Scallop

Audit

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01 | Executive Summary

Overview

Scallop engaged OtterSec to perform an assessment of the `sui-lending-protocol` program. This assessment was conducted between July 3rd and July 15th, 2023. For more information on our auditing methodology, see Appendix B.

Key Findings

Over the course of this audit engagement, we produced 17 findings in total.

In particular, we identified the absence of version validation (OS-SCA-ADV-00) and incorrect key verification during the obligation lock process (OS-SCA-ADV-01).

We also made numerous suggestions around avoiding unnecessary operations (OS-SCA-SUG-00), directly accessing fields for updating delay attributes (OS-SCA-SUG-01), and eliminating obsolete constants in the codebase (OS-SCA-SUG-02).

02 | Scope

The source code was delivered to us in a Git repository at github.com/scallop-io/sui-lending-protocol. This audit was performed against commit 128ffbd.

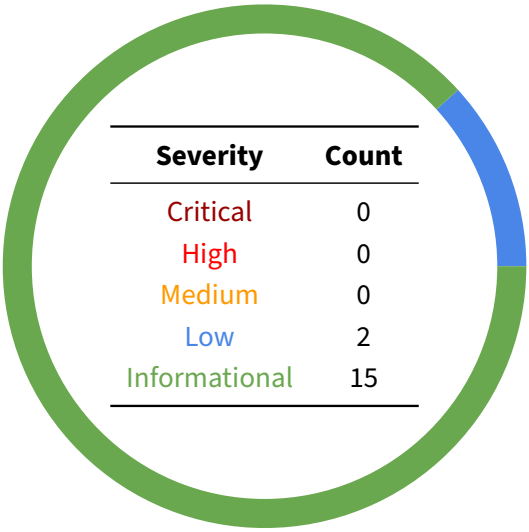
A brief description of the programs is as follows.

Name	Description
sui-lending-protocol	A money market designed specifically for the Sui ecosystem with a dynamic money market that offers high-interest lending, low-fee borrowing, an Automated Market Maker (AMM), and an asset management tool.

03 | Findings

Overall, we reported 17 findings.

We split the findings into **vulnerabilities** and **general findings**. Vulnerabilities have an immediate impact and should be remediated as soon as possible. General findings do not have an immediate impact but will help mitigate future vulnerabilities.



Severity	Count
Critical	0
High	0
Medium	0
Low	2
Informational	15

04 | Vulnerabilities

Here, we present a technical analysis of the vulnerabilities we identified during our audit. These vulnerabilities have *immediate* security implications, and we recommend remediation as soon as possible.

Rating criteria can be found in Appendix A.

ID	Severity	Status	Description
OS-SCA-ADV-00	Low	Resolved	The functions in `accrue_interest.move` omit the version check that prevents execution in the previous version.
OS-SCA-ADV-01	Low	Resolved	`obligation::lock` invokes an incorrect function for validating the lock key.

OS-SCA-ADV-00 [low] | Lack Of Version Check

Description

All user-callable functions perform a version check to ensure they utilize the most recent module whenever the protocol undergoes an upgrade. However, the functions within `accrue_interest.move` do not include this version validation, which may allow them to execute in their previous versions even after a protocol upgrade.

Remediation

Insert a validation step to confirm the current version by calling `assert_current_version`.

accrue_interest.move DIFF

```
@@ -3,12 +3,16 @@ module protocol::accrue_interest {
+ use protocol::version::{Self, Version};

  public fun accrue_interest_for_market(
+   version: &Version,
    market: &mut Market,
    clock: &Clock,
  ) {
+   version::assert_current_version(version);
+
    let now = clock::timestamp_ms(clock) / 1000;
    market::accrue_all_interests(market, now);
  }
@@ -19,11 +23,14 @@ module protocol::accrue_interest {
  public fun accrue_interest_for_market_and_obligation(
+   version: &Version,
    market: &mut Market,
    obligation: &mut Obligation,
    clock: &Clock,
  ) {
-   accrue_interest_for_market(market, clock);
+   version::assert_current_version(version);
+
+   accrue_interest_for_market(version, market, clock);
    obligation::accrue_interests_and_rewards(obligation, market);
  }
}
```

Patch

Fixed in f090a72.

