₀ of 3.17 µg/L. Evaluation of survival over 10 days found no observed effects at 1.24 µg/L. The study examined effects over a shorter duration of 96 hours, and found an LC₅₀ of 10.5 µg/L, and a NOAEL based on survival of 1.24 µg/L, similar to that observed over the 10-day study. There was zero percent mortality observed in midges exposed for 10 days to concentrations of 0.67 µg/L and 1.24 µg/L, and 100 percent mortality at 102 µg/L and 329 µg/L concentrations.

England, D. & J. D. Bucksath. 1991. Acute Toxicity of NTN 33893 to *Hyaella azteca*: Lab Project Number: 39442: 101960. Unpublished study prepared by ABC Labs., Inc. 29 p.

⁵ Now *C. dilutus*

England and Bucksath (1991) studied the effects of imidacloprid on the survival and mobility of the freshwater amphipod, *Hyalella azteca*. They reported a 96-hour LC₅₀ of 526 µg/L (95 percent confidence interval [CI] of 194 µg/L to 1,263 µg/L) and a 96-hour EC₅₀ based on immobilization of 55 µg/L (95 percent CI of 34 µg/L to 93 µg/L). At 0.35 µg/L, there were no observed effects to mortality or mobility over the 96-hour exposure.

Ward, G. S. 1990. NTN-33893 Technical: Acute Toxicity to the Mysid, *Mysidopsis bahia*, under Flow-Through Test Conditions: Lab Project Number: J9008023B/F: 100355. Unpublished study prepared by Toxikon Environmental Sciences. 46 p.

Ward (1990) conducted two acute exposure tests under flow-through test conditions to the mysid, *Mysidopsis bahia*. The first test found a 96-hour LC₅₀ of 37.7 µg a.i./L with a 95 percent confidence limit (CL) of 25.7 µg/L and 46.4 µg a.i./L). A second flow-through test was conducted because the NOEC was not determined within the test concentration range. The second test found a 96-hour LC₅₀ of 34.1 µg a.i./L with a 95 percent CL of 22.9 µg a.i./L and 37.2 µg a.i./L. The NOEC was 13.3 µg a.i./L, based on lack of mortality and sublethal effects after 96 hours of exposure. The authors noted that after 96 hours of exposure, no surviving imidacloprid-exposed mysid displayed any sublethal effects.

Frew, J. A. 2013. Environmental and Systemic Exposure Assessment for Green Sturgeon Following Application of Imidacloprid for the Control of Burrowing Shrimp in Willapa Bay, Washington. Dissertation, University of Washington, School of Aquatic and Fishery Sciences.

Frew (2013) conducted a comprehensive study looking at the potential environmental and systemic (i.e., physiological) effects of imidacloprid on green sturgeon associated with its use to control burrowing shrimp in Willapa Bay. Using white sturgeon as a surrogate, an exposure study found the 96-hour LC₅₀ was 124,000 µg/L, indicating that sturgeon do not possess high sensitivity to imidacloprid. The author calculated a hazard quotient (HQ) using the ratio of the maximum pore water concentration measured during field trials of imidacloprid in Willapa Bay divided by his calculated LC₅₀ value. Frew reports that this HQ was two orders of magnitude (100X) below the threshold for potential effects. Given the observed sediment and pore water concentrations of imidacloprid following treatment to control burrowing shrimp, he concludes that green sturgeon would be at minimal risk for toxic exposure resulting from imidacloprid treatments in Willapa Bay. Frew also modeled a worst-case scenario of exposure to green sturgeon over a 4-hour foraging time window during a high tide following application of imidacloprid. This scenario incorporated sturgeon exposure from both sediment/porewater exposure, and ingestion of burrowing shrimp exposed to imidacloprid. He found that even in these conservative exposure scenarios, uptake of imidacloprid by green sturgeon would be modest and two to three orders of magnitude lower than levels known to cause acute or chronic effects.