OS-SCA-ADV-01 [low] | Incorrect Key Check

Description

`obligation::lock` is designed to lock the obligation functionality. Currently, the function invokes `assert_reward_key_in_store`, which is inconsistent with its intended purpose. Instead, `assert_lock_key_in_store` should be invoked, as the function should handle the locking of the obligation, not the rewards management.

Remediation

Check if `ObligationAccessStore` contains `lock_key` instead of `reward_key`.

obligation.move DIFF

```
@@ -257,13 +257,13 @@ module protocol::obligation {
public fun lock<T: drop>(
    // ...
-   obligation_access::assert_reward_key_in_store(obligation_access_store, key);
+   obligation_access::assert_lock_key_in_store(obligation_access_store, key);
```

Patch

Fixed in f090a72.

05 | General Findings

Here, we present a discussion of general findings during our audit. While these findings do not present an immediate security impact, they represent anti-patterns and may lead to security issues in the future.

ID	Description
OS-SCA-SUG-00	Adding an `else` statement may remove the occurrence of unnecessary operations.
OS-SCA-SUG-01	The initialization of `new_delay` may be avoided by directly updating the value of the structure.
OS-SCA-SUG-02	Remove obsolete constants in the codebase for maintenance and clarity.
OS-SCA-SUG-03	`lock_deposit_collateral` and `lock_withdraw_collateral` are assigned incorrectly in `obligation::lock`.
OS-SCA-SUG-04	The coin type does not need to be stored.
OS-SCA-SUG-05	`fixed_point32::zero` invokes `create_from_rational` instead of `create_from_raw_value`.
OS-SCA-SUG-06	Unnecessary fields in `WitTable` and `AcTable`.
OS-SCA-SUG-07	`balance_bag` holds empty balances without removing them.
OS-SCA-SUG-08	Optimize the process of liquidation of an obligation by avoiding repeated calls to `&get<DebtType>()`.
OS-SCA-SUG-09	`pyth_rule::set_price` does not check the confidence value returned from `pyth_adaptor::get_pyth_price`.
OS-SCA-SUG-10	Add checks to avoid reverts in the future.
OS-SCA-SUG-11	Incorrect naming of variables in `supra_registry::init`.
OS-SCA-SUG-12	The current flash loan implementation may fail with a division by zero error if there is no fee and no discount applied, since the fee calculation attempts to divide by zero.
OS-SCA-SUG-13	Due to the presence of rounding attacks in the share price calculation of the vault, it may allow for the manipulation of share values and prices.
OS-SCA-SUG-14	Anyone may deposit assets into an obligation, preventing its owner from borrowing those assets due to whitelist restrictions, which could lead to denial of service or griefing attacks.

OS-SCA-SUG-00 | Avoid Unnecessary Operations

Description

In `incentive_rewards.move`, `set_reward_factor` executes an unnecessary mutable borrow operation on the `reward_factors` table, where a new `coin_type` has been introduced. This procedure is redundant, considering that the recently incorporated entry already possesses the correct `reward_factor` value.

Remediation

Insert an `else` statement to avoid redundancy.

incentive_rewards.move DIFF

```
@@ -30,9 +30,9 @@ module protocol::incentive_rewards {
         reward_factor: factor,
       };
       wit_table::add(RewardFactors{}, reward_factors, coin_type, reward_factor);
+    } else {
+      let reward_factor = wit_table::borrow_mut(RewardFactors{}, reward_factors,
     ↪  coin_type);
+      reward_factor.reward_factor = factor;
     };
-
-    let reward_factor = wit_table::borrow_mut(RewardFactors{}, reward_factors,
     ↪  coin_type);
-    reward_factor.reward_factor = factor;
   }
 }
```

Patch

Fixed in d6d2de5.