Frew, J.A., M. Sadilek, and C. E. Grue. 2015. Assessing the risk to green sturgeon from application of imidacloprid to control burrowing shrimp in Willapa Bay, Washington –

Part I: Exposure Characterization. Environmental Toxicology and Chemistry. Vol 34, 11: 2533-2541

This document summarizes a major piece of John Frew's 2013 Ph.D. dissertation on imidacloprid toxicology. The paper describes an exposure model used to estimate the ingestion of imidacloprid by green sturgeon, an ESA-listed species, following treatment to reduce burrowing shrimp in Willapa Bay. The exposure model included four components: ingestion of imidacloprid-exposed shrimp, uptake from water containing imidacloprid within shrimp burrows by swallowing, uptake from water passing across the gills, and uptake from ingestion of sediment containing imidacloprid. The paper also includes field counts of sturgeon feeding pits on sprayed and control plots that confirm extensive feeding on treated areas. Conservative assumptions were used throughout the exposure model, the three most important of which were that green sturgeon ate a large volume of exposed shrimp, that uptake of imidacloprid from such shrimp had a 10 percent efficiency (i.e., 10 percent of the imidacloprid in the shrimp was assimilated into the sturgeon), and that sturgeon were exposed to porewater concentrations of imidacloprid for the entire feeding session modeled (4 hours). The authors acknowledge that their conservative assumptions likely result in an overestimation of actual imidacloprid uptake by green sturgeon. Their results indicate that uptake from porewater was 9.5 and 7.5 times greater (at 6 and 30 hours post-exposure, respectively) than estimated uptake from ingestion of exposed shrimp. The authors estimated total imidacloprid uptake, from all four sources, of 196.7 µg/L at 6 hours and 113.2 µg/L at 30 hours post-exposure. The authors cite an LC₅₀ of imidacloprid for white sturgeon of 124,000 µg/L, which is 630 times higher than their maximum modeled uptake, to conclude "*Imidacloprid concentrations and durations of exposure following chemical application in Willapa Bay would be lower than the levels expected to elicit direct acute toxic effects in green sturgeon. Furthermore, no chronic toxic effects would be expected following unforeseen extended periods of exposure.*"

Frew, J.A., and C.E. Grue. 2015. Assessing the risk to green sturgeon from application of imidacloprid to control burrowing shrimp in Willapa Bay, Washington--Part II: controlled exposure studies. Environmental Toxicology And Chemistry Vol. 34. 11: 25420-2548.

This publication is based on the remaining parts of the John Frew's 2013 Ph.D. dissertation. Controlled experiments were conducted using surrogate white sturgeon to determine acute and chronic effect concentrations of imidacloprid, and to examine effects at more environmentally realistic concentrations and durations of exposure. They report the 96-hour median lethal concentration was 124,000 µg/L with a predicted 35-day NOAEC of 700 µg/L. Imidacloprid half-life in plasma was greater than 32 hours. The authors report that no "*overt effects*" were observed in white sturgeon following environmental exposures that could be expected following imidacloprid treatment for burrowing shrimp. Measured concentrations of imidacloprid in porewater were significantly lower than the derived acute and chronic effect concentrations for white sturgeon. Exposure risk quotients were calculated using the effect concentrations and estimated environmental exposure. The resulting values were considerably below the level of concern for direct effects from either acute or chronic exposure to sturgeon.

Key, P., K. Chung, T. Siewicki, and M. Fulton. 2007. Toxicity of three pesticides individually and in mixture to larval grass shrimp (*Palaemonetes pugio*). Ecotoxicology and Environmental Safety. 68:272-277.

Key et al. (2007) examined the toxicity of three different pesticides, both in combination and individually. A mixture of fipronil and imidacloprid resulted in significantly lower toxicity to grass shrimp compared to each insecticide alone. By contrast, addition of atrazine increased the toxicity of the mixture. With respect to imidacloprid, the authors found it was significantly more toxic to grass shrimp larvae than adults. For larval grass shrimp the observed 96-hour LC₅₀ was 308.8 µg/L (95 percent CI 273.6 µg/L -348.6 µg/L). For adult grass shrimp the 96-hour LC₅₀ was 563.5 µg/L (95 percent CI = 478.1 µg/L -664.2 µg/L).

Somers, N and R. Chung. 2014. Case study: Neonicotinoids. Ontario Agency for Health Protection and Promotion, Toronto, ON. 8 pps.

Somers and Chung (2014) provide a short review of scientific literature and regulatory treatment of neonicotinoids, of which imidacloprid is only occasionally called out specifically. The paper is focused on, and largely limits itself to, environmental effects associated with neonicotinoid use on crops, particularly corn and soy beans. The study identifies three pathways for exposure related to agriculture: exposure to airborne dust when planting treated seed, exposure to residues in pollen or nectar, and exposure to guttation fluids (sap droplets on leaves). The authors make few definitive findings, instead concluding that “*sub-lethal concentrations may be of ecological significance*” and “*adverse effects may occur in non-target species*” based on a general view of their literature search rather than on data analysis or specific findings. The authors conclude by calling for more study.

Morrissey, C. A., P. Mineau, J. H. Devries, F. Sanchez-Bayo, M. Liess, M.C. Cavallaro, and K. Liber. 2015. Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates: a review. Environment International 74:291-303.

In common with EPA (2017) and Health Canada (2016), Morrissey et al. (2015) conducted an extensive review of the toxicology data on neonicotinoids⁶ for aquatic organisms. They subsequently use their review to develop recommended limits on water concentrations of this class of chemicals. The paper also includes a good review of the mechanisms of toxicity of neonicotinoids, and a review of evidence that surface water sampling has documented contamination with these substances. They conclude that, “strong evidence exists that water-borne neonicotinoid exposures are frequent, long-term and at levels which commonly exceed several existing water quality guidelines.” Specific papers and findings from the toxicology literature are generally not reviewed. Instead, the authors conclude that differences in relative toxicity among neonicotinoids within taxonomic groups (e.g., freshwater insects, bees, etc.) are minor compared to differences amongst taxonomic groups. Accordingly, their methodology assumes that toxicology data on different neonicotinoid compounds can be combined, and they then use these pooled datasets to determine the average and range of toxicities observed with different groups of organisms. They conclude that “neonicotinoid insecticides can exert significant lethal and sub-lethal effects on many aquatic invertebrate populations.” The authors also propose receptor binding by neonicotinoid insecticides in invertebrates may be near

⁶ Although the paper deals with data for a number of neonicotinoids, the authors note that most of their reviewed studies were on imidacloprid.

irreversible and may result in delayed toxicity, leading to an “underestimation of the true toxic potential of these insecticides” during risk assessments.

The authors indicate that aquatic insects are the most sensitive group, particularly mayflies and caddisflies. LC₅₀ values for these most sensitive insect species were generally in the range of 3-9 µg/L, whereas crustacean toxicity was generally 1 to 2 orders of magnitude higher. The authors use their collected data to produce two SSDs, one based on chronic toxicity exposure data and one on acute data, and then use them to estimate the HC₅ (i.e., the concentration of neonicotinoids expected to be non-toxic to 95 percent of species). The authors then took the lower distribution or confidence limit of the HC₅⁷ as recommended values (one chronic, one acute) for “*thresholds, above which, ecologically relevant population-level effects on sensitive aquatic invertebrate species are likely to occur.*” Their recommended thresholds are 0.20 µg/L for acute exposure, and 0.035 µg/L for chronic exposure.

Smit, C.E. 2014. Water quality standards for imidacloprid. Proposal for an update according to the Water Framework Directive. RIVM Letter Report, 270006001. National Institute for Public Health and the Environment, Ministry of Health, Welfare and Sport. Netherlands.

Smit (2014), again like EPA (2017) and Health Canada (2016), contains a substantial review of scientific literature on the freshwater toxicity of imidacloprid, with a much more modest review of saltwater studies. The author’s goal is to identify organisms that are particularly sensitive to imidacloprid, and to then propose a water quality standard for imidacloprid in surface waters that is substantially below any observed toxic levels to provide a high probability such a standard would be protective to all species. The study evaluated imidacloprid toxicity in three ways: based on standard, laboratory toxicity studies; through development of acute and chronic SSD curves; and using published mesocosm data (multi-species tests meant to mimic natural environments). The calculation methods are complex, and appear to be based specifically on the Water Framework Directive (WFD), a Netherlands-specific regulatory framework. The Maximum Acceptable Concentration in Ecosystems (MAC-EQS) is somewhat similar to an acute toxicity threshold, representing the “standard for short-term concentration peaks.” The document calculates the MAC-EQS using results from a pond mesocosm experiment in which imidacloprid was added at two intervals over 21 days. The 21 day NOEC for this study (on mayflies and true flies) was 0.6 µg/L. Through mathematical manipulation, the author converts this chronic NOEC into a 48 hour NOEC estimate of 0.51 µg/L⁸, and then divides it by a safety factor of three to produce a MAC-EQS of 0.17 µg/L, which is close enough to the existing MAC-EQS of 0.2 µg/L that the author proposed no change in the WFD water quality criterion. The study also includes something similar to a chronic toxicity threshold, the Annual Average Environmental Quality Standard (AA-EQS), “*which should protect the ecosystem against adverse effects resulting from long-term exposure.*” For the AA-EQS, an SSD was constructed and used to calculate an HC₅ of

⁷ The review of Health Canada (2016) contains additional explanation of SSDs and HC₅ values. Health Canada (2016) did not use a similar technique of selecting the lower distribution or confidence limit to set toxicity thresholds.