OS-SCA-SUG-01 | Direct Field Access

Description

In `app.move`, when updating the delay attributes of `admin_cap`, the current implementation involves initializing a new variable `new_delay` and duplicating its value to `change_delay`. This occurs in three functions:

1. `extend_interest_model_change_delay`.
2. `extend_risk_model_change_delay`.
3. `extend_limiter_change_delay`.

However, this step is unnecessary and may be optimized by directly increasing the delay values in `admin_cap`, eliminating the requirement of the `new_delay` variable.

Remediation

Directly increase delay values in `admin_cap` without utilizing `new_delay`.

app.move DIFF

```
@@ -56,24 +56,21 @@ module protocol::app {
    admin_cap: &mut AdminCap,
    delay: u64,
  ) {
-   let new_delay = admin_cap.interest_model_change_delay + delay;
-   admin_cap.interest_model_change_delay = new_delay;
+   admin_cap.interest_model_change_delay = admin_cap.interest_model_change_delay +
    ↪  delay;

  public fun extend_risk_model_change_delay(
    admin_cap: &mut AdminCap,
    delay: u64,
  ) {
-   let new_delay = admin_cap.risk_model_change_delay + delay;
-   admin_cap.risk_model_change_delay = new_delay;
+   admin_cap.risk_model_change_delay = admin_cap.risk_model_change_delay + delay;

  public fun extend_limiter_change_delay(
    admin_cap: &mut AdminCap,
    delay: u64,
  ) {
-   let new_delay = admin_cap.limiter_change_delay + delay;
-   admin_cap.limiter_change_delay = new_delay;
+   admin_cap.limiter_change_delay = admin_cap.limiter_change_delay + delay;
```

Patch

Fixed in 020bcae.

OS-SCA-SUG-02 | Eliminate Obsolete Constants

Description

Several constants in the codebase are declared without being utilized. These unutilized constants may confuse developers and make the codebase harder to maintain. The constants in question are:

1. `u64::DIVIDE_BY_ZERO`.
2. `pyth_rule::rule::U8_MAX`.
3. `cetus_adaptor::cetus_flash_loan::ERepayTypeIncorrect`.
4. `supra_rule::rule::U8_MAX`.
5. `supra_rule::rule::U64_MAX`.

Remediation

Remove the aforementioned unutilized constants.

OS-SCA-SUG-03 | Incorrect Assignment Of Function Parameters

Description

In `obligation.move`, `lock` assigns:

1. `lock_deposit_collateral` to `self.withdraw_collateral_locked`.
2. `lock_withdraw_collateral` to `self.deposit_collateral_locked`.

This assignment is incorrect and may result in unexpected consequences in the program's execution.

Remediation

Update the assignments of `lock_deposit_collateral` and `lock_withdraw_collateral` in `lock`.

obligation.move DIFF

```
@@ -20,9 +20,9 @@ public fun lock<T: drop>(
    obligation_access::assert_reward_key_in_store(obligation_access_store, key);

    self.lock_key = option::some(type_name::get<T>());
    self.borrow_locked = lock_borrow;
    self.repay_locked = lock_repay;
-   self.withdraw_collateral_locked = lock_deposit_collateral;
-   self.deposit_collateral_locked = lock_withdraw_collateral;
+   self.deposit_collateral_locked = lock_deposit_collateral;
+   self.withdraw_collateral_locked = lock_withdraw_collateral;
    self.liquidate_locked = lock_liquidate;
```

Patch

Fixed in f090a72.

OS-SCA-SUG-04 | Coin Type Not Required

Description

Storing the coin type in `incentive_rewards::RewardFactor` is redundant, as the coin type already serves as the key for retrieving the reward factor from `WitTable`.

interest_model.move RUST

```
struct RewardFactor has store {
coin_type: TypeName,
reward_factor: FixedPoint32,
}
```

Remediation

Store the `reward_factor` directly in `WitTable` and remove the redundant coin type storage.

OS-SCA-SUG-05 | Optimize Zero Fixed Point

Description

In `fixed_point32.move`, `zero` creates a fixed point object representing zero utilizing `fixed_point32::create_from_rational(0, 1)`. However, a simpler approach exists. `fixed_point32::create_from_raw_value(0)` may directly generate a fixed point object that represents zero.