⁸ The conversion results in a lower NOEC for 48 hours than was observed in the original study for 28 days. This is counterintuitive, but the provided description of methods is not sufficiently detailed to understand the mechanics of this transformation.

0.025 µg/L. This was divided by a safety factor of three to produce a value of 0.0083 µg/L. This is the lowest toxicity threshold in any of the studies covered in the SEIS's literature review, explained in part by the use of NOEC values, rather than the LC₅₀ and EC₅₀ values used in most of the other reviewed studies to set toxicity thresholds.

Additional Studies

A number of the other studies included in this literature review were on subjects already covered in detail in the large literature reviews (e.g., EPA 2017) and/or were less clearly related to the proposed permit. These additional studies are grouped below into general topic areas, and the specific reviews have been shortened into bullet form.

Scientific Studies of Neonicotinoid Effects on Honey Bees

With declines in honeybee populations observed since the early 1990s, scientists have conducted many studies of the potential role of neonicotinoids generally, and imidacloprid in particular, on honey bees and honey bee colonies. Although the proposed permit is not expected to affect honey bees because they do not visit areas that are proposed for treatment (i.e., saltwater sediments and eelgrass), these studies nonetheless provide insight into the potential impacts of imidacloprid on invertebrates.

- Sanchez-Bayo (2014) reviews and summarizes the effects of neonicotinoid toxicity and chemical behavior in the environment. The author notes that neonicotinoids are systemic and have been found to produce delayed mortality in arthropods at chronic, sublethal levels, but are not toxic to vertebrates. The author reviews experiments in freshwater aquatic ecosystems treated with single or repeated doses of imidacloprid and concludes that midges, ostracods, and mayflies are significantly reduced and do not recover when residues are above 1 ppb; while multi-year field monitoring showed imidacloprid concentrations as low as 0.01 µg/L “led to significant reductions in macroinvertebrates in surface waters.” In addition, the author describes concerns with the effects to pollinators from daily sublethal exposure to imidacloprid. Described effects to these pollinators include olfactory learning, memory, locomotion impairment and inhibited feeding.
- Wu-Smart and Spivak (2016) focused on the sublethal effects of imidacloprid on queen bees. The authors found adverse effects on queen bee egg-laying and locomotor activity, foraging, and hygienic effects on worker bees. They also noted colony development impacts related to brood production and pollen stores. The authors found evidence that a larger colony size may act as a buffer to pesticide exposure, and that exposure in early spring when the colony is smallest will have greater effects.
- Hesketh et al. (2016) studied long term exposure of insecticides, trace metals, fungicides and herbicides to honeybees. The authors argue that short-term studies may not necessarily account for chronic or cumulative toxicity. The results found that honeybees were most sensitive to insecticides (including neonicotinoids), then metals (cadmium, arsenic), followed by the fungicide propiconazole and herbicide 2,4-D. The authors conclude that sensitivity to chronic exposure levels has the potential to affect over-wintering colonies.
- Rondeau et al (2014) evaluated published imidacloprid toxicity data to develop time-to-lethal-effect scaling, which they argue serves as an important tool for estimating the

effect of chronic pesticide exposure to bees. They found that by extrapolating toxicity scaling for honeybees to the lifespan of winter bees that imidacloprid at 0.25 µg/kg in honey would be lethal to a large proportion of bees nearing the end of their life. They conclude that neonicotinoids “are of particular concern because they bind virtually irreversibly” to nervous system receptors. They postulate this could similarly be found in other invertebrates.

- Woodcock et al (2016), evaluated 18 years of data from the United Kingdom national wild bee distribution surveys for 62 species. They compared this census data to the estimated amount of neonicotinoid use in the agricultural crop oilseed rape in the areas around each census location. Through the use of modeling (i.e., a multi-species, dynamic Bayesian occupancy analysis) the authors found evidence of increased population extinction rates in response to neonicotinoid seed treatment use on oilseed rape. They suggest that sub-lethal effects could accumulate, producing impacts at the population level.

Terrestrial insects

A few studies have noted indirect impacts of neonicotinoids, including imidacloprid, to terrestrial insects.