Remediation

Replace the `fixed_point32::create_from_rational(0, 1)` inside `zero` with `fixed_point32::create_from_raw_value(0)`.

fixed_point32.move DIFF

```
@@ -10,7 +10,7 @@ public fun zero(): FixedPoint32 {
-    fixed_point32::create_from_rational(0, 1)
+    fixed_point32::create_from_raw_value(0)
  }
```

OS-SCA-SUG-06 | Unnecessary Fields

Description

`wit_table::WitTable` and `ac_table::AcTable` contain the unnecessary field `with_keys`. The existence of keys may be verified by checking whether the optional keys field is `Some` or `None`.

wit_table.move RUST

```
struct WitTable<phantom T: drop, K: copy + drop + store, phantom V: store> has
  ↪  key, store {
  id: UID,
  table: Table<K, V>,
  keys: option::Option<VecSet<K>>,
  with_keys: bool
}
```

ac_table.move RUST

```
struct AcTable<phantom T: drop, K: copy + drop + store, phantom V: store> has key,
  ↪  store {
  id: UID,
  table: Table<K, V>,
  keys: option::Option<VecSet<K>>,
  with_keys: bool
}
```

Also, the `effective_epoches` field present in the following events may be omitted since it is derivable from the `current_epoch` and `delay_epoches` fields:

- `InterestModelChangeCreated`
- `LimiterUpdateLimitChangeCreatedEvent`
- `LimiterUpdateParamsChangeCreatedEvent`
- `RiskModelChangeCreated`

Remediation

Eliminate the `with_keys` field from `wit_table::WitTable` and `ac_table::AcTable`. Instead, check for the existence of keys by evaluating the state of the optional keys field. Furthermore, remove the `effective_epoches` field from:

- `InterestModelChangeCreated`
- `LimiterUpdateLimitChangeCreatedEvent`

- `LimiterUpdateParamsChangeCreatedEvent`
- `RiskModelChangeCreated`

Instead, derive it by utilizing the `current_epoch` and `delay_epoches` fields.

OS-SCA-SUG-07 | Remove Empty Balances

Description

`obligation_collaterals::decrease` removes collaterals that have a zero amount from `WitTable`. On the other hand, `balance_bag` of `obligation` does not eliminate empty balances. To maintain code consistency and ensure clarity, remove empty balances.

Remediation

Remove the empty balance of `balance_bag` when withdrawing the collateral from `obligation`.

OS-SCA-SUG-08 | Avoid Repeated Calls

Description

In `liquidator.move`, `liquidate_obligation_with_cetus_pool_only_a` and `liquidate_obligation_with_cetus_pool_only_b` each invoke `&get<DebtType>()` twice. Repeated function calls may impact performance. Storing the result of `&get<DebtType>()` in a variable and reusing it would enhance the efficiency of the code.

liquidator.move RUST

```
public fun liquidate_obligation_with_cetus_pool_only_a<DebtType, B>(
  [...]
) {
  /// Make sure the obligation has DebtType, and CollateralType
  if (
    vector::contains(&obligation::debt_types(obligation), &get<DebtType>()) ==
  ↪  false ||
      vector::contains(&obligation::collateral_types(obligation),
  ↪  &get<DebtType>()) == false
  )
  [...]

public fun liquidate_obligation_with_cetus_pool_only_b<A, DebtType>(
  [...]
) {
  /// Make sure the obligation has DebtType, and CollateralType
  if (
    vector::contains(&obligation::debt_types(obligation), &get<DebtType>()) ==
  ↪  false ||
      vector::contains(&obligation::collateral_types(obligation),
  ↪  &get<DebtType>()) == false
  ) return;
```

Remediation

Store the result of `&get<DebtType>()` in a variable to avoid repeated function calls.

OS-SCA-SUG-09 | Missing Confidence Check

Description

In `pyth_rule::set_price`, the confidence value returned from `get_pyth_price` is not validated. While there is a check to confirm the primary oracle's price against at least half of the secondary oracles' prices, it is advisable to verify that the confidence level is not excessively high.