- Parkinson et al (2017) investigated the sublethal effects of imidacloprid on a locust (*Locusta migratoria*), specifically the impairment of neural responses to visual stimuli. They examined dissected eyes and particular enzyme pathways that lead to neural stimulation. At 10 ng/g (10 µg/kg imidacloprid per g of locust body weight), they found that imidacloprid reduced firing of the visual motor sensitive neuron. The authors suggest that reduced firing from exposure to sub-lethal doses of imidacloprid would lead to deficits in collision avoidance in locust.
- Wang et al (2015) exposed red imported fire ants, *Solenopsis invicta*, to sublethal doses of imidacloprid and found that the ants consumed more sugar water containing imidacloprid than untreated sugar water, and ants fed imidacloprid (0.01 µg/mL) showed an increase in digging activity. At greater concentrations (≥ 0.25 µg/mL), exposed ants had suppressed sugar water consumption, digging and foraging behavior.

Vertebrates

Concern over the use of pesticides has led to studies on the potential impacts on vertebrate embryo development.

- Hallman et al. 2014 – The authors conduct a review of many years of field survey data on the abundance and diversity of insect eating birds. They then compared population trends over time in areas where imidacloprid is used on agricultural crops and others where it is not. They conclude that in areas with imidacloprid use insectivorous bird numbers show an annual decline of 3.5% per year even after taking into account land-use changes. Impacts to prey species, specifically reductions in the total food base available for foraging birds, was suggested at the between imidacloprid and bird abundance.
- Wang et al (2016) exposed developing chick (leghorn) embryos to imidacloprid (500uM), and examined the embryos for skeletal and neural effects. They found disruption in the cranial neural crest cells, which led to defective cranial bone development.

Aquatic

Numerous scientists have been studying the toxicity of neonicotinoids in the aquatic environment and have found a diverse response among invertebrate species. As noted above, Health Canada (2016) and EPA (2017) include extensive reviews of these studies. Some additional studies on the effects of neonicotinoids on aquatic environments include:

- Sanchez-Bayo et al (201), a broad review of the toxicity of neonicotinoids to aquatic species, from an individual level to a population and ecosystem level. The study discusses the sensitivity of ostracods, amphipods, and midges to imidacloprid, and differs from some others on its more in-depth analysis of the potential for “delayed mortality” resulting from longer exposure duration under field conditions than those studied in the laboratory. The authors also cite numerous studies identifying sublethal effects on aquatic organisms including: feeding inhibition, impaired movement, reduced fecundity, reduced growth, and immune suppression; and, noted “their consistency in reporting population and community effects at levels well below the LC50s of the aquatic species tested.” Finally, Sanchez-Bayo postulated that the scientific understanding of pesticide relationships to aquatic organisms has lagged behind our understanding of terrestrial (e.g. pollinator) impacts due to a focus on terrestrial systems.
- Chagnon et al. 2015 – This is a largely theoretical paper on the potential effects of systemic insecticides (i.e., those that are transported into plant tissues) on ecosystems. The authors raise concerns that systemic insecticides, including imidacloprid, because of their effects on sensitive animal taxa, could impact carbon and nutrient cycling, and food chains. A focus of the study is on potential effects of systemic insecticides on microbes, invertebrates, and fish and their ecosystem roles as decomposers, pollinators, consumers, and predators. The authors review example studies and scenarios as evidence of the “negative impacts of systemic insecticides on decomposition, nutrient cycling, soil respiration, and invertebrate populations valued by humans.”
- Bottger et al (2012) tested the amphipod *Gammarus* to imidacloprid in the laboratory, with a study design intended to match stream conditions. The authors found seasonal/temperature effects, with animals collected at 12°C being more sensitive than those tested at 17°C, although differences in testing methodology may explain some of these differences. The authors report that the effects of length (as a proxy for age) and season had strongest effects with juveniles. Their most sensitive test group had an EC50 (96-hr) of 14.2 µg/L.
- Camp and Buchwalter (2016) studied a lotic mayfly and found an increase in imidacloprid uptake rates with increasing water temperature. The authors concluded that rates of sublethal impairment and immobility increased significantly with increasing temperature. The 96-hr EC50 (immobility) was 5.81 µg/L for the mayfly *Isonychia bicolor*. In testing other species, they also found increased uptake of imidacloprid as water temperatures increased. They noted sublethal effects at imidacloprid concentrations much lower than those that produce mortality, and concluded that sublethal effects presented a serious risk to exposed invertebrates due to an increased vulnerability to predation.
- Van Den Brink et al. (2016) studied the acute and chronic toxicity of neonicotinoids to the mayfly *Cloen dipterum* and discuss the seasonality of the toxicity of imidacloprid to

several invertebrate species, including *C. dipterum*. The authors found increased sensitivity in the summer and overwintering generations in four invertebrate species. Specifically, for *C. dipterum*, the acute and chronic toxicity of imidacloprid was much higher for the summer generation than for the winter one.

- Hayasaka et al. (2012) studied the combined effects of two pesticides, imidacloprid and fipronil, on zooplankton in rice paddies in Japan. The study is relatively unique in that: 1) it was conducted in field mesocosms (e.g., mini-ecosystems) rather than the laboratory, 2) they evaluated the cumulative effect of two applications of insecticide, and 3) they specifically looked for and evaluated potential ecosystem level effects. They found direct negative effects on the species present and abundance of zooplankton following exposure to the pesticides. In turn, they found an indirect effect on fish in the ponds, suppression of growth of fishes feeding on the zooplankton. Because zooplankton were exposed to both imidacloprid and fipronil, the relative effect of each cannot be determined with certainty. The authors note that fipronil was more persistent in the soil than imidacloprid, and that ecological impacts on benthic species and associated fish were likely more strongly affected by residual fipronil, not imidacloprid.

2014 Experimental Trials of Imidacloprid Spraying in Willapa Bay

WGHOGA, in association with researchers from the University of Washington, Washington State University, and the Pacific Shellfish Institute (PSI), have conducted a number of field experiments and trials with imidacloprid in Willapa Bay over the past decade. Several of these trials were formal experiments to determine the effects of spraying imidacloprid to control burrowing shrimp. These formal trials were conducted under the supervision of the Washington Department of Ecology (Ecology), which reviewed and approved the Sampling and Analysis Plans (SAPs) for the work, and subsequently reviewed and approved the SAP Field Reports containing the results and analyses of these trials. At the time the 2015 FEIS was published, the SAP Field Report was not yet finalized for trials conducted in 2014 (results from trials conducted in previous years were reviewed in the FEIS). The review below is of that 2014 trial. It is based on the final SAP Field Report for that work, but follows the format used in the 2015 FEIS in its review of trials from prior years.

The 2014 field trials were designed to assess the magnitude, extent, and duration of impacts from imidacloprid that could be associated with commercial use of imidacloprid for the control of burrowing shrimp on tidelands used for commercial clam and oyster aquaculture. Whereas the previous year's studies had focused on smaller plots (i.e., 10 acres or less), the 2014 field trials were designed to assess these potential effects when imidacloprid is applied to larger (>50 acre) plots. Commercial treatment of plots of this size is most likely only feasible using aerial spraying, which is not proposed under the WGHOGA 2016 NPDES application. Nonetheless, the 2014 field trials provide data on the potential effects of imidacloprid spraying over larger areas, including clusters of smaller plots that are located in proximity to one another. It also indirectly allowed a test of whether post-spraying recruitment of invertebrates from unsprayed areas to the sprayed plots would be impeded when larger blocks and clusters are sprayed (e.g., due to the greater distance to be traveled, and the smaller amount of unsprayed area available as potential sources of recruitment). The results of the 2014 field trials are described in detail in Hart Crowser 2015, which is available through Ecology.

The 2014 field trials involved two trial plots (“Coast plot,” “Taylor plot”), immediately adjacent to one another, collectively covering approximately 90 acres, located near Stony Point in Willapa Bay. Both sites had high levels of burrowing shrimp, and were owned by members of WGHOGA. The beds were selected both for their larger size, and because they were in close proximity to other beds scheduled for commercial treatment. A total of 90 acres were treated by helicopter with liquid imidacloprid, Protector 2F, at 0.5 lb a.i./acre on July 26, 2014. The control site was matched to the treatment plots, to the extent feasible, to have similar elevation, vegetation and substrate as the treatment plots. The control plot was located near Bay Center, approximately five miles from the treatment plots, to ensure no imidacloprid was carried there from the treatment plots by the rising tide. In addition, two sites (“Nisbet plot,” “Coast plot”) were located in the Cedar River area. These plots were selected to allow collection of water samples over long distances from the treatment plots in order to better understand how imidacloprid in surface waters is diluted by tidal inflow.