Remediation

Check that the returned value of confidence is not too high in `pyth_rule::set_price`.

OS-SCA-SUG-10 | Additional Checks To Avoid Reverts

Description

In `interest_model::create_interest_model_change`, it is advisable to include additional checks to prevent potential reverts in the future, particularly those created by dividing by zero and underflow errors.

Remediation

Integrate the following checks to prevent dividing by zero and underflow errors, thus avoiding potential reverts of this nature in the future.

interest_model.move RUST

```
    public(friend) fun create_interest_model_change<T>(
    _: &AcTableCap<InterestModels>,
    base_rate_per_sec: u64,
    interest_rate_scale: u64,
    borrow_rate_on_mid_kink: u64,
    mid_kink: u64,
    borrow_rate_on_high_kink: u64,
    high_kink: u64,
    max_borrow_rate: u64,
    revenue_factor: u64,
    borrow_weight: u64,
    scale: u64,
    min_borrow_amount: u64,
    change_delay: u64,
    ctx: &mut TxContext,
  ): OneTimeLockValue<InterestModel> {
        [...]
        assert!(mid_kink != 0 && high_kink < 1 && base_rate <=
    ↪  borrow_rate_on_mid_kink <= borrow_rate_on_high_kink <= max_borrow_rate);
        [...]
    }
```

OS-SCA-SUG-11 | Incorrect Variable Names

Description

In `supra_registry::init`, the variables `pyth_registry` and `pyth_registry_cap` should be named `supra_registry` and `supra_registry_cap` respectively for better code clarity.

Remediation

Rename `pyth_registry` and `pyth_registry_ca` to `supra_registry` and `supra_registry_cap` respectively.

OS-SCA-SUG-12 | Division By Zero Error

Description

`borrow_flash_loan` calculates the flash loan fee based on the configured `fee_rate` and a potential discount. If both `fee_rate` and `fee_discount_numerator` are zero (no fee and no discount applied), it will be impossible to obtain a flash loan from this reserve. In this case, both `fee_discount_numerator` and `fee_discount_denominator` will be zero, resulting in an attempt to divide `base_fee` by zero in `u64::mul_div`. Since `u64::mul_div` is called with parameters `a = 0` and `b = 0`, `u128::mul_div` will also be called with `a = 0` and `b = 0`. Consequently, the call to `is_safe_mul` will fail due to division by zero.

sources/market/reserve.move RUST

```
fun borrow_flash_loan_internal<T>(
    self: &mut Reserve,
    amount: u64,
    fee_discount_numerator: u64,
    fee_discount_denominator: u64,
): (Balance<T>, FlashLoan<T>) {
    let balance = balance_bag::split<T>(&mut self.underlying_balances, amount);
    let fee_rate = *wit_table::borrow(&self.flash_loan_fees, get<T>());
    let base_fee = if (fee_rate > 0) {
      // charge at least 1 unit of coin when fee_rate is not 0
      amount * fee_rate / FlashloanFeeScale + 1
    } else {
      0
    };
    let fee_discount = u64::mul_div(base_fee, fee_discount_numerator,
    ↪  fee_discount_denominator);
    let fee = base_fee - fee_discount;
    let flash_loan = FlashLoan<T> { loan_amount: amount, fee };
    (balance, flash_loan)
}
```

A similar case occurs in a standard borrow with ticket, if the `base_borrow_fee_rate` ID is set to zero, and a ticket is created with `borrowing_fee_discount_numerator` set to zero, although there is a relatively low possibility of this occurring since the ticket would have to be issued to give a zero discount.

Remediation

Modify `u64::mul_div` to handle the zero case explicitly. If either a (dividend) or b (divisor) is zero and c (denominator) is not zero, the function should return zero. This will prevent the division by zero error and allow flash loans to proceed even with a zero fee rate and no discount.