The 2014 field trials were intended to assess:

- Pre- and post-application water column concentrations of imidacloprid;
- Whole sediment imidacloprid concentrations after treatment and over time;
- Whole sediment characteristics (texture, total organic carbon, dissolved organic carbon);
- Sediment porewater imidacloprid concentrations after treatment and over time;
- The efficacy of imidacloprid in controlling burrowing shrimp on larger treatment areas;
- The impact of large-scale imidacloprid application on megafauna (e.g., Dungeness crab); and
- The impact of large-scale imidacloprid application on benthic invertebrate communities.

Overall the SAP Field Report found that the 2014 field trials produced results comparable to those of the prior trials: imidacloprid was widely detected in water and sediments shortly after treatment, concentrations diminished quickly with increasing distance from the treatment plots (water) or over 14 to 28 days following treatment (on-plot sediments), and impacts to epibenthic and benthic invertebrate communities were determined to not be significantly different from reference stations. However, as in previous years, variability in benthic abundance collections was high and statistical power was weak.

Screening values were used to determine when levels of imidacloprid in various sample types were high enough to potentially result in environmental consequences. These values were used to determine which samples were analyzed and reported on in the SAP field report.

- Surface water – 3.7 ppb⁹ (screening value);
- Sediment – 6.7 ppb (laboratory quantitation limit¹⁰); and
- Sediment porewater – 0.6 ppb (screening value).

⁹ As noted above, 1 ppb is equal to 1 ug/L. The SAP field reports state concentrations in ppb, whereas many risk assessment and toxicology studies report concentrations in ug/L.

¹⁰ The lowest level the laboratory could analyze and still retain statistical certainty in the results

Water Column Sampling and Analysis. Water column samples were collected from the leading edge of the rising tide, typically about 2 hours after treatment. Imidacloprid concentrations in surface water at the Taylor and Coast sites (on-plot samples) ranged from 180 to 1,600 ppb, with an average value of 796 ppb. The Cedar River sites were designed to test the extent to which imidacloprid concentrations are diminished with distance from the sprayed plots (e.g., due to dilution by the incoming tide). At the Coast plot, the on-plot concentration of imidacloprid was 230 ppb. At approximately 731 meters from the plot (about 2,400 feet) the concentration was 0.054 ppb. For the Nisbet plot, samples were taken on-plot, and at distances of 62 meters (203 feet), 125 meters (410 feet), 250 meters (820 feet), 500 meters (1,640 feet), and on the shoreline (approximately 706 meters or 2,316 feet). This set of samples documented a decrease in imidacloprid concentrations with distance as follows: on-plot= 290 ppb, 62 meters= 0.55 ppb, 125 meters= 0.14 ppb, 250 meters= not detectable, 500 meters= 0.066 ppb, and shoreline= not detectable.

Overall, the surface water data collected during the 2014 trials indicate a strong pattern of high on-plot and low off-plot concentrations during the first rising tide, a result also noted in prior trials. For the Cedar River sites, on plot locations had concentrations up to 1,600 ppb, with an average value of approximately half this amount. Imidacloprid was detected at considerable distances off-plot, but at low concentrations of 0.55 ppb to 0 ppb. Thus, although the 2014 data confirm a greater distance off-plot for movement of imidacloprid (up to 500 meters), the concentrations were much lower than those observed in the off-plot data from 2012. These varying results suggest that site-specific differences in how tidal waters advance and mix during a rising tide are important in determining both the distance traveled and concentration of imidacloprid off-plot.

Sediment and Sediment Porewater Sampling and Analysis. The 2014 field trials confirmed prior studies that demonstrate a rapid, negative-exponential decline in imidacloprid concentrations in whole sediment and pore water after treatment. At 14 days, 4 of 8 sites had concentrations ranging from 6.8 µg a.i./L to 18 µg a.i./L, but imidacloprid was below detection limits at the other four locations. All but one sampling site declined to below detection limits in whole sediment by 28 days after treatment, with one sample (12 ppb) exceeding the 6.7 ppb screening level established for whole sediment. Sediment porewater demonstrated a similar rapid decline of imidacloprid concentrations, with all sediment porewater samples except one below the screening level of 0.6 ppb by day 28. The single sample that was above that screening level at day 28 exceeded that level, with a concentration of 1.2 ppb.