OS-SCA-SUG-13 | Share Price Manipulation

1. The protocol may be vulnerable to a general class of rounding attacks against lending protocols concerning the conversion rate between tokens and shares in a lending pool. The attack involves manipulating the share value (token-to-share conversion rate) and abusing rounding errors. The root cause relates to how rounding decisions are determined in the protocol when dealing with fixed precision, resulting in unintended consequences on share valuation.
2. It should be ensured that non-zero values are returned during the conversion processes, specifically within `reserve::redeem_underlying_coin`. Since such conversions with zero amount are non-sensical.

Remediation

1. Ensure the protocol should lock a certain amount of shares and tokens at initialization or first deposit that can never be withdrawn or borrowed.
2. In `redeem_underlying_coin`, assert that `mint_amount > 0`, as done in `mint_market_coin`.

OS-SCA-SUG-14 | Denial Of Service

Description

There is possibility of griefing or denial of service (DoS) attacks in the context of the borrow module. Specifically, the concern is that anyone can perform deposit and repay actions on behalf of an obligation owner since all arguments are shared objects. Thus, An attacker may deposit a small amount of a specific coin into the obligation of a legitimate user. This may be done by frontrunning or simply executing a deposit transaction on behalf of the user.

sources/user/borrow.move RUST

```
fun borrow_internal<T>(
    [...]
): (Balance<T>, Balance<T>) {
    // check if sender is in whitelist
    assert!(
      whitelist::is_address_allowed(market::uid(market), tx_context::sender(ctx)),
      error::whitelist_error()
    );
    [...]
}
```

The obligation now lists this coin as collateral, even if the amount is minuscule and not intended by the legitimate user. Consequently, when the legitimate user attempts to borrow the same coin, the check in `borrow_internal` prevents this action because the coin is already listed as collateral:

Remediation

Implement stricter access control measures to ensure that only authorized parties can perform deposit and repay actions.

A | Vulnerability Rating Scale

We rated our findings according to the following scale. Vulnerabilities have immediate security implications. Informational findings can be found in the General Findings section.

Critical	Vulnerabilities that immediately lead to loss of user funds with minimal preconditions Examples: • Misconfigured authority or access control validation • Improperly designed economic incentives leading to loss of funds
High	Vulnerabilities that could lead to loss of user funds but are potentially difficult to exploit. Examples: • Loss of funds requiring specific victim interactions • Exploitation involving high capital requirement with respect to payout
Medium	Vulnerabilities that could lead to denial of service scenarios or degraded usability. Examples: • Malicious input that causes computational limit exhaustion • Forced exceptions in normal user flow
Low	Low probability vulnerabilities which could still be exploitable but require extenuating circumstances or undue risk. Examples: • Oracle manipulation with large capital requirements and multiple transactions
Informational	Best practices to mitigate future security risks. These are classified as general findings. Examples: • Explicit assertion of critical internal invariants • Improved input validation

B | Procedure

As part of our standard auditing procedure, we split our analysis into two main sections: design and implementation.

When auditing the design of a program, we aim to ensure that the overall economic architecture is sound in the context of an on-chain program. In other words, there is no way to steal funds or deny service, ignoring any chain-specific quirks. This usually requires a deep understanding of the program's internal interactions, potential game theory implications, and general on-chain execution primitives.

One example of a design vulnerability would be an on-chain oracle that could be manipulated by flash loans or large deposits. Such a design would generally be unsound regardless of which chain the oracle is deployed on.

On the other hand, auditing the implementation of the program requires a deep understanding of the chain's execution model. While this varies from chain to chain, some common implementation vulnerabilities include reentrancy, account ownership issues, arithmetic overflows, and rounding bugs.

As a general rule of sum, implementation vulnerabilities tend to be more "checklist" style. In contrast, design vulnerabilities require a strong understanding of the underlying system and the various interactions: both with the user and cross-program.

As we approach any new target, we strive to get a comprehensive understanding of the program first. In our audits, we always approach targets with a team of auditors. This allows us to share thoughts and collaborate, picking up on details that the other missed.

While sometimes the line between design and implementation can be blurry, we hope this gives some insight into our auditing procedure and thought process.