Megafauna Sampling and Analysis. The 2014 trials differed from prior trials in that they focused on the edges of the plots in surveying effects on crabs, both because it was impossible to survey the entire plot area sprayed due to its size, and because past trials had found that the edges often had higher numbers of Dungeness crab due to tidal depths (Dr. Kim Patten, WSU, personal communication). The monitored areas along the edge of the treated area were generally deeper and contained more eelgrass (*Zostera marina*) than the plots as a whole. Monitoring in 2014 found 137 Dungeness crabs exhibiting tetany (i.e., a reversible paralysis) or that were dead (see Table A-2). Based on their size, these were juvenile crabs. When the number of observed affected crab were divided by the total area sprayed, the 2014 field trials found an average of 2 crabs/acre were affected, of which about two out of three were reported dead, and one out of

three were in tetany. This compares to 0.87–3.8 crab/acre reported dead or in tetany during field trials in 2011 and 2012. When the number of affected crab was divided using only the actual acreage examined, an average of more than 18 crab/acre is calculated.¹¹ One complication in interpreting these results is that most of the dead crab were either eaten by birds or were crushed by the field equipment used to conduct the experimental trials (Dr. Kim Patten, personal communication). It is not clear if these crab were already dead due to imidacloprid exposure, or if they were in tetany, thereby making them vulnerable to predation and crushing. Crabs in tetany that were not eaten or crushed on the day of sampling would remain highly vulnerable to future predation. The 2014 results confirm prior work that imidacloprid treatments result in impacts to juvenile Dungeness crab.

Table A-2 – Summary of Total Affected Crab Observed in 2014

Crab Size Class (carapace length, in inches)	Outside edge of spray zone			Inside edge of spray zone		
	Alive	Tetany	Dead	Alive	Tetany	Dead
< 2	1	4	7	0	1	10
2–3	1	8	20	0	3	18
3–4	0	9	22	2	7	12
4–5	0	5	2	0	7	2
> 5	0	0	0	0	0	0
Total	2	26	51	2	18	42

Note: Observations were recorded one day after treatment.

Efficacy Summary. The 2014 field trials indicated good results using imidacloprid to control burrowing shrimp on shellfish beds, particularly in areas with low densities of eelgrass. Efficacy was variable, ranging from 20 to 97 percent, with most sites showing efficacy levels in excess of 60 percent in assessments conducted by WGHOGA and WSU. Reduced efficacy was noted in areas with flowing water, high eelgrass densities, or both.

Effects of Imidacloprid on Epibenthic and Benthic Invertebrates. Epibenthic and benthic invertebrate samples were collected both within and adjacent to the treatment plots, using a grid-based sampling approach. Epibenthic and benthic invertebrates were sampled prior to the application of imidacloprid and at 14 and 28 days post-treatment. Imidacloprid effects were assessed for nine endpoints (absolute abundance, taxonomic richness, and Shannon diversity index) for each of three primary taxonomic groups: (polychaetes, mollusks, and crustaceans) by comparing invertebrate numbers in the treated plots to those in the control plots at each post-treatment sampling date.

¹¹ During trials in 2011 and 2012 the plot sizes that were sprayed were small enough to allow sampling for crab over the entire area sprayed. As noted, in 2014 most of the plot was not sampled. For clarity two values are presented for the 2014 results, affected crab divided by the entire plot area to allow comparisons to 2011 and 2012 values, and affected crab divided only by the area surveyed. The first calculation underestimates the density of affected crab because crab in unsurveyed portions of the sprayed plot were not counted. And the second calculation overestimates the density of affected crab because the surveyed area was selected because it had the highest density of affected crab.

As in prior years, the invertebrate results showed high variability, both within individual plots over time, and when plots were compared to one another. Thus, the primary finding of the 2014 invertebrate trials, that estuarine epibenthic and benthic invertebrates were similar on control plots as compared to treatment plots, is likely due to weak statistical power to detect differences.

Differences in epibenthic or benthic invertebrates between control and treatment plots fell within the permissible range of Ecology's SIZ standards, a result noted in most trials from prior years as well.

Ecology determined that the "effects of imidacloprid cannot be discerned from seasonality and site variation or that relative recovery or recolonization is occurring within the 14-day period between the treatment date and first round of samples" (TCP April 17, 2015 memo). The 2014 benthic monitoring continued trends to date; all but one of the study monitoring locations have occurred in areas of low total organic carbon (less than 1% TOC) or high oceanic flushing.